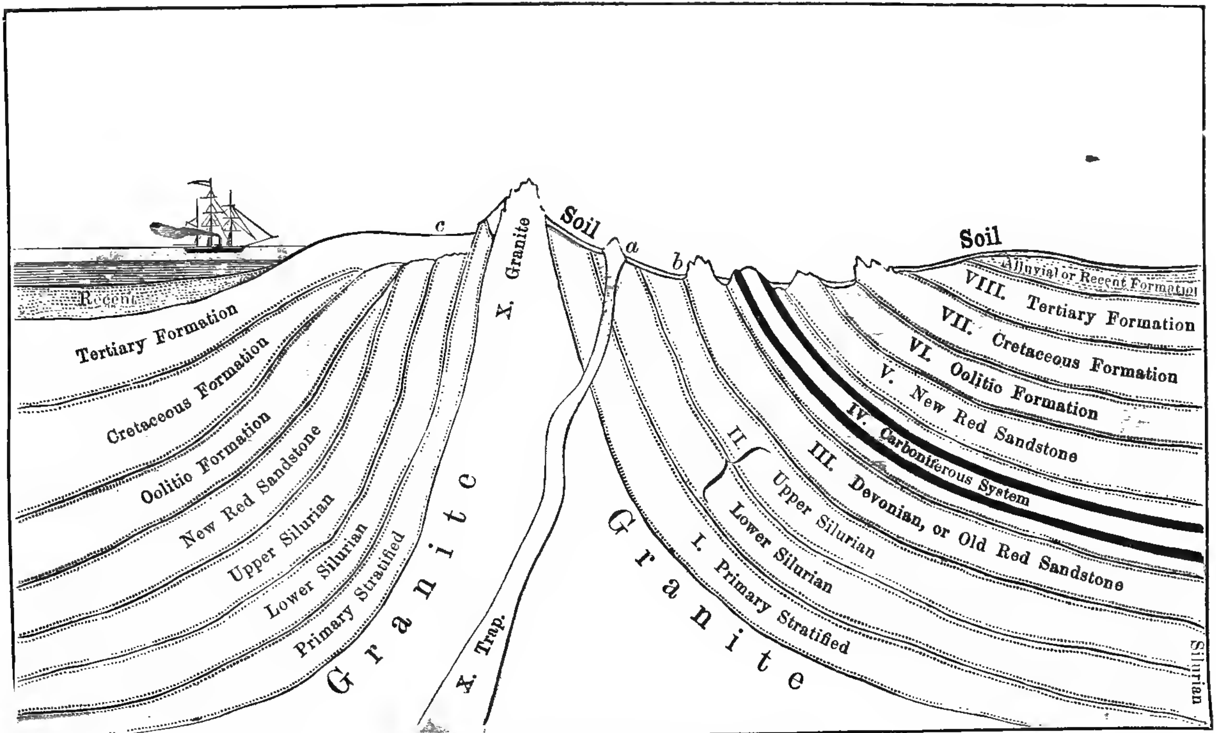

Fig. 41. THE STRATA OF THE EARTH. See page 176.

A MANUAL

OF

SCIENTIFIC AND PRACTICAL

AGRICULTURE,

FOR

THE SCHOOL AND THE FARM.

BY

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With Numerous Illustrations.

Happy the man, who studying Nature's laws,
Through known effects can trace the secret cause.

DRYDEN'S VIRGIL.

PHILADELPHIA:
LINDSAY & BLAKISTON.
1859.

STEREOTYPED BY J. FAGAN. . . . . PRINTED BY C. SHERMAN & SON.

Dedication.

To the many young gentlemen whom I have had the honor and the pleasure of instructing in this important department of APPLIED SCIENCE, this little Work is affectionately dedicated, as a token of the interest still felt in their success in life.

THE AUTHOR.

PREFACE.

There is a rapidly increasing demand for scientific information, reduced to such a form that it may be applied to the daily business of Agriculture. This makes the adoption of the study of Agriculture into our higher schools a matter of great importance. It has already led to the introduction of the subject into several of our best colleges, and into a few of the higher schools; but those teachers who have undertaken the important task of giving to our farmers' sons, that kind of scientific training, which especially fits them for the intelligent pursuit of their future calling, have felt the want of a text-book of the right kind. One of the leading objects which the Author of this little work has kept in view, has been to meet this want, as far as possible.

Another demand for some such work, comes from those already engaged in the cultivation of the soil.

It comes from those who have been long employed as "tillers of the land," as well as from the younger farmers, who desire to improve upon the old system (or rather want of system) of culture, which has worn out so many of our best lands. It is hoped that this demand, also, will be met, to some extent, at least, by what is here offered to the agricultural public.

Hence, the great purpose kept in view has been the preparation of a "Manual" adapted to the *School* and the *Farm*, to serve especially as a guide to the youthful mind in acquiring such knowledge and mental training as might lay a firm foundation for future and higher attainments.

The only *systematic* books on this subject heretofore available, have been either foreign works, or compilations from these, modified to suit limited sections of our country. Not one of them is at all adapted to the agriculture of our Southern and Western States. It is true that the leading principles of science, as applied to the culture of the soil, are the same everywhere; but the *practical application* of these principles is as widely different in different latitudes, as the numerous crops cultivated in the several sections of our wide-spread country. Their application to *Southern Agriculture* has been generally left out of view, in all books of a *general* character hitherto issued on this great subject. This little work will, therefore, come in competition with no other of like character. Some excellent productions, on specific subjects in Agriculture, have appeared from the pens of Southern writers, and will be found alluded to in the text, where they have been made available by the writer. But this is designed to fill a place before unoccupied.

The following general plan has been pursued:—

1. A few preliminary definitions are given as an "Introduction."

2. The agencies, "Heat, Light, and Electricity," have such of their general laws discussed as are necessarily connected with other subjects afterwards introduced, and especially with reference to the relations they bear to *Agriculture* and domestic affairs.

3. The language of chemistry, so far as is necessary to a clear understanding of the subject, is briefly summed up and explained in the form of "Symbols and Nomenclature."

4. The most important elementary substances, both "Metalloids and Metals," with such of their inorganic compounds as are of interest to the agri-

culturalist, are described, and their properties illustrated by simple experiments.

5. The leading principles of "Organic Chemistry" are concisely stated, and applied to the discussion of both "Vegetable and Animal" compounds.

6. The sources from which plants derive their nourishment are described.

7. Then, to show clearly the relation of the plant to its sources of nourishment, and to show what conditions are necessary for healthful and vigorous growth, the various *organs* of plants, and the *functions* they perform are given, under a general outline of "Vegetable Physiology."

8. The "Soil," as the only source of plant nourishment under our control, is then discussed, with reference, *first,* to its "Geological Origin"—showing how the quality of soils is influenced by the rocks from which they are formed; *secondly,* with reference to its "Mechanical Management"—embracing the *principles* involved in "Plowing, Draining, etc.," with their *practical* application; *thirdly,* with reference to its "Chemical Treatment"—showing what is necessary to fertility in a soil, and what constitutes any substance a good fertilizer.

9. "Special Manures"—their composition and chemical relations to one another, and to the soil and crop, with the principles which should govern their "Application," are treated somewhat definitely.

10. The "Selection of Seed," and the leading principles to be observed in "Planting and Culture," are briefly discussed. These principles are then *applied* to the planting and culture of "Indian Corn," "Wheat," "Clover and Grasses," "The Southern Pea," "Tobacco," and "Cotton."

11. The principles, with a few examples of "Rotation of "Crops," are stated.

12. The "Value of different Crops, as Articles of Food," is briefly given.

13. Then, to show the relation between the animal and his food and habits, we have a brief outline of that part of "Animal Physiology" which is most intimately related to the *rearing, feeding,* and *general management of stock,* followed by *practical applications.*

In every part of the work, the Author has endeavored to blend *principles* and *practice*—first in a general way, then more specifically, as applied to particular cases in every-day experience.

The reader must not suppose that this, or any other book *alone*, can make him a good farmer. Books, without *practice*, can no more make successful farmers, than they can make successful lawyers or physicians. The judgment must be exercised by *close observation*, and by varied *experience*, in farming as well as in other pursuits.

The experience of others must be consulted, too, and carefully weighed. To do this, every farmer who expects to be intelligent in his profession, must secure the regular reading of some good Agricultural Journal, and such Essays as are from time to time presented before Agricultural Societies. Fortunately for our young farmers, many of our best agricultural writers are among the most successful cultivators of the soil. The results of their experience may be made familiar, by spending an occasional leisure hour with such papers in hand, as tell us what they have been doing, and how they have succeeded. But do not, by any means, try every man's experiments. Study this little book carefully, and it will aid you to decide on the *probable value* of any given operations. Examine into the *causes* and *effects* involved in what has been done, and you may see at once whether the experimenter has understood his own operations or not.

What is here offered is the result of the Author's labors of several years, in giving instruction to young men on the important topics discussed. The matter, of course, is not all original. It has been gathered up from various sources—partly from books, partly from Agricultural Journals and Essays, partly from observation, and partly from a limited practical experience. The Author is not an entire stranger to the plow-handle and the hoe, and therefore claims a higher position than that of mere "book-farmer."

The experiments given for illustration are very simple, and may be performed by any ingenious youth, or by the teacher of almost any respectable school. The *apparatus* and *chemicals* required to begin with, can be bought for ten or twelve dollars. A list of them will be found in the Appendix.

Prof. LUDWIG, of Lexington, deserves many thanks for valuable and friendly assistance in drawing some of the principal cuts given, and in copying several others. My young friend and pupil, H. T. DARNALL, is the delineator of the cut in Chapter XV, which illustrates so clearly the system of side-hill irrigation there given. To my friend and neighbor, Prof. GILHAM, of the Virginia Military Institute, I am under peculiar obligation for the labor he has undergone, in revising the whole of my manuscript, and in making

some most valuable suggestions, which have been adopted, and which have done much to give clearness and precision to several of my scientific discussions.

My indebtedness to various books and journals has been generally acknowledged in the body of the work.

It is due the engravers, Messrs. BAXTER & HARLEY, to add, that they deserve high commendation for their faithfulness in executing the various cuts with which the work is illustrated. The Frontispiece, especially, presents a rare specimen of artistic skill.

J. L. CAMPBELL.

WASHINGTON COLLEGE,
Lexington, Va., June, 1859.

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SCIENTIFIC AND PRACTICAL AGRICULTURE.

CHAPTER I.

INTRODUCTION.

§ 1. AGRICULTURE may be viewed in the two-fold light of a *science* and an *art*. As a science, it embraces some of the leading principles of *Chemistry*, *Geology*, and of *Vegetable and Animal Physiology*. As an art, it consists in the skilful application of science to the cultivation of the soil, so as to make it yield the largest crops at the least possible cost. It also embraces the proper management and feeding of such animals as belong to the farm.

We shall first define the several branches of science involved in our general subject; then discuss each of them briefly, giving only such principles and illustrations as may be applicable to domestic and agricultural pursuits.

2. *Chemistry* treats of the composition and properties of all substances on the surface of the earth. Soils, manures, and all vegetable and animal substances, have their true composition determined by chemical research. Chemistry also explains the various changes which take place in the growth and decay of plants and animals.

3. *Geology* examines into the structure of the earth, the nature of rocks, and the origin of soils.

4. *Physiology* makes us acquainted with the various organs of plants and animals, and the part they act in promoting growth, nutrition, etc.

5. *Chemical Experiment.*—Take a few grains of iron filings, and mix them with an equal weight of finely-powdered sulphur. If you now examine the mixture, you find the particles of iron and sulphur still distinct from each other—the mass is a simple *mixture.* Place the mixture upon a piece of porcelain cup, and heat it over hot coals or a spirit-lamp, until the sulphur takes fire and all the surplus sulphur is burnt out. The resulting mass will be found to differ entirely from both iron and sulphur. The two substances have united in one; they have become a *compound substance.* While they were still in separate particles they were *simple* or *elementary* substances. The force which caused them to unite when heated, is called *chemical affinity.*

6. *Definition.*—A simple or elementary substance is one which cannot be separated into two or more parts, which differ from each other in their properties.

Illustration.—Sulphur may be ground to a fine powder, yet all the particles will possess the same properties. Sulphur, then, is an elementary substance. Water may be separated by the galvanic battery into two gases, having the form and appearance of the air; but they differ very widely from each other in many of their properties. Water is *not* an elementary substance. But neither of the gases of which water is composed, can be again divided into parts having different properties. These gases are elementary substances, and are called *oxygen* and *hydrogen.*

7. *Definition.*—*A compound substance* is one formed by the combination of two or more elementary substances.

Illustration.—When iron and sulphur were heated together (§ 5), they united into one mass similar in all its parts. This combination of iron and sulphur is a *chemical compound.* We call it *sulphuret of iron.* Oxygen and hydrogen, when combined, form water, which is a compound.

8. *Definition.*—*Chemical affinity* is the force which causes elementary substances to combine and form compounds, and compounds to combine with each other and form new compounds.

Illustrations.—The force which causes iron and sulphur to combine is chemical affinity. A piece of limestone or marble is composed of *lime* and a gas called *carbonic acid.* These are kept together by affinity. If the stone is heated red hot for some time, the gas is expelled, and the lime alone is left. The power of affinity between them has been overcome by heat, and the stone is said to be *decomposed.*

Keeping before our minds the definitions of elementary and compound substances, and of affinity, let us now define *Chemistry.*

9. *Definition.*—*Chemistry* is the branch of science which treats: 1. *Of the history and properties of elementary substances;* 2. *Of the formation and properties of compounds;* 3. *Of the laws which regulate the action of affinity.*

There are certain *agencies* which have a great influence over chemical affinity. These are *Heat, Light, Electricity,* and *Vitality.* We must here study some of their properties and effects, before we enter upon the study of chemistry in its more restricted sense.

QUESTIONS ON CHAPTER I.

§ 1. How may Agriculture be viewed? As a science, what does it embrace? What as an art?

2. Of what does Chemistry treat? How is the true composition of all substances determined?

3, 4. What is Geology? Physiology?

5. What chemical experiment is here given? What is the product?

6. What is a simple or elementary substance? Illustrate it. Is water simple? Of what composed?

7. What is a compound substance? Illustrate.

8. What is chemical affinity? Illustrate.

9. Define Chemistry. What agencies influence chemical affinity?

To Teachers.—The questions inserted at the end of each chapter are merely designed to be suggestive to young teachers. Every teacher should, of course, frame his own questions, to suit circumstances. For my own part, I never use the questions given in any text-book; nor do I regard those given here as of much importance. Still, the young teacher, in the preparation of the lesson in advance of his class, may get some good suggestions by reading the questions over, after he has studied the text.

CHAPTER II.

HEAT—LIGHT—AND ELECTRICITY.

10. THE term *caloric* is often applied to the agency which causes the sensation called *heat;* but we shall use the word HEAT to denote both the *cause* and the *sensation.*

Heat is a most important agent in promoting, modifying, or destroying the force of affinity. Many substances which do not combine at ordinary temperatures, combine rapidly when heated. We had an illustration of this in the experiment with iron and sulphur. In the burning of limestone (§ 7), affinity was destroyed, or at least overpowered, by heat. The action of affinity also produces heat, as in the burning of a lamp or fire.

11. *Sources of Heat.*—The sun is the greatest source of heat. Combustion, electricity, and friction are sources of heat on the earth. Heat is thrown out from its sources in straight lines. It is then said to be *radiated.*

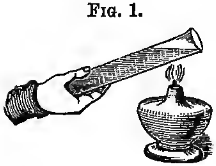
12. When radiated heat falls upon the surface of a body, and, entering, pervades the particles of that body, it is said to be *absorbed.* If the heat is thrown off by the surface upon which it falls, it is said to be *reflected.*

Experiment.—Take two tin vessels of the same form and size. Let one of them be bright, and paint the other with lampblack. Fill both nearly full of cold water, and set them in front of the fire. The water in the vessel with the black, rough surface will be heated most rapidly. The polished, bright surface reflects the heat, while the black, rough one absorbs it. Again, fill the two vessels with hot water, and set them aside to cool. A thermometer in each will show that the black vessel cools off most rapidly. Black, rough surfaces radiate more rapidly than bright ones. A stove should be dark and rough — we wish it to radiate as much as possible. A coffee or tea-pot should be bright and smooth, that it may retain the heat. Dark soils are warmed more rapidly in the spring by the sun, than are those of light color.

13. *Conduction of Heat.* — Heat passes from particle to particle very rapidly in some bodies, while it passes very slowly in others. Hold a piece of iron and a piece of glass in the flame of a candle at the same time. The heat soon reaches the fingers through the iron, but the glass may be held in the flame for many hours without conveying the heat to the hand. Bodies through which heat passes freely are *conductors*. Those through which it passes very slowly are *non-conductors*. Metals are good conductors. Glass, charcoal, dry wood, and most liquids, are *non-conductors*. We clothe ourselves with non-conductors in winter, to confine the heat of the body. We surround ice-houses and refrigerators with non-conductors, to keep out the heat of the sun and earth.

Experiment. — To show that water is not a conductor, drop a little lump of ice into the bottom of a test-tube (Fig. 1), and fasten it down with a coil of wire. The water may then be boiled at the top of the tube, while the ice remains unmelted in the bottom.

FIG. 1.



EFFECTS OF HEAT.

14. *Expansion.* — Bodies of all forms, solids, liquids, and gases, are expanded by heat. *Exps.* — 1. Let the metallic bar (a) be made exactly to fit the frame (b) (Fig. 2), at

ordinary temperatures; then, when heated, the bar will be too long for the frame; and when cooled with ice, it will be shorter than the frame. 2. Fill the glass bulb and tube (Fig. 3) with water to the point *a*, and mark that point; then hold the bulb over a lamp, or dip it into hot water. The water in the tube will soon rise above *a*, by the expansion of the portion in the bulb. Alcohol will expand still more than water with the same increase of temperature. 3. Pour the water out of the bulb and tube, and invert the tube, placing the mouth of it under water, in the tumbler (*b*). The tube and bulb will then be full of air alone, but if the bulb is clasped in the hand until it becomes warm, the heat will be communicated to the air within, and expand it to such an extent, that a portion will be expelled, and pass out in bubbles through the water. A lamp flame applied to the bulb will expel the air still more rapidly. As the bulb cools again, the air within contracts, and, occupying a smaller space, allows the water to be forced upward towards the point *c*, by the pressure of the surrounding atmosphere.

FIG. 2.

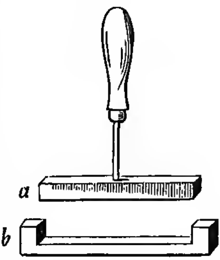
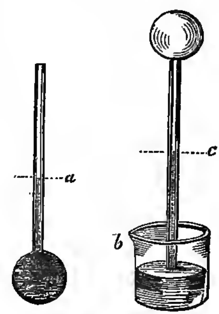


FIG. 3.

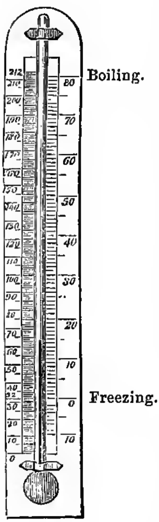


15. *Practical Applications.*—When a blacksmith wishes to fit the tire upon a wagon-wheel, he guages it so that, when cold, it is a little smaller than the wooden rim of the wheel. He then expands it by heat, until it is larger than the wheel. It is then easily put on, and, to cool it, the wheel is turned on an axis, with the rim dipping into a

trough full of water, the workman, meantime, adjusting it properly with his hammer. As it contracts, the wheel is bound together with great force. The wheels of wagons often become loose in hot weather, partly by the drying of the wood of which they are made, but partly, too, by the expansion of the tire under the sun's heat.

16. We have a beautiful and useful application of the expansion of liquids, in the construction of the common thermometer (Fig. 4).

Fig. 4.



"Ordinary thermometers consist simply of a glass tube of an exceedingly small bore, with a bulb blown at one extremity, and filled with mercury to about one-third the height of the stem. The air being expelled, the tube is hermetically sealed, and the freezing-point ascertained by holding it a short time in water containing ice, and the boiling point by holding it in the same manner in boiling water. It is necessary that these two points should be accurately determined, in order that the indications of different instruments may be compared with each other.

"Having determined these points, the intervening space is to be divided into equal parts, called degrees; and in fixing upon the proper number, regard to convenience alone would seem to be our guide. Unfortunately, there have been different opinions with regard to this point, and no less than three different scales are in use. In Fahrenheit's thermometer, which is chiefly used in this country and in England, the space between the freezing and boiling points of water is divided into 180 parts, and the zero is placed 32 degrees below the freezing point, so that the boiling point is at 212. In the Centigrade thermometer, which is generally used in France, the space is divided into 100 parts, zero being at the freezing point, and of course the boiling point is at 100. In Reaumur's thermometer the beginning of the scale, or zero, is at the freezing point; but the boiling point is at 80. This thermometer is used in Germany and Russia."—*Johnston's Turner.*

17. Water follows the ordinary laws of expansion and contraction, only within certain limits. When cooled below the ordinary temperature, it contracts, until the temperature is brought down nearly to 39° F. It then begins to expand, and continues to do so until, at the moment of freezing, there is a sudden expansion, so great as to make ice considerably lighter than water, and thus cause it to float upon the surface. This property of water points us in a striking manner to the wisdom and benevolence of our Creator; for, if water had been so constituted as to follow the law of contraction, as exhibited in bodies generally, it would sink as it freezes, leaving the surface always exposed; and thus, in cold climates, one portion after another would freeze and sink, till all the streams and lakes would become solid masses of ice. But as the ice floats upon the surface, it protects the body of water beneath, and prevents its too rapid freezing.

The expansion of frozen water in the pores of the soil, enlarges those pores; thus rendering the soil easily cultivated, and leaving it, in the spring, in condition to be readily penetrated by the roots of plants.

18. The expansion of air by heat serves many valuable purposes. Heated air, by becoming lighter, is forced upward by the mass of cooler air which surrounds it. Thus, the heated air in a fire-place or stove is made to pass rapidly up the chimney or pipe, and carries the smoke with it. So when some portions of the atmosphere become more highly heated than others, they rise, while the surrounding portions flow in

to take their place. Thus, currents of wind are produced. In this way, the Creator has provided that our atmosphere shall be kept in a state of perpetual circulation, by the varying heat of the sun.

FORMS OF BODIES.

19. *Solids, Liquids, Gases.*—All bodies on the earth have one of three conditions—they are solid, liquid, or gaseous. These conditions are determined chiefly by temperature. For example, water is *solid* below 32°; *liquid* between 32° and 212°; *gaseous* (steam) above 212°. Mercury is solid at 40° below zero; while between that temperature and 662° it is liquid. Heated to a still higher temperature, it assumes the gaseous form. Boiling is the agitation produced by the rapid formation of steam or other vapor at the bottom of a portion of liquid, and the rising of the bubbles of the steam thus produced. The boiling of water may be beautifully exhibited by filling a glass flask (Fig. 5) half full, and placing a spirit-lamp under it until it boils.

Fig. 5.

20. *Insensible or Latent Heat.*—When the heat of a body is so modified as not to be felt by the hand, or so as not to affect the thermometer, it is said to be rendered *insensible* or *latent.* Heat becomes insensible when a solid is changed to a liquid, or when a liquid is changed to vapor.

When ice is made to melt rapidly by mixing it with a substance like common salt, for which it has an affinity, the heat already in it becomes *insensible,* and the temperature falls rapidly.

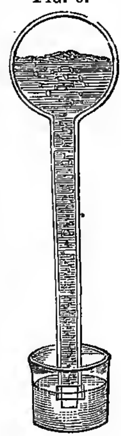
Experiment.—Reduce two pounds of ice to fine powder, and mix it thoroughly with one pound of salt. A thermometer inserted in the mixture will soon fall below zero. A little water in the bottom of a test-tube, immersed into the mixture, will be frozen in a few minutes.

In freezing ice-cream, we have an illustration of a similar kind. But, in this case, a smaller quantity of salt should be used, so that the freezing may not be too rapid. The cream has a finer grain if frozen more gradually, and frequently agitated as it freezes.

21. When water is heated up to 212°, it begins to boil. A thermometer immersed into the water will cease to rise as soon as the boiling commences. Unless the water is confined by external pressure, it cannot be heated above 212°. The steam, as it rises from the water, has the same temperature as the boiling water. But after water has been heated to the boiling point, it still requires a great amount of heat to convert it into steam. This added heat becomes insensible in the steam.

22. The boiling point of a liquid, such as water, is greatly modified by outward pressure. The atmosphere at the surface of the sea exerts a pressure of about 15 pounds on every square inch of surface. On the tops of high mountains, the pressure is much less, because a large portion of the atmosphere is beneath us. Here water will boil below 212°. If the pressure of the air can be diminished in any other way, a similar result follows.

Fig. 6.

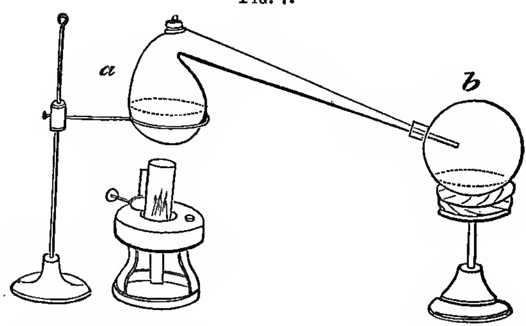


Experiment.—Fill a glass flask half full of water (Fig. 6), and boil it a few minutes, till the air is all expelled by the steam. While still boiling, cork it tightly, and invert it into a glass tumbler or cup, with a little water in the bottom. Apply a cloth dipped in cold water to the top of the flask as now inverted, and the water will boil violently. This will take place even after the flask becomes cool enough to be held comfortably in the hand. If hot water is applied to the outside of the flask, instead of cold, the boiling will cease. To understand this beautiful and interesting experiment, we must remember that the air has all been expelled, and nothing but the vapor of water remains above the surface of the water in the flask. When cold water is applied, this vapor is rapidly condensed, and its pressure on the water diminished. Under this diminished pressure, the water boils at a low temperature. Hot water, however, instead of condensing the vapor, tends to expand it; and thus the pressure is increased, and the boiling checked.

23. DISTILLATION.—Two liquids, which boil at different temperatures, may be separated by distillation; or a volatile liquid may be separated from involatile substances held in solution by it.

Experiments.—1. Put a mixture of equal parts of alcohol and water in the retort, *a* (Fig. 7). Insert the neck of

FIG. 7.



the retort into the receiver, *b*, kept cool by being placed in a basin of cold water. Apply a lamp to the retort, and regulate the heat so that the boiling will go on slowly. As the liquid disappears from the retort, a portion of it will be found condensed again in the receiver. When about the half of it has thus passed over to the receiver, examine the two portions; and it will be found that what is left in the retort is much weaker than the original mixture, while that portion in the receiver is much stronger. The alcohol, being more volatile than water, has passed over more rapidly. 2. Empty the retort and receiver, and use clean spring-water instead of the mixture. The mineral matter, some of which is always found even in the purest springs, will remain in the retort; while pure water will be collected in the receiver. Water should be thus distilled before it is used in preparing solutions of chemical substances.

24. ATMOSPHERIC VAPOR. — Water is continually evaporated from the surface of the earth, from rivers, seas, and oceans, and, ascending, mingles with the air in vast quantities. It is found in the atmosphere in two conditions. (1) In a visible form, as clouds and fogs. (2) In the form of *true vapor*, which is entirely invisible. If the air were removed, that is, if the space above the surface of the earth were a vacuum (with reference to air), evaporation would go on much more rapidly than it now does, until the whole world would be surrounded by an atmosphere of vapor. The air checks evaporation.

The quantity of vapor required to fill a given space, at a maximum density, varies with the temperature (below 212° F.), increasing as the temperature rises, and diminishing as the temperature falls. When the space is entirely filled, the vapor is said to have its "maximum density," for the temperature it then has. The vapor of water required to fill a cubic foot of space, at 32° F., weighs about 2⅓ grains; while that required to fill the same space, at 212°, weighs 258½ grains. If the vapor were heated only to 100°, then 19¼ grains would fill the cubic foot of space.

25. Although the presence of the air causes evaporation to go on more slowly, yet the *quantity* of vapor which will ultimately be required to fill a given space, at any given

temperature, will always be the same, whether the air is present or not. And the vapor will not cease to rise till it has reached its maximum density. Whenever this takes place, the air is generally said to be "saturated with moisture." The temperature of the vapor mingled with the air varies with the temperature of the air. When the vapor has its greatest density at any temperature, and the air is cooled below that temperature, the vapor is also cooled. Less of it will then saturate the air (or fill the space), and the remainder must be condensed into the form of water.

When the air is cooled down until the vapor which it contains begins to be deposited as little particles of moisture, that temperature is called the "dew-point."

26. If the vapor in air has nearly its greatest density, the air is said to be *damp;* but if there is not vapor enough present to give it near its greatest density, the air is said to be *dry*. If damp air has its temperature *reduced* but a few degrees, a part of its moisture is condensed; but if its temperature is *elevated* a few degrees, it becomes *apparently dry;* that is, its vapor, with the increase of temperature, is no longer capable of filling the space it occupies. On the other hand, dry air may become damp by being cooled; for the reduction of temperature may be sufficient to bring the vapor to its state of greatest density for that temperature. It is then readily deposited as moisture.

When the temperature of air is reduced below the dew-point, a portion of the vapor present becomes condensed, and assumes a visible form, either like *dew*, on the surfaces of solid bodies, or like *mist*, floating in the air.

27. Dew and Frost. — *Experiments.* 1. Fill a bright cup of silver or tin half full of water, and place a thermometer in it. Wipe the outer surface of the cup perfectly dry; then drop small lumps of ice into the water at short intervals. On a warm summer day, the moisture from the

air will soon begin to dim the bright surface of the cup. The temperature indicated by the thermometer at that moment, is the temperature at which the vapor of the air begins to be condensed: it is the dew-point. — 2. Put a mixture of ice and salt into the cup, instead of ice-water, and the moisture will be frozen as it collects upon the surface. It is then *frost* — frozen dew.

After the sun, the great source of heat, has gone down, solid bodies on the earth radiate their heat rapidly into the atmosphere, while the atmosphere itself radiates but slowly. As these bodies radiate heat, their temperature gradually falls; and they cool down the particles of air which come in contact with them, and also the particles of vapor mingled with the air. Whenever the temperature is thus brought below the dew-point, dew begins to be deposited. When the receiving surfaces are below 32°, the dew is frozen, and becomes frost.

28. If the air is agitated by winds, dew and frost are not so readily deposited; because no portion of the air is then allowed to remain long enough in contact with the cold surfaces of bodies on the ground, to be brought down to the required temperature. In low valleys we very frequently find vegetation covered with dew or killed by frost, while the same effects are not produced on the surrounding hills. This is owing to the fact, that the confined portions of air along the valleys remain tranquil, while those on the hills are disturbed by currents of wind.

Clouds reflect the heat radiated from the earth's surface, and thus prevent the temperature from being reduced to the dew-point. Hence, there is no dew on cloudy nights.

Surfaces which radiate most freely are cooled most rapidly at night, and consequently collect dew in greatest abundance. This is the case with green vegetable substances. Plants which especially need the dew, have thus been organized by an all-wise Creator, that they might collect it readily from the air. In some countries, the dews are almost the only source of moisture for plants for many successive weeks.

29. RAIN.—When two equal portions of air at widely different temperatures are mingled, the resulting temperature will be a mean between the two. But if both portions were nearly saturated with moisture before they were mingled, this moisture can now no longer remain in the form of vapor; because the quantity of vapor required to fill the space occupied by the two bodies of air at their *mean temperature*, is *less* than was required when they had widely different temperatures. A portion of the vapor, then, must be changed to *mist* or *cloud*.

Illustration.—5000 cu. inches of air at 32° can contain only about 10 grains of vapor.

5000 cu. inches of air at 59° can contain only about 20 grains of vapor.

5000 cu. inches of air at 86° can contain as much as 40 grains of vapor.

Now, suppose the first portion of 5000 cu. inches, at 32°, to be mingled with the third, at 86°: their mean temperature will be that of the second portion (59°); but the resulting 10000 cu. inches, at this temperature, can contain only 40 grains, while they unitedly had 50 grains before they were brought together. The surplus 10 grains of vapor must now appear in a condensed form. When currents in the atmosphere meet and mingle in this way on a large scale, immense quantities of moisture are condensed in the form of minute hollow globules, which, uniting, form rain-drops, and fall to the earth. If, from great elevation, or any other cause, the drops become frozen before they reach the earth, they come down as *hail* or *sleet*. When the moisture is condensed at a temperature below 32°, it forms minute crystals, instead of globules; and these, uniting in clusters, form *flakes of snow*.

30. *Fogs* are clouds formed near the earth's surface. This happens around islands and along the sea-shore, when the cool air from elevated land flows down and mingles with the warm, moist air over the surface of the water. The same phenomenon is witnessed in valleys, and especially along large rivers, in spring and autumn, when the days are warm and the nights cool: the cool, dense air from the surrounding hills flows down and mingles with the warmer air along the water. Whenever such a mingled mass of air has a temperature too low for all its moisture to retain the form of vapor, a portion of fog will make its appearance.

Fortunate is it for our comfort, that the air plays so conspicuous a part in regulating the evaporation of moisture. We can see the hand of a kind Providence in so constituting the air, that it presents a perpetual impediment to evaporation. If it had been so constituted that evaporation and condensation could go on as freely in it, as they do *in vacuo*, the atmosphere would be ever reeking with moisture: no sooner would a slight elevation of temperature take place, than a sudden rise of vapor from the earth would follow, and the vapor of the air be brought to the condition of maximum density. Then, every portion of the atmosphere being in this condition, the least diminution of temperature would produce a cloud or a mist; and every object surrounded by the air would be drenched by a copious deposit of dew, whenever by any means its temperature happened to fall below that of the atmosphere. *Drought* and *drenching* would then be the alternate effects of elevations and depressions of temperature.

LIGHT.

31. We shall not stop to discuss the nature of light, nor any of its effects, except such as relate to our immediate subject.

32. The great natural source of light is the sun. Artificial light is generally the result of heat produced by chemical action; by combustion. Whatever may be the source of light, it passes off from luminous bodies in straight lines; and is either absorbed by the bodies on which it falls; or is thrown back from their surfaces (*reflected*); or passes through them (*transmitted*). Reflected light enables us to see the objects around us, by passing from them to the eye. The colors of objects are determined by the manner in which they reflect light.

33. Light has a remarkable effect upon the heat which accompanies it. This is seen in some of the peculiarities of the heat produced by the sun. The light seems to have the effect of making it pass freely through transparent substances, such as air and glass, without affecting their temperature to any considerable extent. If this were not the case, but little of the sun's heat would reach the earth. The heat of the sun accompanied by light, has the property of being absorbed more freely by dark surfaces, than heat without light.

34. The effects of light on chemical affinity are remarkable. Some substances are decomposed by it, while others are caused to combine.

Experiment.—Moisten a piece of white paper or linen with some solution of lunar caustic (nitrate of silver), and lay it for a few minutes in the sunlight. It will become dark—almost black. Here the light decomposes the nitrate of silver.

Illustrations.—The effect of light upon chemical action is beautifully illustrated in the process of taking Daguerreotypes, ambrotypes, etc.

Light is necessary to the healthful growth of plants and animals. Every one is familiar with the difference in the appearance and vigor of the same kind of plant, when growing in a shaded place, and in the full light of the sun. Very few plants will come to full maturity without a full supply of light. Animals, too, generally require light. The lower animals, as well as men, never attain to much vigor if they are shut up in the dark during the period of their growth.

ELECTRICITY.

35. That form of electrical excitement produced by the galvanic battery, is one of the most powerful chemical agencies within our reach, and enables us to perform some of the most interesting and striking experiments. But our present purpose demands only a few of the leading facts and principles on this subject; such as are necessary to a clear and full understanding of the laws of chemical affinity.

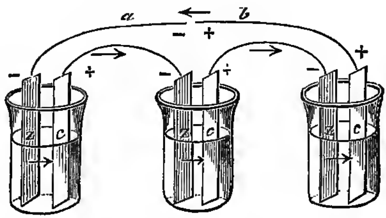
36. "When two solid conducting bodies are plunged into a liquid which acts upon them unequally, the electric equilibrium is also disturbed — the one acquiring what is called the *positive* condition, and the other the *negative*. Thus, pieces of zinc and platinum (or copper), put into dilute sulphuric acid (oil of vitriol, with 5 or 6 parts of water), constitute an arrangement capable of generating electrical force: the zinc, being the metal attacked, becomes negative (above the liquid); and the platinum (or copper) remaining unaltered, assumes the positive condition; and on making the metallic communication in any way (as at *a*, Fig. 8) between the two plates, a discharge ensues, as when the two surfaces of a coated and charged jar are put into connection.

FIG. 8.

"No sooner, however, has this occurred, than the disturbance is repeated; and, as these successive charges and discharges take place through the fluid and metals with inconceivable rapidity, the result is an apparently continuous action, to which the term *electrical current* is given."—*Fownes.*

37. With a single pair of plates, as above described, the degree of excitement is very feeble; but if we arrange several pairs as in Fig. 9, having the zinc and copper in

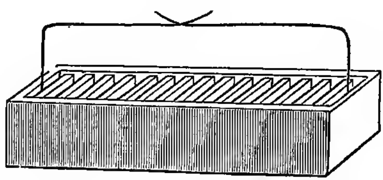
FIG. 9.



contiguous cups connected by wires soldered to each other, and placing them so that the different metals shall succeed each other in the same order; then connect the first and last plate by wires (*a*, *b*), we have a compound circuit. This gives us the simplest form of the galvanic battery. The ends of *a* and *b* are called the poles of the battery. The one marked, +, is the positive; and the one marked, —, is the negative.

38. Another very simple form of the battery is represented in Fig. 10. It consists of a wooden trough with per-

FIG. 10.

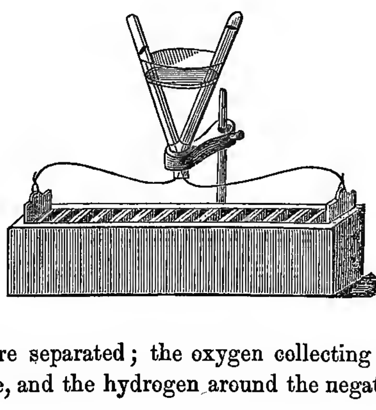


pendicular grooves in the sides, and corresponding grooves across the bottom. Into these are fitted pairs of zinc and copper plates, soldered back to back, and having all the copper plates facing the same way. They are then to be carefully cemented into the grooves. The trough is thus divided into cells for holding the mixture of acid and water with which the battery is charged. At the extremities of the last cells, plates are to be inserted for the connecting wires: one of zinc, so placed as to be opposite to and facing the last copper; the other of copper, facing in like manner the zinc at the opposite end of the trough.

39. There are various other forms of the battery in use, among the best of which is Grove's. This is the one most commonly used on telegraph lines. We have not room for a description of it here. It is described in most of the larger works on Chemistry.

40. Whatever may be the form of the battery, if the poles are tipped with little strips of platinum foil, and immersed into water, to which a little sulphuric acid has been added, bubbles of gas will rise rapidly around both poles. The water is decomposed. The oxygen and hydrogen of which it is

FIG. 11.



composed are separated; the oxygen collecting around the positive pole, and the hydrogen around the negative. These gases may be collected by filling test-tubes with water, and inverting them over the poles of the battery, by some such arrangement as that seen in Fig. 11. The tube over the negative pole, into which the hydrogen passes, will be filled twice as rapidly as the other; showing that the hydrogen of water occupies twice the volume of the oxygen. But if we could weigh the two gases, we would find the oxygen *eight times as heavy* as the hydrogen.

41. *Experiment.*—Mix a few grains of starch with a spoonful of cold water; then add the mixture slowly to half-a-pint of boiling water, stirring as you pour it in. You will thus get a dilute solution of starch. When this has become cold, pour into it a little of the solution of iodide of potassium. Then put the mixture into a tumbler, and bend the poles of the battery over the opposite sides of the tumbler, so that the strips of platinum will dip a little way into the solution. If the battery is now put into action, the solution soon becomes of a deep blue color around the positive pole, while there is no change of color around the negative. The battery decomposes the iodide of potassium, which is composed of iodine and potassium combined. The iodine is collected around the positive pole, free from the potassium, which has gone to the negative pole. But so soon as the iodine is set free, it attacks the starch in the solution, and, uniting with it, forms a beautiful blue compound, called *iodide* of starch. The starch in the solution is not affected by the battery: it is used in this experiment to show the presence of the free iodine around the positive pole.

Many other substances may be decomposed with the battery; but the above will serve to illustrate, sufficiently for our present purpose, the action of this wonderful piece of apparatus.

The influence of *Vitality* will be shown in connection with organic chemistry.

QUESTIONS ON CHAPTER II.

§ 10. How is the term "caloric" applied? In what sense is "heat" here used? Why is heat an important agency to the chemist?

11. What is the greatest source of heat? What are other sources?

12. When is heat said to be absorbed? When reflected? Illustrate. What kind of surface should a stove have? Why? Coffee-pot? Why? How does dark color affect soil?

13. What bodies are *conductors?* Non-conductors? Is water a good conductor? How illustrated by experiment?

14. What is the influence of heat on the dimensions of a body? What experiments illustrate expansion of solids? Of liquids? Of gases?

15, 16. How is a tire fitted to a wagon-wheel? Explain the structure of the common *Thermometer*. What principle does its action illustrate?

17, 18. To what degree of temperature does water contract when cooled? What takes place at the moment of freezing? What would be the result if contraction should continue, with continued reduction of temperature? Why does ice float? How does freezing affect the soil? What are the effects of expansion and contraction in the air?

19. In what conditions do all bodies exist? What determines these differences in form? How illustrated?

20. What is insensible heat? Why does the temperature fall rapidly in a mixture of salt and ice? Explain the preparation of *ice-cream.*

21. At what temperature does water boil? If a thermometer is immersed in it, will it rise above 212°? What becomes of the heat continually added?

22. How does change of pressure influence the boiling point? How illustrated? Why does cold water applied to the flask increase the boiling, while hot water diminishes it?

23. What kind of substances may be separated by distillation? How are alcohol and water separated? How is water purified? Is not spring-water pure? Why not?

24. From what sources does the air receive moisture? In what conditions does moisture exist in the air? What determines the

quantity of vapor required to fill a given space below 212°? When has vapor its greatest density? Illustrate.

25. Does the presence of air diminish the quantity of vapor required to fill a given space? How does the temperature of the air influence the temperature of the vapor present? What is meant by the "dew-point"?

26. When is air *damp?* When dry? What if the temperature of damp air be reduced? What if it be elevated? How may dry air be made apparently damp? When does the vapor become *visible?*

27. Explain the deposition of moisture on the surface of a cool cup. When does it become *frost?* How are *dew* and *frost* formed at night?

28. Influence of winds on the formation of dew? Why is vegetation frequently killed by frost in valleys, while it escapes on the surrounding hills? How do clouds prevent dew and frost? What surfaces receive most dew? Who made this provision? Why?

29. When do mingled portions of air form clouds? How illustrated? How are rain-drops formed? Hail? Snow?

30. What are *fogs?* Where most frequently seen? Why? If the air did not regulate evaporation and condensation, what would be the consequence?

31, 32. Great natural source of *Light?* Sources of artificial light? In what ways is light disposed of when it falls upon the surface of bodies? What determines *color?*

33. Influence of light on transmission of heat? How is the air heated?

34. What is said of influence of light on *affinity?* How illustrated? Influence on *vegetation?*

35, 36. What is said of *Electricity* produced by the galvanic battery? What if two solid conductors are acted upon unequally by an acid liquid? Explain Fig. 8. What is called the "electric current"?

37, 38, 39. Effect of increasing the number of plates? Explain Fig. 9. How is a battery constructed?

40, 41. How is water decomposed by the battery? What experiments are here given?

CHAPTER III.

SYMBOLS—EQUIVALENTS—NOMENCLATURE.

42. THERE are sixty-five elementary substances known to chemists (see § 5). These unite and form all the various compounds of which we have any knowledge. Many of them, however, are rare and unimportant. We shall take time to describe only twenty-eight of the most important. These will be found in a table on the next page.

SYMBOLS.

43. It is not always convenient to write the names of substances in full; hence we employ what are called *symbols*. These consist of the first letter, or some two letters, of the names; thus, C is the symbol for carbon; H for hydrogen; Al for aluminum; Mn for manganese. When the substance has a Latin name, we use the first letter or letters of this as its symbol; thus, K stands for potassium (from *kalium*, its Latin name). So Sb (from *stibium*) is the symbol for antimony; and Fe (from *ferrum*) for iron.

EQUIVALENTS.

44. When elementary substances combine to form compounds (§ 5 and 6), they enter into the compounds in *definite proportions* by weight. Hydrogen and oxygen are combined in water, in the proportion of 1 to 8 (§ 40). That is, the oxygen in water (in all pure water) weighs eight times as much as the hydrogen. When hydrogen and sulphur combine to form the disagreeable gas which rises from sulphur springs, the proportion is 1 of hydrogen to 16 of sulphur. And as hydrogen enters into combination in a less

relative weight than any other elementary substance, we take its combining weight as 1; then that of oxygen will be 8; and that of sulphur 16. These numbers are supposed to represent the relative *weights of the atoms*, or smallest particles, of the substances to which they belong; hence they are called *atomic weights*, or *combining equivalents.*

Iron may take the place of hydrogen in some compounds, and cause the hydrogen to escape; but, for every *single grain* of hydrogen displaced, *twenty-eight* grains of iron must enter to fill its place. If *single atoms* of iron have displaced *single atoms* of hydrogen, the atoms of iron must weigh twenty-eight times as much as the atoms of hydrogen. The 28 parts of iron are said to be *equivalent* to 1 part of hydrogen. The number 28, then, represents the *combining equivalent* of iron; or, which is the same thing, its *atomic weight.* This last is the term by which we shall designate these numbers.

45. The symbols and atomic weights of some of the most important substances are given in the following

TABLE I.

NAMES.	Symbols.	Atomic Weights.	NAMES.	Symbols.	Atomic Weights.
Aluminum	Al	13.69	Manganese	Mn	27.67
Antimony (Stibium)	Sb	129.	Mercury (Hydrargyrum)	Hg	100.
Arsenic	As	75.	Nickel	Ni	29.57
Barium	Ba	68.64	Nitrogen, or Azote	N	14.
Calcium	Ca	20.	Oxygen	O	8.
Carbon	C	6.	Phosphorus	P	32.
Chlorine	Cl	35.50	Platinum	Pt	98.68
Copper (Cuprum)	Cu	31.70	Potassium (Kalium)	K	39.
Gold (Aurum)	Au	98.33	Silicium, or Silicon	Si	21.35
HYDROGEN	H	1.	Silver (Argentum)	Ag	108.
Iodine	I	126.36	Sodium (Natrium)	Na	23.
Iron (Ferrum)	Fe	28.	Sulphur	S	16.
Lead (Plumbum)	Pb	103.50	Tin (Stannum)	Sn	58.82
Magnesium	Mg	12.67	Zinc	Zn	32.50

In some books the atomic weights are given with reference to O, taken as 100. Then H would be 12,50; C would be 75; Hg 1200, etc.

46. When we wish to indicate that two substances combine, in the ratio of their atomic weights, we write their symbols together. Thus, HO denotes that hydrogen and oxygen are combined in the ratio of 1 to 8. FeS denotes a combination of iron and sulphur in the ratio of 28 to 16.

47. One substance may combine with another in several different proportions; but when this happens, it combines in the ratio of *once*, *twice*, or *thrice* its atomic weights, or some other multiple of that weight. In such a case the symbol is written with a number either before or after it, showing how many times its atomic weight is to be taken. Thus, S, 2S, 3S, or S, S_2, S_3, indicate one, two, or three times the atomic weight of sulphur. FeS shows that Fe and S are combined in the ratio of 28 to 16; but FeS_2 shows that they are combined in the ratio of 28 to 32 ($= 16 \times 2$). NO, NO_2, NO_3, NO_4, NO_5, represent five different compounds of N and O. In the first, these elements unite in the ratio of 14 to 8; in the second, of 14 to 16; in the third, 14 to 24; in the fourth, 14 to 32, etc.

48. The atomic weight of a compound is made up of the sum of the atomic weights of its constituent elements. For example, FeO is a compound of iron and oxygen, and represents one atom of that compound. Its atomic weight, then, is $28 + 8 = 36$. SO_3 is the symbol for sulphuric acid, a compound of one atom of sulphur united to three atoms of oxygen. Its atomic weight is $16 + 24 = 40$. FeO and SO_3 unite, then, in the ratio of 36 to 40, and form a compound having for its symbol FeO,SO_3.

NOMENCLATURE.

49. No one could possibly remember the names of all the various compounds he meets with, nor could he remember their composition, unless the name and composition were in

some way associated. This has been most happily done by the system of *naming*, first adopted by the French Academy of Sciences in 1787, and now in general use—modified only to suit the progress of science, and the languages of different countries. In this system of *nomenclature*, the more common substances which have been long in use are allowed to retain their old names; as, iron, gold, sulphur, etc. Some newly-discovered elements have received names from some of their prominent properties; as chlorine, from *chloros*, pale green, the color of the gas. So bromine, from *bromos*, referring to its bad odor.

50. *Two* elements combined form a *binary* compound; *three* a *ternary; four* a *quarternary*, etc. The names of such compounds are so constructed as to indicate their composition. When oxygen combines with another element, the compound is called an *oxide* (unless it has *acid* properties); as, FeO, called *oxide* of iron; CuO, oxide of copper; CO, oxide of carbon. When a *single* atom of oxygen combines with another element, it is called the *protoxide;* when there are two atoms of oxygen, it is called the *deutoxide*, or *binoxide;* when three, the *tritoxide*, or *teroxide;* as, PbO is *protoxide* of lead, PbO_2 the *deutoxide*, etc. When there is one atom of O to two or more of the other element, it forms a *suboxide;* as, Cu_2O, the *suboxide* of copper; and Pb_2O, the *suboxide* of lead. A *sesquioxide* is a compound having *three* atoms of oxygen to *two* of the other element; as, Fe_2O_3, the *sesquioxide* of iron; Al_2O_3, *sesquioxide* of aluminum. *Peroxide* indicates the *highest* degree of oxidation, next below the acid compounds of the same element; as, MnO_2 is the *peroxide* of manganese; and Fe_2O_3 is the *peroxide* of iron.

51. If we have compounds containing *chlorine, bromine*, or *iodine*, instead of oxygen, we call them *chlorides, bromides*, or *iodides.* AgCl is *chloride* of silver; and KI is *iodide*

of potassium. Many compounds containing *sulphur*, *phosphorus*, and some other elements, have the termination *-uret* to their names. CuS is *sulphuret* of copper; FeS_2 is *bisulphuret* of iron.

52. Many compounds containing oxygen are *acids*. These have their names from substances with which the O is combined, with the terminations *-ous* and *-ic*. Thus, NO_3 is nitr*ous* acid; and NO_5 is nitr*ic* acid. The acid ending in *-ic* is stronger than that ending in *-ous*. Sulphur*ic* is a stronger acid than sulphur*ous*.

53. When the oxides of the metals have such properties as cause them to unite readily with acids, they are called *bases*. The compound resulting from the union of an *acid* and *base* is called a *salt*. The name of a salt is made up of the names of the acid and base of which it is composed—the acid giving the first, or generic, part of the name. When the acid name ends in *-ic*, the corresponding part of the salt name ends in *-ate*. Sulphuric acid forms sulph*ates*. When the acid name ends in *-ous*, the salt name ends in *-ite*. Sulphurous acid gives sulph*ites*. KO is potassa. SO_3 is sulphur*ic* acid. SO_2 is sulphur*ous* acid. Then KO,SO_3 is sulph*ate* of potassa; and KO,SO_2 is sulph*ite* of potassa.

Where several acids contain different proportions of oxygen, the prefixes *hyper* and *hypo* are sometimes used—the former denoting *above*, and the latter *below*. For example, NO_3, NO_4, NO_5, are nitrogen acids. The *first* is nitrous acid, the *third* nitric; and the *second*, coming between them, is usually called *hypo*-nitric acid, because it is *below* nitric acid in its oxidation. It might, with equal propriety, be called *hyper*-nitrous acid. The salts formed in the combination of such acids with bases, retain the same prefixes. Thus, hypo-nitric acid, with soda, forms what is called hypo-nitrate of soda.

QUESTIONS ON CHAPTER III.

§ 42. How many elementary substances are known? Are many of them important?

43. Why are symbols used? Of what do they consist? For what do C, H, and Al stand? What if the substance has a Latin name? Of what are K, Sb, and Fe the symbols?

44, 45. What is an elementary substance? What is a compound? How do elementary substances always combine? In what proportion do H and O combine in pure water? The proportion of H and S in the gas of sulphur springs? Why is H taken as the unit, or = 1? What are atomic weights? Why are 28 parts of iron said to be *equivalent*, in chemical combination, to only 1 part of hydrogen? What are given in Table I?

46. How do we write substances, so as to indicate that they combine in the ratio of their atomic weights? Explain the compound symbols, HO, FeS, KO, CaO, and NaCl?

47. If one substance combines with another in several proportions, what is the law? How are the symbols then written? Explain FeS, FeS_2; NO, NO_2, NO_3, NO_4, NO_5.

48. How is the atomic weight of a compound made up? Explain FeO and SO_3; also FeO,SO_3.

49. Would it be easy to remember the names of all chemical compounds? Why not? What system has been adopted to aid the memory? How are common substances named? Those newly discovered?

50. What are *binary*, *ternary*, and *quarternary* compounds? What are *oxides?* What do FeO, CuO, and CO indicate? What do you call PbO and PbO_2; Cu_2O and Pb_2O? What are Fe_2O_3 and Al_2O_3 called?

51. If a compound contains iodine, chlorine, etc. what name is given to it? Name AgCl, KI, and NaCl. When is the termination *-uret* used?

52. How are *acids* named? Names of NO_3 and NO_5? What difference between *sulphurous* and *sulphuric* acids?

53. What is a *base?* A *salt?* How named? How are *hyper* and *hypo* used? Illustrate.

CHAPTER IV.

METALLOIDS.

54. Let us now examine the leading properties of the most important elementary substances, and of some of the compounds which they form by their various combinations.

Of the elements given in Table I (§ 45), carbon, chlorine, hydrogen, iodine, nitrogen, oxygen, phosphorus, silicon, and sulphur, are usually regarded as non-metallic substances, or *metalloids;* while all others there given are regarded as *metals.**

OXYGEN (*Symbol,* O; *At. Wt.* 8).

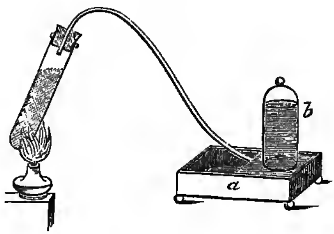
55. This is the most important, as well as the most abundant, of the elementary substances. It enters into the composition of almost everything we see around us. It constitutes $\frac{8}{9}$ of the weight of water, about $\frac{1}{5}$ of the air, a large portion of the substance of all rocks and soils, and is an abundant element in nearly all animal and vegetable substances. Hence, we take it first in order.

56. The properties of oxygen may be best studied in connection with a few experiments. For this purpose it is most conveniently prepared from *chlorate of potassa,* by the following process. *Exp.* Pulverize an ounce of the chlorate, and mix with it about half-an-ounce of black oxide of manganese, (or fine, clean sand will do tolerably well instead of the manganese). Fill a large test-tube about two-thirds full of the mixture, and attach a bent tube to the mouth of it,

* The distinction between metals and metalloids is not very definite. *Hydrogen,* for instance, has more of the chemical properties of a metal, than are found in *arsenic.*

fitted air-tight by means of a cork, as in Fig. 12. Apply a spirit-lamp, moving the flame upward and downward along the tube a few times, to prevent it from breaking. The gas will soon begin to escape rapidly, and may be collected over

FIG. 12.



a vessel of water (*a*), in an inverted jar (*b*)—the jar being previously filled with water, and supported on a perforated shelf fixed in one side of the vessel, at such a height that it shall be covered to the depth of an inch or two by the water. A vessel thus arranged is called a *pneumatic cistern*, and may be in the shape of a box (or a *tub*, which answers the purpose very well). This method is generally employed in collecting all gases which are not absorbed by water. Bottles with wide necks, and common fruit-jars, may be used as receivers in which to collect gases.

Let us now see what change the heat has produced on the chlorate of potassa, so as to send off oxygen gas. An atom of the chlorate has for its symbol, KO,ClO_5: when heated, the K and Cl unite, and all of the oxygen escapes. The result is expressed thus: $KCl + O_6$, being one atom of chloride of potassium, and six of oxygen. The whole of the KCl remains in the tube with the manganese.

57. *Experiments.*—1. Fill three or four quart bottles or jars with oxygen gas at the pneumatic cistern. Slip them off the shelf, with the mouths still inverted, into saucers or

small plates, without lifting them out of the water; and set them upon your table for further use. A little water around the mouth of the bottle or jar, as it stands inverted in the saucer, will prevent the gas from escaping. 2. Wrap one end of a piece of wire around the lower end of a short candle, and turn the straight part of the wire upward. Light the candle, turn up the mouth of one of your bottles of gas, and immerse the lighted candle into it (Fig. 13). The candle will burn much more brilliantly than it did in the open air; and if blown out and returned to the gas with the smallest spark on the wick, it is immediately relighted. 3. Scoop out a small cavity in a lump of chalk, and suspend it by a piece of wire in the same way the candle was suspended, with the cavity turned upward, so as to form a little cup. In this place a lump of phosphorus half the size of a pea, ignite it, and immerse it into a second bottle or jar of gas; and you will have a most dazzling light as the result. 4. Make a coil of small iron or steel wire, by bending it around a tube or stick. Wrap a bit of twine around the lower extremity of the wire, and dip it into oil or melted tallow. Insert the upper end of the wire into a cork, fitted to one of your bottles (Fig. 14). Ignite the twine at the bottom of the coil, and let it down into the gas. The burning of the oiled twine will ignite the wire, and the coil will be rapidly consumed, throwing off sparks on all sides, and affording one of the most beautiful of our experiments. A watch-spring may be burned in the same way.

Fig. 13.

Fig. 14.

From the foregoing experiments we conclude: (1) That oxygen is a colorless gas, not rapidly absorbed by water. (2) That bodies which burn in air, burn still more brilliantly in this gas. (3) That some bodies not easily burned in air, may be rapidly consumed in pure oxygen. If we weigh this gas, we shall find it a little heavier than air.

58. The presence of oxygen in the air is necessary to support combustion, and also to sustain animal life; but our Creator has wisely and kindly diluted it with a harmless gas (nitrogen), which modifies its effects. If our atmosphere were pure oxygen, everything combustible on the earth would soon be consumed. Our blood, too, would become overcharged with the gas, and death would be the speedy result.

For the effects of oxygen on decaying organic matter, see § 147.

HYDROGEN (*Symbol*, H; *At. Wt.* 1).

59. We have seen H set free by the galvanic battery (§ 40). It constitutes $\frac{1}{9}$ of the weight of water, and forms an essential element in almost all animal and vegetable compounds.

Experiments.—1. Put a few fragments of zinc* into a common bottle with a wide neck, and fit to it a cork provided with two tubes—one leading to the pneumatic cistern; the other, with a little funnel at the top, extending nearly to the bottom of the bottle (Fig. 15). A little water is to be poured into the bottle through the funnel-tube, until the lower end of the tube is covered. A little hydrated sulphuric acid (HO,SO_3) added, will be acted on by the zinc in such a way as to have its hydrogen set free. The first portions which pass over will be mixed with the air previously in the bottle, and should, therefore, be allowed to escape before the bent tube is placed under the receiver. The action of affin-

Fig. 15.

* Zinc melted and poured into cold water is divided into porous fragments (granulated), and is then in a good condition to be used in this experiment.

ity between the Zn and HO,SO_3 may be expressed by a formula, thus:

$$HO,SO_3 + Zn = ZnO,SO_3 + H.$$

Here we see that Zn has taken the place of H in the sulphuric acid. Sulphate of zinc (ZnO,SO_3) remains dissolved in the water of the bottle. 2. Having collected several jars of the gas, lift one of them slowly from the shelf of the cistern, keeping the mouth downward. The gas, being much lighter than air, will remain in the jar. Insert a lighted candle into it, as in Fig. 16. A slight explosion will follow, whilst the gas will burn with a pale flame around the mouth of the jar. 3. Fill a tin tube, having a small hole near the closed end, about one-third full of H, and two-thirds full of air, and close the mouth of the tube loosely with a cork. A flame applied to the hole in the tube will instantly ignite the mixture, causing a loud report, and throwing the cork out with considerable force. 4. Put a handful of zinc fragments into a pint bottle (*a*) with a small neck, and adapt a piece of clay pipe-stem (*b*) to it with a cork (Fig. 17). Fill the bottle half-full of a mixture of one part of sulphuric acid with four or five of water. Insert the cork and tube, and after waiting a minute or two, till the air has been expelled by the gas, you may ignite the jet of gas at the top of the tube: you then have the "*philosopher's candle.*" 5. Hold a cool, dry jar with its mouth just over the burning jet of H; and the inner surface of the jar will soon be coated with a film of moisture.

FIG. 16.

FIG. 17.

60. We infer, then: (1) That H is a colorless gas, not readily absorbed by water, and much lighter than air. (2) That it explodes when mixed with air. (3) That when burned in air, the resulting compound is water.

61. *Water.*—Although we say that water is composed of H and O (and so it is, when perfectly pure), yet water free from foreign matter is seldom found in nature. Rain-water, which is the purest, collects impurities from the air. Spring-water always has more or less of some soluble salts, carried out by it from the soils and rocks through which it has passed. Sea-water contains several salts, of which common table-salt (chloride of sodium) is the most abundant. Medicinal springs owe their peculiar properties to substances dissolved from the earth. The waters of many springs contain substances (such as salts of lime, ammonia, etc.) which are beneficial to soils; hence, meadows and fields watered by them are increased in fertility (§ 425).

Seeds will not germinate, nor will plants grow, even in the best soil, without moisture. All the elements of nourishment received by the plant through its roots, must be dissolved before the plant can absorb them. A supply of water is also necessary for the health and growth of animals.

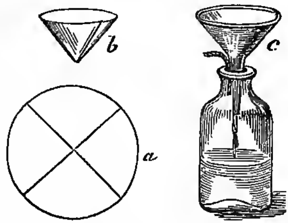
CARBON (*Symbol*, C; *At. Wt.* 6).

62. Carbon is one of the most important elements in nature. It constitutes the greater part of the solid matter of both plants and animals. It is the chief ingredient in the vast beds of mineral coal deposited among the rocks of the earth. The *diamond* is the purest form of carbon.

FIG. 18.

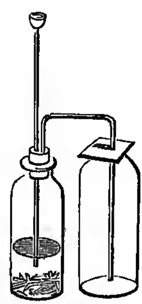
Experiments.—1. Ignite a dry stick (*b*) (Fig. 18), and as it burns to a coal, slip the tube (*a*) over the burnt part. The air is thus cut off, and the combustion checked. The volatile matter burns out first, and the black residuum is nearly pure carbon. 2. Weigh a piece of charcoal recently extinguished, and, after exposing it in the air for several hours, weigh it again. It will be found to have increased in weight. This is owing to its absorbing air and other gases. 3. A piece of porous paper, like that on which books and newspapers are printed, cut into a circular form, *a* (Fig. 19), and folded by the lines which cross it, may be opened in the form *b*, and placed in the funnel *c*, so as to form its inner lining. Such an arrangement constitutes a *filter*. Into a half-pint of colored vinegar stir a spoonful of finely-powdered charcoal; put a little of the charcoal also in the filter; then pour in the vinegar. As it trickles down from the funnel, it will be almost colorless. The charcoal has absorbed the coloring matter. Stagnant water may be rendered clear and sweet by a similar process.

FIG. 19.



63. *Carbonic Acid* (*Symb.* CO_2). — *Experiments.* 1. Suspend a piece of ignited charcoal in a bottle of oxygen gas (§ 57), and it will be rapidly consumed. The oxygen combines with the carbon, and forms carbonic acid, which is a colorless gas. If the bottle has been corked while the charcoal was burning, a candle let down into it will be extinguished. 2. Put a handful of fragments of marble or limestone into the same bottle used in collecting hydrogen (Fig. 15), and pour upon them a mixture of one part of sulphuric acid with five parts of water. The gas will escape with a brisk effervescence, and may be collected over warm water: cold water absorbs it rapidly. 3. It may also be conveniently collected in open bottles and jars, by the arrangement in Fig. 20. The gas, being about one and a half times as heavy as air, sinks to the bottom of the receiver, and, gradually

FIG. 20.



displacing the air, takes its place. 4. Stir a little freshly burnt lime into a bottle of water which has been recently boiled; cork it, and set it aside until the excess of lime has settled, and the solution becomes perfectly clear. You then have "lime-water." Pour a little of it into a bottle containing carbonic acid, and the solution at once becomes turbid — carbonate of lime is formed. 5. Put a mouse or other small animal into a jar of this gas, and it will soon die. 6. Invert a jar full of it over cold water: in a few hours the water will have absorbed a considerable quantity of the gas, as will be seen by the rising of the water in the jar.

64. The chemical changes which take place in the preparation of CO_2 from marble, may be represented in a formula, thus:

$$CaO,CO_2 \ (\textit{marble}) + HO,SO_3 \ (\textit{sulph. acid}) = CaO,SO_3 + HO + CO_2.$$

65. *Natural Sources.*—Combustion, respiration, and volcanic action, are some of the chief natural sources of CO_2. It is formed abundantly in the burning of wood or coal—the carbon of the fuel combining with the oxygen of the air. During the decay of vegetable and animal substances, which is a slow combustion, this gas is abundantly generated. Hence its accumulation in old cellars and wells. During the breathing of animals, large quantities of CO_2 are thrown out into the air (see § 625). It also rises abundantly from many springs, ponds, lakes, etc. especially in volcanic regions. The air, thus continually receiving supplies of this poisonous gas (poisonous except in very small quantities), would soon become unfit to sustain life, had not Providence furnished one of those compensating arrangements so often met with in the study of nature. It is this: growing plants extract CO_2 from the air. It is an important article of food for the plant. But while the plant consumes CO_2, it gives out a fresh supply of oxygen. Combustion and respiration con-

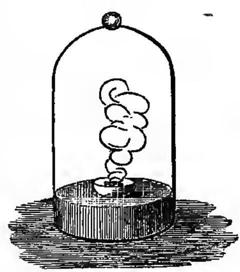
sume oxygen and generate carbonic acid, while vegetation consumes carbonic acid and generates oxygen; and thus the equilibrium of the air is preserved, in respect to these gases.

Carbonic acid is abundant in combination with different bases, as lime, potassa, soda, etc. forming a class of salts called *carbonates.*

NITROGEN, OR AZOTE (*Symbol,* N; *At. Wt.* 14).

66. *Preparation.*—This gas, as before stated, constitutes about $\frac{4}{5}$ of our atmosphere. From this source it is most conveniently procured. A little metallic capsule, or a flat piece of chalk with a cavity in the top, may be placed on a flat cork, and thus made to float on the surface of the pneumatic cistern. Place on this a little lump of phosphorus, ignite it, and immediately invert a jar over it, as in Fig. 21. The burning phosphorus consumes all of the oxygen within the receiver, and leaves the *nitrogen.* The water rises to take the place of the oxygen. The vapor of phosphoric acid, produced by the burning phosphorus, will subside in a few minutes, and leave the nitrogen as a transparent, colorless gas, a little lighter than air. For experiments, it may easily be transferred to bottles, by inverting the bottles, filled with water, over the hole in the shelf of the cistern; then slipping the mouth of the jar of gas beneath the shelf, and gradually turning it up, till the gas can escape, and pass up into the bottle.

FIG. 21.



Experiments.—1. Immerse a candle into a bottle of nitrogen, and it goes out at once, from the want of oxygen. 2. Place a small animal in a bottle of it, and it soon dies.

The N is not poisonous to the animal, but death is caused by the absence of oxygen.

The Atmosphere.

67. Besides the mixture of O and N, which constitutes the chief part of the atmosphere, small quantities of carbonic acid and other gases are found at every point accessible to man. The atmosphere is also a great reservoir of moisture, as we have seen (§ 24). It is the great agency, too, by which the circulation of water on land is kept up. The vapor of water is continually rising and mingling with the air, and, by the mechanical agency of winds, is carried from those parts of the earth where evaporation goes on most rapidly, to those parts where rain is most needed.

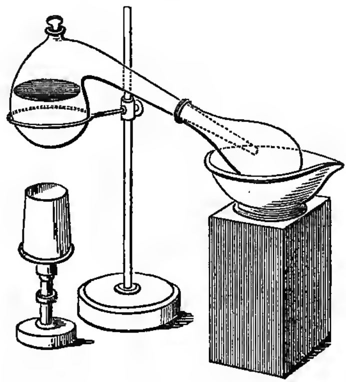
68. The atmosphere is one of the most important sources of nutrition for plants. If the air were deprived of moisture, all plants would wither, droop, and finally die. If carbonic acid and ammonia were taken away, our crops would soon be starved. Carbonic acid, absorbed by the leaves, and taken up by the roots in rain-water, which brings down large quantities of it from the air, is the great source of carbon in plants. Ammonia, too, affords nutriment no less important.

Nitrogen and Oxygen.

69. Nitrogen forms several interesting compounds with oxygen, but only one of these is important for our present purpose. This is *nitric acid* (NO_5).

Preparation. — Put three or four ounces of saltpetre (nitrate of potassa) into a retort (Fig. 22), and pour upon it an equal weight of sulphuric acid; then apply heat gradually, by means of a spirit-lamp or charcoal furnace. The neck of the retort must pass into a receiver or bottle, kept cool by being immersed in cold water, or by having a wet cloth spread over it, on which cool water is made to drip continually. The apparatus will at first be filled with red vapor, which is hyponitric acid, formed by the decomposition

FIG. 22.



of the first portions of nitric acid. This, however, will disappear after a while, and the nitric acid be distilled into the cool receiver, and there condensed as a liquid, colored by the presence of nitrous or hyponitrous acid. When nitric acid is pure, it is a colorless liquid, about once and a half times (1.52) as heavy as water.

Experiments.—1. Put a drop of it on a piece of colored cloth: it will destroy the color, and finally corrode the material of which the cloth is made. 2. Pour a little of the acid upon some powdered charcoal heated red-hot in a cup or crucible; brilliant combustion takes place. It will also ignite hot spirits of turpentine. 3. Dilute a little nitric acid with an equal quantity of water, and drop a fragment of copper into it. The copper will gradually disappear. It decomposes one portion of the acid, by taking away a part of its oxygen. This decomposed acid rises and forms the same red vapor in the air which we saw in the retort, when preparing nitric acid. After the copper has become oxidized at the expense of one portion of the acid, it at once combines with another portion, and forms *nitrate of copper* (CaO,NO_5). The solution has a green color. 4. Pour a little of this solution into some clear water in a saucer: the water will scarcely be colored; but add some ammonia-water (spirit of hartshorn), and you will have a beautiful blue color. This is one of the best tests for the presence of copper in a solution.

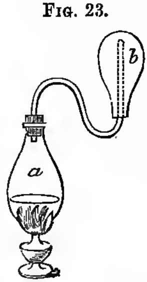
Nitric acid combines with a great number of bases, giving us an important class of salts called *nitrates.*

Nitrogen and Hydrogen.

70. *Ammonia* (NH_3).—This most valuable and interesting compound is not formed by the direct union of its two elements, under ordinary circumstances; but electricity will cause them to combine. This is supposed to take place high up in the air, under the influence of lightning. By the sam agency, nitric acid is also formed by the union of N and O, and this, combining with the ammonia, forms the nitrate of ammonia often found in rain-water.

Preparation.—Put equal weights of slacked lime and pulverized sal-ammoniac into a flask, and apply a gentle heat. A gas having a strong suffocating odor will be set free. The lime decomposes sal-ammoniac (NH_4Cl), thus: $CaO + NH_4Cl = CaCl + HO + NH_3$. It cannot be collected at the water-cistern, because water absorbs it with great rapidity. A small cistern filled with mercury, instead of water, enables us to collect it readily; but if there is no mercury-cistern at hand, it may be collected, with tolerable success, in a bottle (Fig. 23) inverted over the neck of the flask where it is generated.

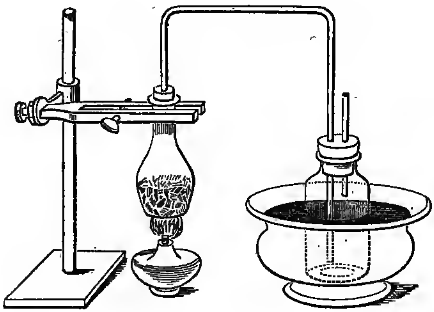
FIG. 23.



The gas, being much lighter than air, rises to the upper part of the bottle, and displaces the air.

Experiment.—By attaching a bent tube to the mouth of the flask in which ammonia is generated (Fig. 24), and

Fig. 24.



causing the end of it to dip into a bottle of cold water, kept cool by surrounding ice, or by being set into a larger vessel of cool water, we can obtain the solution of this gas called "*aqua ammoniæ.*"

71. *Chemical Properties.*—Ammonia is a strong alkaline base,* sometimes called "volatile alkali." It neutralizes the strongest acids, and, by its union with them, forms definite salts. But it is readily set free from its combinations by potassa or lime.

Experiment.—Rub a little sal-ammoniac and fresh lime together, and you may at once perceive the odor of the escaping ammonia. Ammonia is one of the most valuable ingredients in all animal manures, and every precaution

* An alkaline base is any compound which has a strong affinity for acids, and which, when combined with them, forms salts. Potassa, soda, and lime are alkaline bases.

should be taken to prevent its escape. Hence, fresh lime *should never be mixed* with animal manures, because it sets the ammonia free.

During the decay of many organic substances, such as dead animals and animal manures, ammonia is generated chiefly as a carbonate (NH_4O,CO_2), which is volatile, and will escape, unless in some way prevented. If gypsum in fine powder (ground plaster) is mingled with such manures, and water sprinkled freely over the heap, the gypsum, which is sulphate of lime (CaO,SO_3), will act upon the carbonate of ammonia in such a way that both compounds will be decomposed. The sulphate of lime will become the carbonate, and the carbonate of ammonia will become the sulphate. The carbonic and sulphuric acids exchange places. The sulphate of ammonia thus formed is not volatile, and hence the ammonia is said to be "fixed." But this sulphate is soluble; and hence the manure should not be exposed to heavy rains before it is applied to the soil, else much of the ammonia will be washed out and lost. Every farmer should be familiar with the properties of ammonia, and its relation to other compounds; hence, we shall have more to say about it under the head of "Fertilizers."

SULPHUR (*Symbol,* S; *At. Wt.* 16).

72. This is a well-known yellow, brittle solid, often called "brimstone." It is insoluble in water, but dissolves readily in hot spirits of turpentine. If heated in a test-tube to about 230°, it melts, forming a thin yellow liquid. When heated to a higher temperature, it gradually forms a thick, viscid mass, which will not run out of the tube when inverted. At a still higher temperature, it again becomes more liquid, and may be poured into cold water. Thus cooled, it forms a soft, elastic mass, not unlike gum-elastic. At about 600° it begins to boil, and rises in the form of a

dense brown vapor, which condenses in the upper part of the tube as a fine yellow powder (flowers of sulphur).

Sulphur is found abundantly in some volcanic regions, mixed with clay, ashes, and other impurities. From these it is separated by being distilled into large chambers, where it is condensed on the walls in tufts or clusters of fine yellow powder: these clusters are the *flowers* of sulphur. When melted and cast in wooden moulds, it forms *roll sulphur*.

73. Both plants and animals contain small quantities of sulphur. Plants find it in the soil in the form of sulphates. Animals derive it from the plants upon which they feed. It exists more abundantly in the hair than in any other part of the animal. It is the sulphur in black mustard and in eggs which tarnishes silver spoons—forming sulphuret of silver on the surface.

Sulphur and Oxygen.

74. When sulphur is burned in the open air or in oxygen, it unites with two atoms of oxygen, and forms an acid gas (SO_2) of very disagreeable odor. *Exp.*—Hold a rose, or any colored flower, over burning sulphur, and it will lose its color. A yellow straw treated in the same way will be whitened. This gas is used extensively in bleaching. It is called *sulphurous acid.*

75. *Sulphuric Acid.*—This is the most important and valuable compound of sulphur and oxygen. It is a heavy, oily liquid, nearly twice as heavy as water. It was formerly obtained by heating sulphate of iron (green vitriol) to a high temperature, and distilling the oily acid from it; hence it derived its common name, "*oil of vitriol.*" Its symbol is HO,SO_3. For the process by which it is now prepared, the reader is referred to the larger works on chemistry.

Sulphuric acid has a strong affinity for water. This may be illustrated: 1. By leaving a weighed portion of it in an open glass vessel for a day or two. It will be found to have increased in weight, owing to the moisture absorbed from the air. 2. Fill a large test-tube one-third full of water; then fill it up quickly with sulphuric acid: the tube will become too hot to be held in the hand. The rapid combination of the acid and water produces the heat. 3. A piece of wood dipped for a few minutes into strong sulphuric acid, is blackened (charred). The acid takes out hydrogen and oxygen from the wood, in the form of water, while the carbon is left in an uncombined condition.

76. Sulphuric acid is used extensively in the arts. It is also valuable to the farmer. We shall hereafter (§ 378, *d*) recommend its use for preserving ammonia in animal manures.

With bases it forms *sulphates*. Gypsum is a sulphate of lime. Glauber's salt is a sulphate of soda. These are both valuable fertilizers.

Sulphur and Hydrogen.

77. The disagreeable gas which rises from sulphur springs, is a compound of sulphur and hydrogen (HS). It is usually called *sulphuretted hydrogen*, or *hydrosulphuric acid*. It is produced during the decay of eggs, and of many animal substances. When bright silver is exposed to this gas, it is soon tarnished, by the sulphur from the gas combining with the silver.

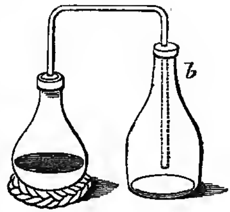
CHLORINE (*Symbol*, Cl; *At. Wt.* 35.5).

78. *Experiment.*—Put an ounce of black oxide of manganese into a flask (Fig. 25), and pour upon it two liquid ounces (half a teacupful) of muriatic acid. Stir up the mixture well, and let it stand a few minutes. A gentle heat from a lamp, or pan of coals, will cause a heavy *green* gas to pass over into the bottle (*b*).* This gas is nearly two

* $MnO_2 + 2HCl = MnCl + 2HO + Cl$.

and a half times heavier than air. It will, therefore, sink to the bottom of the bottle; and, by gradually filling it up, will displace the air entirely—just as water, poured into a bottle of oil, would cause the oil to flow out, while the water alone would fill the bottle.

Fig. 25.



79. This gas is called "chlorine," because of its green color. It cannot be collected over water, because water absorbs it freely. But over a hot solution of salt it may be collected, as this does not absorb it. This gas should not be inhaled freely, else it will irritate the throat and lungs.

Experiments.—1. A burning candle let down into a bottle of chlorine gas, burns but slowly, and gives off a dense smoke. This is because the chlorine combines with the hydrogen alone of the flame, while the carbon (for which it has no affinity) is set free in the form of smoke. 2. A fragment of phosphorus suspended in this gas takes fire spontaneously. 3. Suspend in chlorine a moistened strip of paper on which there is writing done with common ink, and the writing will soon disappear. This is owing to the strong affinity between chlorine and iron. The iron, which gives the black color to ink, is removed by the chlorine, and the color thus destroyed; while the new compound of chlorine and iron is colorless.

80. *Chlorine* is one of the elements in common salt, which is chloride of sodium ($NaCl$). It is found in small quantities in nearly all plants, and quite abundantly in sea-weeds. In the fluids of animals it is found in considerable abundance. The compounds of Cl with the metals are called "*chlorides.*"

Chlorine and *Hydrogen* combine and form a strong acid. When free, it is a gas; but a solution of it is generally sold by druggists under the name of "muriatic acid." It is a cheap acid, and may be employed in preserving manures (§ 378, *d*).

Iodine, Fluorine, and *Bromine* resemble chlorine in most of their chemical properties and relations.

PHOSPHORUS (*Symbol,* P; *At. Wt.* 32).

81. This remarkable substance is obtained from bones. When freshly prepared, it is a transparent, waxy substance, generally bought in the form of round sticks. A stick of it, placed in a tube, covered with water, and exposed to the light of the sun a few days, becomes brown. The light seems to cause some rearrangement of its atoms, without any essential change of its properties.

82. Phosphorus has a very strong affinity for oxygen. If exposed to the air it undergoes slow combustion, gives off a white vapor, and in the dark emits a faint light. It takes fire from a slight elevation of temperature, or from friction; hence its value in making friction matches. It must be kept under water, to exclude it from the air. It must be handled cautiously, lest it be ignited by the heat of the hand. Burns produced by it are exceedingly painful. In its free condition, as well as in some of its compounds, phosphorus is very *poisonous.*

83. When ignited in the open air or in oxygen gas, phosphorus combines with five atoms of O, forming phosphoric acid (PO_5). This acid forms a very important class of salts, called "phosphates." Phosphate of lime is the white substance left when a bone is burned in an open fire. It forms a large proportion of the bones of all animals. Phosphates also exist in other parts of animals, and in different parts of plants, but especially in the seeds.

For a more full description of the phosphates, we must turn to the bases with which phosphoric acid combines.

SILICON (*Symbol*, Si; *At. Wt.* 21).

84. This substance possesses but little practical interest, except in its combination with oxygen.

Silica (SiO_3) is a very abundant mineral, found in nearly all the rocks and soils on the surface of the earth. We often find it in beautiful crystals, having the form of six-sided prisms with six-sided pyramids at the ends (Fig. 26). Flint and sand are nearly pure silica, but often colored with a little of the oxides of iron and other metals. Agate, carnelian, amethyst, opal, and some other gems, are composed of silica. The strongest acids will not dissolve nor decompose silica. It is also so hard as to scratch glass readily, and is very infusible alone.

FIG. 26.

Although silica is so very hard, insoluble, and tasteless, it is classed among the *acids*, and called "silicic acid." It is regarded as an acid, because, when heated to a high temperature with potassa, soda, or lime, it combines readily with these bases, and forms a class of salts called "silicates."

The stalks of grains and grasses contain considerable quantities of silica (§ 185). It must, therefore, be found in a soluble form in every fertile soil.

BORON (*Symbol*, B; *At. Wt.* 11).

85. The only interesting compound of boron is boracic acid (BO_3). In combination with soda, this acid forms the *borax* used in the arts: it is a borate of soda. Borax is used as a flux for cleaning the surfaces of metals, and for excluding the air in welding and soldering with hard solder. It forms a thin and very fusible film over the surface of the metal, and thus prevents oxidation, until the two surfaces to be united can be brought together.

QUESTIONS ON CHAPTER IV.

§ 54. Subject of this chapter? Which are the metalloids of Table I?

55, 56. Symbol and atomic weight of *Oxygen?* Is oxygen important? Abundant? Where found? From what most conveniently prepared? Explain the process. Describe the apparatus in Fig. 12. Use of its different parts? What changes take place in KO,ClO_5 in the preparation of oxygen?

57. Detail the first experiment here given; the second; the third; the fourth. What is the first conclusion drawn from these experiments? the second? the third?

58. Why is oxygen necessary in air? What advantage from being mixed with nitrogen? What if our atmosphere were pure oxygen?

59. Symbol and atomic weight of *Hydrogen?* In what compounds is it found? How prepared? Explain formula $HO,SO_3 + Zn = ZnO,SO_3 + H$. Explain experiment second. How may a mixture of hydrogen and air be exploded? Is hydrogen combustible? How illustrated? Product of the combustion?

60. First inference drawn? second? third?

61. Of what is water composed? Is it generally pure? Its purest form? What does spring-water always contain? Sea-water? Relation of water to the growth of plants?

62. Symbol and atomic weight of *Carbon?* Why important? Various forms? First experiment? What does it illustrate? Second experiment? third? How may stagnant water be purified with charcoal?

63, 64. What is carbonic acid? First method of preparing it? Second method? Why collected over warm water? Why in open bottles? How is lime-water prepared? How affected by carbonic acid? Experiment with a mouse? Explain the chemical changes in its preparation from CaO,CO_2.

65. What are the natural sources of CO_2? How formed by combustion? by decay? by breathing? Why is not the quantity in the air increased?

66. Symbol and atomic weight of *Nitrogen?* How much of it in

the atmosphere? How procured for experiment? Explain Fig. 21. Experiments first and second?

67, 68. What are the constituents of the *Atmosphere?* How does the air cause circulation of moisture? What relation does it bear to plants? What does it provide for their nourishment?

69. What is the most important compound of nitrogen and oxygen? How prepared? Its properties? First experiment with NO_5? second? third? What is the product? Fourth experiment? What are nitrates?

70. What compound does nitrogen form with hydrogen? Its symbol? Do its elements generally combine directly? How prepared? Explain the process. Can it be collected over water? Experiment illustrated in Fig. 24?

71. Chemical properties of ammonia? Its effect on acids? How is it readily set free? Experiment. Why should lime not be mixed with animal manures? When is carbonate of ammonia generated? How is its escape prevented? Explain the chemical action between carbonate of ammonia and gypsum.

72. Symbol and atomic weight of *Sulphur?* Its form and properties? Influence of heat upon it? What are flowers of sulphur? Where is sulphur found? How purified?

73. Is it found in plants and animals? Whence do they obtain it? In what part of the animal is it most abundant? Why do eggs tarnish silver spoons?

74. Product of sulphur burnt in open air? Experiment with SO_2? What is SO_2?

75. Describe sulphuric acid. Its symbol? Affinity for water? First experiment? second? third?

76. Uses of sulphuric acid? What are sulphates? Examples.

77. What compound of S and H is mentioned? What is it called?

78, 79. Symbol and atomic weight of *Chlorine?* How prepared? Why collected in an open bottle? Why called "chlorine"? Experiment first? second? third?

80. What is *common salt?* What are chlorides? What compound does Cl form with H? Its properties?

81. Symbol and atomic weight of *Phosphorus?* Its source? Properties? Influence of light upon it?

82, 83. Its affinity for oxygen? How illustrated? For what used? How is phosphoric acid formed? The most important phosphate?

84. Symbol and atomic weight of *Silicon?* Its only important compound with oxygen? Forms under which it occurs? Its properties? Why regarded as an *acid?* What are "silicates"? In what part of plants is silica abundant?

85. Symbol and atomic weight of *Boron?* What valuable compound? What is borax? For what used? Why?

CHAPTER V.

METALS.

86. There are about fifty metals known to chemists, but only a few of these are important to our present purpose. These we will briefly describe. They are generally found in the earth, combined with other substances in the form of *ores*. A few of the metals, such as gold and silver, are often found uncombined, and are then called *native* metals. Oxygen, sulphur, chlorine, and some of the acids, are the substances with which the metals are generally combined in ores.

With oxygen some metals form both *oxides* and *acids*. Thus, FeO and Fe_2O_3 are both oxides of iron; but FeO_3 is "ferric acid." So, CrO and CrO_2 are oxides of chromium; whilst CrO_3 has strong acid properties, and is called "chromic acid."

With sulphur the metals form *sulphurets:* FeS, KS, and SbS_2 are sulphurets of iron, potassium, and antimony. With chlorine they form such chlorides as $NaCl$ (chloride of sodium), $AgCl$ (chloride of silver), etc.

The oxides of the metals nearly all combine with acids, and form what are called "salts" of the metals. The protoxide of iron combined with sulphuric acid forms the salt (FeO,SO_3) called sulphate of iron. So, ZnO,SO_3 is sulphate of zinc; KO,NO_5 is nitrate of potassa; and CaO,CO_2 is carbonate of lime.

87. *Alkalies.*—Potassa and soda (KO and NaO) were formerly the only substances called alkalies; but that term

is now frequently used in a wider sense, and applied to other bases which have a strong affinity for acids. Lime, magnesia, and other compounds of similar character, are regarded as alkaline bases.*

POTASSIUM (*Symbol*, K; *At. Wt.* 39).

88. This is a metal so soft that it may be moulded to any shape with the fingers, and so light that it will float on the surface of water. *Exp.*—Drop a little lump of potassium upon the surface of a cup of water: it will at once take fire, and float about over the surface until it finally disappears. The affinity of the potassium for oxygen is so strong, that the oxygen is rapidly taken from a portion of the water, while the hydrogen is set free. The heat generated by the rapid union of the potassium and oxygen is sufficient to ignite the liberated hydrogen. The flame thus produced is tinged by the potassium with a purple hue. The water will have oxide of potassium in solution. When evaporated to dryness, a white mass remains, which is oxide of potassium (potassa) combined with one atom of water (HO,KO). This combination is called "hydrate of potassa."

89. *Carbonate of Potassa* (KO,CO_2) exists abundantly in wood-ashes. It is the substance which gives strength to lye. It is found in the ashes of nearly all plants; hence potassa must be an abundant element in the vegetable kingdom. *Exp.*—Mix half-a-pound of ashes from wood, with a quart of hot water, and after stirring the mixture for a few minutes, pour it upon a paper filter (see Fig. 19); then evaporate the water to dryness in a saucer. The solid matter left in the saucer will be the carbonate of potassa, dissolved out of the ashes by the water.

90. *Nitrate of Potassa* (Saltpetre).—*Exp.* Pour a little

* For an explanation of the term "alkaline base," see § 71, *note.*

water upon the carbonate of potassa obtained by the last experiment; then add nitric acid, drop by drop. It will be seen that bubbles of gas escape as soon as the nitric acid mingles with the solution: these bubbles are carbonic acid. The nitric acid combines with the potassa, setting free the carbonic acid, and forming a new salt (KO,NO_5), nitrate of potassa. If the solution is again evaporated nearly to dryness, and set aside to cool, it will deposit crystals of nitre. This valuable salt is used extensively in making gunpowder, in the preservation of meat, and in preparing nitric acid. It is a powerful fertilizer on nearly all soils, but is too costly to be generally used in that way.

91. *Sulphate of Potassa* (KO,SO_3) is formed when sulphuric acid is added to a solution of potassa, or of carbonate of potassa.

92. *Chlorate of Potassa* is the salt we have used (see § 56) in preparing oxygen gas. There are many other salts of potassa which we must pass by for the present.

SODIUM (*Symbol*, Na; *At. Wt.* 23).

93. Sodium is very much like potassium in all of its properties. It is a little heavier, but still light enough to float on water. It combines rapidly with the oxygen of the water, but gives out less heat. It will not cause ignition unless confined to one place on the water. Oxide of sodium (NaO) is the base of all the salts of soda.

94. *Chloride of Sodium* ($NaCl$) is our common table-salt, and is the most abundant, as well as the most important, of all the compounds of sodium. It is often found in beds of "rock-salt" in the earth, but is most commonly obtained from the water of salt springs, and of the ocean.

95. SULPHATE OF SODA is prepared on a very large scale by heating together common salt and sulphuric acid ($NaCl + HO,SO_3 = HCl + NaO,SO_3$). Hydrochloric acid is thus set

free, and when collected in water forms "muriatic acid." Sulphate of soda often passes under the name of "Glauber's salt." It is a cheap article, and may be employed to great advantage as a fertilizer.

96. CARBONATE OF SODA (NaO,CO_2).—This useful salt is prepared by decomposing the sulphate, by means of heat, and a mixture of sawdust and carbonate of lime. The *bicarbonate* or *supercarbonate* of soda is formed by passing a current of carbonic acid gas through a strong solution of the carbonate, or by passing the gas over a moist mass of the carbonate. The bicarbonate is used extensively in making bread. When mingled with a mass of dough, together with cream of tartar, sour milk, or some other acid substance, the carbonic gas is set free by the acid used, and little bubbles of gas are formed at all points throughout the mass of dough. In the process of baking, these bubbles are greatly expanded by the heat, and the bread is thus rendered porous, or "light."

97. NITRATE OF SODA abounds on the coasts of Peru, and is exported to other countries, and employed in the manufacture of nitric acid. The acid is set free by the action of sulphuric acid (see § 69). The sulphate of soda, which is generated by the operation, is a valuable fertilizer.

98. When *soda* salts abound in a soil, they often take the place, to some extent, of potassa salts, in plants growing upon that soil. The same species of plant near the shore, where the spray of sea-water is blown over the land, generally has more soda and less potassa than it has when it grows far inland. We may often observe this fact in the different analyses of ashes of the same grain from different localities.

CALCIUM (*Symbol*, Ca; *At. Wt.* 20.5).

99. Metallic calcium (the base of *lime*) is not easily procured, and possesses no practical interest. But its compounds, known as *lime* and *salts of lime*, are of the highest import-

ance, both in the arts and in agriculture. It exists most abundantly as carbonate of lime (CaO,CO_2); in the forms of common limestone, marble, chalk, etc.; and as gypsum, or sulphate of lime.

100. *Lime* (CaO).—*Exps.* 1. Throw a few fragments of limestone or chalk into a fire of wood or charcoal, where they may be kept at a bright red heat for several hours. The carbonic acid will be expelled, and quick-lime will be left. 2. Weigh a few of these fragments of lime carefully, then pour over them slowly about one-third of their weight of water; the water will be rapidly absorbed, the lime will become quite hot, and soon crumble to a dry, white powder. The water has combined with the lime, and assumed a solid form. This is called "hydrate of lime" (HO,CaO), with reference to its having water combined with it. It is said to be "slaked" with reference to the same fact. It is also called "slacked lime" from the fact of being reduced to a fine powder. The term "caustic lime" is applied to it, because of its corroding influence on vegetable and animal substances. The water absorbed by lime in slacking, increases the weight by about one-third of the weight of the newly-burnt lime. This fact is of importance in buying lime by weight. 3. Expose a portion of stone lime (unslacked lime) to the open air for a few weeks, and it will absorb moisture from the air; but in the meantime it will also absorb carbonic acid, and will be converted again into carbonate of lime. Such lime is said to be "air-slacked." It is also called "mild lime," or "weak lime," because the carbonic acid has destroyed its caustic character. When thrown into an acid, it effervesces. Caustic lime spread on a field, and left exposed upon the surface, soon becomes changed to a carbonate. 4. Rub a little caustic lime and sal-ammoniac together in a cup or mortar, and the odor of ammonia will at once be perceived. Such will be the case, too,

if any other salt of ammonia, or even a little guano, is treated in the same way with caustic lime. This property of lime shows that it should never be mixed with manures which contain ammonia, because the ammonia, the most valuable ingredient, is thus expelled. The use of lime as a fertilizer will be discussed in a subsequent chapter.

101. *Mortar.*—"A mixture of lime and sand, on exposure to the air, gradually forms into a hard, stony mass. This consolidation is to be ascribed to three causes: 1st. The water evaporates, and the hydrate of lime remains behind as a cohesive mass; 2d. The lime attracts carbonic acid from the air, and there is formed a mixture of hydrate of lime and carbonate of lime, which possesses greater firmness than either body separately; 3d. On the surface of the sand a chemical combination is gradually formed of the silicic acid with the lime, both becoming, as it were, incorporated together. This explains the remarkable hardness of mortar in old buildings." —*Stockhardt.*

102. Carbonate of Lime constitutes the common limestones, marbles, and chalk so widely scattered over the earth. It is found in the various forms of *marl*, and is a constituent of all good soils. The carbonate may be distinguished from other salts of lime by its effervescing when an acid is poured upon it. Water charged with carbonic gas has the power of dissolving carbonate of lime: it then becomes "hard water." The water which issues in springs from limestone rocks, always has carbonate of lime dissolved in it, and is called "limestone-water." When such water is boiled, the carbonic acid is expelled, and the carbonate of lime is set free as a white powder. This forms incrustations on the inner surface of tea-kettles, steam-boilers, and other vessels in which limestone-water is boiled. The stalactites which hang from the roofs of caves are carbonate of lime, which has been deposited by the water dripping from the roof.

Carbonate of lime is often beautifully crystallized in white or transparent crystals.

103. GYPSUM (SULPHATE OF LIME) is an abundant mineral, found in extensive beds in many parts of the world. It often occurs in transparent, flat crystals, and is then called "selenite." When very compact and white, it is called "alabaster." It is slightly soluble in water, requiring about 500 parts of water for its solution. Gypsum passes also under the name of "plaster." Its composition is shown by this formula: $CaO,SO_3 + 2HO$. When heated to two or three hundred degrees, the two atoms of water are expelled, and it becomes CaO,SO_3, which is "plaster of Paris," or "calcined plaster."

Experiments.—1. Heat a few ounces of ordinary ground plaster in an iron vessel, stirring it constantly, until moisture will not be deposited on a clean, cool piece of glass held over it; taking care not to let the heat rise much above 300° F. You now have some calcined plaster. 2. Wind a narrow strip of paper around a piece of money, so as to make a little paper-box, of which the coin shall form the bottom. Mix your calcined plaster with water, so as to form a paste. Fill the paper-box with this paste, and set it aside for an hour or two: you will then find it to have become so hard, that you can unwrap the paper, and remove the coin. The face of the coin will leave a reversed impression on the plaster. This illustrates the formation of plaster casts. Calcined plaster is said to "set" with water. The water combines with it like water of crystallization, and thus forms a solid mass.

Gypsum is well known as a valuable mineral fertilizer, to which we shall frequently allude hereafter.

104. PHOSPHATE OF LIME is found as a mineral in some parts of the world; but its most abundant source is in the earthy matter of bones. When a bone is burned for a little while in a hot fire, it becomes white and brittle. This white

substance is chiefly phosphate of lime ($3CaO,PO_5$). For its use see § 405.

105. NITRATE OF LIME is found with clay in the bottoms of many caves. The soils in some places, too, abound in this salt. If lime is mingled with a mass of decaying animal and vegetable matter, it is converted into the nitrate of lime. The nitric acid is generated in the presence of a strong base, like lime, by the oxidation of the nitrogen of ammonia from the decaying matter, or the nitrogen of the air confined within the porous mass.

Silicate of Lime.—This salt of lime is one of the constituents of several varieties of rock, especially what are called "trap rocks." It is formed in variable quantities during the burning of lime. This process, and its value in the soil, are discussed under "Mineral Fertilizers."

BARIUM (*Symbol*, Ba; *At. Wt.* 68.6).

106. The oxide of barium (BaO) resembles lime in some of its properties. The chloride (BaCl) is used by chemists to detect the presence of sulphuric acid in solutions. *Exp.*—Dissolve a few grains of sulphate of soda in water, pour in a few drops of muriatic acid, and then add a little of the solution of chloride of barium: a beautiful white precipitate of sulphate of barita will be formed.

Sulphate of Barita, called "barites," has been used as a substitute for gypsum on grass lands, with some success. It is used also for adulterating white paints.

MAGNESIUM (*Symbol*, Mg; *At. Wt.* 12).

107. Magnesia (MgO) is the oxide of magnesium, and forms compounds, some of which resemble the corresponding salts of lime. *Calcined magnesia* is formed by heating the carbonate red hot, and thus expelling the carbonic acid. *Carbonate* of magnesia frequently occurs in combination with

the carbonate of lime, in limestone rocks. It is also found in nearly all soils. *Epsom salts*, so much used as a medicine, is the *sulphate of magnesia*. *Silicate of magnesia* forms the mineral called "talc," and enters largely into the composition of serpentine and other minerals.

108. Magnesia is found in the ashes of nearly all plants. It is, therefore, an important element of fertility in the soil. But soils generally have a sufficient supply of it, and hence its compounds are not often sought after as fertilizers; though the sulphate has sometimes been applied with decided benefit. An excess of magnesia, in some forms, is regarded as injurious to soils. This is especially true of the caustic magnesia, often formed in abundance, with caustic lime, from such limestones as abound in carbonate of magnesia.

ALUMINUM (*Symbol*, Al; *At. Wt.* 13).

109. Aluminum has recently been separated from its compounds in considerable quantities, and is found to possess such properties as will probably make it a useful metal.

110. ALUMINA (Al_2O_3) is the only oxide of this metal known. In combinations with silica it forms clay, and also a large proportion of some of the most important minerals, such as *mica* and *feldspar*.

111. CLAY is a silicate of alumina,* and possesses the highest interest with the farmer. Its purest forms are pipe-clay and porcelain-clay. In soils it exists in widely different proportions. Some sandy soils contain no more than 8 or 10 per cent of clay; and from this they vary to 50 per cent, and still have a sandy texture. As the quantity increases, the soil becomes more and more tenacious. 80 or 90 per cent of clay makes a stiff clay soil.

Clay absorbs water freely, and retains it firmly. When

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* Formula for clay: $Al_2O_3,3SiO_3$.

wet, it forms a compact, tenacious mass, and when dried becomes very hard; hence the difficulty of cultivating stiff soils. If sand be mingled with the clay in proper proportions, the texture of the soil is greatly improved (see § 335).

112. Clay is found in many rocks combined with other silicates, such as the silicates of lime, potassa, and soda. Rain and frost reduce such rocks slowly to small fragments, and these again are decomposed by atmospheric action, and by the silicates of potassa and soda being gradually dissolved out. The remainder is clay.

113. ALUM* is a double sulphate of alumina and potassa, combined with 24 atoms of water. The water may be driven off by heat, and the remaining porous mass is *burnt alum*. *Exp.*—Dissolve 5 ounces of alum in a half-pint of boiling water, and set it aside in a saucer to cool. When cold, the bottom of the saucer will be lined with a coating of beautiful crystals.

IRON (*Ferrum*), (*Symbol*, Fe; *At. Wt.* 28).

114. Although gold and silver are sought after with so much eagerness, they are not half so important to man as *iron*. Fortunately for our race, this most valuable metal is also the most widely diffused of all the metals used in the arts. Our Creator has so placed it, that, with the proper exercise of industry and skill, man, in all lands, may supply himself with it in abundance. Prof. Stockhardt says: "It is the only metal which is not injurious to the health—the only metal which forms a never-failing constituent of the body, especially of the blood—the only metal, finally, which is found everywhere on the earth, in all stones and soils, and in almost every plant. Although we are ignorant wherein

* *Alum* = $KO,SO_3 + Al_2O_3,3SO_3 + 24HO$.

consists the influence which it exercises upon the life of animals and plants, yet its universal diffusion must lead us to conclude that it has pleased the Highest Wisdom to invest iron with an importance for organic life, similar to that possessed by common salt, lime, phosphoric acid, and some other substances."

115. We find the iron used in the arts under several different forms. 1. *Cast-iron* is the crude iron obtained by heating in large furnaces a mixture of some ore of iron with coal and limestone. The carbon and lime together remove nearly all of the substances combined and mingled with the ore; while the metal, set free in a melted condition, runs to the bottom of the furnace, and is there drawn off. In making the finer kinds of castings, the iron from the furnace is re-melted in foundries, from which it is poured into moulds of various shapes. Cast-iron is much more *fusible* than the purer bar-iron; hence its value for making stoves, ploughs, and a thousand other articles. The fusibility of iron is increased by the presence of a small quantity of carbon. In passing through the furnace, the iron combines with a portion of the carbon used in separating it from the ore. This not only makes it more fusible than pure iron, but also makes it *brittle*.

2. When articles such as rakes and forks are made of cast-iron, and then kept red hot for several days in contact with an oxide of iron, the carbon is nearly all removed from them, and they become soft and flexible. The metal thus treated is called "malleable cast-iron."

3. *Bar-iron* is formed by burning the carbon out of cast-iron, in a forge-fire, and then hammering it into bars. It may then be passed between heavy rollers, and formed into *sheet-iron;* or drawn through holes in steel bars, and formed into *wire*.

4. *Steel* is prepared by embedding bars of iron in pow-

dered charcoal, and keeping it heated to redness for some time. The iron combines with some of the carbon of the coal, and is thus rendered both harder and more fusible. When bars thus prepared are melted and cast in moulds, they form *cast-steel.*

116. Iron and Oxygen.—At ordinary temperatures iron combines readily with the oxygen of the air, if moisture be present, and the result is "*rust.*" At a red heat the surface of a piece of iron soon becomes coated with an oxide of iron. We have seen (§ 57) how rapidly iron may be consumed in pure oxygen gas. *Exp.*—Sprinkle some fine iron filings into the flame of a spirit-lamp, or hold a piece of iron over the flame, and rub the metal with a file, so that the small fragments cut off will fall into the flame: they will take fire, and burn with the appearance of bright sparks.

117. The protoxide (FeO) is the base of most of the salts of this metal. This oxide cannot be obtained in a separate form, on account of its strong affinity for an additional quantity of oxygen, by which it is changed to the sesquioxide (Fe_2O_3). The sesquioxide is also the base of several important salts of iron. The brown sediment we find about chalybeate springs is Fe_2O_3, with an atom of water (HO,Fe_2O_3). The sesquioxide of iron is often called "peroxide:" it is found in the earth in vast deposits, and is regarded as one of the most valuable ores of this important metal. It is the chief *coloring matter* in rocks and soils, except in cases where organic matter abounds, as in many limestones, and in dark alluvial soils. The red and brown varieties of clay are colored with this oxide. Oxide of manganese is, however, frequently associated with oxide of iron.

Black Oxide of Iron, called "magnetic oxide," seems to be a combination of protoxide with peroxide; the formula being, FeO,Fe_2O_3. The black, scaly particles which drop from the surface of iron, as it is wrought with the blacksmith's hammer, are composed of this oxide. When found as a mineral, it has the property of being attracted by the *magnet;* and many masses of it are *native magnets,* or "load-stones."

118. Salts of the Oxides of Iron are numerous, but we can notice only a few. 1. *Carbonate of iron* (FeO,CO_2) is one of the most valuable ores, and is often found beautifully crystallized; and hence called "sparry iron-ore." 2. *The sulphate* (FeO,SO_3), called "copperas" and "green vitriol," is the most common salt of iron, and the one most extensively used in the arts. It is a crystalline salt of a green color, and very soluble in water. Its preparation is given in § 119. In the manufacture of ink, and in dyeing black colors, it is extensively used. Its use in agriculture will be mentioned in connection with fertilizers.

119. Iron and Sulphur.—When sulphur unites with a metal without oxygen, we call the compound a "sulphuret." There are several sulphurets of iron. The protosulphuret (FeS) is formed when sulphur and iron filings, or tacks, are heated together in a covered crucible (§ 5). It is used in preparing sulphuretted hydrogen.

Bisulphuret of iron is commonly called "pyrites," or "iron pyrites" (FeS_2). It is a very abundant mineral, and occurs in beautiful yellow crystals, in the form of cubes and octohedrons. Because so many people suppose, when they discover it in the rocks, that they have found gold, it has received the significant name of "fool's gold." When heated to a high temperature, the bisulphuret of iron parts with a portion of its sulphur, which may be collected in the form of "flowers of sulphur." The iron still remains combined with a portion of the sulphur; and if exposed to air and moisture, the sulphur and iron both unite with oxygen. The sulphur becomes sulphuric acid, and the iron becomes protoxide of iron. The two combined, then, form sulphate of iron (copperas). Copperas is prepared on a large scale by exposing certain slaty rocks, abounding in pyrites, to the action of the air. The sulphuret of iron being converted, as we have just seen, into the sulphate, the impure mass is treated with water, which dissolves out the newly formed salt. When most of the water has been driven off by evaporation, the copperas is deposited in a crystalline mass, as the concentrated solution becomes cool.

MANGANESE (*Symbol*, Mn; *At. Wt.* 27.6).

120. This is a hard and very infusible metal, resembling iron in many of its chemical properties. It forms numerous compounds with oxygen; but the only one of sufficient interest to demand our attention now, is the *peroxide*, or *black oxide* (MnO_2). The principal use to which it is applied, is in the separation of chlorine from muriatic acid (§ 78). From its being employed in glass factories to remove the green color from glass, it has received the name of "glass-maker's soap."

ZINC (*Symbol*, Zn; *At. Wt.* 33).

121. We have learned something of the properties of zinc from its use in preparing hydrogen (§ 59). When polished, it is a bright metal of a blueish white color. It is brittle when cold; but when heated to 250°, it may be rolled into thin sheets. Zinc is combustible. *Exp.* Place a few fragments of the metal in an iron spoon, and cover them with a little plate of iron. Put the spoon into the fire till it becomes red-hot; then remove the cover quickly, and the zinc will take fire. A white, flocculent substance will be formed, which is *protoxide of zinc.*

Zinc is used on a large scale in the manufacture of galvanic batteries. This makes it one of the most important of the metals. In the form of thin sheets, it is used for various purposes; being a cheap metal, and not so liable as iron to be destroyed by rust. Chains, wire, and other articles, are frequently coated with zinc, to prevent their rusting. They are then said to be "galvanized."

COPPER (*Cuprum*) (*Symbol*, Cu; *At. Wt.* 32).

122. This is an abundant and useful metal, and is readily distinguished by its brownish red color. A bright surface of copper becomes slowly tarnished in the air, having a coat of red oxide formed on it.

BLUE VITRIOL is the sulphate of copper (CuO,SO_3), and is easily prepared by heating copper with sulphuric acid, in a glass or porcelain vessel.

Experiments.—1. Dissolve an ounce of blue vitriol in two ounces of boiling water, and set the solution aside in a saucer. As soon as it becomes cool, the saucer will be found to contain a quantity of beautiful blue crystals. 2. Pour off from the crystals the remaining solution, and add a little ammonia water to it; the color will be greatly deepened. Ammonia is a good test for the presence of copper in solutions.

Acetate of copper is formed when copper is exposed to the action of vinegar and sour fruits. It is commonly called "verdigris," and is very poisonous, as are all the salts of copper.

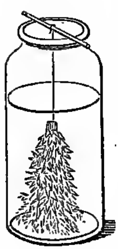
LEAD (*Symbol*, Pb; *At. Wt.* 103).

123. The external properties of lead, and the various uses to which it is applied, are familiar to every one. We will briefly notice some of its chemical properties, and some of its most important compounds.

At ordinary temperatures, a bright surface of lead is almost immediately tarnished by the oxygen of the air, forming over it a thin coating of oxide of lead. This prevents further action of the air, and preserves the metal from continued oxidation. The oxide thus formed is called "suboxide," and has two atoms of lead united to one of oxygen (Pb_2O). An unmelted film of this oxide is generally seen floating as "dross" on the surface of melted lead. If melted lead is exposed to a free current of air, it rapidly combines with oxygen, and forms PbO, which is sold under the name "litharge." If kept at nearly a red heat, it combines with still more oxygen, and becomes *red lead* (Pb_3O_4, or $2PbO,PbO_2$).

White lead, used so extensively in painting, is the carbonate (PbO,CO_2). *Sugar of lead* is this metal combined with the acid of vinegar; it is *acetate of lead*. *Exp.* Boil a quart of water, and dissolve in it a half-ounce of sugar of lead. Pour the solution into a bottle with a wide neck, and let it stand until it becomes clear; then suspend in it a lump of zinc attached to a thread (Fig. 27), and set it on a shelf where it will not be disturbed; in a day or two, the zinc will be coated with beautiful clusters of bright crystals of lead, which will soon form branches extending to the bottom of the bottle, like an inverted tree. This is the "leaden tree." It shows that acetic acid has a stronger affinity for zinc than it has for lead. Acetate of lead is decomposed, and acetate of zinc formed.

Fig. 27.



Galena, the most common ore of lead, is a sulphuret (PbS).

TIN (*Symbol*, Sn; *At. Wt.* 59).

124. Tin is a whiter metal than lead, and also much more fusible, melting at 442°. It is not readily tarnished by exposure to the air and moisture. Common *tin ware* is made of sheets of iron coated with tin.

MERCURY (*Symbol,* Hg; *At. Wt.* 100).

125. This is the *liquid* metal used in making thermometers and barometers. It boils at 662°, and freezes at 40° below zero. With oxygen, mercury forms the common and useful compound (HgO) called "red precipitate." *Calomel* is mercury combined with chlorine — *two* atoms of mercury being united to *one* of chlorine (Hg_2Cl). *Corrosive sublimate,* which is a dangerous *poison,* also consists of mercury and chlorine; but it has only *one* atom of mercury united to *one* of chlorine ($HgCl$). If corrosive sublimate should, by any mistake, be taken into the stomach, the most sure and simple remedy is to beat up ten or twelve raw eggs, with a quart of water, and give the patient a tumbler full every two or three minutes, till he vomits. Common emetics should not be given.

The beautiful red compound sold under the name of "vermilion," is a sulphuret of mercury, HgS.

ANTIMONY (*Symbol,* Sb; *At. Wt.* 129).

126. The dark powder sold by druggists as "antimony," or "crude antimony," is a sulphuret (SbS_3). This compound is sometimes given by farmers to horses and hogs, as a remedy for diseases of the skin. The fourth of an ounce of crude antimony, mixed with the same quantity of flowers of sulphur, and an ounce of cream of tartar, forms a good alterative medicine for a horse.

Tartar emetic is formed by boiling oxide of antimony and cream of tartar together. It is the double tartrate of potassa and antimony.

Antimony is of great value in the preparation of printers' type. The *type metal* is an alloy of lead and this metal.

ARSENIC (*Symbol,* As; *At. Wt.* 75).

126 (*a*). Arsenic (or Arsenicum) is found in some rocks as a dark crystalline substance, which is very brittle, and

volatile at a high temperature. Its presence in iron is often injurious by rendering the iron brittle. The only compound of arsenic possessing much practical interest, is *arsenious acid* (AsO_3), which is sold under the names "arsenic," "rats'-bane," etc. It is a terrible poison, and should be so kept that it may not be liable to improper use by vicious persons, and that it may not be used by mistake for other substances of similar appearance.

For a more full description of this substance and its compounds, the reader is referred to works on chemistry.

The best antidotes for arsènic are: (1) A powerful emetic; and (2) A free dose of hydrated oxide of iron (§ 117), or calcined magnesia. White of eggs, beaten and stirred into milk, should then be given promptly and freely.

SILVER (*Symbol*, Ag; *At. Wt.* 108).

127. This is the whitest of the metals, and, when highly polished, gives a beautiful and brilliant lustre. In the form of coins, and of various useful and ornamental articles, it is well known. For the preparation of such articles, the pure metal is not used. It is too soft to be used alone. About ten per cent. of copper is added, to give it proper hardness and durability.

Silver dissolves readily in nitric acid, forming "lunar caustic," which is nitrate of silver. The sulphur of sulphuretted hydrogen, or of any soluble sulphuret, combines readily with silver, and gives it a dark surface.

GOLD (*Symbol*, Au; *At. Wt.* 98).

128. Gold is the most beautiful of the metals, owing to its fine color and lustre; but, like silver, it is too soft to be used in its pure form. The standard gold of coins contains ten per cent. of copper.

ALLOYS.

129. An alloy is a compound formed by the union of two or more metals, in any proportions whatever.

Gold and silver coins have been mentioned as alloys of 90 parts of gold or silver, with 10 of copper.

Type metal is composed of 3 parts of lead, and 1 part of antimony.

Brass contains about 1 part of zinc to 2 parts of copper. *Pinchbeck* is also an alloy of copper and zinc.

Bell metal, bronze, and *gun metal,* are alloys of copper with different quantities of *tin.*

German silver has no real silver in it, but is a compound of copper, zinc, and nickel, in the proportion of 10 parts of copper to 6 of zinc, and 4 of nickel. The nickel gives whiteness to the compound, and also makes it malleable.

Britannia is an alloy of 100 parts of tin, fused with 10 parts of antimony, and 2 of copper. Sometimes, instead of 10 parts of antimony, 8 of antimony and 2 of bismuth are used.

Soft solder is formed by fusing tin and lead together. *Fine solder* has 2 parts of tin, and 1 of lead; *coarse solder,* 1 part of tin and 2 of lead.

QUESTIONS ON CHAPTER V.

§ 86. How many *metals* are known? Are they all important? What are *ores?* Native metals? What do metals form with oxygen? What are FeO, Fe_2O_3, and FeO_3? What are sulphurets? Mention some, and give their symbols. What are *salts* of the metals? Mention some.

87. What are *alkalies?* What is the "volatile alkali"?

88. Symbol and atomic weight of *Potassium?* Its properties? Experiment? Product of the combination?

89. Where is carbonate of potassa abundant? How procured? What is common lye?

90, 91, 92. How can you form *nitre?* Explain the experiment.

For what is this substance used? What is said of sulphate of potassa? For what is the chlorate used?

93. Symbol and atomic weight of *Sodium?* Properties? What is the base of soda salts?

94, 95. For what is chloride of sodium used? Whence obtained? How is sulphate of soda prepared? What acid is liberated at the same time? Of what use is sulphate of soda in agriculture?

96, 97, 98. Preparation of carbonate of soda? Of the bicarbonate? Use of the bicarbonate? How does it make bread light? Where is nitrate of soda found? What is said of soda salts when they abound in a soil?

99, 100. Symbol and atomic weight of *Calcium?* Its most important compounds? — What is lime? How prepared? Explain the process of slacking lime? What change takes place in the lime? How is the weight affected? What is air-slacked lime? How is it shown to be a carbonate? What influence has lime on a salt of ammonia? How illustrated? Effect of lime mixed with organic manures?

101. What is mortar? Explain its consolidation.

102. What are common forms of carbonate of lime? How distinguished from other salts of lime? When does water dissolve carbonate of lime? Explain the formation of stalactites.

103. Of what is *gypsum* composed? What names are given to it under its several forms? Explain the first experiment with gypsum; the second. Of what use in agriculture?

104, 105. In what condition is phosphate of lime found? How obtained from bones? What is said of nitrate of lime? How formed in the soil? What is said of silicate of lime?

106. What does oxide of *barium* resemble? For what is the chlorate used? Illustrate. What salt of barium has been used in agriculture?

107, 108. Symbol and atomic weight of *Magnesium?* What is magnesia? How is calcined magnesia formed? Composition of Epsom salts? — of talc? Is magnesia found in plants? Is it important in plants? Is it ever injurious?

109, 110, 111. Symbol and atomic weight of *Aluminum?* Is this a useful metal? Composition of alumina? In what minerals is it found? Composition of clay? Purest forms of clay? Absorbent power of clay? Are stiff clay soils easily managed?

112, 113. How is clay combined in many rocks? How are such rocks decomposed? What is alum? Burnt alum?

114. Symbol and atomic weight of *Iron?* Its importance? Its abundance? Stockhardt's remarks about iron?

115. Forms of iron used in the arts? What is cast-iron? How is fusibility of iron increased? How is malleable cast-iron prepared? Bar-iron? Sheet-iron? Wire? Steel? Cast-steel?

116. What is iron-rust? How may iron be burnt? Experiment.

117. Base of most of the salts of iron? Influence of air upon it? Sediment of chalybeate springs? Coloring matter of rocks and soils? Magnetic oxide? Load-stone?

118, 119. What of carbonate of iron? Of sulphate? Its uses? Sulphuret of iron? Bisulphuret? Its uses?

120. Symbol and atomic weight of *Manganese?* What oxide is here mentioned? Its uses?

121. Symbol and atomic weight of *Zinc?* For what have we used Zn? Properties? Experiment? For what used on a large scale? Galvanized iron?

122. Symbol and atomic weight of *Copper?* Properties? What is blue vitriol? Explain the experiments. "Verdigris"?

123. Symbol and atomic weight of *Lead?* External properties? How tarnished? Dross of lead? How is "litharge" prepared? Its composition? "Red lead"? "White lead"? "Sugar of lead"? Describe the leaden tree. Galena?

124, 125. Describe *Tin.* What is "sheet-tin"? What is there peculiar about *Mercury?* For what used? What is "calomel"? "Corrosive sublimate"? Antidote? "Vermilion"?

126. What is "crude antimony"? Uses? Tartar emetic? Type-metal? Describe *Arsenicum.* What is white arsenic? Antidotes?

127, 128. Describe *Silver.* Its uses? Why alloyed? "Lunar caustic"? What of *Gold?*

129. What is an alloy? Type-metal? Brass? Bell-metal, bronze, and gun-metal? German-silver? Britannia? Solders?

CHAPTER VI.

ORGANIC CHEMISTRY.

130. If we examine closely a piece of wood, or a part of any plant, we find it consisting of fine fibres, and little tubes or cells of a peculiar form. Any part of an animal, when examined in the same way, is found to have a structure peculiar to itself. The plant has its roots, its leaves, its fibres, its sap-vessels; the animal its stomach, its lungs, its muscles, its veins, etc. These are *organs;* hence the *matter* of which the different parts of plants and animals are composed, is called "*organic matter.*"

131. The greater part of all organic matter is composed of four simple elements; namely, *carbon, hydrogen, oxygen,* and *nitrogen.* These are, hence, often spoken of as "*the* organic elements." Sometimes they are all found in the same substance, as in a piece of *cheese.* At other times we find only three of them associated together, as in *sugar,* which is composed of carbon, hydrogen, and oxygen. Then again, only two may be found together, as in the oil of turpentine, where we find only carbon and hydrogen.

Sulphur and *phosphorus* frequently enter into the composition of organic bodies, in small quantities. The white of the egg contains some sulphur. The brains of animals contain phosphorus.

132. *Mineral Part of Plants and Animals.*—When we burn any portion of vegetable or animal matter, we always find something left, which we call "ashes." The organic elements, carbon, hydrogen, oxygen, and nitrogen, form

volatile compounds with each other, or with the oxygen of the air, during combustion, and disappear; but the ashes, being involatile, remain, forming what is known as the "inorganic part" of the burnt substance.

In ashes we find a variety of substances. The bases, *potassa, soda, lime, magnesia, oxide of iron,* and *oxide of manganese;* with the acids, *phosphoric, sulphuric,* and *silicic;* also *chlorine* and *fluorine,* are found in the ashes of plants, and most of them also in the ashes of animal bodies.

133. Proximate Constituents.—The four principal organic elements of plants and animals (§ 131) unite in a great variety of forms, giving rise to compounds which exist together in the same body, but are distinct from one another, and may generally be separated without change. The compounds, then, which, united, form any part of a plant or animal, are its "proximate constituents."

Illustration.—Take a little lump of flour-dough, and knead it on a fine sieve, or piece of muslin tied over the mouth of a bowl, while some one pours a small stream of water upon it (Fig. 28). Continue the operation till the water passing through the sieve ceases to have a milky appearance. There will be a cohesive mass still left on the sieve: this is the *gluten* of wheat. Let the water with which the dough was washed, stand a few hours, till it becomes clear: the white powder which settles in the bottom is *starch.* *Gluten* and *starch* are two of the "proximate constituents" of wheat.

Fig. 28.

We will now study the composition and properties of the proximate and mineral constituents of plants and animals, separately, under the heads of "Vegetable Chemistry" and "Animal Chemistry."

VEGETABLE CHEMISTRY.

134. Groups.—Many of the proximate elements found in different plants, or in different parts of the same plant, are very similar in composition, and may frequently be transformed into one another. When we find a number of such compounds, we may place them together in one *group*.

135. Starch Group.—There are a number of substances, composed of carbon, united with hydrogen and oxygen in the proportion in which they form water. Among these, *starch* is conspicuous; and hence they constitute the "starch group." We shall notice a few of the most important. These are: 1. *Vegetable fibre or cellulose;* 2. *Gum;* 3. *Starch;* 4. *Sugar;* 5. *Pectose.*

136. *Vegetable fibre* is found almost perfectly pure in the fibre of cotton, and in clean white linen. It forms the solid, insoluble part of wood, and of the stalks of plants. In the stalks and leaves of green vegetable substances, it is soft, and, to some extent, digestible by animals. In dry straw, it is harder and less digestible. It forms the outer coating of grain—*the bran.* In the outer part of peach and plum stones, and in the shells of nuts, it is very firm and hard. The formula, representing a compound atom of cellulose, is $C_{24}H_{20}O_{20}$. If we multiply the atomic weights of the carbon, hydrogen, and oxygen, by the number of atoms of each found in this compound atom, we find them in the proportion of 144 parts of C, 20 of H, and 160 of O.

The great importance of vegetable fibre is evident, when we reflect for a moment upon the various purposes it serves. It is the frame-work of the vegetable kingdom; it is the chief component of fuel; cotton and linen goods are made of it, in its purest natural form; it is the principal constituent of all varieties of paper.

137. *Starch* ($C_{24}H_{20}O_{20}$).—Starch has the same proportions of its elements as vegetable fibre, but these elements seem to be combined in somewhat different form, so as to give different properties to the two substances.

The cultivated grains are the most abundant source of starch. It is also obtained abundantly from the potato. It exists in greater or less quantities in numerous plants, especially in their green state.

To the naked eye, starch appears to be a very fine white powder, but when examined with a microscope it is found to consist of little granules, having an organized structure. Fig. 29 represents the form of starch grains as they exist in the potato.

FIG. 29.

Experiment.—Cold water will not produce any change on starch, but when the granules are first mixed up with a little cold water, and then poured into a much larger quantity of boiling water, they at once burst, and form an almost transparent solution, called "starch water." If dry starch is heated to 300° or 400°, it becomes soluble in cold water. In this form it is sold as "British gum."

138. Starch water is rendered more perfectly fluid and transparent by being moderately heated with a little dilute sulphuric acid, or with an infusion of malt. The starch undergoes a slight change, and becomes what is called "dextrine." If the solution of dextrine with sulphuric acid is boiled for several hours, the dextrine is converted into grape-sugar.

SUGARS.

139. *a. Grape-sugar*, $C_{24}H_{24}O_{24}+4\ (HO)$.—This variety of sugar is found in many ripe fruits, but especially in the sweet kinds of grape; hence its name. Raisins are dried

grapes, and the white sweet grains found amongst them are particles of this sugar. Starch will yield more than its own weight of grape-sugar by the process mentioned in § 138. By a somewhat similar process it may also be prepared from linen or cotton rags!—(See *Fowne's Chemistry*, p. 335.)

"Many unripe fruits, as the apple, contain a large quantity of starch, but no sugar. After the fruit is fully grown, the starch gradually disappears, and we find in its place grape-sugar. This change constitutes the ripening of fruits, and, as is well known, will take place after they are gathered."—*Silliman.*

140. *b. Cane-sugar* ($C_{24}H_{22}O_{22}$) is obtained in immense quantities from sugar-cane, sugar-maple, and beets. It is also found in green corn-stalks, grass, and a variety of other substances. It is much sweeter and more soluble than grape-sugar.

141. *c. Sugar of Milk* (*Lactose*) $C_{24}H_{20}O_{20}+4$ (HO).—This is a variety of sugar found in milk. After the curd of milk is taken out, as in making cheese, the whey holds this sugar in solution. By boiling either cane-sugar, or lactose, with dilute sulphuric acid, grape-sugar is formed.

142. *Gum* ($C_{24}H_{20}O_{20}$) has the same composition as starch and vegetable fibre. One of its purest forms is seen in gum Arabic. It also exudes from the peach and cherry trees. In the seeds of many plants it is abundant. The mucilage of flaxseed is a form of gum. There is also a portion of it in all of our cultivated grains, and in almost all plants. Boiled in dilute sulphuric acid it becomes grape-sugar.

143. *Pectose*, or *Pectine*, is closely allied to gum. It is the substance which gives to the juices of many fruits the property of forming *jellies*. In such roots as the turnip and parsnip, pectine takes the place which starch occupies in the potato. As an article of food, it serves the same purpose as starch.

144. All the substances here described as having a composition similar to vegetable fibre, may be converted into that substance during the growth of plants, under the influence of that mysterious principle which we call "vitality."

NATURAL PRODUCTS OF THE STARCH GROUP.

145. PEAT is the product of decaying vegetable fibre under water. In bogs, large quantities of vegetable matter are often accumulated. Then, different mosses grow upon the surface of the water, die, and sink to the bottom, there to undergo the process of deeay. During the decay of such masses of vegetable matter, carbonic acid escapes, with some carburetted hydrogen (C_2H_4). The residue is chiefly carbon, a part of which is combined with a little remaining hydrogen and oxygen, forming a sort of bituminous substance. Long-continued pressure, and a little further advance in the decomposition of peat, would convert it into *bituminous coal.*

146. Peat bogs are found generally in latitudes north of 37°. In some countries, peat is used for fuel. It is also regarded as a valuable source of gas for lighting houses and cities. For agricultural purposes, it is valuable, especially as an absorbent of ammonia, when mingled with stable and barnyard manures.

147. HUMUS is another valuable product of the decay of vegetable fibre. The *vegetable mould,* which is produced so abundantly in forests, by the decay of leaves and twigs of trees is *humus.* So, the dark coloring matter of soils, abounding in organic substances, is *humus.* Its formation requires the presence of air and moisture. A mass of moist straw, leaves, or hay, lying upon the surface of the ground, so that the air can have access to it, soon begins to *rot,* as we say. The change produced on the vegetable fibre is somewhat different from that which results in the formation of peat. It resembles a slow *combustion.* The oxygen of the air com-

bines with a part of the carbon, converting it into carbonic gas which escapes into the air; but the hydrogen and oxygen of the vegetable fibre disappear much more rapidly than the carbon, and the large excess of carbon thus accumulated gives the dark brown color to the vegetable mould or humus. Humus is different in composition at different stages of its formation. It contains several distinct substances, some of which are acids. Of these, *humic* and *ulmic acids* may be mentioned as important. They have a strong affinity for ammonia, and combine also with other bases, forming soluble salts. In this condition, they are supposed to enter the roots of plants, and afford them nourishment.

Experiment.—Dissolve an ounce of carbonate of soda in a quart of water; then add two or three ounces of well decayed mould, and boil the mixture a few minutes. A brown solution of soda, combined with the humic and other acids of the mould, will be formed. If muriatic acid is now added till the solution becomes sour, the soda will be taken up by the muriatic acid, and the vegetable acids (humic, ulmic, etc.), being set free, soon fall to the bottom as a brown insoluble precipitate.

The value of humus in soils, and in the preservation of manures, will be mentioned under the composition of soils, and management of manures.

148. ALCOHOL ($C_4H_6O_2$).—This is one of the important products of the starch group. It is generally produced from *grape sugar*, by a process which we call the "vinous fermentation." It consists in breaking up an atom of grape sugar into four atoms of alcohol, and eight atoms of carbonic acid. An atom of the sugar, $C_{24}H_{24}O_{24} = 8\ (CO_2) + 4\ (C_4H_6O_2)$.

A solution of pure sugar will not undergo this change, even in the open air; but if a little *yeast*, or white of egg, be stirred into the solution, and the temperature be kept up to about 75° or 80°, little bubbles of gas will soon begin to rise rapidly, and the odor of alcohol will become perceptible.

It has already been stated that starch and cane sugar are readily changed to grape sugar by an infusion of malt. Yeast produces the same effect. This change is always supposed to take place before starch and cane sugar can be converted into alcohol.

149. Alcohol is separated from the water, and other substances with which it is mixed, by distillation (§ 23); but during the first distillation, a large quantity of water passes over with it, giving but a weak solution. By repeated distillations, the temperature being reduced each time, the alcohol may be obtained so nearly pure as to contain only about 15 per cent. of water. This is "commercial alcohol." If absolutely pure alcohol is required, the common alcohol must be mixed with unslacked lime, or fused chloride of calcium, either of which will combine with the water, and not with the alcohol. The latter may then be distilled from the mixture in a pure form.

Alcohol burns with a pale blue flame, without smoke, producing a high degree of heat. This makes it valuable to be used in lamps for heating purposes.

The alcohol of wines is produced by the fermentation of the sugar of the grapes. So alcohol is generated in cider, and in the juices of many fruits containing sugar.

150. "*Raising Bread.*" — Flour contains some *sugar*. When yeast is added to a mass of dough, and the mixture set aside for several hours in a warm place, fermentation takes place throughout the mass; alcohol and carbonic gas are generated. The bubbles of gas set free make the dough porous, and cause it to "rise." During the baking, the heat expands the little gas bubbles, and this causes an increased rising. The vapor of alcohol generated within the dough

may aid in producing this result, but the alcohol is expelled by the heat before the baking is completed.

151. ACETIC ACID (*vinegar acid*).—This is the most important product of alcohol. It is produced by removing a part of the hydrogen from alcohol, and adding more oxygen. Pure alcohol, or alcohol diluted with pure water, will not undergo this change by exposure to the air; but if a little yeast, or mother of vinegar, or some similar compound, be added to a solution of alcohol, the change to acetic acid soon begins. Thus alcohol is $C_4H_6O_2$; if two atoms of its hydrogen are removed, it becomes $C_4H_4O_2$, which is called "aldehyde." If two more atoms of oxygen combine with the aldehyde, it takes the form $C_4H_3O_3,HO$,* which is acetic acid in its most concentrated form.

152. VINEGAR.—The juices of fruits, such as cider and wines, contain enough of albuminous matter to cause their sugar to be changed first into alcohol; and then, if air be freely admitted, acetic acid begins at once to be produced from this alcohol. If there is any dextrine (soluble starch) in the liquid, it will also produce, first sugar, then alcohol, then acetic acid. The strength of the vinegar formed from wine or cider, or from a solution of sugar or molasses, will depend upon the quantity of fermentable matter (sugar and dextrine) present, and the completeness of the fermentation. Free access of air is necessary to produce acetic acid, because the air is the agency by which part of the hydrogen is removed from alcohol, and an additional quantity of oxygen supplied. The very rapid fermentation of vinegar is sometimes caused by passing it over a mass of beech or sugar-maple shavings placed in a large barrel, with holes near the bottom for allowing a free circulation of air. When vinegar is fermented in a half-filled cask (the common way), it should be frequently agitated, so as to cause the air to mingle with it.

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* Sometimes written $C_4H_4O_4$ (see Silliman).

ACETATES.—Acetic acid combines with bases such as potassa, soda, lime, etc., forming a class of salts called "acetates." Acetate of potassa ($KO,C_4H_3O_3$) is easily formed by dissolving carbonate of potassa in vinegar until effervescence ceases. The vinegar loses its sour taste, being now a solution of acetate of potassa. A solution of acetate of *soda* may be prepared in the same way. Acetate of *alumina* is extensively used in dyeing, for the purpose of fixing the colors. *Sugar of lead* is the *acetate* of lead, with 3 atoms of water of crystallization ($PbO,C_4H_3O_3 + 3HO$). *Verdigris* is acetate of *copper.* This, as well as acetate of lead, is very poisonous. When liquids containing acetic acid are heated, or kept for some time in copper or brass vessels, acetate of copper is formed to some extent.

153. LACTIC ACID.—When sugar in solution is mixed with a little curd of milk, a peculiar kind of fermentation takes place, by which the sugar is converted into an acid different from acetic acid. The same acid is formed from *lactose* during the spontaneous souring of milk. From the fact of its being the natural acid of sour milk, it is called "lactic acid."

PROTEINE GROUP.

154. We find in plants associated with the starch group, another very important class of compounds, which are known as *proteine bodies.* Besides carbon, hydrogen, and oxygen, they all contain *nitrogen;* hence the term "nitrogenized" is often applied to them. They also contain small portions of sulphur and phosphorus. The most important of them are *gluten, vegetable albumen,* and *vegetable caseine.* They all resemble the *white of eggs* in composition.

155. GLUTEN.—When the starch is washed out of a piece of dough, by the experiment in § 133, the adhesive mass which remains is *gluten.* It has nearly the same composition

as the fibrous part of lean meat, and is hence called "vegetable fibrin." It is insoluble in water.

156. Vegetable Albumen.—If the water used in washing the starch out of dough be allowed to stand till it becomes perfectly clear, and is then poured off and boiled, it becomes turbid. It had removed from the flour a form of proteine matter, which was soluble until heated to a temperature above 160°; above that temperature it becomes insoluble (coagulates), like the white of an egg dissolved in water, and heated to the same temperature. It is called "vegetable albumen," because of its similarity to the white (albumen) of the egg.

157. Vegetable Caseine.—This is a form of proteine matter found most abundantly in peas and beans. *Exp.* Crush some beans or peas in a mortar, or in any other way, to the condition of coarse meal, and soak them in water for several hours; then add a little vinegar to the clear solution. A white substance is set free and deposited, which, from its likeness to the *caseine* or *curd* of milk, has received the name we have applied to it. It is also called "*legumen.*"

158. These proteine compounds are of the highest importance in all vegetable substances used as food for animals. We shall hereafter learn that the greater part of the animal body is composed of proteine substances, similar to those we have found in vegetables. As all animals derive their nourishment either directly or indirectly from vegetable food, this food must possess a nutritive value somewhat proportional to the quantity of proteine matter it contains.

159. Our ordinary crops all contain some form of proteine, but the quantity is found to vary considerably even in the same kind of plant. The grains, such as wheat, Indian corn, etc., contain from 8 to 20 per cent. Hay contains from 2 to 8 per cent. It is found also in the sap of trees, and in various fruits.

If proteine compounds are dried, they may be preserved for any length of time in that condition; but when exposed to the united action of air and moisture, they very soon undergo decomposition — they become putrid. The result of their decomposition is the production of carbonic gas, water, and *ammonia*. The sulphur and phosphorus escape in combination with hydrogen, producing two gases of very disagreeable odor (sulphuretted and phosphuretted hydrogen).

160. The *presence* of proteine compounds causes rapid changes in other bodies with which they are in contact. The abundance of albumen in the sap of trees causes the sap-wood to decay more rapidly than other parts of the tree. Animal matter, being made up largely of proteine substances, becomes putrid very soon after life is extinct.

VEGETABLE OILS.

161. Oily matter of some kind is found in almost every variety of plant. It is found in the stalks, leaves, flowers, and seeds. Some vegetable oils are *volatile;* some on exposure to the air form a solid, dry film over the surface of any body upon which they are spread — these are "drying oils." Others are not readily changed by exposure to the air — these are "fixed oils."

162. VOLATILE OR ESSENTIAL OILS. — These are called "essential" oils, because, when dissolved in alcohol, they form "essences." We can notice only a few of the most important.

163. OIL OF TURPENTINE (*Camphene*) is prepared by distilling the crude turpentine which exudes from pine-trees. It is distilled with water (§ 23); and as the oil and water become condensed in the receiver, they at once separate, the oil floating on the surface. After the first distillation, it is called "spirits of turpentine," and still contains some resinous matter. To free it from this, it is distilled

again, and is then called "camphene." Its composition is represented by the formula: C_5H_4 (or, $C_{10}H_8$).

Camphene is a clear liquid, volatile and combustible. It burns with the production of a large quantity of smoke. The smoke consists of unburnt carbon. The hydrogen of the oil is more combustible than the carbon, and combines first with the oxygen of the surrounding air: the supply of oxygen not being sufficient for both, the carbon is set free as smoke. There are lamps constructed so as to throw a strong current of air against the sides of the flame, and in this way oxygen enough is supplied to make the combustion complete.

164. USES.—Oil of turpentine is extensively used as a solvent for varnishes, and in the preparation of paints; also for dissolving india-rubber and gutta-percha. But for no purpose is it so largely used as for producing light. It is frequently burnt alone in lamps constructed for the purpose (§ 163), but most largely consumed in the form of

BURNING FLUID.—We have already learned, that camphene alone has too much carbon in it to adapt it well for burning. Alcohol, on the other hand, has too little carbon in it to produce much light. The brightness of flame is caused by atoms of carbon suspended in it, and kept at a white or yellow heat until they reach the outer part of the flame, where they meet with the oxygen of the air, and are entirely consumed. If there is a deficiency of carbon, it is consumed too quickly to give much light, as in alcohol; if an excess of carbon, smoke is the result, as in camphene alone. Now, when a portion of camphene is dissolved in alcohol, it supplies the deficiency of carbon; and in this way the two liquids counteract the defects of each other. Such a solution is common "burning fluid."

Oils of orange, lemon, citron, bergamot, pepper, etc. are similar in composition, and in some of their properties, to oil of turpentine. *Camphor* is also a volatile oil, obtained from a tree (*laurus camphora*).

Drying Oils are obtained chiefly from the seeds of plants. Among the most common and useful are *linseed oil* (from the seed of flax), *hempseed oil*, *walnut oil*, *castor oil* (used also in medicine and perfumery), and *oil of cotton-seeds*, which seems to have some drying properties, and is hence sometimes classed with drying oils. These oils are used for mixing paints; and by the action of the air they are converted into a firm resinous substance, which adheres to the surface painted, and retains the particles of coloring matter, which were not dissolved in it, but simply *mixed* with it.

166. Fixed Vegetable Oils are such as retain their oily character when exposed to the air. They often absorb oxygen when exposed to the air for some time, and produce acids of strong odor: they become *rancid.*

Olive Oil is one of the most common and useful of the fixed vegetable oils. It is obtained from the pulp of the olive fruit. It is used for food, for oiling machinery, and for various other purposes. *Palm oil*, from the fruit of the palm-tree, is solid at common temperatures. It is used extensively for making soap. *Almond oil*, obtained from the sweet almond, is highly valuable in the manufacture of soap, and in the preparation of some ointments.

167. *Oil* is one of the necessary articles of food for animals; and, in order to meet this necessity, the kind hand of Providence has made the crops produced by the earth, an abundant source of this, as well as the other elements of nutrition demanded by the animal kingdom.

RESINS.

168. Some of the vegetable oils become oxidized by exposure to the air, and form solid bodies called "resins."

Of these, we find the one most common and most important, formed by the oxidation of oil of turpentine. As the crude turpentine collects in the wounds cut in the sides of trees for the purpose, it gradually absorbs oxygen, and becomes partially converted into resin. By distillation the oil of turpentine is removed, and an involatile resinous mass remains. This generally passes under the name of "rosin."

169. USES OF ROSIN.—(1) It is frequently employed in the preparation of illuminating gases. (2) Mixed with animal fats, it is used in the manufacture of "rosin soap." (3) A soap prepared from rosin is used for giving compactness and smooth surface to paper. It is mingled with the material in making the paper. (*Porter.*)

Copal, Lac, and *Mastic* are some of the resins commonly employed as varnishes. Lac dissolves most readily in alcohol. Besides its use in varnishing, it is largely consumed in making *sealing-wax,* which consists of lac (shellac) mixed with a little Venice turpentine, and some coloring matter.

170. GUM RESINS are the products of plants in warm climates. They contain both gum and resinous matter. Of these, *india-rubber* and *gutta-percha* are the most important.

171. INDIA-RUBBER (*Caoutchouc*).—"This well-known substance is obtained by making incisions through the bark of certain trees of the fig or banyan species, which grow in S. America and the E. Indies: a milky juice flows out, which, upon evaporation, yields about 32 per cent of caoutchouc. The poppy, the lettuce, and other plants having viscid, milky sap, seem also to contain it. Caoutchouc, when pure, is white and transparent; its dark color being due to the blackening effect of the smoke in drying. It is highly elastic, and the freshly-cut surfaces adhere strongly, if pressed together. It is insoluble in water, alcohol, and acids; but dissolves in ether, naphtha, spirits of turpentine, and other essential oils. The solutions in ether and naphtha

leave the caoutchouc in an elastic state. It is a simple hydrocarbon, containing no oxygen, and burning with a luminous sooty flame. Its uses are very various. Dissolved and applied to fabrics, it forms water-proof cloth: it is also used for shoes; and when cut into thin shreds, and boiled with linseed oil (4 ozs. caoutchouc to 2 lbs. of oil), it forms a mixture used for making boots water-tight."—*Youmans.*

Vulcanized India-rubber is that which has been exposed to the action of melted sulphur. The sulphur, uniting with it, makes it more firm, and less liable to be influenced by changes of temperature.

GUTTA PERCHA is a substance obtained, like India-rubber, from the sap of certain trees. It is not so elastic as India-rubber, and has the property of becoming so soft, when immersed for a few minutes in hot water, that it may be moulded to any shape with the fingers. It becomes very firm and hard on cooling.

VEGETABLE ACIDS.

172. OXALIC ACID is found in the different kinds of sorrel, and gives them their sour taste. It is easily prepared from sugar or starch by the action of nitric acid. *Exp.*—Mix three ounces of nitric acid with two ounces of water, and add half an ounce of sugar. Heat the mixture in a glass or porcelain vessel. Red vapor will soon begin to escape freely. Continue the heat until the solution is evaporated to one-half the original quantity, and then set it aside to cool. In a few hours the bottom of the vessel will be covered with beautiful, slender crystals of oxalic acid. Its composition is C_2O_3,HO. This acid is very poisonous, and if accidentally taken into the stomach, magnesia or lime-water should be given immediately.

173. TARTARIC ACID is procured chiefly from grapes. During the preparation of wines, a hard crust is deposited

on the inner surface of the vessels in which the wine is fermented. This crust is an acid tartrate of potassa, and when purified is called "Cream of Tartar." By mingling powdered chalk with cream of tartar in water, tartrate of lime is formed. This is again decomposed by sulphuric acid, which removes the lime in an insoluble form, leaving the free tartaric acid in solution; from this it is crystallized by evaporation. The composition of this acid is $C_8H_4O_{10},2HO$. Tartaric acid is extensively used in the preparation of effervescing powders. With carbonate of soda or potassa it causes rapid effervescence.

One atom of a base is not sufficient to neutralize an atom of this acid. It requires two atoms of any one base, or one atom of two different bases. *Cream of Tartar* consists of only *one* atom of potassa, united to each atom of acid, and is therefore an acid salt. If an additional quantity of potassa or soda were added to cream of tartar in water, the acid would unite with a *second* atom of either of these bases; or if the carbonates of the bases were added, the same result would take place, and the *carbonic gas would be set free.* This is what takes place when cream of tartar and carbonate of soda are mingled together in making bread.

174. CITRIC ACID is found abundantly in lemon juice, and in the orange. *Malic acid* is the acid of apples, gooseberries, and many other fruits. It is also the acid of *garden rhubarb.*

175. TANNIC ACID is the astringent substance in oak bark, and in the leaves and bark of many trees. It is found in *tea,* to which it gives an astringent taste. When the skins of animals are steeped for some time in an infusion of oak or hemlock bark, the tannic acid combines with the skin and forms *leather* (see § 589).

Ink is a compound of iron and tannic acid, or rather of peroxide of iron and this acid. For making ink, the tannic acid is obtained from nut-galls (a kind of excrescence found on the leaves of some species of oak).

VEGETABLE BASES.

176. Plants often produce *bases*, as well as acids. These are not free, as they exist in the plant, but generally in combination with acids. They possess the property of neutralizing acids, and are hence called "vegetable alkaloids." They all contain *nitrogen*, and are in some respects similar to ammonia. Many of them are valuable for their medicinal properties. We can notice only a few of the most important.

177. *Quinine* is obtained from *Peruvian bark*. It is this alkaloid, together with another called "cinchonine," which gives Peruvian bark its medicinal value.

Morphine and *Narcotine* are the alkaloids of *opium*, and give that drug its peculiar properties. *Strychnine* is found in the *nux-vomica*, *St. Ignatius's bean*, and some other substances. It is a most fatal poison. *Theine*, or *caffeine*, is a substance found in both tea and coffee, having stimulating properties, which give these articles their value as beverages. *Nicotine* is a very poisonous alkaloid existing in tobacco. Taken in small quantities into the stomach, as it is by tobacco-chewers, or into the lungs, as it is by smokers, it produces a kind of mild intoxication, and on this account is esteemed a great luxury.

COLORING COMPOUNDS (*dye-stuffs*).

178. INDIGO.—This common blue substance is obtained from plants. It is colorless in the juice of the plant, but when exposed to the air it becomes blue. Its use in dyeing is well known.

MADDER is the root of a plant cultivated in different parts of the world. The root is dried and ground to a powder, from which the coloring matter is extracted for dyeing purposes.

LOGWOOD is found as a common tree in Central America, and is sold either in the form of wood, or an *extract* from the wood, and used as a coloring substance.

179. COLORS OF FLOWERS, LEAVES, &c.—The beautiful colors of flowers are caused by some transient compounds, seldom permanent enough to be separated, or even to survive the drying of the bodies in which they exist.

CHLOROPHYLL is the name given to the *green* coloring matter of leaves, and other green parts of plants. It "is one of the most widely diffused substances in the vegetable kingdom, since it occurs in all parts of the plant which possess a green color. As found in plants, it is a mixture of wax and of several coloring matters not well known. It need hardly be said that it is not soluble in water; for if it were, the water would become green on flowing over meadows. The expressed juices of the herbs are indeed green, but it is obvious from their turbidness that the leaf-green is only mechanically mixed with the liquid. We become still more fully convinced of this by the separation of the coloring matter which takes place when the juices are boiled, or allowed to remain for some time in repose. If, on the other hand, alcohol, ether, or weak lye, is poured on the green leaves, we obtain green solutions; hence all the tinctures of pharmacy which are prepared from leaves or stalks have a green color. The green color appears only in those parts of the plant which are exposed to the light; it is obvious from this, that the chemical compound which we call chlorophyll is only generated with the coöperation of light. When separated from plants, this coloring matter is very soon decomposed; it is, therefore, not at all suited for a coloring substance, except, perhaps, for cordials and other liquids. In the autumn it is converted in the leaves themselves, into leaf-yellow and leaf-red, probably by a process of oxidation." —*Stockhardt.*

Chlorophyll contains *nitrogen* as well as carbon, hydrogen, and oxygen; and the importance of nitrogen in fertilizers may give to this compound a value in green crops, of which we are not fully aware.

QUESTIONS ON CHAPTER VI.

§ 130. What do we find peculiar in a plant or an animal? What is *organic matter?*

131. Of what elements are organic bodies chiefly composed? What example is given of a substance containing *all* of them? of one containing only *three?* containing only *two?* What two elements are less abundant in organic bodies? Examples?

132. What is always left when an organic body is burnt? What elements disappear? What is the inorganic part of a body? What substances are found in ashes?

133. What is said of the compounds formed by the union of the organic elements? What are proximate constituents? How illustrated?

134, 135. When may we group substances together? What substances constitute the starch group?

136. Where is pure vegetable fibre found? In what other form is it abundant? What formula represents its composition? The proportions by weight of C, H, and O? What shows the great importance of vegetable fibre?

137, 138. Composition of *Starch?* What does it resemble in composition? Most abundant sources? How does it appear under the microscope? Effect of cold water? Of hot water? "British Gum?" Effect of dilute sulphuric acid on starch water? What is the starch then called? If boiled several hours with the acid, what change takes place?

139, 140, 141. Composition of *Grape Sugar?* Where found? How formed from starch? Explain the ripening of fruit. Formula of *Cane* Sugar? From what chiefly obtained? Its qualities? What is sugar of milk? How prepared?

142, 143, 144. Composition of *Gum?* Examples mentioned? How converted into grape sugar? What is *Pectose?* What change may *vitality* produce in any member of the starch group?

145, 146. What is *Peat?* Describe its formation. How converted into coal? Where are peat-bogs generally found? Uses of peat?

147. What is *Humus?* In what forms does it exist? Conditions necessary to its formation? Explain the chemical changes which take place during its formation. Its influence on ammonia? What experiment is mentioned?

148, 149, 150. Formula of *Alcohol?* From what produced? Explain the chemical changes in its formation. What is necessary to produce vinous fermentation in sugar? How are starch and cane sugar converted into alcohol? Explain the distillation of alcohol. How does it burn? Alcohol of wines? Explain the raising of bread. How does baking increase its lightness?

151, 152. What is the acid of vinegar? How produced? Explain its formation. How is vinegar formed? What determines its strength? Why is air necessary to its formation? Methods of promoting its fermentation? What are *Acetates?* Examples given? Uses?

153. What is the influence of curd on a solution of sugar? Why called lactic acid?

154. What elements are contained in the proteine group? Most important compounds in this group?

155, 156, 157. Describe *Gluten.* Why called vegetable fibrin? What is vegetable albumen? How obtained from flour? Why called albumen? From what is vegetable *Caseine* produced? What experiment shows its properties?

158, 159, 160. What of the importance of these? Why necessary in animal food? Are they present in all crops? How may they be preserved unchanged? Effect of air and moisture? Products of their decomposition? Their influence on the decay of other bodies? Why do animal bodies readily decay?

161, 162. Where is *oily matter* found? What are drying oils? Fixed oils? Essential oils?

163, 164. How is *Oil of Turpentine* formed? When called spirits of turpentine? Camphene? Its formula? Describe camphene. Why does it smoke when burning? How is this prevented? Its uses? What is burning fluid? What are the advantages of combining camphene and alcohol? What other oils are similar to oil of turpentine?

165. From what are drying oils obtained? Give examples. For what are they used? Explain the drying of paint.

166, 167. What are *Fixed Oils?* How do they become rancid? What is olive oil? Palm oil? Almond oil? Why are all forms of vegetable food provided with oil?

168, 169. What are *Resins?* Which is the most important? Uses of rosin? What of copal, lac, etc.?

170, 171. Where is *India Rubber* obtained? What other name has it? Its properties? Uses? How vulcanized? What of gutta percha?

172. Where is oxalic acid found? How prepared artificially? Give the experiment. Formula of its composition? Effect on the stomach? Antidotes?

173, 174, 175. How is *Tartaric Acid* procured? Explain the collection of cream of tartar. How is tartaric acid prepared? Its uses? Does one atom of a base neutralize it? What is cream of tartar? Why used in bread-making? What of *citric* and *malic* acids? Sonrces of *tannic* acid? What is leather? Ink?

176, 177. What of *bases* in plants? What are they called? With what do they combine? What of *Quinine?* Of *Morphine, Narcotine,* and *Strychnine?* Of *Thein* and *Caffeine?* *Nicotine?*

178, 179. How is *Indigo* obtained? *Madder?* Logwood? What of the colors of flowers, the leaves, etc.? What is *Chlorophyll?* Where found? Is it soluble in water? On what part of the plant does the green color appear? What of the influence of light upon it? Of what is chlorophyll composed?

CHAPTER VII.

MINERAL CONSTITUENTS (ASHES) OF PLANTS.

180. In § 132 the *ashes* of plants have been defined, and the substanees generally found in them have been mentioned. The mineral constituents of the same species of plants differ but little, no matter where the plant may grow. The ashes of the oak have very nearly the same composition all over the world. Wheat cultivated in America differs but little, in the quantity and quality of its ashes, from that which is cultivated in Europe. Local causes may produce slight variations, some of which will be hereafter noticed.

181. Quantity of Ashes.—1. *Different parts of the same plant yield different quantities of ashes.* For example, 100 pounds of the dry grain of *wheat* yield, when completely burnt, about two pounds of ashes; while 100 pounds of the *straw* yield about 6 pounds of ashes. So the grain of corn yields about 1½ per cent. of ashes, while the stalk yields about 5 per cent.; and so of other erops.

2. *Different plants yield different quantities of ashes.* The oak, for example, gives about 2½ pounds of ashes from 100 pounds of the wood well dried; but hickory gives about 4 or 5 pounds of ashes from 100 pounds of the dry wood.

182. The relative quantity of ashes from *different parts* of the same plant, as well as from *different kinds* of plants, will be seen at once, by examining the following table:

TABLE II.

100 lbs	of dry	Oak *	yield about	2½	lbs	of ashes.
"	"	Ash or Hickory	"	4 or 5	"	"
"	"	Pine	"	1	"	"
"	"	Wheat Straw	"	6	'	"
"	"	Stalks of Indian Corn	"	5	"	"
"	"	Grain of Wheat	"	2	"	"
"	"	" Corn	"	1½	"	"
"	"	Potato (sliced and dried)	"	4	"	"
"	"	Potato Stalks	"	12	"	"
"	"	Tobacco Leaves	"	20 to 23	"	"
"	"	" Stalks	"	10 to 12	"	"
"	"	Cotton-wool	"	1	"	"
"	"	" Seeds	"	4	"	"
"	"	Hay	"	7 to 10	"	"
"	"	Peas	"	3	"	"
"	"	Pea Straw	"	8	"	"

183. The quantity of ashes, in the same kind of crop, varies but little, as above stated, wherever that crop may be cultivated. A difference in soil and climate may cause slight difference in the quantity of ashes, but, as a general rule, the crops cultivated in this country give about the proportions represented in the above table, provided the crop has been cut in the proper state of maturity. The grain of wheat always gives about 2 per cent of ashes, while tobacco leaves seldom vary much below 20, or above 23 per cent; and so of other plants.

184. Ashes from different sources vary in *composition*, as well as in *quantity*.

1. *The ashes from different parts of the same plant differ in composition.* If we analyze the ashes of the grain of any

* The bark and wood taken together. The bark alone yields about three times as much per cent. of ashes as the wood alone.

ordinary crop, as wheat, rye, or corn, and at the same time analyze a like quantity produced from the straw or stalks of the same crop, we shall find a striking difference between them, in some respects. In the ashes of the grains, for instance, we find a great abundance of the *phosphates* of lime, magnesia, and potassa; while in those from the stalks, we find a much smaller quantity of these phosphates, but a very large quantity of *silica*, of which there was very little in the grain.

2. *The ashes of different plants differ in composition.* If we examine a hundred pounds of ashes of *potatoes*, we shall find in them about 50 *lbs. of potassa*, about 2 *lbs. of lime*, about 12 or 13 *lbs. of sulphuric acid*, and about 4 *lbs. of silica.* But in the same quantity of ashes of *hay*, we shall find only about 18 *lbs. of potassa*, whilst we find there about 23 *lbs. of lime*, and only about 3 *lbs. of sulphuric acid.*

185. The table opposite (III) gives a close approximation to the average composition of ashes from various sources. This table consists of the *mean* results of the most reliable analyses of ashes, made by different chemists. The author has made several analyses of this kind himself, and has compared them with others — taking the mean of all, as representing what might be regarded as the nearest approximation to a fair average composition of all the varieties here given.

It will be observed that the quantity of each crop required to produce 100 lbs. of ashes, is given at the top of the column in the table assigned to that crop. We must, for example, burn 5000 lbs. of wheat grain, 1600 lbs. of wheat straw, or 450 lbs. of tobacco, in order to get 100 lbs. of the ashes of either of these crops; while it would require about 10,000 lbs. (5 tons) of potatoes, in the condition in which they are taken from the ground, to yield 100 lbs. of ashes.

186. The mineral matter in plants is essential to their

TABLE III.

ASHES OF CROPS.

Quantity of crop required to yield 100 lbs. of ashes.	5000 lbs. of	6600 lbs. of	4000 lbs. of	1600 lbs. of	2000 lbs. of	3300 lbs. of	1200 lbs. of	1000 or 1200 lbs. of	450 lbs. of	10,000 lbs. of	10,000 lb. when undried
Composition of 100 lbs. of ashes.	Grain of Wheat.	Grain of Ind. Corn.	Grain of Oats.	Straw of Wheat.	Stalks of Corn.*	Beans and Peas.	Bean or Pea Straw.	Hay.†	Tobacco.	Cotton Wool.	Potatoes.
Potassa........................	25.7	27.2	23.4	10.0	28.6	41.06	14.58	18.2	5.70	40.15	53.8
Soda..............................	6.1	5.3	3.2	2.7	9.6	2.03	9.56	2.3	7.61	5.35	2.4
Lime..............................	2.8	1.4	5.0	7.5	8.3	5.20	30.63	22.9	32.13	20.75	3.6
Magnesia........................	13.5	15.7	9.5	5.0	6.6	6.57	6.95	5.7	19.12	10.47	5.8
Oxide of Iron..................	.7	.3	.4	1.2	0.8	2.00	1.15	1.7	0.64	2.65	0.7
Phosphoric Acid..............	48.6	47.0	46.5	3.0	17.1	38.56	10.81	6.0	11.36	6.50	13.7
Sulphuric Acid................	1.0	1.2	9.6	3.8	0.7	1.44	8.21	2.7	7.14	4.45	9.5
Silicic Acid (Silica)..........	1.5	1.6	2.3	66.0	27.0	1.00	10.75	37.9	12.15	2.18	7.6
Chlorine.........................	.1	.3	.1	.8	1.5	2.14	7.36	2.6	4.15	7.50	2.9
	100.	100.	100.	100.		100.	100.	100.	100.	100.	100.

* Johnston.

† Porter.

growth, as we learn: 1. From its being present in the same plant, in about the same proportions, wherever that plant may grow, provided it has come to full maturity; and, 2. From the fact that a plant will not grow in a soil destitute of the mineral matter peculiar to the ashes of that plant.

187. The mineral ingredients of plants, being involatile, cannot constitute any part of the atmosphere; hence, they must find this part of their nourishment altogether in the soil. Of this part of the subject, a more full discussion will be given in a subsequent chapter.

QUESTIONS ON CHAPTER VII.

§ 180. What are the *ashes* of plants? What is said of their composition in the same plant, wherever found? Examples.

181, 182, 183. What of different quantities in different *parts* of the same plant? Examples. Quantities yielded by different plants? Examples. What does Table II. represent? Influence of soil and climate on the quantity of ashes?

184, 185, 186, 187. What of the composition of ashes in different parts of the same plant? How illustrated? What of ashes from different plants? Illustration. Explain Table III. What do the numbers at the top of each column represent? From what source do plants receive their mineral ingredients?

CHAPTER VIII.

ANIMAL CHEMISTRY.

188. In studying the organic elements of plants, we have found the "starch group" most conspicuous. Vegetable fibre and starch make up the greater part of all ordinary crops. But when we examine the composition of animals, we find a different group holding the first place. The "proteine group" aids in the formation of almost every part of the animal system. These nitrogenized compounds constitute the greater part of the skin, the muscle, and the tendons.

189. Let us now examine the composition and properties of the most important elements found in the animal kingdom.

Proteine Group. — Several substances under different names, but very similar in composition, constitute this well-defined group. They are *Fibrine, Albumen,* and *Caseine.*

190. *Fibrine* is the fibrous part of lean meat or muscle of animals. *Experiments.* — 1. Cut a few ounces of lean beef into small particles, and pour over the mass a little cold water; after allowing it to stand a few minutes, press the water out of it in a linen rag. Repeat this two or three times, and what is called "flesh fluid" will be all washed out. Then boil the meat in a small quantity of water, and again press it as dry as possible in a cloth. The solid residue will be nearly pure *fibrine.* 2. Heat the cold water, with which the meat was first washed, nearly to the boiling point; a frothy mass will separate from it. This is *albumen,* which is soluble in cold water, but coagulates when the water is heated to 160° or 170°. 3. Set aside the small quantity of water, in which the meat was boiled, until it becomes cool,

and it will form a gelatinous mass. This is owing to the presence of *gelatine* extracted from the flesh by boiling water. *Gelatine* is soluble in boiling water, but when the water becomes cold it becomes insoluble, and forms "*jelly*."

191. *Albumen* is found in its purest form in the white of the egg, which consists of a solution of this substance in water. In a boiled egg the albumen is *coagulated*, and rendered insoluble. A solution of corrosive sublimate will coagulate albumen, hence the value of raw eggs as an antidote for this dangerous poison.

192. CASEINE is most abundant in milk. When the cream has been removed from milk, the remainder is chiefly a solution of *caseine*. *Exp.*—Pour a little vinegar, or very dilute muriatic acid, into a tumbler of milk, and the caseine will be set free from solution, in the form of "curd." When milk becomes sour, through the formation of lactic acid, it curdles spontaneously. When the inner coating of a calf's stomach (rennet) is steeped in water, the solution has the property of separating the caseine from milk. When sweet milk is taken into the stomach, it is at once curdled by the acids of the gastric juice. *Caseine* pressed into cakes forms *cheese*. The oily matter (butter) from the milk is mingled with the curd, in making cheese from milk which has not been skimmed.

193. The composition of these three principal proteine bodies of the animal kingdom is presented in the following *table*, according to Mulder's analysis:

TABLE IV.

In 100 parts.	Fibrine.	Albumen.	Caseine.
Carbon	54.56	54.84	54.96
Hydrogen	6.90	7.09	7.15
Oxygen	22.13	21.23	21.73
Nitrogen	15.72	15.83	15.80
Sulphur	0.36	0.68	0.36
Phosphorus	0.33	0.33	

It will be seen that these substances closely resemble each other in composition, with the exception of the absence of phosphorus in caseine.

194. GELATINE is a nitrogenized substance, already mentioned (§ 190) as extracted from animal muscle by boiling water. It may be obtained much more abundantly from the bones, skin, tendons, and some other parts of the animal, by boiling them for some time. In the bones of young animals there is a large quantity of this compound, and comparatively little mineral matter. Hence, calves' feet are a source of gelatine in the preparation of jelly. Common *glue* is a form of gelatine; it is dried jelly. *Isinglass* is dried gelatine. One of its purest forms is found in the dried air-bladder of a species of fish. The gelatine from other animal substances is often dried and sold under the name of "Isinglass."

195. All animal, as well as vegetable compounds, containing *nitrogen*, pass very readily into a state of putrefaction, and emit a strong, disagreeable odor. This is especially the case with fibrine and albumen, which contain both sulphur and phosphorus. These form *sulphuretted* and *phosphuretted hydrogen*, two gases which give the disgusting odor to rotten eggs and decaying meat. Carbonate of ammonia is also set free in large quantities by the decay of animal matter containing nitrogen. These bodies also induce decay, or fermentation, in other substances with which they are in contact. *Cooking* coagulates albuminous substances, and makes their decay less rapid. Hence, cooked meat may be preserved longer in warm weather than the same meat in a raw state.

196. Gelatine forms an insoluble compound with tannic acid (§ 175), which may be kept an indefinite time without decomposition. *Leather* is such a compound. The gelatine, of which the skins of animals are chiefly composed, com-

bines with the tannic acid of the bark used in *tanning*. *Exp.*—Dissolve a little glue or isinglass in boiling water, and, before the solution gets entirely cold, pour into it a little water in which oak bark has been steeped. A precipitate will be formed, which has the same composition as leather.

197. Hoofs, horns, hair, and feathers, are similar in composition to gelatine, having the addition of some *sulphur*. These forms are not converted into jelly by boiling, but they swell and become soft. They decay very slowly.

ANIMAL FATS.

198. The fats of ordinary animals used for food, consist chiefly of two compounds, called "Stearine" and "Oleine." Another called "Margarine" is abundant in olive oil, and exists to some extent also in animal fats. *Stearine is solid* at ordinary temperatures, while *oleine* is fluid (oily). Margarine holds a medium place, being less solid than the former, and less liquid than the latter. *Exp.*—Take several pieces of thick wrapping-paper, six or eight inches square. Spread over one of them, with a knife, a thin layer of beef or mutton tallow. Lay a second piece of paper upon this, and give it a similar layer of tallow. Continue this, until several pieces are treated in the same way. Place the whole mass between two smooth boards, a little larger than the pieces of paper, and lay a heavy weight on the upper board. After an hour or two, separate the pieces of paper, and they will be found coated with a substance apparently drier than tallow. This is almost pure *stearine*. The *oleine* has been absorbed by the paper.

Tallow and *lard* are both mixtures of stearine and oleine. Tallow has a larger proportion of stearine, and less oleine, than lard; and is consequently more solid.

199. Stearine and oleine are compounds of two acids

called "stearic and oleic acids," combined with a compound base called "glycerine." When animal fats are boiled with caustic solutions of potassa or soda, these bases unite with the stearic and oleic acid, and form *soaps*. The potassa compound is *soft soap*, and the soda compound *hard soap*. The glycerine is set free, and remains partly mingled with the soap and partly in the refuse liquid. Lime and lead, with these fatty acids, form *insoluble* soaps.

COMPOSITION OF DIFFERENT PARTS OF ANIMALS.

200. Besides the substance above described, there are others which enter in small quantities into the various parts of the animal; and, where they seem important to a *general* view of animal chemistry, they will be mentioned in their appropriate connections; but many of them must be passed over unnoticed.

201. Skin, Hair, Horns, etc.—These have already been mentioned (§ 197), as being composed chiefly of gelatinous matter. In the outer coating (epidermis) of the skin, a little sulphur is found; and still more in the hair, horns, and hoofs, which may be regarded as appendages to the skin. The tendons, ligaments, etc., have a composition analogous to that of the skin.

202. Flesh.—The solid part of the muscle, or flesh, has been described in § 190 as being composed of a proteine substance called "fibrine." It has an organized structure, and is insoluble in water. In acetic acid, or strong vinegar, it dissolves to some extent. If potassa solution be added to the acetic acid in which a piece of flesh has been digested for some time, the dissolved fibrine will be precipitated, and give the liquid a turbid appearance.

203. There is some *fat* mingled with the fibrine in the muscular part of nearly all animals; but about 80 per cent of the weight of fresh, lean muscle, consists of a fluid called

"flesh-fluid." It holds *albumen* in solution; but when heated nearly to the boiling-point of water, this albumen is coagulated. The flesh-fluid also contains an acid, and some other substances, which give peculiar flavor to meats, and to soups prepared from them. If the water in which fresh meat is to be cooked, is heated to the boiling-point before the meat is put into it, the albumen near the outer surface is at once coagulated; and other portions, as they come near the surface, or as the heat penetrates the mass, are also coagulated; and in this way much of the highly flavored and nutritious juice of the meat is prevented from escaping. But if the object is to get a broth or soup containing as much as possible of the richness and flavor of the meat, the heat should be very gradually applied to the water after the meat has been placed in it.

The most abundant mineral matter in flesh-fluid consists of salts of potassa; but the potassa is not sufficiently abundant to neutralize all the acids of the fluid, for it is found always to be acid in its character.

204. BONES form the framework of the animal. They contain an organized form of *gelatinous* matter, associated with a large quantity of mineral matter, which is chiefly *phosphate of lime*, with a little carbonate of lime; and in some parts of the bones, a trace of fluoride of calcium is found.

Experiments.—1. Boil a fresh bone for some hours in water. Evaporate the water to a small quantity, and set it aside in a cool place. The solution soon becomes jelly. 2. Throw a bone into the fire, and let it remain some time, and it will become white when cool. The gelatinous matter will then be burnt out, and the remainder (bone-earth) is chiefly *phosphate of lime* ($3CaO,PO_5$), with some carbonate of lime, and a little of other salts. 3. Burn a bone in a covered crucible, or small iron pot. The air being thus excluded, the heat will char the organic part without consuming it; and the result will be *bone-black* (ivory-black). 4. Pour dilute muriatic acid over a bone, and set it aside for a day or two; the phosphate of lime will be dissolved out by the acid, and the gelatine will be left as a soft elastic mass, having the same form as the bone. When washed and boiled, this gelatine will be dissolved, and form *glue.*

Bones possess a very high value for fertilizing purposes, as we shall learn in another chapter.

According to Berzelius, 100 parts of the bones of an ox consist,—of animal matter, 33.30; phosphate of lime, and a little fluoride of calcium, 57.35; carb. of lime, 3.85; phos. of magnesia, 2.05; soda, with some chloride of sodium, 3.45.

205. NERVOUS MATTER, of which both the brain and nerves are composed, is a mixture of albuminous matter with some peculiar oily substances.

206. BLOOD.—If fresh blood is stirred for some time with a bundle of small rods or twigs, a fibrous substance will be found adhering to the rods. When washed in clean water, this substance becomes nearly white. It is animal *fibrine,* having the same composition as muscle. But if blood is allowed to stand for a short time without being stirred, it coagulates, or forms a clot. After standing for some time, a colorless liquid separates from the clot. This liquid is called the "serum," and is a solution of albumen. When heated to a boiling temperature, the albumen is coagulated.

The coloring matter of blood consists of small globular bodies, called "blood corpuscles," which are diffused all through the blood when in the veins; but, after exposure to the air for a short time, these corpuscles are separated, and, becoming entangled with the fine threads of fibrine, form the clot.

The chief constituents of blood are *water, fibrine, albumen,* and *corpuscles.*

207. *Mineral salts* are found in the blood; chiefly common salt and phosphate of soda, with some sulphates of soda and potassa. Iron is found in considerable quantity in the coloring matter.

The different conditions of the blood, effects of respiration, and the functions performed by the blood, will be found under the head of Animal Physiology.

208. DIGESTIVE FLUIDS.—These are the *saliva, gastric juice, pancreatic fluid,* and *bile.*

209. *Saliva* is a slightly alkaline fluid, secreted by the glands of the mouth. It is water holding in solution a little organic matter, with some alkaline phosphates and chlorides.

GASTRIC JUICE is secreted from the inner coating of the stomach (mucous membrane). It contains a little *hydrochloric acid* in solution, also some *lactic acid.* These give it an *acid* character. There is a peculiar organic substance found in gastric juice, called "*pepsin.*"* This substance, obtained from the stomach of the ox, is often employed as a medicine, in cases of *dyspepsia.* The gastric juice holds common salt in solution, with small portions of other salts. The acid character of this fluid gives it the power of dissolving (digesting) fibrine, albumen, and other forms of proteine matter.

210. PANCREATIC FLUID is an *alkaline* secretion, from a peculiar organ near the stomach called the "pancreas." This fluid is mingled with the food as it passes out of the stomach into what is called the "duodenum." It has the power of digesting starch and oily compounds.

211. BILE is a secretion from the liver, and is alkaline. It is thrown into the duodenum with the pancreatic fluid; but physiologists differ as to the office it performs in digestion. It is supposed to aid especially in the digestion of fatty substances.

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* From *pepto,* "digest."

MILK.

212. Milk has been mentioned (§ 192) as the chief source of *caseine*. Besides caseine, it contains little globules of *oily matter* (*butter*), and a peculiar kind of sugar, called "sugar of milk," or "lactose." The method of separating caseine has been already given. If the clear *whey*, left after the caseine is removed, be evaporated to dryness, a mass of crystalline sugar will be obtained (see § 141). When milk becomes sour, this sugar is converted into *lactic acid*. *Churning* consists in simply agitating the milk so as to cause the little globules of butter to unite into masses of sufficient size to be easily separated from the liquid. Butter is composed chiefly of two fats: *oleine*, which is oily at common temperatures, and *margarine*, which is solid. When exposed to the air for some time, butter becomes *rancid*, by a portion of volatile acid being generated in it, which gives it a disagreeable taste and odor. It may be again sweetened, at least to some extent, by boiling it several times in two or three times its own volume of water, or by careful washing with fresh milk.

213. Ashes of Milk.—When milk is evaporated to dryness, one hundred ounces of it will yield about 12½ ounces of solid matter. About 87½ ounces of water have disappeared, while caseine, butter, sugar, and mineral matter are left. If you now burn this 12½ ounces of solid matter to *ashes*, the caseine, butter, and sugar, will disappear, being all decomposed and expelled by the heat. The ashes left will weigh about a half-ounce. That is, one hundred ounces of milk contain about a half-ounce of mineral matter. Nearly the half of this mineral matter is *phosphate of lime*, a little more than one-fourth of it is chloride of potassium, while the remainder is made up of phosphate of magnesia and salts of soda and iron. Milk contains just those elements best

fitted to promote the growth of the young animal for whose nourishment an all-wise Creator designed it.

EXCREMENTS.

214. The refuse portions of the food, and the waste matter of the animal system, are thrown off partly in a solid and partly in a liquid form. The *solid excrements* (fæces) consist, for the most part, of those constituents of the food which are not dissolved in the stomach — not digested; in the herbivorous animals, they consist principally of vegetable tissue, chlorophyll, wax, and insoluble salts; in the carnivorous animals, dogs for instance, frequently almost wholly of inorganic substances, as phosphate of lime, magnesia, &c., mixed with but a very small quantity of organic matter. The beneficial influence of solid excrements on vegetation is principally owing to the *inorganic* compounds contained in them (lime and magnesia, phosphoric acid and silicic acid).

215. By the *urine,* which is separated in the kidneys from the arterial blood, the soluble salts contained in the food, and also the *nitrogen compounds,* no longer necessary for the vital process, are removed again from the body; it is natural, therefore, that the constituents of it, as likewise of the fæces, should correspond exactly with the *food* consumed. If this is rich in soluble salts, the urine will also be rich in them; if this contains only a few soluble, and many insoluble salts, the urine will be poor in soluble salts, while the fæces will be rich in insoluble salts. Consequently the amount of inorganic substances in the animal excrement, or manure, may be just as accurately ascertained from the food which the animal consumes, as from the manure itself. The food has only to be burned, and the remaining ashes examined; those parts of it which are soluble in water, correspond with the salts of the urine; those which are insoluble, to the salts of the

fæces. We find in the urine of cows and horses principally alkaline carbonates, muriates, and sulphates of potassa, soda, and ammonia; in the urine of men, moreover, some alkaline phosphates.

216. "*Nitrogen* is contained in the urine, either in the form of *urea, uric acid,* or *hippuric acid. Urea* occurs in the greatest abundance in the urine of the higher animals, especially the carnivorous quadrupeds. . . . . In a practical point of view, that decomposition which urea undergoes in urine, when the latter putrefies by long standing in the air, is of great importance. During this decomposition, the urea combines with the constituents of two atoms of water, and becomes thereby *carbonate of ammonia;* from

Urea =	Carbon, Oxygen,		Nitrogen, Hydrogen;
and Water =	Oxygen		Hydrogen
are formed,	*Carbonic acid*	and	*Ammonia.*

217. "*Uric acid* (lithic acid) predominates in the urine of the lower animals. The white excrements of birds and snakes (a mixture of fæces and urine,) consists chiefly of *urate of ammonia.* In the pure state it consists of fine white crystalline scales, which are dissolved in water only with extreme difficulty. On account of this difficult solubility, it sometimes separates spontaneously from the urine, as gravel and urinary calculi. If the excrements, which are rich in uric acid, are allowed to remain for some time exposed to the air they will absorb oxygen, and afterwards contain *oxalate of ammonia;* but if the latter takes up more oxygen, it passes over into *carbonate of ammonia.* Thus is explained the cause why we frequently find in some sorts of guano only traces of uric acid, but in place of it, large quantities of oxalates.

218. "*Guano,* which in recent times has been in such demand as a manure, owes its efficacy chiefly to the *uric acid*

(as urate of ammonia) contained in it; or, in as far as this has already undergone decomposition, to the *ammoniacal salts* formed from it, and in part also to inorganic salts (sulphate, phosphate, and muriate of potassa, soda, lime, magnesia, &c.) present in it. On account of the great difference in the article, it is indispensable that the farmer should test it before its application. This is done with sufficient accuracy for agricultural purposes in the following ways:

Experiments. — *a.* Pour some strong vinegar over guano; no perceptible effervescence should ensue. A brisk effervescence would indicate an admixture of carbonate of lime. *b.* Heat half an ounce of guano in an iron spoon, over an alcohol lamp or over glowing charcoal, till it is burnt to white ashes; good guano should only leave behind, at most, one dram ($\frac{1}{8}$ ounce) of ashes. How much alkaline salts this ashes contains, may be ascertained by extraction with hot water; what remains (undissolved) are lime and magnesian salts. The inferior sorts of guano often yield, after burning, three-quarters of ashes. *c.* Treat an ounce of pulverized guano several times with hot water, and decant the liquid after it has become clear on settling; then dry and weigh the muddy mass which finally remains; it should not weigh more than half an ounce.

219. "*Hippuric Acid.*—This azotized acid always occurs in the urine of herbivorous animals: it crystallizes in long, white needles, and is difficultly soluble in water. On the putrefaction of the urine, it is converted into benzoic acid and ammonia.

"Human urine contains the above-named compounds (rich in nitrogen)—urea, uric acid, and hippuric acid; the first (urea) in the largest quantity.

220. "When urine remains for some time exposed to the air, it undergoes a decomposition, by which volatile substances having a disagreeable odor are formed: it passes

into *putrefaction.* It is obvious, from what has been stated, that *carbonate of ammonia* is to be regarded as the principal product of this decomposition. . . . . This change takes place when the urine is collected in manure heaps, or is poured upon the soil. To prevent the escape of the volatile carbonate of ammonia, it is best to add gypsum, dilute sulphuric acid, etc." — *Stockhardt.* See also § 378.

QUESTIONS ON CHAPTER VIII.

§ 188, 189. What group of proximate constituents did we find most conspicuous in the chemistry of plants? What group is most conspicuous in animal chemistry? The most important substances of the proteine group?

190. What is *fibrine?* First experiment? second? third?

191. What is *albumen?* Influence of heat upon it?

192. Where is caseine most abundant? How separated? Effect of rennet on milk? Of the acid juices of the stomach? What is cheese?

193. What does Table IV represent? How do these substances differ?

194, 195, 196, 197. What is *gelatine?* What of the bones of young animals? What is glue? Isinglass? What of the putrefaction of animal bodies? What substances are set free? Influence of decaying animal matter on other substances? How does cooking prevent putrefaction? What is the chemical process in tanning? How illustrated? What of hoofs, horns, etc.?

198, 199. Of what are fats of ordinary animals composed? Properties of *stearine* and *oleine?* How separated? Of what are tallow and lard composed? How do they differ? What is the chemical composition of stearine and oleine? How are soaps formed? Soft soap and hard soap? Soaps of lime and lead?

200, 201. Of what are skin, hair, and horns composed? What of sulphur in these? Tendons and ligaments?

202, 203. Of what is the flesh of animals composed? Its structure? Effect of acetic acid upon it? How precipitated? What is mingled with fibrine in the muscles? What constitutes the greater part of the weight of fresh lean meat? Composition of flesh fluid?

What of cooking meat?—making soup? Most abundant mineral substance in flesh fluid?

204, 205. Describe the *bones* of animals. First experiment? second? third? fourth? For what are bones valuable? Composition of an ox-bone? What is *nervous matter?*

206, 207. How may fibrine be separated from fresh *blood?* When does blood coagulate? What is the serum? Coloring matter of blood? Chief constituents of blood? Mineral salts?

208, 209, 210, 211. What are the *digestive* fluids? Describe saliva. Gastric juice? For what is pepsin used? Describe the pancreatic fluid. What substances are digested by it? Secretion of bile? Its office?

212, 213. Chief solid constituent of *milk?* What is butter? How is sugar of milk obtained? Explain the souring of milk. What is churning? How does butter become rancid? How may it be sweetened? How much solid matter in milk? How much ashes in milk? Chief mineral constituent? For what is milk peculiarly fitted?

214, 215, 216. Office of the *urine?* How is its composition influenced by food? Chief salts in the urine of cows and horses? What substances in urine contain nitrogen? What changes take place in the putrefaction of urine? What are the products? Excrement of birds?

217, 218. Properties of uric acid? Result of the decomposition of urate of ammonia? Most valuable ingredient in *guano?* Mineral salts of guano? Experiment *a?* Experiment *b?* Experiment *c?*

219, 220. Where is *hippuric* acid found? What of human urine? Its putrefaction? How may its carbonate of ammonia be preserved?

CHAPTER IX.

SOURCES FROM WHICH PLANTS DERIVE THEIR NOURISHMENT.

221. It has been stated (in § 132) that plants are composed of two sets of elements: (1) The "organic elements," which are volatile, and disappear during combustion; (2) The "inorganic or mineral elements," which are incombustible, and constitute *ashes*. These two classes seem equally necessary to the healthy growth and full development of the plant. They constitute the food of the plant, as they are taken up by it while growing.

222. *Sources of Plant Food.*—Plants do not get *all* their food from the soil on which they grow, as many persons suppose. The *soil* and the *air* both furnish nourishment to the growing crop. Through its *roots*, the plant is in constant contact with the soil, and through its *leaves* it is in constant contact with the air. The roots are so constructed as to be able to absorb from the soil such food as is required from that source, whenever it is found there in a proper condition. But all substances taken up by the roots must be first rendered soluble, as these organs can absorb matter only in the liquid form.

223. *The mineral elements*, being involatile, are not found in the air; hence, they must be derived from the soil alone. Besides these, the soil must have a sufficient quantity of water to dissolve whatever is required by the plant. The soil also contains, generally, a considerable quantity of organic matter, the use of which we shall see in the next section.

224. *Whence do plants get their organic elements?* These have been stated to be chiefly four—carbon, hydrogen, oxygen, and nitrogen. *The carbon* of plants is derived chiefly but not entirely, from carbonic acid. This gas is one of the constituents of the atmosphere, and is found to make about the $\frac{1}{1500}$ part of the weight of air, whether this air be collected in the lowest valley or on the top of the highest mountain. Plants have the power of collecting carbonic gas from the air through their *leaves.* As the organic matter in the soil undergoes decay, this gas is freely generated, and, being absorbed by the water of the soil, is conveyed abundantly to the roots of the growing plant. As rain descends through the air, it absorbs a considerable quantity of carbonic gas, and conveys it to the soil. Thus we find both the atmosphere and the soil to be sources of this carboniferous food. Whether the carbonic acid be absorbed by the roots or by the leaves, it circulates through the plant in solution in the sap; and under the influence of light it is *decomposed,* the plant retaining the *carbon,* and throwing off the oxygen through the leaves. This action goes on chiefly by day, and most rapidly under the direct rays of the sun. Hence, plants grow more rapidly by day than by night. If light be excluded entirely, the plant soon dies.

The *humus* of the soil, or rather some of its constituents, become soluble in certain combinations. In this form, too, *carbon* is doubtless taken up by the roots, and conveyed through the sap to the different parts of the growing plant.

225. *Hydrogen and Oxygen* are supplied to plants in the form of *water.* If you look back over the vegetable compounds which we have studied, you will find a large part of them containing H and O in the proportions in which these exist in water. Take, for example, starch ($C_{12}H_{10}O_{10}$). Here we find the elements of *ten atoms of water.* In the formation of such a compound as starch, twelve atoms of carbonic

* Also written ($C_{24}H_{20}O_{20}$).

acid must be decomposed, and their carbon combined with ten atoms of water, to form *one* atom of starch. The *leaves* absorb water *from the air;* the *roots* absorb it *from the soil.*

226. *Nitrogen* is not so abundant in plants, as the other three organic elements; but it is not less important, and even essential, to their growth. *Ammonia* (NH_3) is no doubt the chief source from which plants get their nitrogen; and some chemists believe it to be the only form in which nitrogen is taken into the growing plant. But nitric acid (in the nitrates), and several other nitrogen compounds, are doubtless sources from which this important element is often derived. Prof. Johnston says: "There seems, indeed, very little solid foundation for the opinion held by some, that the plants *in our cultivated fields* derive the *whole* of their nitrogen from ammonia and nitric acid together—still less, that they obtain it from ammonia alone." Still, ammonia is *the great* source of nitrogen to the vegetable world.

227. *Ammonia* is found both in the atmosphere and the soil. From the atmosphere it is carried down by rain and snow. In the soil it is generated by the decay of such animal and vegetable compounds as contain nitrogen. It is retained by the clay, as well as by the *humus* of the soil (see § 367). Some plants are believed to absorb it from the air, through the leaves; but in most cases it enters through the roots from the soil. Although nitrogen is so abundant as the chief constituent of our atmosphere, it rarely (perhaps never) enters directly in its pure, gaseous form, into any of the combinations in which it occurs in organic substances. In contact with decaying organic matter in the soil, and in other closely confined localities, nitrogen from the air unites with nascent hydrogen, forming ammonia. The ammonia formed in this way, as well as that which is set free by the decay of proteine matter, may be again decomposed in the presence of strong bases, such as lime and alka-

lies; the nitrogen of NH_3, becoming oxidized, forms nitric acid (NO_5), while the hydrogen, combining with an additional quantity of oxygen, becomes water. The nitric acid thus generated combines with whatever bases may be present, forming nitrates. "Nitre (nitrate of potassa) is often generated in arable land, whence it passes into the juice of plants; thus it is known that beets and tobacco, growing upon very strongly manured soil, and also those rank plants growing on manure heaps, such as henbane, thorn-apples, etc., are frequently so rich in nitre, that when dried they emit sparks, if burnt on charcoal.

"Nitric acid is also naturally formed, and in some countries probably in large quantities, by the passage of electricity through the atmosphere. The air consists of oxygen and nitrogen *mixed* together; but when electric sparks are passed through a quantity of air, minute portions of the two gases unite together chemically, so that every spark which passes forms a small portion of nitric acid. A flash of lightning is only a large electric spark; and hence every flash that crosses the air, produces along its path a sensible portion of this acid. Where thunder-storms are frequent, much nitric acid, and probably some ammonia, are produced in this way in the air. They are washed down by rains — in which they have been frequently detected—and thus reach the soil, where the acid combines with potash, soda, lime, etc."—(*Johnston.*)

228. The *soil* and the *air*, then, are the great fountains of nourishment for the vegetable world. The soil provides mineral matter, carbonic acid, humus, water, ammonia, and nitric acid. The air, too, provides all these except mineral matter and humus.

QUESTIONS ON CHAPTER IX.

221, 222, 223. Of what two classes of elements are plants composed? Are they equally necessary? Do plants get all their food from the soil? From what other source? How are plants brought in contact with their sources of nourishment? Are the mineral elements found in the air? In what condition must they be when taken up by the roots?

224. Whence do plants get their *Carbon?* Is carbonic acid abundant in the atmosphere? How collected by plants? How does organic matter in the soil furnish food to plants? What change takes place on carbonic acid in the organs of the plant? What if light be excluded from a plant? How does Humus furnish food for plants?

225. In what form are *Hydrogen* and *Oxygen* supplied to plants? Do they constitute a large proportion of vegetable compounds? What is the composition of starch?

226. Is *Nitrogen* as abundant as other organic elements? Chief source of nitrogen? From what other source may it also be derived?

227, 228. Where is *Ammonia* found? How does it reach the roots of plants? How generated in the soil? How retained? Is nitrogen ever absorbed directly from the atmosphere? How may ammonia be converted into nitric acid? What plants contain nitrate of potassa? How is nitric acid generated in the atmosphere? What do the soil and air respectively provide for the plant?

CHAPTER X.

VEGETABLE PHYSIOLOGY.

229. *Plants* and *animals* constitute the two great departments of organic nature. They all consist of those organs necessary to sustain life, to promote growth, and to reproduce their own species. Plants, as well as animals, are endowed with *vitality;* but they differ from animals in not possessing *sensation.* In some plants there seem to be some evidences of sensation, as in the sensitive plant (*Mimosa*); and it may be that all plants have some kind of sensation, which is so obscure as not to be ordinarily perceptible. Still we generally regard plants as destitute of this property.

230. BOTANY *is the science of plants.* It gives us a knowledge of their names, classification, structure, the functions of their various organs, and the uses to which they are applied.

231. VEGETABLE PHYSIOLOGY is that department of Botany which treats of the organs of plants—their structure, and the part they severally perform in promoting life and reproduction. A distinction is drawn between vegetable Anatomy and Physiology; the former treating of the *structure* of the organs, and the latter of their *functions.* But we shall embrace both of these in the term *Physiology.* An intelligent view of this subject is of high importance to every one engaged in the cultivation of the soil.

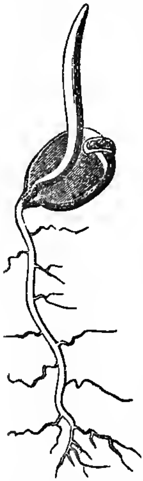
232. Skilful cultivation always increases the productiveness of plants; and, in many cases, improves their quality to

such an extent as to render what was once worthless, now highly valuable. The apple, the potato, and the tomato, are examples of plants reclaimed from a wild and almost worthless state, to one of the highest value and importance.

233. GERMINATION.—The plant is first found as an *embryo* in the seed, from which it springs. *Exp.* Place a bean in warm water, and let it remain a few hours, until it becomes swollen. Then separate the two lobes of which it is formed, and you will discover, near what is called the "eye" of the bean, the embryo, consisting of two parts, one to be developed into roots, and the other into the stalk and leaves of the plant.

When a seed is placed in a moist, warm soil, it soon begins to absorb water, and also oxygen from the air mingled with the soil. A chemical change begins at once within the seed, by which the material of the grain is so modified as to become the food of the embryo plant. Seeds consist chiefly of starch and gluten; but these being insoluble, cannot be taken up by the germ in their present form. Under the combined influence of air, water, and heat, the gluten becomes *diastase*, and begins to act as a ferment (§ 138); and, under its influence, the starch is soon converted into dextrine, and then into sugar. Being thus rendered soluble, it enters the circulation of the embryo, which begins to expand, and soon bursts the seed. It "sprouts," sending forth two branches, one of which turns downward, and puts forth roots; this is called the *radicle*. The other turns upward to seek the light and air; this is the *plumule*, and is soon developed into the stalk and leaves. *Exp.* Put grains of corn into several cups or bowls filled with fine soil, and place them in a warm place for three or four days, keeping the soil moist. At the end of this time examine one of them, and observe the change the grain has undergone. Then examine one on each successive day, and you will see the *radicle* and *plumule* in their various degrees of development, until the one becomes roots, and the other rises to the surface, and sends forth a green blade. Meanwhile the grain has been consumed, and will soon disappear entirely; the plant being now able to get nourishment from the soil through its roots, and from the air through its blades or leaves, no longer requires the store of nourishment which an all-wise Providence had laid up for its infancy. Fig. 30 will give some idea of the appearance of a grain of Indian corn, in one of its stages of germination.

Fig. 30.



The covering of the seed is called the *integument* (the *bran*); the starchy part within the integuments, and surrounding the embryo, is known as the *albumen.* The albumen and integuments together form what is called the *cotyledon,* or seed-lobe. When a seed consists of only one lobe or cotyledon, the plant producing it is said to be *monocotyledonous:* Indian corn is an example of a monocotyledonous plant. If the seed has two lobes, as the bean, the plant is *dicotyledonous.*

234. The stems of plants whose seeds have only one cotyledon, increase in size by *internal growth.* Such plants are called *Endogens.* The dicotyledonous plants, on the other hand, generally grow by the formation of new layers on the *outer* part of the stem, and immediately beneath the bark. They are hence called *Exogens.* The *grasses* (including wheat, corn, etc.), the *palms,* and plants generally having the veins of their leaves parallel, are endogens. Beans, peas, and the trees and shrubs of our forests, are exogens.

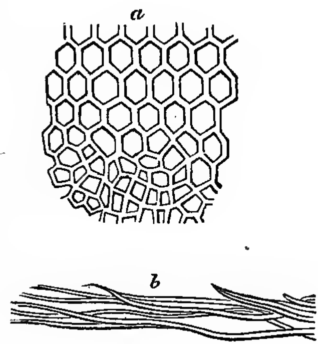
235. Tissues of Plants.—The various organs of plants are composed chiefly of several kinds of structure, called

tissues. These are made up of *fibres* or *membranes*, or both together.

There are five kinds of tissue: 1. *Cellular tissue;* 2. *Woody tissue;* 3. *Vascular tissue;* 4. *Vasiform tissue;* 5. *Laticiferous tissue.*

236. *Cellular tissue* is composed of minute cells, resting upon and pressing against each other, so that the sides where they meet become flattened, and give to the cell a somewhat regular form. Fig. 31 (*a*) is a section of cellular tissue from pith of elder, as viewed with the microscope.

Fig. 31.



237. *Woody tissue* has a fibrous structure — the fibres being in the form of slender tubes overlapping each other at their extremities, as in Fig. 31 (*b*). It is this structure which gives strength to wood, and the various kinds of fibrous material used in the arts, such as flax, hemp, cotton, etc.

238. *The vascular tissue* resembles the woody in external form, but differs in having a long slender fibre coiled within it from end to end.

239. *The vasiform tissue* consists of tubes much larger than those of the woody fibre. These tubes may be seen in a cross-section of oak-wood. It is chiefly through these that the sap passes in ascending from the roots to the leaves.

240. *Laticiferous tissue* consists of very small tubes and cells, found most abundantly in the bark and leaves. After the sap has been prepared in the leaf for nourishing the plant, it is called *latex.* Those vessels of the leaf in which this preparation or elaboration goes on, and those which

afterwards convey the latex to the part of the plant to be nourished by it, are formed of the laticiferous (latex) *tissue.*

These various kinds of tissue hold and transmit the fluids of the plant, the different tubes and cells having no communication with each other, except through minute pores. These vessels are sometimes charged with liquid matter, and sometimes with gases.

Let us now examine the structure and functions of the various organs so beautifully constructed out of these several forms of tissue.

QUESTIONS ON CHAPTER X.

§ 229, 230, 231. In what respect are plants and animals similar? How do they differ? What is *Botany?* *Vegetable Physiology?*

232, 233, 234. How does *cultivation* influence plants? Examples. Where is the *germ* of a plant found? Experiment. When a seed is placed in moist, warm soil, what change takes place? How does the material of the seed nourish the embryo plant? What is the *radicle?* *Plumule?* Experiments with a grain of corn? The integuments of seeds? The albumen? Cotyledon? What plants are called *Endogens?* *Exogens?* Examples?

235—240. Of what are the organs of plants composed? How many kinds of *tissue?* What are they? Describe cellular tissue? Woody tissue. Examples. Vascular tissue. Vasiform tissue. Where seen? Laticiferous tissue? What part do these tissues perform?

CHAPTER XI

ORGANS OF PLANTS.

241. The chief organs of the plant are the *Bark, Root, Stem, Leaf,* and *Flower.*

242. *Bark.*—The bark is the external covering of the plant; and, in the widest sense, may be regarded as enveloping every other part of it, except the extremities of the roots, and the stigma of the flower. It consists of *three layers.* The *outer* one, called the *Epidermis,* is a thin, and often transparent integument, which covers every part of the plant, with the exceptions above mentioned. It may be easily separated from the surface of the leaves and green stems of many plants. On trees of many years growth, it becomes thick and rough, forming an uneven, scaly surface. The *inner* layer of the bark, which is in contact with the surface of the wood, is called the *liber.* It is generally thin, and often strong enough to serve many valuable purposes of art. The ancients used it as we use paper (hence, *liber,* a book); while in more modern times it has been used in the manufacture of mats, and of cloth of various qualities, from the coarsest coffee-sack to the finest Irish linen. Between the epidermis and liber is the *cellular integument,* which in many trees is quite thick. In the bark of the cork-tree (*Quercus suber,*) it forms the material of which corks are made.

The epidermis and cellular integument are both composed chiefly of cellular tissue. The liber consists of cellular and woody tissues.

There are little openings in the epidermis, called *stomata* (mouths). These are very minute, requiring the aid of the microscope to see them. They are most numerous on the surface of the leaves, and on parts of the plant of recent growth. These stomata perform important offices, which will be discussed in connection with the leaves.

243. *Glands* are minute masses of cellular tissue, of various forms, and situated in different parts of the plant. Their office is to elaborate and discharge the peculiar secretions of the plant. The gums, oils, &c., are secreted by glands.

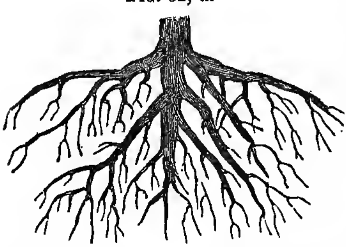
Hairs, stings, and prickles, are protuberances of the epidermis, or of the cellular integuments, covered by the epidermis.

ROOTS.

244. The roots serve the double purpose of sustaining the plant in its proper position, and of absorbing from the soil appropriate nourishment. Their office is somewhat similar to that of the mouths of animals. They take in both food and water.

245. *Variety of forms.*—Roots have a great variety of form, but we have room to notice only a few of the most common and conspicuous varieties. (1.) The *ramose*, or *branching root*, is one which sends off branches of various size in every direction. It is the kind of root common to all trees and shrubs. (See Fig. 32, *a*). (2). *The spindle root* tapers from the top downward, often branching near the lower end. It sends off little branches, or rootlets, all along the sides.

FIG. 32, *a*.

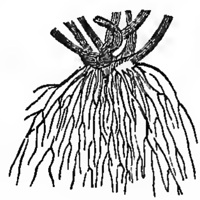


We have examples of this form in the radish and parsnip (Fig. 32, *b*). The *turnip*, or *napiform root*, differs from the spindle root, only in swelling out considerably, just at the surface of the ground. (3.) *The tuberous root* consists of fleshy masses connected together by fibres. It closely resembles the potato, which was formerly regarded as a tuberous *root;* but the proper tuberous root has no buds (eyes), while the potato has, and it is, therefore, classed with underground *stems.*

FIG. 32, *b.*

(4.) *The fibrous root* is one which consists of numerous thread-like divisions, or fibres, extending out from a common head near the base of the plant. Wheat, corn, and most of the other grasses have fibrous roots (Fig. 32, *c*).

FIG. 32, *c.*



Other varieties we cannot now stop to notice. The student should collect the different varieties of roots, and wash them carefully, so as to preserve every part unbroken, that he may become familiar with them as they actually grow.

245. *Floating*, or *aquatic roots*, are such as belong to plants which float upon the surface of water, without having any connection with the soil.

246. *Aerial roots* are such as shoot forth in the air. (1.) Sometimes they remain suspended in the air, without attaching themselves to any other substance, except so far as may be necessary to sustain the plant to which they belong. Their office, then, is to absorb nourishment from the air, and the rain which falls upon them. Of such plants are the pendent mosses, which festoon the trees so remarkably in

some of our Southern States. (2.) They sometimes attach themselves to the bark, and even penetrate the tissues of other plants, from which they get their nourishment. The mistletoe is an example of such beggar-plants. They are aptly called "*parasites.*" (3.) The roots which shoot forth from the joints of some prostrate plants, as the tomato, are regarded as aerial roots, but these soon penetrate the soil. (4.) Another variety of aerial roots are such as spring from the stems of erect plants, at some distance above the surface of the ground, and extending downward into the earth, stand like a circular row of *braces* around the base of the stalk. We have a beautiful example of this kind of root in the Indian corn, when growing on a good soil. These are often called *brace-roots.* They serve to support the plant, and prevent its being prostrated by winds; and, at the same time, collect nourishment from the soil.

247. *Parts of the root.*—Whatever may be the shape of the root, it generally has several distinct parts worthy of notice:

(1.) The *Caudex* is the main body of the root, generally descending vertically into the soil. It is frequently called the *tap-root.*

(2.) The *Fibrils* are the branches sent off from the caudex, often passing into many sub-divisions.

(3.) *Spongioles* are the soft, pulpy points of the fibrils, through which the plant gets its nourishment from the soil in a liquid form.

248. *Structure.*—The root has a structure similar to that of the stem to which it belongs. The bark of the root is more soft and spongy than the bark of the stem. Its epidermis terminates near the spongioles, leaving them uncovered. The fibrils are composed chiefly of vasiform tissue, covered with the epidermis. The extremities of the fibrils

consist of this vasiform tissue in very soft and delicate form, spongy in structure, and hence called "spongioles."

249. *Functions of the Root.*—These have several times been alluded to. The *first* is the mechanical office of *attaching the plant to the soil, and keeping it in its proper position.* The *second* is the *absorption of food and moisture* from the soil.

THE STEM.

250. The stem originates in the plumule. The ascending of the plumule and descending of the radicle, seem to be owing chiefly to the mysterious influence of light. When seeds are planted in a box of soil, with a few stalks of hay or a little moss spread over it, and then some narrow strips of wood placed over all, so that the contents of the box will not fall out when it is inverted; and the box then turned with its open side downwards, over a mirror, a bright surface of tin, or even over white paper, so that the light will reach the soil only from below: the seeds will germinate, and the plumule *descend* towards the light, whilst the radicle will *ascend* into the dark soil above it.

251. Stems are *aerial* when they grow above the surface of the ground, and *subterranean* when they grow beneath the surface. *Erect* stems continue to grow in a vertical direction. *Creeping* and *trailing* stems are such as grow along the surface of the ground. Many of these have *tendrils* (coiling fibres) by which they sustain themselves on the branches of other plants; as we see in the grape-vine.

252. Subterranean stems generally grow just below the surface of the soil. They are distinguished from roots in having buds, from which aerial or other subterranean branches may be sent forth. The roots of many plants have the power of developing buds, and thus sending up "shoots" from their

surface; but still *buds* are the chief mark of distinction between roots and stems.

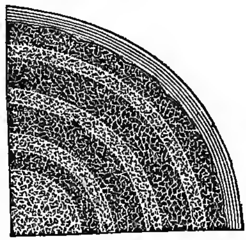
253. *Forms.* — Some of the most general forms of subterranean roots are: (1) The *tuber*, a familiar example of which we have in the potato. Its buds (eyes) are the germs of new stems, to be developed the next year. (2) The *bulb*, which consists of concentric layers surrounding one or more germs or buds, from which stems spring up, developing new bulbs at their base during the succeeding season of growth. Examples — the tulip and onion.

254. Stems are further distinguished by the terms *ligneous* and *herbaceous*. A *ligneous stem* is one which has a woody structure, such as we see in ordinary trees and shrubs; and is composed of *pith*, *wood*, and *bark*. An *herbaceous stem* is composed of tissues similar to those of the ligneous stem (the cellular predominating), but less compact, softer, usually of a single year's growth, and without the distinctions of pith, wood, and bark. Ligneous stems are usually distinguished, in temperate climates, by concentric layers of wood, marking the annual growth, and thus enabling us to determine the age of the tree. Herbaceous stems usually grow but one season: in many cases coming to maturity and dying with the ripening of the seed.

255. Physical Structure of Exogens.—The exogens (outside growers), when they first spring from the seed (and also branches, during their first year's growth), have a soft, spongy centre of cellular tissue, called *pith*. This is covered by a thin layer of vascular tissue, having its spiral vessels connected with the leaves, and called the *medullary sheath*. Surrounding this is the *bark*. Such is the structure of the infant plant; but this condition lasts but a short time. The sap, carried up by the pith, and elaborated in the leaves, descends through the vessels of the liber, and soon forms a layer of wood around the medullary sheath. This layer

consists, first, of *ducts* or sap-tubes, formed during the early part of the season; then of a more compact layer of woody and vasiform tissue. Such a layer is added every year, giving to a cross-section of oak or ash an appearance similar to that represented in Fig. 33.

FIG. 33.



256. The pith soon ceases to be the channel through which the sap ascends — the newly-formed ducts performing this office. Again the layers of wood become gradually hard, the sap-tubes partially obstructed by the deposition of matter, which gives a reddish or brown color to the wood, and the sap ceases to ascend through them. They then form the red-wood, called the *duramen*, on account of its compactness and strength. For several years the newly-formed layers continue to circulate the sap, and retain their light color: they form the *alburnum* (white-wood — sap-wood). The *duramen* is the most valuable portion of the tree, on account of its strength and durability. The *alburnum* is softer, and decays readily, on account of the albuminous matter present in it (see § 160),

257. Passing from the centre of the trunk or stem to the bark, and cutting the annual layers at right angles, are many plates formed of fine fibres. These are called the *medullary rays*. They are conspicuous in a piece of split wood of oak or maple.

258. PHYSICAL STRUCTURE OF ENDOGENS. — "In the endogenous stem, there is no distinction of pith, wood, and bark; nor does a cross-section exhibit any concentric arrangement of annual layers. It is composed of the same tissues and vessels as that of the exogen; that is, of cellular tissue, woody fibre, spiral vessels, and ducts — the first exist-

ing equally in all parts of the stem, and the rest imbedded in it in the form of bundles. Each bundle consists of one or more ducts, with spiral vessels adjoining their *inner* side next the centre of the stem, and woody fibres on their outer side, as in the exogens."—*Wood's Botany.*

Most of the endogenous herbaceous stems are hollow, and have hard joints at nearly regular intervals. A bladed leaf is usually attached at each one of these joints. The joints give strength to the stem. Examples are seen in many of the grasses. Some stalks, like those of the Indian corn, are jointed, but not hollow.

259. *Functions of the Stem.*—These are, *first*, to convey the sap from the roots to the leaves, where it is prepared for the nutrition of the plant, and thence to carry it to the various parts to be nourished by it; *secondly*, to sustain the leaves, flowers, and fruit, so as to expose them properly to the action of air and light. Where it is necessary that a very large surface of leaf should be exposed, the plant is constructed with numerous branches, forming a spreading top, such as we see on trees generally. In a tree, that part of the stem below the branches is called the *trunk*. The trunk is the most valuable part of those trees used for timber.

THE LEAF.

260. *Buds.*—Plants have two kinds of buds: (1) *The leaf-buds*, the first of which is the plumule as it bursts from the seed. This is developed into the stalk and leaves, and is itself perpetually renewed on the summit of the stalk. Just above the base of each leaf, a new bud makes its appearance; and in ligneous plants it is subsequently developed into leaves alone, or into a branch and leaves. (2) The *flower-bud*, which has a different structure, generally having enveloped within it the germs of both leaves and flowers.

In cold climates, buds are protected in winter by a scaly covering, which opens and frequently drops off soon after the bud begins to swell and grow in the Spring.

261. The leaf combines, in a striking manner, the useful and beautiful, in its structure and color. The almost countless shapes, from the straight and slender blade of grass to the deeply lobed oak leaf and the broad palm, present to the eye a wonderful variety of Nature's most delicate handiwork. The *green color*, the most pleasant to the eye, seems to have been provided by a kind Providence to soften the bright glare of the summer's sun, and thus to promote the comfort of his creatures.

To the plant itself the leaf bears the most important relation. It is the *breathing* organ of the plant—its *lungs*. It is the *digestive* organ, too—its *stomach*.

262. STRUCTURE.—The leaf consists of several parts worthy of distinct notice. The *leaf-stem*, or that by which it is attached to the branch or stalk to which it belongs, is called the "*Petiole*." Some leaves have no petiole, but are connected by their base directly with the branch or stem. They are then said to be *Sessile*. The broad expansion of the leaf is called the "blade." The framework consists of numerous *veins* and *veinlets*. The *mid-vein* is the extension of the petiole, running through the centre of the leaf. The other veins either branch off from the base of the mid-vein, or run parallel with it. The branches of the veins are called *veinlets*.

263. A leaf is said to be (1) "*Net-veined*," when the veinlets so intersect and cross one another as to form a sort of net-work. The leaves of exogens, such as our forest trees, peas, beans, etc., are net-veined; (2) "*Parallel-veined*," when the veins run parallel with the mid-vein, and the veinlets parallel with one another, as in grasses, and most of the endogens; (3) "*Fork-veined*," when the veins and veinlets are *forked*, as in the fern leaf.

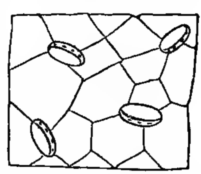
264. *Forms.*—The form of the leaf is determined by the direction and extent of the veins and veinlets, and the development of the intervening tissue. It may be *orbicular*, round; *ovate*, egg-shaped; *cordate*, heart-shaped; *lanceolate*, lance-shaped, etc., according as the outline of the framework assumes one or other of these imitative forms.

265. PHYSIOLOGY OF THE LEAF.—The veins and veinlets may be regarded as a prolongation of the medullary sheath, and are composed of the *woody* and *vascular tissues*. The thin, membranous part of the leaf, or *lamina*, is formed of *cellular tissue*, and generally consists of two layers; that which forms the upper side of the leaf differing somewhat in structure from that which forms the lower side. In some cases, the plane of the leaf is nearly or quite vertical when in its natural position. In such cases, both sides being equally exposed to light, have the same structure.

266. The cells, which abound in the lamina, have their inner surface lined with little green globules of *chlorophyll* (§ 179), which give the green color to the leaf. The different *shades of green* are produced by the greater or less compactness of the cellular tissue, and consequent compactness of the chlorophyll (leaf-green).

267. Every part of the leaf is enveloped in the *epidermis* (§ 242). Beneath the epidermis, and among the cells, we find many open spaces, especially near the lower surface of the leaf. These are called *air-chambers*, and have communication with the air through openings (stomata) in the epidermis, which are too small to be seen with the naked eye, but with the aid of a powerful microscope, they may be seen in great numbers. Fig. 34 represents a magnified view of some of the stomata, as seen in the leaf of the lily. They are so numerous on most leaves,

FIG. 34.



that many thousands of them are embraced within the space of a single square inch of surface. The stomata are chiefly confined to the lower surface of the leaf; but in leaves whose natural position is vertical, exposing each side alike to the sun, they are found on both sides.

FUNCTIONS OF THE LEAF.

268. When the sap ascends from the root to the leaf, it carries with it in solution a portion of the material necessary for the nourishment of the growing plant. But this nourishment is still in a crude form, and too dilute to be adapted to the purposes for which it is designed. It must, therefore, undergo certain modifications. These take place chiefly in the leaves, as described in the next three sections.

269. *Exhalation.*—The sap must be condensed; that is, the surplus moisture must be thrown off. This takes place through the stomata, and is similar to the *perspiration* of animals. It is generally called *"exhalation,"* and occurs chiefly under the influence of light, and to a great extent independent of *temperature*. The stomata are *open* in the *light*, and *closed* in the *dark;* but the *direct* rays of the sun are unfavorable to their action.

270. *Respiration.*—Plants derive a large proportion of their nourishment from the air, through their leaves, in the form of carbonic acid gas. They also absorb small quantities of oxygen from the air, but throw off a much larger quantity into the air. This inhalation of carbonic gas, and exhalation of oxygen, we shall call *"respiration."* In one respect it is the reverse of respiration in animals, inasmuch as animals inhale oxygen and exhale carbonic gas (§ 65). The respiration of plants goes on chiefly by day, the stomata being opened under the influence of light. As the carbonic gas enters the leaf, it is at once dissolved by the sap, and carried through the circulating vessels of the leaf, where it

is decomposed, its carbon being retained, and its oxygen thrown back into the air.

271. *Digestion.*—The food taken up by the roots, and carried by the sap to the leaves, there meets with the gaseous food from the air, all together forming, by their solution, "crude sap." This is greatly modified during its circulation through the leaf, if an abundant supply of light be present. The changes which the plant-food thus undergoes, we call "digestion," because of its resemblance to the changes produced on animal food by animal digestion. When the sap has thus been prepared for nourishing the plant, it is called "*latex*," or *true sap*. It is then conveyed by the circulating organs to the various portions of the plant, and in some mysterious way, under the guiding finger of Omnipotence, assumes various forms of organic structure, producing stems and leaves, flowers and fruits. Here we have a beautiful analogy between the circulation of sap in plants, and the circulation of blood in animals (§ 612).

FLOWERS AND FRUIT.

272. Growth, decay, and death, mark the history of every individual upon our globe, whether plant or animal. If, then, organized beings possessed not the power of reproduction, our world would soon become a bleak and barren waste. But the Creator has wisely ordained that the earth shall bring forth "grass, and herb yielding *seed after his kind*, and the tree yielding fruit, whose seed was in itself, after his kind."

273. *Reproductive organs.*—The reproductive organs of plants are found in the flower, which is the expansion of the *flower-bud* (§ 260). These, by their combined influence, bring the seed to maturity, and thus produce the embryo of a new plant.

274. *Structure of the Flower.*—As a general rule, flowers have several distinct organs or parts worthy of note:

(1.) Many flowers are attached to the plant by a stem, called the "flower-stalk" (Fig. 35, *a*). When the flower rests upon the stem, or branch of the plant, without a flower-stalk, it is said to be "sessile."

Fig. 35.

Stamen. Lily. Pink.

(2.) The head or top of the flower-stalk on which the other organs rest, and to which they are usually attached, is called the "receptacle" (*b*).

(3.) The "calyx" is the external *cup* which surrounds the flower at its base. It is generally *green*, but sometimes colored like the other parts of the flower. It is sometimes in one entire piece, having its edge notched. At other times it consists of a whorl of separate leaves. These divisions of the calyx are called "sepals" (*c*).

(4.) The delicate and beautifully colored circle of leaves, forming the inner coating of the flower, is the "corolla." Its divisions are called "petals" (*d*).

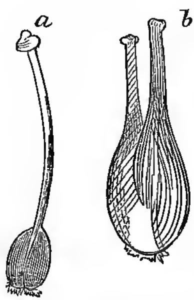
(5.) The "stamens" are the slender organs of thread-like structure, situated within the corolla, and generally (though not always,) equal to the petals in number (*e*).

The three divisions of a stamen are: the *filament*, or slender stem; the *anther*, which is a little two-lobed organ at the extremity of the filament; and the *pollen*, or fine yellow dust found in the anther. The pollen, when viewed with a microscope, is found to consist of minute membranous sacks filled with a fluid substance (Fig. 35, *f*, *g*, *h*).

(6.) Within the circle of stamens are the "pistils." These occupy the centre of the flower. Some flowers have but one pistil, others have a great many (Fig. 35, *i*).

275. The pistil has three divisions: the *ovary*, which is the enlarged part of the pistil at its base, and contains the germs of the future seeds; the *style*, the slender part of the pistil rising above the ovary; the *stigma* is the top of the pistil, and usually consists of one or more rounded lobes.

Fig. 36.



The ovary is often *simple*, consisting of a single cell, or *carpel;* but more frequently it is *compound*, having two or more carpels. When the ovary is simple, it has but one style and stigma; when compound, it has a style and stigma for each carpel; unless the style is wanting, as sometimes happens. In that case, the stigma rests upon the ovary, and has one division for each carpel. (Fig. 36, *a*, shows a simple pistil with its different parts; *b*, one of compound form.)

276. *Stamens* and *pistils* are essential organs for the production of seed in any plant. But they are not always found in the same flower. (1.) They often *grow in different flowers upon the same stalk.* In such cases, the flowers containing the stamens are called "staminate," and those containing the

pistils are called "pistilate." For example, Indian corn has its stamens in the *tassel*, and its pistils in the *ear-shoot*. The tassel then is the staminate flower, while the shoot, with its silk, forms the pistilate flower; the tassel, with its beautiful, pendulous stamens, and the shoot with its fine glossy silk, present interesting objects of study. (2.) *The staminate and pistilate flowers sometimes grow on separate plants*. Of this, we have an example in common *hemp*. A little examination will enable the student to distinguish between the staminate and pistilate plant. The staminate is barren — the pistilate produces seed.

FUNCTIONS OF THE FLOWER

277. The corolla is the breathing organ of the flower; but, unlike the leaf, it absorbs large quantities of oxygen, and exhales corresponding quantities of carbonic gas. The same process is carried on to some extent by the stamens and pistils.

278. The end to be accomplished by the stamens and pistils, is to fertilize the seed. Pollen is produced in the anthers; and by them is so discharged at the proper season, that portions of it fall upon the stigma. The little granules of pollen then burst, and their contents are absorbed by the stigma, and carried through the style to the ovary, where they take part in the formation of the seed. If the pollen is cut off from the stigma entirely (as may be done in an isolated stalk of corn, by destroying the tassel before the silk makes its appearance), no seed can be produced. But if other tassels are near at hand to provide pollen, the stalk may produce an ear without a tassel of its own.

There are certain periods in the growth of crops, when the pollen, and even the stamens, may be beaten off by violent rains and hail, to such an extent as greatly to diminish the quantity of grain which would otherwise have been produced.*

279. By a wise provision of the Creator, the flower is so constructed that the pollen is readily transferred from the anther to the stigma. When the flower grows erect, like the tulip, the pistil is shorter than the stamen; and the anther rising above the stigma, readily discharges its pollen where it is wanted. So, when the flower droops, as the lily, the pistil is longer than the stamen, in order that the pollen may still fall upon the stigma, (see Fig. 35).

When the staminate and pistilate flowers are on different plants, the pollen is sometimes carried from the one to the other by the wind; sometimes by bees, and other insects.

280. Fruit.—When the ovary is fully developed, it forms the *fruit*. The fruit consists of two parts: (1) The *pericarp*, which surrounds the seeds; and, (2) The seeds, which contain the germs of new plants.

In the apple, peach, etc. the pericarp is the most valuable portion of the fruit. In cereal or grain crops, the seed is of chief value—the pericarp being the chaff or husk.

281. The seed may be divided into: (1) The *integuments* (bran), which consist of several layers, forming the outer coating of the grain; (2) The *albumen*, which is the white, starchy mass within the integuments; and, (3) The *embryo*, or germ of the new plant, which is also within the integuments, and generally surrounded in part by the albumen.

The albumen constitutes the larger part of cereal grains, and serves not only as food for the embryo plant, but also constitutes a large proportion of the food of man and beast.

* The wheat crops, in the summer of 1858, were seriously damaged, in some places, by the heavy rains which fell while the grain-fields were in full bloom.

DURATION OF PLANTS AND THEIR ORGANS.

282. When a root or stem lives through only *one summer*, it is said to be *annual.* When it lives through *two*, it is said to be *biennial;* and when it lives through *three or more*, it is said to be *perennial.*

(1) The root and stem are often *both annual*, as in flax, hemp, Indian corn, cotton, and tobacco. (2) The *root* may be *biennial*, and the *stem annual.* In such cases the stem does not usually make its appearance until the second season. Examples—the common thistle and winter wheat. (3) The *root* may be *perennial*, and the *stem annual*, as in most varieties of grass. (4) *Both root and stem* may be *perennial*, as we see in trees and shrubs.

283. *Leaves are deciduous* when they die and fall at the close of summer, or as soon as the plant has reached maturity. They are *evergreen*, when they endure until the new leaves of the next growth have made their appearance. It is, properly speaking, the *plant*, and *not the leaf*, which is evergreen; for the old leaves of evergreen plants, like the pine, drop off in the spring, as the new leaves come out to take their place; and thus the succession of leaves keeps the plant ever green.

Climate modifies the duration of the leaf. A plant may be ever green in a warm climate, while its leaves become deciduous when removed to a colder region.

QUESTIONS ON CHAPTER XI.

§ 241, 242, 243. What are the chief organs of a plant? What is the *bark?* Its divisions? Describe each. Of what kinds of tissue composed? What are *stomata?* What are *glands?* Their office? Hairs, stings, and prickles?

244, 245, 246, 247, 248, 249. Purposes served by the *roots?* Varieties of form? Describe the branching root. Spindle root? Turnip root? Tuberose root? Fibrous root? Aquatic roots? Aerial roots? How do they grow? When called brace roots? The *caudex* of a root? The *fibriles?* The *spongioles?* What does the root resemble in structure? How does it differ from the stem? The two principal functions of the root?

250, 251, 252, 253, 254. Where does the *stem* originate? Influence of light? How illustrated? Aerial stems? Subterranean stems? Creeping stems? What are tendrils? Where do subterranean stems generally grow? What are tubers? Examples? Bulbs? Examples? What is a ligneous stem? Herbaceous stem?

255, 256, 257. Describe the *structure* of exogens? How do they grow? Changes in the layers of wood? Duramen? Alburnum? Medullary rays?

258, 259. Give the structure of endogens. What kind of stems have they? What form of leaf? Use of joints? First *function* of the stem? second? Use of branches?

260, 261, 262, 263, 264. What does the leaf combine? Variety of forms? Its color? Its use to the plant? How many kinds of *bud?* Describe each. How protected in warm climates? What is the *petiole* of a leaf? Blade? Describe the frame-work. When is a leaf net-veined? Parallel-veined? Fork-veined? What are some of the forms of leaves?

265, 266, 267. How may the veins and veinlets be regarded? Describe the lamina. How do the two sides of a leaf generally differ? Where is the chlorophyll found? In what is the whole leaf enveloped? Describe the air-chambers. The stomata.

268, 269, 270, 271. What does the sap carry up from the roots? How is the sap condensed? When are the stomata open, and when closed? What do plants absorb from the air by their leaves? Describe the process of *respiration.* How is sap modified in the leaf? What is it then called? How does it promote growth? Analogy?

272, 273. If organized bodies had not the power of reproduction, what would be the consequence? Where are the reproductive organs found? What is the flower?

274, 275, 276. What is the *flower-stalk?* When is a flower "sessile"? What is the receptacle? The calyx? Sepals? Corolla and petals? Stamens? Its parts? Pistil and its parts? Simple and compound ovary? Describe Figs. 35 and 36. What organs are essential to the production of seed? Are they always in the same flower? Example? Are they always on the same plant? Example?

277, 278, 279. How is the respiration of the flower carried on? Functions of the stamens and pistils? How is the seed fertilized? What if the pollen is cut off from the pistil? Illustrate. Effects of violent storms? What provisions are made to secure the transfer of pollen to the stigma? What if the pistilate and staminate flowers are on different plants?

280, 281. What is the *fruit?* Its parts? What is the valuable part of apples, peaches, etc.? Of cereal grains? Divisions of the seed?

282, 283. What is an *annual* root or stem? A biennial? Are the root and stem ever both annual? Examples? Can a root be biennial and a stem annual? Examples? May the root be perennial and the stem annual? Examples? May both be perennial? Examples? When are leaves deciduous? When is a plant evergreen? Influence of climate?

CHAPTER XII.

THE SOIL.

284. HAVING before us the composition of the plant and its organic structure, we may now study more minutely its *nutrition and cultivation.* We have given some attention to the sources from which crops get their nourishment. These are the atmosphere and the *soil.* We can exercise no control over the condition of the air. Our Creator has established laws by which its chemical composition is made almost invariable. The quantity of moisture, too, which it brings and pours out as rain upon our farms, is a matter entirely beyond our influence.

The management of *the soil alone* has been committed to our hands. Then, leaving the atmosphere in the hands of that all-wise and beneficent Being who has made it an inexhaustible source of food for plants, and of fertility to the soil, let us turn our attention to those principles and laws which will guide us to a knowledge of the origin and nature of different soils, and to the means by which they can be best cultivated and improved

AGRICULTURAL GEOLOGY.

285. "*Geology* is the history of the mineral masses that compose the earth, and of the organic remains which they contain."—*Hitchcock.*

286. In its relations to agriculture, geology points us to the origin of soils, and the influence which the rocks have had in determining the physical and chemical characters of different soils. They have their origin, generally, in those

masses of mineral matter upon which they rest. On the mineral character of different rocks, then, the mineral character of soils must, to a great extent, depend. Alluvial and drift soils are exceptions.

287. The term "rock" embraces all the solid mineral matter of our globe; that is, not simply the firm, unyielding masses, ordinarily called *rocks*, but also deposits of clay, and other loose material, which may not be very coherent in its character.

288. When we examine the rocks of the earth we find them under two general forms. (1.) Some of them are in layers, which are nearly parallel, and lying one above another. Each one of such layers is called a "stratum;"* and masses of rock of this structure are said to be "stratified."

Fig. 37.

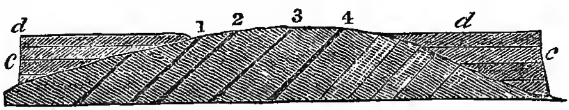


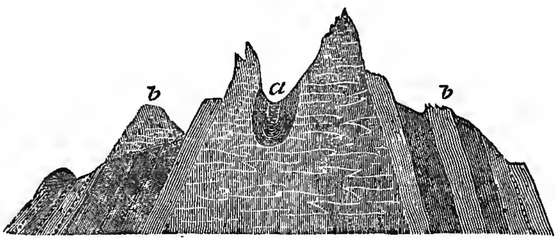
Fig. 37 represents a section cut through stratified rocks. The strata are sometimes horizontal, as at *c, c*. At other times we find them inclined, as at 1, 2, 3, 4. They are then said to have a *dip*. The *angle*, which the face of the stratum makes with the horizon, measures the *dip*. But few of the stratified rocks are entirely horizontal, most of them having a greater or less dip.

289. (2.) The other general form under which rocks are found, is that of large, irregular masses, having no regular layers; these are termed *unstratified*. The unstratified rocks seem generally to have been thrust up through the stratified, and often form the central part and tops of long ranges of

* Plural, "strata."

hills or mountains. The rocks at *a*, *a*, Fig. 38, are unstratified, and form the central part, or axis, of the mountain;

FIG. 38.



while those at *b*, *b*, are stratified, and seem to have been elevated from their original position by the upward force of the central mass, *a*, *a*.

290. Stratified rocks generally bear marks of having been deposited by water, just as we find them undergoing formation now. Such being the case, they must have been originally formed in a horizontal position, or nearly so.

The unstratified rocks bear evidence of having been subjected to great heat, and seem often to have been thrown up from beneath the earth's surface in a melted state. Hence, they are frequently called "igneous rocks."

All the rocks, whether stratified or unstratified, are composed chiefly of a few minerals.

291. A MINERAL *is any substance which is not the result of animal or vegetable growth.*

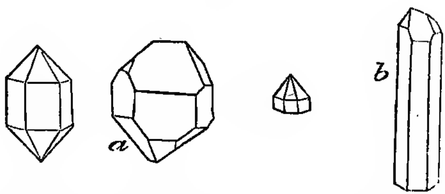
All objects which we can perceive by our senses, have been assigned to some one of what are called the three great kingdoms of nature: the animal, vegetable, and mineral. Every object, then, upon the earth, which has not resulted from the action of *vitality*, must be mineral in its character.

292. Let us examine some of the simple minerals which

enter most largely into the composition of rocks and soils. These are Quartz, Talc, Clay, Feldspar, Mica, Hornblende, and Limestone.

293. *a.* QUARTZ.—The purest specimens of quartz are found in crystals of the forms seen in Fig. 39. The crystals

FIG. 39.



are six-sided prisms, terminated by six-sided pyramids. The different faces of the crystals often vary very much in size, as those at *a* and *b*. The sharp angles of this mineral scratch glass very readily. It is the same mineral which we find in the form of flint, sand, carnelian, agate, &c. When particles of sand are cemented into masses, they form *sandstone*, one of the most common forms of quartz.

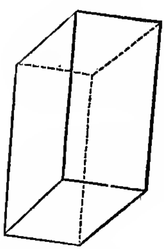
294. *Chemical relations.*—We have already learned (§ 84,) that quartz (or silica) is an *acid* in its chemical relations, and has the symbol SiO_3; its proper chemical name being *silicic acid.* At a very high temperature, silica combines readily with strong bases, such as soda, potassa, and lime, forming silicates. Natural silicates are very numerous, as we shall presently see.

295. *b.* TALC is a silicate of magnesia. It is sometimes found in layers as thin as paper, and of a green, or greenish-white color. The surface, when rubbed with the fingers, feels *greasy.* When a layer of it is bent, it does not regain its former condition like mica, a mineral of the same form. *Soapstone* and *French chalk* are compact forms of talc.

296. *c.* CLAY is a silicate of alumina ($Al_2O_3,3SiO_3$), and is found abundantly all over the world in fine grains, which form a cohesive mass when wet. *Slate* is a compact form of clay. Mingled with sand, pebbles, and organic matter, clay constitutes the body of the great majority of soils. When pure, it is white, but we generally find it colored with oxides of iron and manganese. Although not a fertilizer, in the sense of affording nourishment for the plant, it serves an important purpose in giving compactness to the soil, and in retaining moisture, ammonia, and other fertilizing substances.

297. *d.* FELDSPAR is a double silicate of potassa and alumina. Soda occasionally takes the place of the potassa in whole or in part, and modifies to some extent the character of the mineral. When feldspar occurs in regular crystals, they have the form represented in Fig. 40, called an oblique rhombic prism. The crystals are often quite *flat,* and have their ends so modified as to appear less regular than the figure here given. The surface of a crystal has the lustre of glass, with a somewhat pearly appearance. White, gray, and flesh colors are very common in this mineral. It is not quite so hard as quartz, but is sufficiently hard to scratch glass.

FIG. 40.



298. When exposed to the weather this mineral is decomposed. Most of the silicate of potassa is removed, while the silicate of alumina remains as a finely-divided clay. This clay is called "Kaolin," and is the best material for making porcelain ware.—(*Kane.*)

299. In the disintegration and decomposition of feldspar, we have a striking illustration of the part which carbonic acid performs, in connection with other agencies, in producing changes of character in rocks. The silicate of

potassa is decomposed by the strong affinity between potassa and carbonic acid, a carbonate instead of a silicate being produced. This carbonate of potassa is readily dissolved and carried off by rains, while the silicate of alumina remains, as a minutely divided clay. But there is always enough of potassa (and soda, if it be present) retained to meet the wants of the resulting soil. If other minerals, such as quartz and mica, are contained in the same rock with the feldspar, these generally remain in fragments, mingled with the clay.

Soils formed chiefly from feldspar are usually of a light color, becoming darker where any considerable quantity of iron is present. And while they abound in potassa and soda, they are deficient in lime, magnesia, and some other important mineral ingredients.

300. *e.* MICA is frequently known as *mineral isinglass.* It occurs in thin transparent leaves, and in shining scales mingled with other minerals. When found in masses, it is easily split into extremely thin layers. These are much more tough and elastic than those of talc. It varies in color from very light to quite black shades. Heat of a lamp or ordinary fire has but little effect upon it; hence the transparent varieties are used for making windows in stoves, and instead of glass for lanterns. Mica is a double silicate of potassa and alumina, but differs in composition from feldspar chiefly in having only about half so much potassa; nor is it so readily decomposed as feldspar.

301. *Quartz, feldspar,* and *mica* are the constituents of *granite.* They are not chemically combined in the rock, but mechanically mingled. Granite is one of the most important of the unstratified rocks (§ 289), and is extensively used as a building material. Masses of this rock are found at many points over the region of country between the Blue Ridge and Tide-water. When exposed to air and rain,

granitic rocks are gradually broken down into mixed masses of clay, sand, and mica. The clay results from the decomposition of feldspar, as mentioned (§ 299) above; while the silica and mica are liberated in fragments more or less crystalline—the former constituting fine or coarse sand, or quartz pebbles, according to the original texture of the rock; the latter generally appearing in small shining scales, varying greatly in both size and color.

Gneiss is another rock having the same mineral ingredients as granite, but differing from it entirely in structure. While granite belongs to the igneous rocks, gneiss belongs to the primary stratified rocks. It has great variety in its structure; sometimes existing in thin layers, or laminæ, passing gradually into what is called mica-slate; at other times more compact and finely granular, and having a less distinct stratification. The minerals (quartz, feldspar, and mica) composing it are always crystalline. This rock abounds in the Piedmont country lying along the eastern side of the Blue Ridge, as well as in all regions where the primary stratified rocks make their appearance. It is often improperly called "granite." The soils resulting from its disintegration are similar to those from real granite. But different specimens of both granite and gneiss vary widely in the proportions in which their constituent minerals occur, and of course must give a corresponding variation in the soils they produce.

302. *f.* HORNBLENDE is composed of silica combined with magnesia, lime, oxide of iron, and alumina. The different varieties, however, vary slightly in composition. Its crystals are sometimes short, stout prisms, and at other times are long and slender. In fine fibres, easily separated, and very flexible, it forms *asbestus*, a substance used for making incombustible cloth.

303. *Trap* is a hard, unstratified rock, not unfrequently called "greenstone." It is an intimate mixture of feldspar

and hornblende. When worn down to the proper condition, it makes a fertile soil. The feldspar furnishes an abundant supply of potassa, while the hornblende gives lime, magnesia, and oxide of iron. Besides, rocks of this kind, like most others, have no inconsiderable traces of phosphates, sulphates, and chlorides about them.

304. Hornblende may take the place of mica in granite. The rock is then called "syenite."

305. *g.* Carbonate of Lime is found under a great variety of forms. Common limestone, marble, and tufa are forms of carbonate of lime. It is often seen in white crystalline masses or veins, with common limestone. Again, it hangs like beautiful icicles from the roofs of caverns, and accumulates in huge porous masses of tufa around limestone springs.

306. By burning any one of these forms of this mineral, it is converted into lime. The quality of the lime depends upon the purity of the rock from which it is prepared. Carbonate of magnesia, and the silicates of lime and magnesia, are very common constituents of limestone rocks. (See sections on lime.)

CRUST OF THE EARTH.

307. Geologists generally believe that the inner part of the earth is a mass of mineral matter in a molten state, as we see it issuing from the craters of volcanoes; and that only a crust of solid rocks surrounds it on all sides. The thickness of this crust is supposed to be *less than one-fortieth* of the distance from the surface to the centre of the globe. Some of the rocks of the earth, as heretofore stated, are *stratified* and others *unstratified.*

308. The stratified rocks have been formed under water, in the bottoms of oceans, seas, and lakes, or at the mouths of rivers. The material of which they are composed, when

deposited by water, would naturally assume a horizontal position. By the varying action of freshets, waves, and currents, layer upon layer would be built up. Embedded in rocks thus formed, we might well expect to find the remains of plants and animals; and so we do, in most of them. Nearly all of the higher stratified rocks contain shells, the bones of fish and land animals, with many varieties of plants, among which are the leaves, branches, and even trunks of trees. These remains of animals and plants thus found in the rocks are known as "fossils," and the rocks containing them are said to be *fossiliferous.*

The fossils deposited in the rocks are sometimes so abundant as to constitute the whole mass, except mineral matter deposited from water, either in the fossil body itself, or between the different fossils, so as to solidify (petrify) them in the first instance, and then cement them together. In all cases where fossils abound, they have exerted a considerable influence on the chemical, as well as the physical, character of the rocks in which they occur; and have, consequently, taken part in determining the quality of soil formed from those rocks.

By volcanic forces, acting from beneath, the stratified rocks have been elevated to various heights, and thrown into various positions, and now form a large portion of the surface of the continents and islands inhabited by man.

309. Formations.—The strata of the earth have been classified into several distinct *formations.* Of these we can take but a brief general view. Fig. 41 * will aid the memory in retaining their names and relative position. It is designed to represent an *ideal* section of the earth's crust, made at some point where all the formations are found. The reader must beware of falling into the mistake of supposing that each one of these formations may be found everywhere on the earth's surface; or that any one of them ever enveloped

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* See Frontispiece.

the whole globe; or that one of them cannot occur without being accompanied by the others; or that, when found, they uniformly all succeed each other in the order here given. By examining the surface of the earth, as represented in the figure, it will be seen that one formation alone may give character to the soil and rocks for several miles together, as in the space from *a* to *b*. Again, the *silurian* formation, for example, may have been deposited over a very wide section of ocean-bottom: a part of this may have been subsequently elevated, while the *old red sandstone* was being deposited over the remainder; then above this the other formations, up to the *tertiary*, at which period the whole (or perhaps some portion of the original sea-bottom on which the *silurian* rocks alone had been formed) may have subsided during the period when the tertiary were formed; and thus the tertiary might be found to rest upon the surface of the Silurian formation. Such is the case at *c*, in the figure.

310. I. *Primary Stratified Rocks.*—These are lowest in the series, and contain no fossils. They consist chiefly of—(1) *Gneiss*, described in § 301. (2) *Mica-slate*, composed mostly of quartz and mica, the latter being in such quantity and form as to give a slaty structure to the mass. (3) *Talcose-slate*, similar to the above, but having *talc* in the place of mica. It often contains some mica and feldspar. The surface of this slate generally feels smooth or greasy, but not to the same degree as pure talc or soapstone. (4) *Hornblende-slate*, in which hornblende predominates. It also contains portions of quartz, feldspar, and mica in many of its specimens. (5) *Clay-slate*, a finely granular rock, in thin layers. Its structure is frequently such, that it can be split into *tiles* for covering houses; and when dressed off and framed, it forms the "slates" used in schools. (6) *Sandstone*, of various shades of color. (7) *Primary limestone* is in some places found in strata lying between other primary

strata. Primary stratified rocks are also called *"Metamorphic Rocks."* They are crystalline in their structure.

311. II. THE SILURIAN FORMATION lies next above the primary. We shall not take any notice of the *subdivisions* of this, or of any of the following formations. The silurian rocks are: (1) *Sandstone;* (2) Several varieties of *slate;* (3) *Limestone* in great abundance; (4) *Conglomerates;* that is, rocks composed of little rounded pebbles and sand cemented together.

Fossil shells and coral abound in this formation. The remains of fish and plants, too, are sometimes found in it.

312. III. THE OLD RED SANDSTONE (OR DEVONIAN) is the third in order, and derives its name from the abundance of red sandstone found in it. Its rocks are chiefly sandstones and conglomerates, with some limestones and slates.

The most remarkable fossils of this formation are its peculiar fishes, which are described in recent works on geology.

313. IV. THE CARBONIFEROUS FORMATION is chiefly distinguished by its immense beds of *mineral coal.* The great quantity of carbon found in it gives it the name by which it is known. The coal is found in seams or strata of various degrees of thickness, lying among strata of slate and sandstone, with an occasional stratum of fossil limestone.

Besides a great variety and abundance of fossil plants, this formation contains fishes, shells, insects, etc.

314. V. THE NEW RED SANDSTONE forms the boundary of the coal formation above, as the old red forms its boundary below. Sandstones of various colors, magnesian limestones, slates, etc. make up the rocks of this division. No distinction has been made by us between the Upper New-red, and the Lower New-red, or Permean system. Bird-tracks and fish-bones are abundant here.

315. VI. THE OOLITIC AND LIAS. — "In many of the

rocks of this series, small calcareous globules are imbedded, which resemble the roe of a fish; and hence such a rock is called roestone, or oolite. But this structure extends through only a small part of this formation, and it occurs also in other rocks.

"The oolite series consists of inter-stratified layers of clay, sandstone, marl, and limestone. The upper portion, or that which is oolite proper, is divided into three systems or groups, called the upper, middle, and lower, separated by clay or marl deposits.

"In this country no genuine oolite has been found. But the remarkable coal-field in Eastern Virginia, near Richmond, is most probably of the age of the oolite and lias, as has been shown by Prof. W. B. Rogers.

"Lias is a rock usually of a blueish color, like common clay; and it is, indeed, highly argillaceous, but at the same time generally calcareous. Bands of true argillaceous limestone do, indeed, occur in it, as well as of calcareous sand. It has been usual to describe it as a member of the oolite series. But it is widely diffused, is very marked in its characters, and contains peculiar and very interesting organic remains."—*Hitchcock.*

Fossil coral and fish are abundant in this formation, but its most striking peculiarity consists in the number and immense size of its *reptiles.*

316. VII. THE CRETACEOUS FORMATION takes its name from the chalk (*creta*) in which it abounds in some countries, especially in Europe. In this formation the *green sand,* so successfully employed as a fertilizer in some parts of our country, is found. Green sand is also found in the higher strata.

317. VIII. THE TERTIARY FORMATION is the highest division of the stratified rocks. The strata in it are generally more nearly horizontal than in any of the lower forma-

tions. It is composed of clay, limestone, marl, and sand, with occasional beds of gypsum and rock-salt.

Many of the fossils of this period are the remains of plants and animals closely resembling those now living upon the earth. But in the rocks of lower ormations, the fossils indicate that our earth was formerly inhabited by beings differing widely from any now known to man. The most remarkable feature of the tertiary period, is seen in the number and size of its mammalia.

318. IX. ALLUVIUM AND DRIFT.—Above all the stratified rocks we discover, everywhere, quantities of loose material, broken down and worn off from rocks of every kind, and scattered over the surface. When this material is carried by water, and deposited along the valleys and in the bottoms of ponds and lakes, it forms what is called "Alluvium," and soils thus formed are *alluvial.* The material of which they are composed, is generally collected from a considerable variety of rocks, and hence they have all the mineral elements necessary to render them fertile.

In many places vast currents of water, accompanied most probably by masses of ice, have swept over extensive regions, carrying with them the abraded material from the various rocks, and hills, and mountains over which they have passed, and again depositing it, as a mixed mass of sand and clay, full of pebbles and boulders of almost every conceivable size and shape. This constitutes the "Drift formation."

The Drift forms a very important feature in the geology of some of our Eastern States, and also at many points in the Northern and North-western States; but it rarely occurs farther south than the Ohio River, except as local drift. It differs, of course, from the rocks beneath; and frequently gives a fertile soil, immediately over rocks which would have produced only a barren desert.

319. X. Beneath the stratified rocks, in many places rising

up through and often over-lying them, we find the *unstratified* rocks. These bear no marks of having been deposited by water, but seem to be of *volcanic* origin.

The most prominent minerals which enter into the composition of these rocks are Feldspar, Hornblende, Quartz, and Mica. These combining, give us Trap rocks, Granite (including Syenite), and many less abundant varieties, of which we have not room to give a description.

320. Whenever the rocks, whether stratified or unstratified, are long exposed to the influence of air, rain, and frost, or even of air and rain alone, they are gradually broken down, as heretofore stated, into small fragments. These undergo many subdivisions, until the little separated particles of sand and clay, mingled with such organic matter as previously existed in the rock, or has meanwhile been growing among the fragments of its half-formed soil, become one mixed mass, and at the same time pass through such chemical changes as adapt them to the great end for which they were designed.

321. The original quality of the soil must, then, be greatly dependent upon the character of the rocks out of which it has been formed. Yet it is not difference in the mineral composition of rocks alone, that causes differences in the nature of soils; the organic, fossil matter, deposited when the rocks were formed, seems often to have had a most striking influence. Any one may observe for himself, in traversing a hilly or mountainous region, how suddenly he sometimes passes from one quality of soil to another, even in the same field. And in uncultivated lands, he may frequently meet not only with abrupt changes in the rocks and soil, but changes just as abrupt in the *trees, shrubs,* and *weeds,* which nature seems to have adapted to the varying quality of their mineral food.

322. Pure *granitic* soils contain the disintegrated particles

of quartz, feldspar, and mica, from the granite rock. The feldspar is soon decomposed, by the action of carbonic acid, into carbonate of potash and fine clay. The little crystals of quartz are but slightly modified, forming, when set free, *sand* of various degrees of fineness. From hilly lands the fine clay is gradually carried down into the low grounds, and a covering of sand, generally with clay beneath it, is left to form the poor, barren soils of the surrounding hills. But even where all the material of the granite is retained, the soil is generally deficient in *lime*, *magnesia*, and *oxide of iron.*

When granite contains *hornblende*, as it often does, this furnishes *lime*, *magnesia*, and *iron*, and such a soil is generally productive. Or, if granite and trap rocks occur on the same hill, the soils from both may become mingled by the action of rain and frost, or by tillage, and thus form a better soil than either would form alone.

323. *Trap rocks*, being composed, as we have learned, of feldspar and hornblende, are acted upon by air and water, both mechanically and chemically. The result is a finely divided soil, to which the feldspar furnishes an abundance of clay and potassa, with some soda; while the hornblende yields lime, magnesia, and oxide of iron abundantly; hence such soils are generally fertile. Some of the best soils of Eastern Virginia are formed from Trap.

324. The primary stratified rocks differ widely in composition, and, as a consequence, give a great variety of soil. We have a most extensive illustration of this in the greater part of the wide area, extending from the eastern side of the Blue Ridge, on the one hand, to the slope over which the rivers flowing into the Atlantic fall, before they reach tide-water, on the other; then, extending northward, it becomes narrower as it passes into Maryland, and extending southward into North and South Carolina, it spreads out to a still

greater width than it has in Virginia. In this region there are some belts of fine soil, formed from rocks composed largely of feldspar and hornblende. There are other sections, in which the soils are composed of the ruins of gneiss and granite. These soils are sandy, and less valuable. Again, there are localities in which the soil has originated from rocks composed chiefly of quartz, with small quantities of mica or feldspar, or both. Such regions are hopelessly deficient in the most important elements of mineral fertility.

325. The Great Valley of Virginia is an example of the Silurian formation. The western slope of the Blue Ridge belongs to this. The rocks here, and on the spurs, which often extend out some distance into the valley, are chiefly slate and hard sandstone. These form light, unproductive soils; and where the rocks are hard sandstones, they disintegrate very slowly, break off in large fragments under the influence of frost, and form rough, unmanageable soils. As we descend into the open valley, we find the formation consisting of a great variety of limestones, with vast beds of interstratified slates and shales,* all containing fossil shells and coral. By their disintegration, these rocks generally give soils of fine quality. In most parts of this valley, the rocks have been very much tilted and warped at the time of their upheaval, thus giving rise to a peculiar and interesting variety of landscape. In many places we meet with abrupt precipices, such as are common along the banks of water-courses; in other places we find deep gorges, like that spanned by the Natural Bridge; while the less sublime but no less beautiful hills, with their gently undulating slopes and rounded tops, are found to cover the greater part of the surface throughout the whole length and breadth of this delightful section of our State.

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* Shale is a brittle, imperfect form of slate.

As century after century has passed away, the solid rocks, as well as the more brittle shales, have been gradually broken down into minute fragments by rain and frost, while the carbonic acid brought down by the rain-water has dissolved out much of the carbonate of lime, and left the clay to form soils varying in depth from less than an inch to many feet. The depth of these clay deposits depends partly upon the steepness of the land, but still more upon the structure and composition of the rock. If the surface is steep, the greater part of the liberated clay may have been washed down into some neighboring valley, forming there a deep, rich soil, and leaving the rocky hill-side almost naked. If the rocks were pure carbonate of lime, there could be no residuum of clay and sand to produce soil; but the truth of the case is, that nearly all the compact limestones contain a considerable amount of these impurities, while some contain not more than fifty per cent of carbonate of lime; and many of the beds of calcareous shale have but a small quantity of the carbonate, combined with a large quantity of clay. These last not only disintegrate more rapidly, but also leave a much larger amount of residuary matter than any of the more solid rocks. Hence we generally find them underlying deep beds of clay.

The soils resulting from limestone formations are generally productive, and remarkably well adapted to the culture of grass and grain crops, and also produce good tobacco. Where the ancient coral reefs are found among the limestones of this formation, the clay which they leave after their decay, as well as that formed from the adjacent shales, is rich in *organic* matter, as well as the mineral elements required in soils of the best quality. The author has detected ammonia in very perceptible quantities, in clay found in a quarry of coraline limestone, at a considerable distance beneath the surface of the ground. If we suppose this ammonia to have been produced in the rock by the decay of the coral, by which it was built up, and then retained by the clay after the rock has been disintegrated, and has had its carbonate of lime dissolved out, it affords us a most striking illustration of the tenacity with which ammonia is held by clay. [For more detailed information, see Prof. Gilham's valuable Essay on the Soils of the Valley of Virginia, Journal of State Ag. Soc., vol. iii.]

The mountain ridges lying along the western side of the valley, belong also to what we have called the Silurian formation. Here slate and sandstone prevail. The slate forms a soil capable of considerable improvement; but the sandstone is too hard to form a soil suitable for tillage, except along the lower slopes of the ridges and in the valleys, where the abraded material has been collecting for many centuries. When clay from one ridge is carried down by water, and mingled with the sand brought down from some neighboring ridge, and deposited along the banks of streams,(plants, insects, fresh-water shells, etc., being mingled with it,)very fertile bottom lands are often formed, running in long narrow strips through extensive sections of almost barren mountains. —(*Rodgers.*)

326. The soils of the Old Red Sandstone are extremely variable in our country. Where marl and limestone are found in this formation, the soil is generally productive; but where the sandstones prevail, as they do extensively in the mountainous parts of Western Virginia, lying along the eastern side of the coal regions, the soil is generally poor.

327. In the Carboniferous or coal formation, many of the slates and sandstones form soils of no great value; but belts of limestone and calcareous shale sometimes give corresponding belts of good land. The accumulations of detritus in the valleys, and along the streams, also afford good soils. Where the slaty lands of this, or any other formation, lie in a hori-

zontal position, they are impervious to water, and hence are cold and wet. These must generally be drained before they can be successfully cultivated (see Chap. XIII).

What has been said of the influence of the various kinds of rock upon the soils overlying the formations already mentioned, will lead us to the general conclusion that the quality of the land upon all the higher strata, must be as variable as the character of the rocks themselves. The sandstones generally give light, infertile soils, while those produced from slates and shales are better; and, when free from bituminous matter, and supplied with lime, are often very productive.

328. Some of the formations have the elements of their own improvement treasured up within themselves. A striking example of this is seen in the *marl beds,* so abundantly deposited in the tertiary strata lying along our eastern coast. Many farms in the tide-water sections of Virginia, Maryland, and other States, have been most successfully and profitably reclaimed from almost hopeless exhaustion, by the judicious application of these tertiary marls. Besides the marl proper, little mineral nodules of a dark color occur in the same beds, or in contiguous deposits; and, on being analyzed, they are found to contain a large per cent of *phosphate of lime.* Prof. Johnston, of England, says: "This crag [a tertiary deposit] is chiefly interesting to the agriculturalist from its containing hard, rounded, flinty nodules—often spoken of as *coprolites*—in which as much as 50 per cent of phosphate of lime (bone-earth) has been found. These nodules are scattered through the body of the marls, and through the sub-soils of the fields far inland; and are collected for sale to the manufacturers of super-phosphate of lime, and other artificial manures." (*Ag. Chem.* p. 94.) Similar black pebbles occur in the Olive Earths and Marls of the tertiary strata of Eastern Virginia. Mr. Ruffin, the

venerable and distinguished President of the Virginia State Agricultural Society, first brought these to the notice of Prof. Gilham, of the Military Institute, by whom some specimens were analyzed. "After being crushed and thoroughly mixed, they were found to contain 56 per cent of phosphate of lime!"—(*Southern Planter*, Dec. 1858.)

329. The experience of the agricultural world has established a conclusion of great practical importance in the selection of lands for tillage. It is this — *that, among the upland soils, none are so uniformly and permanently fertile, as those formed from calcareous rocks.* And next to these, *the soils from the lime-bearing trap-rocks occupy the first place.* Alluvial and drift soils, of course, are exceptions.

STRUCTURE OF THE SOIL.

330. In examining any soil which has been left undisturbed to pass through its natural stages of formation, we find the surface portions differing considerably from those nearer the original rocks. They differ not simply in appearance, but also in composition, and consequently in fertility.

It is both interesting and instructive to trace out the various changes which have taken place, in reducing the original rocks of the earth to the condition of arable soil. Let us take, for example, a calcareous formation, made up of limestones and calcareous shales, which have just been upheaved by volcanic agency, and for the first time exposed to the disintegrating influence of the weather. The shales are rapidly crumbled down to the condition of clay, from which the rain gradually dissolves out much of the carbonate of lime, carrying it off to form "limestone springs." The more solid rocks are worn down more slowly, but not less surely, by the operation of the same causes. In this way a soil is gradually formed, supplied with all the mineral ingredients of the rocks. But such a soil, produced by such a process alone, would still lack one important class of its elements of fertility: it would still want the organic matter, which we shall hereafter find performing most important offices in the production of plants. If the rocks have been highly fossiliferous, more or less organic matter may be already present; but the supply soon begins to be collected from another source. The new soil is gradually provided with the seeds of grasses, herbs, and trees of various kinds, from older lands; and such of them as find here their appropriate mineral food, soon germinate, take root, and send out their blades and leaves to collect carbonic acid from the air (§ 270), while the roots themselves drink in the same kind of nourishment from rain-water, together with ammonia and mineral matter. Some of the roots soon penetrate the lower parts of the soil for many feet, whence they draw up mineral substances, and send them out in the sap, to be incorporated with the organic food from the air, in the body, and branches, and leaves of the growing plant. As the grass, the weeds, and the leaves of trees fall and decay upon the surface, they leave a dark rich deposit of humus, to serve as food for the same or other kinds of growth. In this way, great quantities of organic matter are often accumulated, forming with the clay a deep, rich vegetable mould.

The mineral matter which once fed the decayed leaves and grass, has not only been increased in quantity near the surface, but has also been so elaborated in the plants through which it has passed, as to be now in the best possible condition to afford nourishment to subsequent crops growing upon the same soil.

The portion of soil which has thus become enriched with organic and mineral substances, is called the "surface-soil," and is the part usually cultivated. The "sub-soil" is the layer upon which the surface-soil rests. It generally has but little organic matter in it; and, in the majority of fields in our Southern and Western States, it has never been disturbed by the plow. On rolling lands which have been long under cultivation, the surface-soil on different parts of the same hill is generally more uniform in its character than the sub-soil; because the loose material on the surface becomes mingled, by the mechanical action of the plow, rains, and frost; while the sub-soil, having been less frequently disturbed, lies nearer to the rock from which it originated, and more nearly resembles it. The value and importance of the sub-soil, and its proper management, will be discussed hereafter.

331. CLASSIFICATION.—*Sand, clay, oxide of iron, carbonate of lime*, and *organic matter*, make up the body of all soils. Other ingredients, such as *potassa, soda, phosphates*, and *sulphates*, are not less essential to a good soil; but they generally form only a small proportion of the whole mass.

We may reduce all soils to *six general classes*. And yet these divisions will be found to blend into each other, so that it will be difficult often to tell where the line of separation is to be drawn. Still, a general classification may serve some valuable purposes. It may, at least, direct the attention of the young farmer to the mechanical differences found among different soils, and thus prepare him the better for their mechanical management. The classes we propose are: (1) *Sandy soils*; such as have not less than 75 per cent of sand, may be placed under this first class. The quantity of sand may be determined with considerable accuracy, by very simple means. *Exp*. Dry and weigh a pound of soil, and put it into a vessel which will hold a gallon or two of water. Pour clean water over it, and stir it up thoroughly; then pour the water off gradually. The sand will at once subside, on account of its weight; while the particles of clay and organic matter, being lighter, will be held longer in suspension by the water. By repeating this washing with fresh portions of water, until the water passes off clear, the sand alone will be left, and may be dried and weighed, and the quantity in a pound of soil thus determined. (2) *A sandy loam* is a soil containing from 50 to 75 per cent of sand, which may be separated and determined by the process above given. (3) *A clay loam* has only from 25 to 50 per cent of sand, and the remainder chiefly *clay*. (4) *A clay soil* has less than 25 per cent of sand, the remainder being chiefly clay. The dark red clay soils have a large per cent of oxide of iron. (5) Any soil containing 10 per cent, or more, of carbonate of lime, may be called a *calcareous soil*, whether the remainder be clay or sand, or both. Hence, that proportion of calcareous matter would exclude a soil from either of the first four classes. To determine the quantity of carbonate of lime: heat *two ounces* of *well-dried* soil, on a piece of sheet-iron, or in an iron ladle, till all the organic matter is burnt out. Then pour over it a pint of water, and add a fluid ounce of muriatic acid. The acid will dissolve all the lime, while it will dissolve very little else from the mass. Stir the mixture several times, and let it stand until the remainder of the soil settles; then pour off the clear solution. Stir it up with another pint of fresh water, let it settle, and again pour off. Repeat the same washing with another portion of water. Spread the undissolved part of the soil on paper, and dry thoroughly. Then weigh again, and the loss of weight will be about the quantity of carbonate of lime. This is but a rude experiment, and is only applicable where the quantity of carbonate of lime is large, and the result aimed at, a mere approximation. (6) *A peaty soil* is one which contains 20 per cent or more of dark decayed organic matter — such soils as are common in low and swampy places. The quantity may be very nearly determined by burning out the organic matter, and ascertaining the loss of weight.

332. *Compactness* is a quality of importance in a soil. It

must be sufficiently firm to hold the roots of the growing crop firmly in place. This is especially important in wheat and grass crops, which are exposed to the frosts of winter. Yet it must not be so compact that the roots cannot readily penetrate it.

The property of absorbing and retaining moisture is important. Clay-loam and peaty soils absorb the largest quantity of moisture, and retain it best; except those peaty soils which have a large excess of organic matter in them. Pure clay soils are generally too compact, while sandy soils are generally too loose either to absorb or retain moisture well. On a level clay soil, the water is apt to become *stagnant.* This is the case, too, on sandy or peaty soils which have a clay sub-soil. Under such circumstances, draining is required.

333. Air should be allowed to circulate freely in the soil. (1) It carries the elements of plant-food contained in it, to the roots. Carbonic gas and ammonia are both furnished, and conveyed to the spongioles of the roots in this way. (2) It promotes the decay of organic matter present, and thus again provides the same articles of food. (3) Moisture is often supplied to a dry soil from damp air brought in contact with it. (4) The proper chemical changes in the mineral elements of the soil, are promoted by the action of the carbonic acid and oxygen of the air. (5) The germination of seeds, and growth of the germ, require the circulation of air.

Let us now turn to the investigation of the principles which are to guide us in the mechanical management of lands.

QUESTIONS ON CHAPTER XII.

§ 284. From what sources do plants get their nourishment? Over which of these have we any control?

285—290. What is *Geology?* Its relations to agriculture? Where have *soils* their origin? What exceptions? How is the term *rock* used? What two general forms have rocks? What is a *stratum?* Explain Fig. 37. What are unstratified rocks? How situated? Explain Fig. 38. How have stratified rocks been deposited? Why are unstratified called "igneous rocks?" Of what are all rocks composed?

291, 292. What is a *mineral?* What are the three great kingdoms of nature? What are the minerals that enter most largely into the composition of rocks and soils?

293, 294. Describe *Quartz.* When called sandstone? Symbol for silica? Why called silicic acid?

295, 296. What is *Talc?* Its form? How distinguished from mica? What is *Clay?* Slate? What gives clay its color?

297, 298, 299. What is *Feldspar?* How does it vary in composition? Form of its crystals? How are they modified? Its colors? Effect of exposure to weather? Of what does its disintegration give us an illustration? How does carbonic acid act upon this mineral? Quality of soils from feldspar? In what deficient?

300, 301. In what form does *Mica* occur? Influence of heat upon it? Its chemical composition? Constituents of *Granite?* Its importance? What kind of soil does it produce? What is *Gneiss?* Its structure? Where found in abundance? Its soils?

302, 303, 304. Composition of *Hornblende?* Its forms? When called Asbestus? What is *Trap?* What kind of soil does it yield? Why? How may hornblende enter into granite? What is it then called?

305, 306. Forms of *Carbonate of Lime?* Effect of burning? Quality of lime? What other substances are constituents of limestone?

307, 308. What do geologists believe concerning the inner part of the earth? How have stratified rocks been formed? What are imbedded in these rocks? What are they called? What of the abundance of fossils in some rocks? How have the stratified rocks been thrown into their present position?

309. What does Fig. 41 represent? Is any one formation found everywhere? Did any one of them ever envelope the whole globe? Illustrate.

310, 311. Where are the *primary stratified rocks* situated? Of what composed? What is the structure of their mineral ingredients? What formation next above the primary? Of what composed?

312. *Old Red Sandstone?* Its constituents? Its fossils?

313. How is the *carboniferous* formation distinguished? Its fossils?

314—317. How is the *New Red Sandstone* situated? Of what rocks is it made up? Point out its position in Fig. 41. How is the *Oolitic* formation characterized? Of what does it consist? What coal field has been found in this formation? Describe the *Lias.* What remarkable fossils in the Oolite and Lias? Why is the *cretaceous* formation so called? What valuable mineral is found in it in this country? Position of the *Tertiary* formation? Trace it out on Fig. 41. Of what composed? What of its fossils?

318. Where are *Alluvium* and *Drift* found? What kind of deposits are called alluvium? Character of its soil? How has the drift formation been produced? What kind of soils does it give?

319. How are the unstratified rocks situated? Their origin? Chief minerals?

320—323. Influence of long exposure upon rocks? How do they become soil? What determines the original quality of a soil? Influence of fossil matter? How does natural vegetation indicate differences of soil? Describe the disintegration of *Granite.* In what are granitic soils deficient? Effect of hornblende on granitic soils? What are the constituents of trap rocks? Quality of trap soils?

324. What kind of soils from *primary rocks?* What extensive region belongs to this formation?

325. To what formation does the great valley of Virginia belong? Rocks of the western slope and spurs? Character of their soils? Rocks of the lower part of the valley? Character of the soils from these rocks? The landscape? How have the soils been formed? Upon what does their depth depend? Are the rocks here generally pure carbonate of lime? The general character of limestone soils? How has organic matter been communicated to some of these soils? What of the mountain ridges west of the valley?

326, 327. Old Red Sandstone soils? Influence of marl and limestone? Soils of the coal formation? Detritus of the valleys? Why are the soils of the higher formations so various?

328. Example of a formation, having the means of improving its soils within itself? What besides marls are found in the tertiary deposit? Example in England? Example in Eastern Virginia?

329. What general conclusion in regard to soils from calcareous rocks? Class of soils next to these?

330. How do the different parts of a soil differ? First step in the formation of a soil? Do the rocks furnish everything necessary to fertility? How is a new soil soon provided with plants? How do these increase the quantity of organic matter? How do they affect the quantity and quality of mineral matter? What is the surface soil? Sub-soil? Which most nearly resembles the original rocks?

331, 332. What minerals make up the main body of all soils? What other ingredients must be present? Can soils be very definitely *classified?* Why not? What are *sandy* soils? How is the quantity of sand determined? A sandy loam? A clay loam? A clay soil? A calcareous soil? To determine the quantity of carbonate of lime? A peaty soil? Why are such soils common? Why is compactness important in a soil? For what crops especially? Absorbent power of soils? Why is draining often necessary?

333. What should have free circulation in the soil? First reason? Second? Third? Fourth? Fifth?

CHAPTER XIII.

MECHANICAL TREATMENT OF SOILS.

334. In reducing soils to their proper mechanical condition, three points must be kept distinctly in view: (1) *They must be sufficiently pulverized to allow the roots of plants to spread and grow freely;* (2) *They must permit a free circulation of air;* (3) *The water which falls upon them must be readily absorbed, and have, at the same time, such free circulation, that any surplus moisture will pass off, without becoming stagnant, and without washing away the surface.*

To accomplish these objects, several methods may be pursued, one or all of which may be employed, as the condition of the land, or other circumstances seem to require. Those means best adapted to the farming operations of our own country will be described in this chapter.

335. (*a*) *Mixing soils* may be resorted to, where those of widely-different classes are sufficiently near each other to admit of transportation. For example, the best and most durable remedy for a stiff clay is the application of sand; while, on the other hand, the best remedy for a very loose, sandy soil, is the application of clay. If a farmer has both kinds of soil on contiguous portions of his land, he may often find it profitable to haul sand upon his stiff clays, and, for each load of sand, bring back a load of clay to be applied to the loose, sandy surface. This method is extensively and most successfully employed in Holland. Clay soils may also be greatly benefited by being mixed with peaty soils, or, still better, by applying pure peat. So, those of peaty character,

being often too porous, may be improved with clay, or clay and sand together.

336. (*b*) *Plowing* is the most common, and most economical means of giving a soil its proper mechanical condition. All past experience proves that, without the plow, or its equivalent, successful agriculture is impossible; while the history of the world shows that nations have generally been prosperous (other things being equal,) just in proportion to the skilful use they have made of this most important of all instruments. If two men, with equal force and capital, are placed upon contiguous farms of equal size and fertility, they will *prosper* very much as they *plow*. The one who scratches the surface to the depth of only three or four inches, will soon find both his farm and himself growing poor; while the one who is not satisfied with breaking and cultivating less than twelve inches in depth of his land, will, most probably, soon find it necessary to "pull down his barns and build greater."

337. (*c*) *Repeated plowing* during the growth of many crops, not only cleans the land, by destroying weeds and grass, but also serves another most important purpose not to be overlooked, even if the land is already clean: that is, it keeps the soil in a proper condition for the growing roots, and for the free circulation of air and moisture. These advantages are seen every season, where corn, tobacco, and cotton crops are properly cultivated.

338. (*d*) *Deep plowing* is absolutely necessary on almost every farm, in order to get the highest profit from the soil. The reasons for this may be rendered plain enough for any mind, in a few sentences. (1.) The space in depth, to which the roots of crops penetrate, and from which they derive nourishment, is limited chiefly by the extent to which the plow has run. Beneath that point, especially in clay soils, the roots make but little progress. (2.) The unbroken sub-

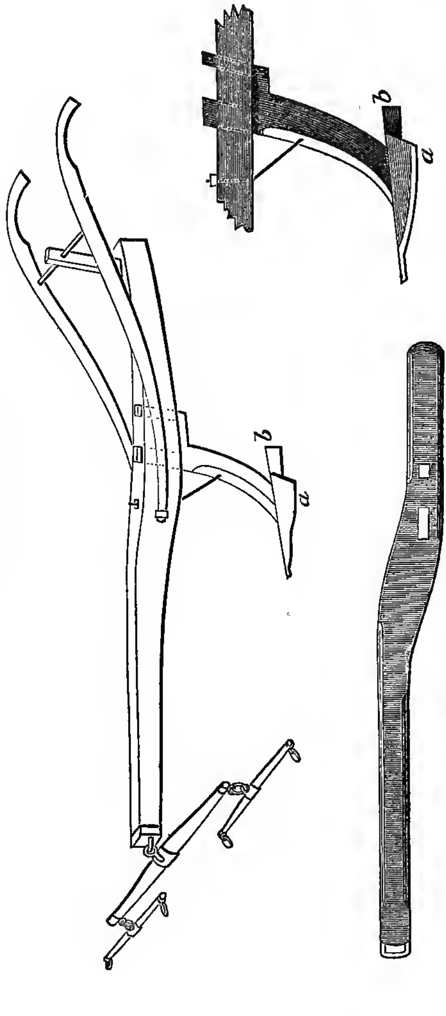
soil, when composed of clay, is not easily penetrated by rain. Hence, after the plowed mass has become saturated, the surplus water escapes from the surface, frequently carrying off valuable portions of the fertility, and leaving unsightly gullies behind it. Deep plowing tends *to prevent washing.* (3.) A deeply-broken soil is a sort of *store-house for moisture,* holding a portion always in reserve for periods of drought. When the sun, the air, and the growing crop have taken up the surface moisture, some of the roots are still deep down in the earth, where the supply is abundant. Then, again, this moisture from below constantly rises toward the top during drought, by the force of capillary attraction, thus keeping up the supply to those roots nearer the surface. Besides this, it brings with it some elements of fertility in solution, and as the evaporation at the surface goes on, these are left to aid in enriching the surface-soil. Drought may thus improve land which has been properly plowed.

339. SUB-SOILING.—The sub-soil plow is designed to follow the ordinary or surface-plow, in the furrow left by the latter. By this means the bottom of the furrow is broken and pulverized, without being turned up. The surface-plow then throws its next furrow upon this loosened portion of the sub-soil; and, again, the sub-soil plow following, breaks another portion beneath; and so the process is continued till the whole field has its surface stirred to a depth which cannot ordinarily be reached by any one plow operating alone.

One of the simplest and best sub-soil plows is constructed upon the following plan: It has a strong, sharp coulter, extending about fifteen inches below the beam, having a share, or wing, on one side of it, about two-thirds as wide as the share of the surface-plow (Fig. 42, *a*). The hind part of this share-wing should be elevated about three inches, so as simply to raise the clay, and let it fall back in a pulverized

FIG. 42.

Left-hand Sub-soil Plow.



Coulter.

Top view of Beam.

condition behind the coulter. The bar forming the point, should extend backward from the heel of the coulter four or five inches, to give steadiness to the plow, and enable the plow-man to regulate its depth (Fig. 42, *b*).

If the plow is to be worked by two horses, which it generally requires in a stiff soil, one of the horses should walk in the furrow, and the coulter must then run with its share directly behind him. In order to throw the coulter thus more nearly in the track of the furrow-horse, than of the one on the unbroken land, the beam may be made crooked. The accompanying figure will give a good general idea of the parts and structure of this implement. It can be made by any ordinary plow-maker, at a cost of three or four dollars. A straight beam will do, if the point of the coulter is inclined towards the furrow. But the handles are then thrown too far out of the line of draught.

340. Benefits. — The benefits of sub-soiling are very similar to those of deep plowing, already given (§ 338). It opens up a new source of fertility, for the sub-soil always contains many of the substances demanded by the growing crop. It gives a deeper space for the circulation and retention of air and moisture, and thus serves as an antidote to drought. Again, if the soil is level, and of such a character as to retain too much of the water which falls on it, and thus becomes swampy, the broken sub-soil lets it pass off more freely from the surface-soil, and the sub-soiling thus becomes akin to draining. But, on horizontal lands, in case there is still a stratum of impervious clay beneath the broken subsoil, there will be no outlet for the surplus water, which will then be confined in the level field, as in a shallow basin. In such a case, draining must precede sub-soil plowing, else the latter will be of no avail. If land is level, then subsoiling will be of little service to it, unless it be either naturally or artificially drained.

But one peculiar advantage which sub-soiling has over ordinary deep plowing, is that it gives a deeply-pulverized mass, without exposing upon the surface that portion which is often unfit for such a purpose. If, for example, the sub-soil is a tenacious clay, which would readily form a hard crust on the surface, it had best not be turned up; or if it is of a lighter color than the surface-soil, it would not absorb heat so freely, and would hence be, in that respect, injurious.

Sub-soiling need not be resorted to in all cases. In very deep loamy and sandy soils, it is sometimes better to run two ordinary plows, the one after the other, in the same furrow — the second being set deeper than the first. In this way the surface and sub-soils are inverted, to some extent, or, at least, completely mingled; and where the surface has been exhausted by long-continued tillage, its place is thus supplied by fresh soil. This is called "*trench-plowing.*"

The sub-soil plow serves a valuable purpose, when run through meadows and grass-lands which have become too compact. The soil beneath the sod is loosened to a great depth, without the sod being seriously broken. This plow may also be used for loosening the earth beneath the roots of corn, or cotton, before the plant has attained any considerable size.

The Harrow and Cultivator are important auxiliaries to the plow, in reducing the soil to a more completely pulverized condition; in mixing fertilizers more entirely with it; in giving a smooth surface; and in covering the seeds of some crops. The cultivator is especially useful in stirring the soil between corn-rows, when the roots have become too much extended to allow very deep tillage; and in covering wheat, when sown broad-cast.

The Roller is an important instrument on many soils. Where clods are too hard for the harrow to reduce, the roller affords the best means of crushing them. When very light soils are cultivated in wheat or grass, the roller is frequently wanted to render the surface sufficiently compact.

DRAINING.

341. The chief object of draining is to carry off the surplus moisture from the soil. In our country, especially in the South and West, where land is abundant, it is confined almost entirely to swamps, and to such lands as (by their level surface and impervious sub-soil, or tenacious strata beneath) collect and retain stagnant water. Thousands of acres of swamp-lands have by this means been reclaimed from a worse than worthless condition, and rendered extremely fertile; while millions lie yet unreclaimed, in our Southern States, fit now to produce nothing but loathsome reptiles and insects, together with fatal *malaria*, which often make much of the surrounding country almost uninhabitable.

342. *Why are swampy lands infertile?* (1) The *stagnant water* excludes the air, and causes the organic matter so abundantly accumulated to be converted into vegetable acids, such as the humic and ulmic, in large excess, with small but sometimes very perceptible quantities of acetic and tannic acids. Such soils are said to be "sour," and produce nothing but coarse, worthless vegetation. (2) The air is also necessary to keep up the proper chemical activities in the soil, in order to produce the required changes in its mineral ingredients. Stagnant water prevents this, by excluding the air. (3) Swampy lands are *cold.* Water neither absorbs nor conducts heat so freely as soil; hence lands covered, or even saturated with water, are not readily penetrated by the heat of the sun. Besides this, the constant evaporation which goes on from the surface of such lands, carries off heat rapidly.

343. Draining, then, by admitting the circulation of air, promotes the proper kind of chemical changes in both organic and inorganic substances, and thus sweetens a sour soil; and, by admitting heat and checking evaporation, brings the ground under the warming influence of the sun.

The decay of organic matter, and consequent generation of gases in drained lands, has the mechanical effect of rendering their soils more porous, in a short time after the surplus water has been withdrawn. The winter frosts greatly aid in bringing about the same result.

As soon as drained lands have become sufficiently dry for the plow, they should be treated with a free dressing of quick-lime or unleached ashes, to neutralize the excess of vegetable acids, and then be broken up to as great a depth as possible, in order to aid the circulation of air.

344. Modes of Draining.—There are two modes of draining in common use. The one by *surface (or open) drains;* the other by *blind (covered) drains.*

345. I. The *open drains* consist (1) of one or more main channels, or ditches, as deep as they can conveniently be made, running through the lowest part of the field. A natural channel often serves the same purpose. (2) The spaces between the main channels are traversed by the smaller drains, leading into these, and situated at distances apart, varying from 25 to 100 feet, according to the nature of the soil. The depth of each cross-drain, if the ground is level, should vary—increasing towards the main channel, in order to give some "fall" to the water in that direction. (3) The spaces between these have to be cultivated as separate strips or beds.

346. *Advantage.*—The only advantage this kind of draining can claim, is its *present cheapness.*

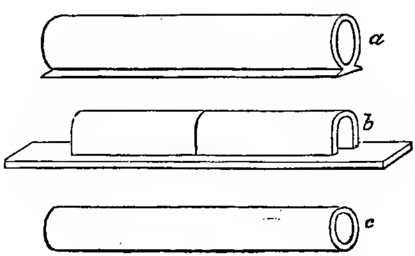
Disadvantages.—(1) It is not a *thorough* method. The drains cannot be made very deep without endangering the safety of horses and other animals; and the soil can only be drained to the depth of the ditches. (2) It wastes land, by occupying considerable spaces which might be cultivated, if the ditches were covered. (3) Heavy rains carry away much of the valuable matter of the soil, through such drains. (4) They are very much in the way of convenient tillage.

347. II. *The covered drains.*—These are in every respect preferable to those above described. They are constructed by digging deep ditches parallel to one another, and leading into a larger *main channel*, like the open drains. But, instead of being left open, a tube or pipe, formed of tiles, is laid in the bottom to carry off the water, and the ditch then filled up.

348. The following figures, with their descriptions, taken from the "Patent-Office Reports" for 1856, will give a good idea of the construction of covered drains.

"Draining tiles are made of clay, similar to brick-clay, moulded by a machine into tubes, usually 13 inches long, and burnt in a kiln or furnace to be about as hard as what

FIG. 43.



are called hard-burnt bricks. They are of various forms and sizes. Some are round, with a sole or flat bottom moulded with the tile, and are called "sole tiles," as shown in figure *a;* others are of a horse-shoe form, open at the bottom, to be laid on the hard bottom of the ditch without a sole, or in soft places with a sole or flat bottom of the same material with the tile, made separate from it, as shown in figure *b*. For some localities, pipe-tiles, merely of round tubes, as represented in figure *c*, are preferred."

The tiles are generally laid end to end, and the water always finds its way in, readily and freely, at the joints.

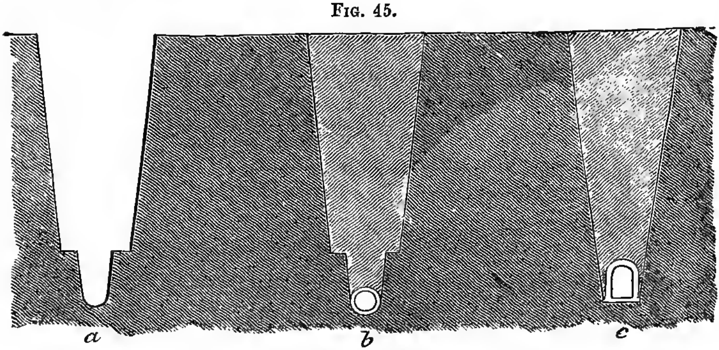
"Where there is danger of displacement, by reason of the soft condition of the ground at the bottom of the trenches, pipe-tiles are often kept in position by means of collars of the same material as the tiles themselves, made loosely to fit over the joint, as represented in the following cut:

Fig. 44.

"The size of tiles to be used varies from 2 to 6 inches calibre, according to the quantity of water to be conveyed. It is a question of expediency whether to use very large tiles, or to lay two or more courses of smaller size, side by side, when the flow of water is very great.

349. "A glance at the following diagrams will give a correct idea of the general process of opening and finishing the drains with the pipes laid:

Fig. 45.



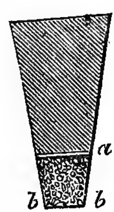
"Figure *a* represents a trench cut in clay, ready to receive pipe-tiles; and figure *b*, a section of the same drain finished. Figure *c* represents a section of a finished drain, with a sole tile, as usually constructed in common soil."

350. Where stones can be conveniently procured, the following method, as described in "Norton's Scientific Agriculture," is cheap and simple.

"The ditch should of course be wedge-shaped, for convenience of digging, and should be smooth on the bottom.

"Where stones are used, the proper width is about six inches at the bottom. Small stones should be selected, or large ones broken to about the size of a hen's egg, and the ditch filled in with these to the depth of nine or ten inches. The earth is apt to fall into the cavities among larger stones, and mice or rats make their burrows there; in either case, water finds its way from above, and washes in dirt and mud, soon causing the drain to choke. With small stones, choking from either of these causes cannot take place, if a good turf be laid grass-side down above the stones, and the earth then trampled in hard. Cypress or cedar shavings are sometimes used, but are not quite so safe as a good sound turf. The water should find its way into the drain from the sides, and not from the top. The accompanying figure (46) represents the arrangement of the stones: *a* is the turf on top; if the water enters at the sides, *b*, *b*, it comes in clear, having filtered through the soil, and deposited everything in the way of mud, which might tend to choke the drain. . . . In very swampy, soft ground, it is sometimes necessary to lay a plank or slab on the bottom of the drain before putting in the stones. This is to prevent them from sinking, and making an uneven bottom, before the soil becomes dry enough to be firm."

FIG. 46.



Unbroken stones have been very successfully used in constructing drains. The method of laying such stones, in ditches, two feet wide at the top and one foot at the bottom, is very clearly stated by Mr. P. Slaughter, in his Premium Essay on this subject, submitted to the Virginia State Agricultural Society in 1854. He says: "A careful hand, in choosing suitable stones, places them on each side of the ditch as side walls, treading upon them as he goes along, to be assured that they are firm in their places. A second hand follows, placing flat stones upon these side walls. A third fills the spaces with small stones. Another levels the surface with still smaller fragments, upon which, straw, leaves, grass, or even shavings, are laid in thin layers to exclude the earth from remaining crevices."

Timbers—even unhewn poles—have been frequently substituted for the stones. Two lines of poles are laid in the bottom of the ditch, and a third over the space between them. These have been found to last many years, and are especially applicable in swamps, where stones or tiles would sink.

351. There are several points to be observed in the construction of covered drains. (1) What should be their direction, with respect to the slope of the ground? If the land is nearly level, the main or cross channel should run along the lowest part of the space to be drained by the small channels, and should have as much fall as possible towards the final outlet of the water from the field. The side drains should run at right angles (or nearly so) to this, with as much fall as can be given them. If the drained land is a hill-side, the large cross drain should run along the base of the hill, but have sufficient fall to carry off water freely. The smaller drains should run directly down the slope into the cross drain.

352. (2) How far apart should the drains be placed? This depends upon the nature of the soil. If the soil is a very impervious clay, it may be best to place them not more than twenty-five feet apart. But if the soil is gravelly or peaty, they may often be separated by a space of 50 or 100 yards. A large field, with a sandy or pebbly sub-stratum, may be drained by a single ditch.

In hilly regions, there are frequently very narrow valleys, where the bases of hills come nearly together, forming strips of land more or less swampy, or at least too wet to be productive. The meadows in the Valley of Virginia abound in such localities. A *single drain*, run from end to end along each one of these, would generally make them productive of either good grass or grain crops. Where they are wide, short side drains may be required.

353. (3) How deep should drains be laid? At least so deep, that the top of the line of tiles will be several inches below the lowest depth to which the sub-soil plow can be made to run. If the sub-soiling reaches fifteen inches, short of which no farmer should be satisfied, and which can easily be attained in a few years, by increasing the depth at each successive plowing, then the ditches should be at least thirty inches. But the great object of draining is to remove the surplus water, and give free access of air to *as great a depth of soil as possible.* Hence, if drains can be economically laid at a depth of five or six feet, so much the greater will be their benefit. The roots of crops run to a great depth in soils which are in a proper physical condition to be penetrated by them, and in a proper chemical condition to give them nourishment. Indian corn has been known to send its roots to the depth of five or six feet. At a place where an opening had been made for the foundation of a house, to the depth of about five feet, and afterwards filled up, a most

luxuriant bunch of clover was found growing. I had it carefully dug out, and found the main root extending to a perpendicular depth of forty-two inches. It will generally be found that the tops of plants vary nearly in proportion to their roots, and by furnishing a deep rich soil for the roots, we will ultimately reap an abundant reward from the harvest which they produce.

354. When swampy lands have been drained, they will not generally be at once productive. Time must be allowed for the proper chemical changes to take place, but these changes may be greatly hastened by artificial means. (1) *Plowing*, as soon as the ground is sufficiently dry, will aid in giving the air free circulation, and this we know to be one of the great chemical agencies by which soils are improved. (2) The application of *caustic lime*, or *unleached ashes*, will help to neutralize the excess of organic acids generally present, and thus sweeten the soil.

Draining in clay soils is one of the best preventives of drought. Stiff soils are generally very wet during the winter and spring, and, by their own weight, settle down into a compact mass; and, although the surface-soil may be broken up and pulverized, the sub-soil may still be left in its compact form; or, if broken up, there will still be a layer below, to prevent the free escape of surplus water. In wet weather the whole will become like a bed of mortar, and will tend to settle down again into its original compactness. Then, in a drought, the small quantity of water, which the few remaining pores can hold, will soon disappear. But, if the *surplus* water is let off by drains as soon as it collects, the surface and sub-soils will retain their porous character — the larger pores being filled with air, and the smaller ones with moisture, which will be held by capillary attraction, *in readiness for future drought.*

QUESTIONS ON CHAPTER XIII.

§ 334. In reducing soils to their proper mechanical condition, what three points are to be kept distinctly in view?

335. When may mixing soils be adopted? Best remedy for stiff clay? Best remedy for loose sand? How may the mixing be adopted?

336–338. Most common means of reducing the soil? Is the *plow* indispensable? What connection has its use with the prosperity of an individual, or a people? Repeated plowing? Deep plowing? Its first advantage? Second? Third? How does it cause moisture to circulate? How does it increase fertility?

339, 340. What is the *sub-soil?* Use of a sub-soil plow? Describe the plow represented in Fig. 42. Why is the beam made crooked? What is said of the benefits of sub-soiling? When should draining accompany sub-soiling? What peculiar advantage has sub-soiling over common deep plowing? When is sub-soiling not needed? Use of sub-soil plow in grass lands? What is said of the *harrow* and *cultivator?* The *roller?*

341–343. The chief object of *Draining?* To which kind of land is it chiefly applied in this country? Why are swampy lands infertile? Influence of stagnant water? How does draining promote circulation of air in the soil? How does it render the soil warmer? Effect of decaying organic matter? What dressing should be applied to drained lands?

344–346. How many *modes of draining?* Describe the open drains. Advantage of this method? First disadvantage? Second? Third? Fourth?

347–350. How are *covered drains* constructed? How are draining-tiles made? What does Fig. 44 represent? Size of tiles? Explain Fig. 45. How are drains made with broken stones? Explain Fig. 46. How have unbroken stones been used? Timbers substituted for tiles?

351–354. First point to be observed in the construction of drains? Second point? How may narrow valleys be drained? How deep should drains be made? Objects to be aimed at? Depth to which roots run? Will swampy lands be immediately productive after draining? What means may be adopted to hasten their productiveness? How does draining prevent drought in clay soils?

CHAPTER XIV.

CHEMICAL TREATMENT OF THE SOIL.

355. A SOIL may receive all the attention possible, in the way of plowing, draining, &c., and still not be productive. It may yet lack some of the proper chemical elements necessary to supply the wants of the growing crop. By referring back to Table III. (p. 123), we see that the mineral ingredients taken from the soil by different crops are nearly identical in *kind*, but vary considerably in the *proportions* in which they enter into the constitution of the ashes of different plants, or different parts of the same plant.

356. That a soil may be fertile for a particular crop, several chemical properties are essential. (1) It must contain a sufficient excess of the mineral elements required by the crop, to allow the roots to find an abundant supply within the limited spaces which can be reached by the rootlets. Of course, this would require in the whole mass of the soil, much more of each element than could be removed by a single crop. (2) *The plant-food must be in the proper chemical and physical condition to be taken up and appropriated by the plants.* Silica, in the condition of *sand*, cannot act as a fertilizer, because of its insolubility; but, in such combinations as render it soluble, it is one of the most important elements of nutrition for plants. (3) *The soil must be free from an injurious excess of any of the elements of fertility.* Too much magnesia, or even too much carbonate of lime, may be injurious; as in the chalk lands of England, which are among the least productive of that country. The acids in humus are useful to a certain extent, but in large excess

they become injurious (§ 342). (4) *Organic matter is essential to a high degree of fertility.* In a soil having the proper *mineral* elements alone, a plant may come to maturity, and bear seed, obtaining the necessary organic food from the air, through its leaves and roots; but a *full crop* cannot be expected in such a case. The soil, to be fertile, must contain both humus and ammonia.

357. The analysis of a soil is not *always* sufficient to decide the question whether it is fertile or not. The per cent of some ingredients taken from the land, by even several successive crops, is so extremely small, that the most delicate chemical tests would barely indicate *traces* of their presence. Far less than one per cent of phosphoric acid, or chlorine, or potassa, or lime, would be sufficient for all the crops that could be cultivated on a soil for many successive years. Even *one-hundredth* of one per cent is more than sufficient to supply many crops. But chemical analysis can detect far less than this, and yet not be able to say *positively* whether the soil is fertile or not for a particular crop; for the substance may be present in sufficient quantity, but not in the proper *condition* to be used by the plant. Chemistry is not able, in every case, to say in what combination elements exist in soils, where the proportions are extremely small; much less has it been able to tell us in what combinations the plant takes up its mineral food. Still, this valuable science has thrown much light upon the relation subsisting between the soil and the crop.

Analysis tells us, in the first place, that productive soils always contain the same mineral matter found in the ashes of the plants which grow upon them. In the second place, it tells us which elements of fertility exist in very minute quantities, and which in abundance, and then points to the sources from which we may supply those in which the soil is deficient; but it *cannot always predict* the influence which a particular fertilizer is to have upon the crop to which it is applied. It frequently tells us, too, when an injurious excess of any substance is present, and what applications are to be made, to counteract the influence of such substance.

358. We shall place side by side, in the following table, the analyses of three soils, differing in quality. The *first* is fertile for all ordinary crops, *without manure*. The reason of this will be seen in the presence of an abundance of those substances found in the ashes of plants. The *second* is a soil which produces well, with the application of *gypsum* (furnishing lime and sulphuric acid) and *ashes* (furnishing potassa, lime, etc.). The deficiencies in the table are thus filled up. The *third* is a poor soil, requiring much manuring. Observe in how many ingredients it is deficient.

TABLE V.

In 100 lbs. of soil.	Fertile.	Fertile with ashes and gypsum.	Infertile.
Organic matter	10.00	5.60	6.00
Potassa	0.40	0.01 (def.)	Deficient.
Soda	0.20	0.20	Deficient.
Lime	5.90	1.80	0.50
Magnesia	0.80	0.70	0.80
Oxide of iron	2.10	4.10	8.00
Oxide of manganese	0.10	0.30	1.00
Alumina	10.70	25.60	25.30
Phosphoric acid	0.40	0.20	Deficient.
Sulphuric acid	0.30	Deficient	Deficient.
Carbonic acid	5.20	1.40	0.50
Silica	63.90	60.00	58.00
Chlorine	0.02	0.07	Deficient.

359. It will be seen, from the first column of the above table, that even a fertile soil may have but a small percentage of several ingredients which are absolutely necessary in the production of every crop. No crop, for example, can be be produced without potassa and phosphoric acid; and yet these form a very small proportion of any ordinary soil. A

single crop takes away but little of any one element of fertility; but still, repeated cultivation of similar crops for many years, must greatly diminish the supply of those mineral elements found in the ashes of such crops.

Every bushel of wheat, every hogshead of tobacco, every ton of hay, and every bale of cotton sold, carries with it a portion of potassa, lime, phosphoric acid, and other mineral matter. Every fatted ox carries with him to market a good many pounds of phosphate of lime, which came from the soil on which his food was produced.

360. If every article of produce sent to market carries with it a portion of the mineral fertility of the farm, this must in some way be restored, else the land must become poor. Some soils may contain all the mineral elements of fertility in such abundance, that even centuries of cultivation would not exhaust them entirely; but such is not generally the case. Some of the fields in the central and northern parts of Kentucky, have been cultivated for more than half a century without manure, and are still fertile. Some of the James river bottoms, in Virginia, have been cultivated for more than a century without manure, and still produce well. But we must not draw general conclusions from a few extraordinary cases. The *general* experience of the world is, *that lands become exhausted by long tillage without manure.*

361. The *organic*, as well as the inorganic, matter is exhausted by *improper* cultivation. The *humus* of the soil is decomposed, and gradually disappears; and unless fresh portions are supplied from time to time, a *deficiency* must be the result. The *ammonia* is still more rapidly exhausted. The natural supply of ammonia in soils is not generally abundant, while its volatility and chemical activity, cause it to be constantly escaping, or undergoing changes of form and combination. Hence, we see the necessity for artificial fertilizers.

FERTILIZERS.

362. *A fertilizer is any substance which, applied to a soil, will preserve or increase its productiveness.*

363. From what has been said of the *origin* of soils, and of their proper *physical* and *chemical* condition, we infer that they may demand fertilizers:

a. From original infertility. If the rocks* from which the soil is formed have not the required elements of fertility, they must be supplied from other sources, before the land can become productive. *Exs.* Granite soils generally require lime. Limestone soils are often deficient in potassa.

b. From the presence of some substance unwholesome to crops. We have seen that too much water is injurious. The remedy in such a case is draining. Organic acids we have also found to be injurious, when in excess, as is generally the case in swampy lands.

c. From exhaustion by long-continued cultivation. The reasons for this have been already given; and we have illustrations of it in all countries where the lands have been tilled for many years without proper application of manures.

d. From too long application of the same fertilizer. If a soil is deficient in only one or two of its proper elements, and these are supplied, its fertility may be at once restored. But if the application of these same substances *alone,* be made for several successive years, they will be found in many cases to cease having their former influence, and will appear to prove injurious rather than beneficial. Such has been the case with many a field in the Valley of Virginia, under the influence of oft-repeated applications of gypsum alone.

To understand the reason of this, we have only to remember, that, while we are applying one or two elements of fer-

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*By "rocks" we mean all solid mineral matter which, by disintegration, helps to form soils.

tility to the soil, we are taking away many others. Gypsum can supply lime and sulphuric acid, but it cannot supply potassa and phosphoric acid. By applying gypsum, then, year after year, we may accumulate a large excess of its own elements, while the soil is becoming poor from the exhaustion of something else equally necessary, such as potassa or phosphoric acid.

363. Whether, then, we would enrich a barren waste, neutralize some unwholesome ingredient of the soil, restore exhausted lands, or supply neglected fertilizers, we must resort to the proper artificial means. To do this intelligently requires some knowledge of the various fertilizers; their composition, mode of application, influence, etc.

364. CLASSIFICATION. — Fertilizers naturally form *two general classes,* worthy of note: (1) *Organic manures;* that is, such as have a vegetable or animal origin. Barn-yard and stable manures, crops plowed down upon the soil, guano, etc. come under this class. (2) *Mineral manures* are such as are obtained from the earth, from water, or by burning out the organic matter of plants and animals. Gypsum, common salt (NaCl), ashes, and bone-earth are examples of mineral manures.

We may with propriety subdivide organic manures into: (1) Those which, by their decay, produce chiefly *humus.* These we shall call "*humiferous.*" * (2) Those which, by their decay, produce much *ammonia,* we shall call "*ammoniferous.*" *

Illustration.—When leaves, straw, and such like substances decay, the product is chiefly *humus;* hence, these are *humiferous.* When the flesh and urine of animals decay, they

* So far as I know, these terms have not been employed before; but every student of Agricultural Chemistry will see, at once, that they are needed in our vocabulary, conveying ideas which could not be otherwise expressed without circumlocution.

set free large quantities of ammonia; hence, these are *ammoniferous.*

365. INFLUENCE OF ORGANIC MANURES.—They increase the supply of organic matter in the soil, and generally have a favorable influence on both its mechanical and chemical condition. (1) If the soil is a stiff clay, the particles of humus, mingling with the particles of clay, prevent their forming a cohesive mass. The soil being thus rendered more loose and porous, is more easily cultivated, absorbs and retains moisture better, and is more easily penetrated by the roots of plants. The carbonic gas set free during the decay of humus, no doubt aids in rendering soils porous. The gas being liberated in all parts of the soil, as it is throughout a loaf of bread, becomes entangled among the particles, and forces them asunder. (2) The increase of organic matter gives a darker color to the surface, and thus renders it *warmer* and *earlier.* This influence may be readily perceived, by observing how much more quickly corn, or other grain, germinates in those parts of a field where the soil is darkened with humus, than it does where the surface is lighter in color. In such places the crop generally starts more promptly, and at first grows more rapidly, but often fails to be as heavy in the end as that which started more slowly; because, while the soil is in a bettter physical condition, its chemical condition may, in some important particulars, be less favorable.

366. (2) Organic manures improve the *chemical* condition of the soil, by keeping up the supply of humus, which becomes gradually exhausted by repeated tillage. The humiferous manures do this in part; but it may, to a great extent, be accomplished by the roots and stubble left upon the ground. The other class of organic manures—the ammoniferous—are still more important. Reasons have been already given for the rapid disappearance of ammonia from the soil. It is also true of all ammoniferous compounds, that they un-

dergo spontaneous decay with great rapidity, under the influence of air, moisture, and heat; and are, hence, not very *durable*. They must, therefore, be frequently applied. Then a supply of such substances being essential to the vigorous growth of almost every valuable crop, we readily perceive their great value. In fact, the value of organic manures may be estimated chiefly by the quantity of ammonia they are capable of yielding.

367. (3) Besides furnishing organic food in the form of carbonic gas, the acids of the humus combine with liberated ammonia in the soil, and prevent its escape ("fix it"). Such compounds, being soluble, are probably absorbed directly by the roots of the crop, and yield both carbon and nitrogen compounds to the sap. These are afterwards elaborated in the leaf, and fitted to promote the subsequent growth of the the plant. A proper admixture of humus, by fixing ammonia as it is generated, makes the influence of ammoniferous manures more durable than they would otherwise be.

368. (4) The organic manures do more than simply supply organic food to crops. They bring back much of the mineral matter which they have previously collected from the soil. They return this, too, in the form best adapted to meet the wants of the plants to be nourished; for they have already been subjected to the modifying influence of vitality in one set of plants, and will most probably require very slight changes to adapt them to another set. Reasoning from analogy, we may conclude that plants take up most readily those substances having the form required in their new combination. The phosphates from the stable and the barn-yard are certainly in a better condition to nourish a crop of wheat or tobacco, than is the phosphate of lime in bone ashes.

369. Forms of Humiferous Fertilizers. — (1) *Dry*, undecayed vegetable substances, in the form of *straw*, *corn-stalks*, *forest leaves*, etc. are often plowed down into the soil.

These gradually undergoing decay, produce a fresh supply of *humus*. From a little albuminous matter which they usually contain, a small portion of ammonia is also generated. The decay of such substances is slow, and hence an immediate effect is not to be expected; but the ultimate influence is always beneficial, unless there is already an excess of organic matter in the soil. If straw, leaves, etc. are thrown up in heaps (compost heaps) with other substances, such as the scrapings of stables and barn-yards, which will hasten their decomposition, and allowed to lie in that condition until partial decay has taken place, their benefit to the soil will be more immediate. After the process of decay has commenced, it will continue to go on rapidly in the soil; and there will be less loss from the escape of volatile matter, than if the decay is completed in the heap.

370. (2) GREEN CROPS, plowed down into the soil upon which they have grown, make one of the cheapest, as well as most efficient, means of enriching land. They possess several advantages over dry substances of similar character. In the first place, they are already spread upon the soil, without the inconvenience of hauling. Secondly, they decay more quickly, and sooner become food for other crops. Thirdly, they contain a larger quantity of ammoniferous matter. The albuminous substances gradually diminish in the stalks and leaves of plants, as they approach their period of decay, or as their seeds ripen.

In this country, clover, grasses, buckwheat, peas, oats, and some other crops, are plowed down as green manures; but of all these, *clover* is probably the best, especially on limestone lands. Clover not only produces a good crop above the surface, but it produces one still more valuable beneath, in the form of roots. The large, fleshy roots of the clover, as they decay in the soil, yield both humus and ammonia, in considerable quantities. *Peas* are, perhaps, next in value.

The *increase* of organic matter added to the soil, by plowing down crops, comes, of course, from the air. Carbonic acid and water are taken in by the leaves and roots, and converted into vegetable tissues, which by their decay become *humus;* while ammonia, collected from the air, forms the albuminous parts of the plant, and these again generate ammonia in the soil. Such roots as run deep, like those of clover, bring up mineral matter from a considerable depth, and accumulate it near the surface, so that it becomes more available for the use of other crops. This is an advantage, arising from this process of manuring, not to be disregarded. Sub-soiling aids in this elevation of the mineral ingredients of the soil, by allowing the roots to descend to a greater depth.

There are some soils too light, or too far exhausted, to produce clover or grass, which will produce buckwheat or peas. By planting and plowing down a few of such crops as these, the land may be greatly recruited, and may afterwards be treated with clover, if desired, in order to give it still greater fertility, or to keep it up to its improved condition.

371. (3) PEAT (the half-decayed vegetable matter collected in swamps), when thrown up in heaps, and exposed to the air for some time — when mixed with lime or ashes, and applied to the soil, is a valuable source of humus; and when dried and thrown into stables and barn-yards, it forms one of the best means of absorbing the liquid parts of animal manures, and of fixing their ammonia. The *spent-bark* of tanneries, the scrapings of wood-yards, and the *muck* formed in forests by the decay of leaves, may all be treated in the same way. *Charcoal* and *soot* (finely-divided carbon) improve the physical condition of clay soils.

372. FORMS OF AMMONIFEROUS MANURES, AND BEST MEANS OF PRESERVING THEM. — These are chiefly of animal origin, consisting of the excrements of animals, and

such refuse matter as accumulates about slaughter-houses and fisheries; also the ammoniacal liquids of gas-works. The reasons for attaching a high value to manures of this class, have been given (§ 366); but to impress a matter of so much importance still more deeply upon the mind of the reader, the following paragraph is given from Norton.

"Manures containing nitrogen in large quantity are so exceedingly valuable, because this gas is required to form gluten, and bodies of that class, in the plant: this is particularly so in the seed, and sometimes also in the fruit. Plants can easily obtain an abundance of carbon, oxygen, and hydrogen from the air, the soil, and manures. Not so with nitrogen. They cannot get it from the air [in its free form]; there is little of it in most soils; and hence manures which contain much of it produce such marked effect. Not that it is more *necessary* than the other organic bodies, but more scarce, at least in a form available for plants."

373. EXCREMENTS.—Under the term "excrement," we shall include both the *fæces* and *urine* of animals.

The fæces, or solid excrements contain: (1) Some portions of proteine compounds, which soon undergo putrefactive decay, and set free ammonia. The quantity of ammonia from this source, except in the fæces of hogs, is but small, compared with that from the urine. (2) Vegetable fibre in considerable quantities, being the undigested portions of the food. This is an abundant source of humus; and on account of its predominance over that portion which forms ammonia, the fæces might with propriety be classed as humiferous manure. (3) Portions of mineral substances from the food, too valuable to be overlooked, are found in solid excrement. Among these, the most abundant are those which are least soluble, such as the phosphates of lime and magnesia.

374. *Urine* contains about twice as much ammoniferous matter as the same weight of fæces. That of horses and

sheep is especially rich in ammonia. Some farmers are sufficiently careful not to lose the *solid* portions of the manures of their stables and yards, while they take but little pains to make provision for having the *liquid* portions absorbed, and thus preserved. They may not be aware that a pint of urine from a horse is equal in value to at least three pounds of his solid excrement.

The next most valuable ingredients of urine are the salts of potassa and soda. These being *soluble*, naturally pass more readily into the urine, while less soluble phosphates are carried off with the solid excrements.

There are several advantages arising from having these two forms of excrementary matter *mixed*. First, it gives a proper supply of both humiferous and ammoniferous substances. Secondly, it gives the necessary variety of mineral matter—phosphoric acid, silica, lime, and magnesia from the fæces, with sulphuric acid, chlorine, and the alkalies, from the urine. Thirdly, the presence of ammoniferous matter causes rapid fermentation, and consequent decomposition of the humiferous matter; and the whole mass is thus more quickly brought into the proper state to furnish nutriment for the crop.

375. Fixing Ammonia.—During the fermentation of a mixed mass of animal manure, large quantities of ammonia escape in the form of a *volatile carbonate.* This must result in great loss of value, unless the escaping substance can be arrested, and *rendered involatile* ("fixed"). It becomes a question, then, of the highest importance to the farmer, how this can best be done. Before we consider the properties of the different kinds of animal manures, we must examine a little more fully the chemical relations between ammonia and certain means which may be employed for its preservation (§ 71). and the principles upon which this preservation depends.

376. Arresting Fermentation.—What is usually termed "fermentation" in heaps of organic manures, is a form of spontaneous combustion, which takes place most readily and most rapidly in a mass of matter containing considerable quantities of ammoniferous compounds. The conditions necessary to this decomposing process are (1), a temperature not below 45° F.; (2) the presence of a considerable amount of moisture; (3) a full supply of air. The chief products are carbonic acid gas, water, and ammonia, which are volatile; and humus, which is involatile. The rapidity of the fermentation (after the three conditions above mentioned are fulfilled), depends upon the accumulation and retention of the heat always developed by the process. When the chemical changes commence in a moist mass of manure, which is sufficiently porous to admit the air, the result is similar to that which follows the igniting of a mass of combustible material; while the combustion increases the heat, this increase of heat makes the combustion still more rapid. But if the burning material is spread out, so that the heat will be dispersed, the rapidity of the process is greatly checked. So, if a mass of fermenting manure is spread over a wide surface, the accumulation of heat is prevented; and if the weather is dry, the moisture is evaporated, and thus two of the conditions affecting the rate of fermentation are partially removed.

Hence we see how *spreading manure upon the surface of land*, may to a great extent arrest the fermentative process, and thus prevent the escape of the most valuable of its constituents—ammonia and carbonic acid. When manures are hauled out and scattered during the Fall and Winter, upon clover and grass, or as preparatory to Spring crops, there is but little danger of serious loss, except from washing rains, which may run over the surface, and carry off the soluble portions of the manure. The extent of the risk in this respect must be judged of from the steepness of the land and the structure of the soil.

If the weather of Winter is favorable to the removal of stable and yard manures as they accumulate, the cheapest, and ordinarily the most convenient way of preserving them, is to spread them as soon as possible upon the fields for which they are designed. This plan is especially applicable to porous lands which are not very steep. The rain then carries the soluble portions down into the soil, while the fermentation of the insoluble portions goes on but slowly, and the loss of ammonia is but trifling, compared with what it would have been in heaps; unless the heaps had been treated with some of the absorbents of ammonia hereafter to be mentioned. For something more on this subject, see § 430.

377. Plowing Down.—If it is found convenient to apply animal manures to the soil as soon as they are collected, they may at once be spread upon the land, and buried with the plow, provided a crop is to be planted very soon. The fermentation then goes on beneath the soil; and as the volatile matter (of which the ammonia is the most valuable part) arises, it is absorbed by the clay, the humus, and the moisture, with which it immediately comes in contact, and is soon found by the roots of the crop. The fertilizing action is slow in this case, but is long continued; and the effects are often more marked in the second crop, than in the one immediately following the application of the manure. An illustration of this is very common where farmers are in the habit of applying to their corn crop, in the Spring, the fresh manures collected during the Winter. Such manures are unfermented, and frequently have no great influence upon the corn crop; but if the corn is followed by wheat, the effects of the manure upon it are very conspicuous.

378. It is not always convenient to apply manures to the soil as soon as they are collected; they must, therefore, re-

main for some time in heaps, subject to fermentative decay. By this decay their action is rendered more prompt, and the farmer can sooner reap their beneficial effects; but to prevent serious loss, something must be mixed with the fermenting mass to fix the ammonia. The following are some of the best substances to be used for this purpose.

(*a*) *Clay* and *humus*, either separately or mixed, have the property of rendering large quantities of ammonia involatile. Clay alone is generally too tenacious to be conveniently mixed with manures; but when mingled with a large quantity of decayed vegetable matter, it forms a rich mould which may be conveniently used in compost heaps. *Humus*, under the form of peat, muck, etc., contains organic acids which readily combine with ammonia, forming involatile compounds.

(*b*) *Gypsum* is valuable as an absorbent of ammonia. Its action is chemical, and has been given in § 71, which the student is requested to read in this connection.

(*c*) *Sulphate of iron* (copperas) acts in a manner similar to gypsum. It gives up its sulphuric acid to the ammonia, forming an involatile sulphate of ammonia, while the iron becomes first a carbonate, then an oxide. The copperas must be applied in solution. One pound to four gallons of water is sufficient. It may be sprinkled over the different portions of manure as they are thrown upon the heap, or sprinkled over the whole before it is thrown up.

(*d*) *Acids.*—Sulphuric and muriatic acids both have a strong affinity for ammonia. If either of them be diluted with twenty parts of water, and sprinkled over a fermenting manure heap, the escape of ammonia will be at once arrested in every part of the mass to which the acid liquid has access.

(*e*) *Caution.*—Avoid the use of caustic lime with all manures containing ammonia. It will expel ammonia from any and all of its compounds. Sulphate of lime, on the other hand, is beneficial; carbonate of lime has no effect, while caustic lime is ruinous when mingled with ammoniferous fertilizers (§ 100). Such a mixture may still possess considerable value, and often produces decidedly beneficial effects upon growing crops; but this benefit is independent of the presence of ammonia, and is to be attributed either to the lime, or to such organic matter as the lime has not removed. These circumstances sometimes lead farmers into the mistake of supposing that stable and yard manures are improved by the lime, while in reality the most valuable ingredient has been expelled from them.

QUESTIONS ON CHAPTER XIV.

§ 355. Why may a well-plowed soil still be unproductive? What do we learn from Table III?

356, 357, 358, 359, 360, 361. That a soil may be fertile, what is the *first* property required? Why? Second property required? Illustrate. Third? Example? Fourth? What forms of organic matter must a fertile soil contain? What is said of *analysis of soils?* What relation does it show between the ashes of the crop and the soil? What does Table V illustrate? Explain it. Is a large percentage of every mineral ingredient necessary? What does every article sent to market carry with it? What effect will this ultimately have upon the soil? May not soils be cultivated for many years without manure? What does general experience decide? What becomes of the organic matter of soils? Which escapes most rapidly?

362, 363. What is a *fertilizer?* *First* cause which renders fertilizers necessary? Second? Remedy? Third? Reasons? Fourth? Explain this. Knowledge required on this subject?

364. How are fertilizers *classified?* Organic manures? Mineral manures? Illustrations? Subdivisions of organic manures? Illustrate each.

365, 366, 367, 368. *Influence* of organic manures? How do they influence a stiff clay? Explain. How do they render a soil warmer? Illustrate. How do they improve the chemical condition? Why must *ammoniferous* substances be frequently applied? How does humus fix ammonia? What mineral substances do organic manures add to the soil?

369, 370, 371. First forms of *humiferous* fertilizers? How do they form humus? Influence of stable manures upon humiferous matter? What of *green crops?* Their first advantage? Second? Crops most commonly ploughed down? Which are most valuable? How do they increase the organic matter of the soil? Influence on the mineral ingredients? What is *peat?* How does it form humus? Spent-bark?

372, 373, 374. Chief source of *ammoniferous manures?* Why are these so highly valued? What are included under the term "*excrements*"? First constituent of *fæces?* The second? The third? In what does *urine* abound? Best from what animals? Illustrate its value. What minerals does it contain? Should humiferous and ammoniferous manures be mixed? The three reasons given?

375. What is meant by "*fixing*" *ammonia?* Why is it important?

376, 377. Explain fermentation in manure heaps. First condition necessary? second? third? What are the products? What determines its rapidity? How does *spreading* check it? How does spreading manure *preserve* it? When is there danger of loss from washing? What generally becomes of the soluble matter of manures spread on the soil? What is said of *plowing down* manures? What then becomes of the ammonia? Is the fertilizing action rapid? How illustrated?

378. Why must manures be sometimes thrown in heaps? What advantages from this? What of *clay and humus,* as means for fixing ammonia? Of *gypsum?* How does it act (§ 71)? *Sulphate of iron?* How applied? How does it act? What acids are mentioned? How applied? What caution is given? Do the sulphate and carbonate of lime act like caustic lime? Into what mistake do farmers sometimes fall?

CHAPTER XV.

SPECIAL MANURES.

379. THE *stable manure* collected from the stalls of horses, is highly valued by all farmers. But the readiness with which it undergoes fermentation, and sends off ammonia, together with its abundant supply of soluble organic and mineral matter, makes it necessary to exercise care in its collection and preservation, so as to avoid loss.

The urine must be kept from running off. (1) This is sometimes done by keeping the horses on close plank floors, sloping backward from the trough. At the lower edge of the floor, a trench or gutter is so constructed as to receive the liquid. This trench is kept constantly supplied with some absorbent substance, such as dry peat, muck, or spent-tan, which will take up the fluid, and, during the subsequent decay, will fix the volatile part, and prevent its loss. A little gypsum strewed in the trench every day, would make the preservation of the ammonia more certain, and also add to the value of the manure. The trench should be cleaned out, and filled with a fresh supply of the absorbent very frequently. (2) Another method is to have a firm clay floor (which is better for the feet and legs of horses than a plank floor), and to keep it well supplied with litter of straw, leaves, muck, etc., which will absorb the liquid part of the manure. The wet portions of the litter should be removed every morning, and, as they are thrown out into the manure-shed, should have a little gypsum, humus, copperas-water, or other absorbent, sprinkled over them, to arrest the ammonia, which will begin to escape in a few hours.

380. It must never be forgotten by the farmer, that however well he may succeed in rendering the most valuable portion of his compost, or manure heaps *involatile*, it is still very *soluble;* and every rain which passes through the mass, carries off much of its value. The loss sustained on many of our farms, in two or three years, by exposure of manures to the influence of rain, would, if saved, be quite sufficient to cover the cost of a few sheds, which would shelter all the manures of the farm for twenty years or more.

The labor of collecting the manure from cattle-pens into sheds, is, perhaps, generally too great to make that an economical method of preserving it. Whenever this is the case, it should be hauled out and spread upon the soil, before it undergoes fermentation, and before its soluble ingredients have been washed away by the rain.

381. *Excrements of cows, sheep, and hogs* require no less care for their proper preservation than those of horses. Similar means may be adopted. The urine of cows is not much inferior to that of horses in value. That of sheep is more valuable than either; while that of hogs, though abundant, is less valuable than any of those above mentioned, but still too important to be neglected. Of all domestic animals, the hog gives the most valuable solid excrement, which compensates for the want of value in his urine. The solid excrement of the sheep is next in value; then that of the horse stands next; while that of the cow is inferior to either. Still, all are sufficiently useful to be worth preserving.

382. *Human Excrement* requires special attention: (1) Because of its high fertilizing value; and, (2) Because of the little regard paid to it by the majority of families. When compared with the excrementary matter from other animals, that of man stands above all, except perhaps that of well-fed sheep and fowls. The urine has a much higher value than the fæces. "Very accurate analyses have shown that the

amount of *urine* contains double the quantity of phosphoric acid, four times as much azotized [ammoniferous] substances, and six times as much alkalies and alkaline salts, as the solid fæces. Hence, therefore, it follows that the former possesses a *far higher value* than the latter, and deserves to be most carefully collected. . . . .

"From the preceding observations it may be incidentally perceived what an immense capital is lost in large cities, where the greater proportion of urine runs into the sewers and drains."—*Stockhardt.*

Arrangements may easily be made about every country dwelling for the careful collection and preservation of this valuable kind of fertilizing matter. The simplest methods are, to have, in the first place, a compost heap of vegetable mould, the scrapings of wood-yards, &c., at some convenient place, *under shelter,* upon which all the slop from chambers may be thrown. Let the heap receive occasionally a fresh layer of material, and a free application of gypsum. This will keep down all disagreeable odor. Then, in the construction of privies, let the vaults be above ground, large, and so arranged that they can be kept constantly charged with such absorbent substances as are used in the above compost heap. This should be renewed frequently, and what is removed from time to time be thrown upon the compost heap. A little dilute acid, copperas water, or gypsum, should be applied to the vaults frequently, to keep down unpleasant odors and preserve ammonia.

383. GUANO.—This fertilizer, which is now so extensively used, is the excrement of birds which feed chiefly upon fish, and have their habitations upon rocky, desolate islands and coasts. It has been stated (§ 217) that the urine of birds is solid. Guano, then, is a mixture of the urine and fæces of birds. From the quality of the food upon which these live, we would naturally expect to find in their excrements large

quantities of ammoniferous compounds and phosphates. Analysis shows that these are the most abundant and most valuable ingredients of guano; while experience proves that the most valuable varieties are those which contain the largest per cent of salts of ammonia. The best guano is found in localities where rain seldom falls — where the ammonia salts have not been washed out. Parts of Peru, and the islands lying along the coast of that country, are seldom visited by rains. Here immense beds of guano, which must have required thousands, and probably tens of thousands of years for their accumulation, are found in great numbers. The deposits of guano are vast stores of ammonia, which a kind Providence has been treasuring up through many centuries for the use of man. While the rivers have been carrying off the ammonia from the land in vast quantities, either in solution or in the form of dead animals and insects, the sea-birds have been bringing it back in the form of fish; and thus we have another of those compensating arrangements, by which the balances of nature are kept properly adjusted. The reader must be struck, too, with the analogy between these deposits of agricultural wealth, and the great deposits of mineral wealth laid up in past ages, in the extensive coal-beds found all over the world. In Peru and her adjacent islands, there are supposed to be many *millions of tons* of this rich fertilizer yet undisturbed. The African, Chilian, and Mexican guanoes are not so valuable as the Peruvian, because of their having been more exposed to rains.

384. The following table gives about the average composition of several varieties of guano.

TABLE VI.

In 100 parts of Guano are found	Peruvian.	Chilian.	African.
Water	9	12	20
Salts of Ammonia and other organic matter	60	50	38
Phosphates	20	28	20
Salts of Soda and Potassa	5	6	10
Carbonate of Lime	4	2	3
Sand and Clay	2	2	3
	100	100	100

385. The ammonia of guano is combined chiefly with organic acids, such as the uric and humic, forming urate and humate of ammonia. These, by exposure to air and moisture, are gradually converted into the volatile carbonate of ammonia, the presence of which is readily perceived on opening a bag of Peruvian guano. Hence, if it is to be kept on hand for some time, a dry, close place is best for its security.

386. Application.—In applying a manure so costly as guano, the greatest economy should be carefully studied. All real economy in such cases, consists in such management as will realize the largest income from the least expenditure of money and labor. The economical use of guano demands, (1) the application of the smallest quantity required to accomplish the object in view; (2) such treatment of it as will secure it against loss, either before or after it is applied; (3) a judicious regard to the ultimate improvement of the soil.

The quantity varies with the quality of the soil, and the kind of crop. For wheat and corn, from 100 to 300 pounds per acre is generally a sufficient quantity; but every farmer should decide questions like this for his own soils, by numerous experiments. Small quantities may often be most economically used, by being mixed with other manures. This is especially the case where the guano is to be brought directly in contact with the seeds in the soil. But the labor of mixing thoroughly is, in many cases, greater than the advantages gained.

The most common method of applying guano to wheat, is to sow it upon the wheat, and harrow or plow both into the soil together; or, when the wheat is drilled, to drill the guano with it. To make such applications safe to the grain, very minute portions only must be allowed to come in contact with each separate grain of wheat. When applied in the hill with corn, cotton, potatoes, or any other crop, it is best to "dilute" it with other substances. The following general directions may be of use to guide the young farmer to successful experience.

387. (*a*) As soon as the bags are opened, the lumps should be carefully pulverized by the use of any convenient instrument, such as a pestle with a broad base. To separate such parts as may not be fully reduced to powder, a sieve may be used. This should be done just before it is to be applied, so that it may not be long exposed. If the lumps are very hard, it is best to moisten them, and let them lie in a heap several days.

(*b*) When the guano is to be mixed with something else, some form of humus, or rich vegetable mould, serves well for this purpose. Spread a layer two inches deep, of moist mould, upon a floor of boards or earth, and over this a layer of guano half an inch or an inch thick, with a free sprinkling of plaster. Then add another layer of mould and another of guano and plaster, in the same order, until as much has been employed as is wanted for use. Mix the whole mass carefully with a shovel; or, if a more perfect mingling is desired, pass it through a coarse sieve. Such a mixture preserves the guano, and puts it in a good condition to be applied to almost any crop.

* A convenient method of moistening the lumps, is to dip the unopened bags into a large tub of *hot water* for 5 or 10 minutes, and then lay them up in piles, or stacks, for two or three days, till they are thoroughly penetrated by the moisture, and incipient fermentation takes place. This will relax the lumps completely.

(*c*) The effects of guano have been found to be more energetic, when it is dissolved in dilute sulphuric acid. About twelve or fifteen pounds of acid, and ten gallons of water, poured upon 100 pounds of Peruvian guano, would decompose the organic salts of ammonia, and form the sulphate of ammonia, which is a most energetic fertilizer; and, at the same time, another portion of the acid would so act upon the phosphate of lime present, as to convert it into the more soluble super-phosphate (§§ 395 and 406).

(*d*) In whatever condition guano may be employed, it should be thoroughly incorporated with the soil. This will tend to preserve its ammonia, and will so distribute its particles, that some of them will be found by the roots of the crop in every part of the soil.

388. ACTION OF GUANO. — Some farmers say that guano, while it produces fine crops for a few years, ultimately exhausts the soil. In the opinion of many, this results from a kind of stimulating influence which it produces upon plants, causing in them a kind of artificial or forced growth, by which they take away from the soil more fertilizing matter than the guano has brought into it. This influence has been compared to the influence of alcohol on the human system. But, as guano contains nothing which is not an appropriate article of nutrition for plants (real food), such a comparison is rather absurd. It has also been satisfactorily shown, that an ordinary application of guano gives more mineral matter to the soil than the resulting crop takes away,* at least so far as some of the mineral ingredients are concerned. But when we remember that guano continues its influence through several successive crops, the quantity of some of the mineral substances of the soil may, in the meantime, be diminished more than they have been pre-

* See Dr. P. B. Pendleton's "Essay on Guano."—Proceedings of Virginia State Agricultural Society, Vol. III., p. 39.

viously increased by the guano. This is especially true of potassa, lime, and sulphuric acid. In such cases, the long-continued application of guano to some soils may exhaust their supply of mineral fertilizers, at least the supply of those in the proper condition to be taken up by the roots of plants (§ 356).

The long-continued application of guano exhausts the *humus* of the soil. While guano has an excess of ammonia, it has but little humiferous matter in it; and, while the caustic character of the ammonia hastens the decomposition of humus already present, the loss is not made up from the guano. But if we mix with it *leached ashes, plaster,* and *humus,* there can be but little danger of injury ever resulting from its application; while a corresponding improvement will be the general reward.

389. The best method of using guano for the permanent improvement of soils, is to employ it in connection with green manures. It greatly increases the growth of clover, peas, &c.; and when these crops are plowed down, they not only carry back with them the mineral matter of the guano, but add largely to the supply of humus and ammonia in the soil. The guano thus has the power of causing plants to convert the carbonic acid and water of the air and soil into humiferous compounds, much more rapidly than they would have done if the guano had not been applied. It also causes the same plants to thrust their roots more deeply into the subsoil, and thus bring up an increased supply of mineral matter in the proper condition to feed succeeding crops.

390. A great deal of swindling has been practised in the sale of guano. The best safeguard against being imposed upon, is to buy only from *reliable men,* regularly engaged in the business of selling it. But in case the quality is suspected, one or two simple tests may be useful in removing or confirming suspicions. *Exps.*—Burn 100 grs. to ashes in a

crucible, or iron spoon. The remaining ashes should not weigh more than from 35 to 45 grs., and should be nearly all soluble in dilute muriatic acid. 2. Rub a little of the guano with a few grains of freshly-slacked lime, and if a strong odor of ammonia is not given off, the quality is not good.

391. *Domestic Guano* may be collected about hen-roosts, and, although not equal in value to the same weight of the Peruvian, it is still the most powerful fertilizer produced upon our farms. It should be carefully collected, and treated in the same way as guano.

ANIMAL COMPOUNDS.

392. The refuse of slaughter-houses and fisheries consists of blood, entrails, hair, and other animal compounds, all of which contain the elements of ammonia in large quantities, and also a considerable amount of soluble mineral salts. Hence they possess a high agricultural value. They should be mixed with humus, and kept under shelter till they can be applied to the soil. If an animal dies on the farm, it may be made less offensive by being buried in a mass of humus and clay, which will soon be highly charged with ammonia from the decaying animal, and will serve to enrich some poor spot on an adjacent field.

Fish are caught in many places, and used for manure. They soon decay, and set free ammonia abundantly.

Insects of various kinds make their habitations in the soil. By eating vegetable substances, they help to collect and concentrate the ammoniferous portions of their food; and when they die, their remains add something to the fertility of ground in which they are buried.

393. *Bones* yield ammonia by the decay of their gelatinous substance (§ 204), which makes them a valuable source of this important element of fertility. We have also learned

that their mineral part is chiefly phosphate of lime, which is well adapted to almost all ordinary crops.

394. *Value.* — Bones, when dried and ground to powder without burning, are inferior only to good guano, in agricultural value. They yield about *half* as much ammonia, about *twice* as much phosphoric acid, and about *three times* as much lime. Hence, their value in the form of bone-dust is more than half that of guano.

When applied *alone*, their effect is much slower than that of the guano, but much more durable. This is owing to the fact that the gelatine undergoes decay more slowly than the ammonia salts in guano. In fact, the ammonia of the latter is already, to a large extent, ready to afford food for the plant, while the ammonia of the former is yet to be generated from the decaying gelatine. The phosphate of lime, too, seems to require *time* to adapt it to the nutrition of crops (§ 429, *e*).

395. If bone-dust is treated with an excess of sulphuric acid, the phosphate gives up a portion of its lime to the acid, forming sulphate of lime, and a superphosphate of lime is thus left, which is much more soluble than the ordinary bone-earth, and is hence a much more energetic fertilizer. The gelatine of the bones is at the same time reduced to a pulpy mass, which soon undergoes decay in the soil, and generates ammonia. While the gelatine is not injured, the phosphate is greatly improved by being thus treated.

396. PREPARATION. — "To every 100 pounds of bones, about 50 or 60 of acid are taken; if *bone-dust* is used, from 25 to 45 pounds of acid are sufficient. The acid must be mixed with two or three times its bulk of water, because if applied strong it would only burn and blacken the bones, without dissolving them.

"*a.* The bones are placed in a tub, and a portion of the previously-diluted acid poured upon them. After standing a day, another portion of acid may be poured on; and finally, the last on the third day, if they are not already dissolved. The mass should be often stirred."

"*b.* Another good way is to place the bones in a heap, on any convenient floor, and pour a portion of the acid upon them. After standing a day, the heap should be thoroughly mixed, and a little more acid added: this is to be continued so long as necessary. It is a method which I have known to prove very successful. . . . .

APPLICATION.—"A convenient method, in most cases, is to thoroughly mix the pasty mass of dissolved bones with a large quantity of ashes, peat-earth, sawdust, or charcoal dust. It can then be sown by hand, or dropped from a drill-machine. Two or three bushels of these dissolved bones, with half the usual quantity of yard manure, are sufficient for an acre."—*Norton.*

Some who have tried this method, contend that it will not succeed well, unless the bones are first broken into fragments, then boiled in water—the sulphuric acid being added while the water is still hot. The bones and boiling water must be thrown together into a large wooden vessel before the acid is added, as the acid would rapidly corrode the kettles used in the boiling process.*

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* "TO DISSOLVE BONES.—If no mills are accessible, bones may be dissolved in sulphuric acid. For 100 pounds of bones take about 30 pounds of acid (2 gallons), and mix with it say 32 pounds of water (4 gallons). First put the water into a strong wooden-hooped cask or barrel, and add the acid slowly, stirring it, as added, with a stick. Crack the bones or not, as may be convenient, and put them in and above the fluid. Punch them down, and stir them occasionally with a stick. Let them stand four, six, or eight weeks, until softened and mostly dissolved. Many assert that they cannot dissolve whole bones, but *they do not take time enough.* From repeated trials, we know they *will* dissolve. The time will depend upon the dryness of the bones, and their freedom from fat. After standing two months,

MINERAL FERTILIZERS.

397. While the mineral fertilizers are less important than the organic, they still serve valuable purposes on many soils. A soil may contain even a large excess of some mineral substance required by a particular crop, and yet that crop be benefited by the application of that same substance under some other form. Granite soils, for example, contain potassa in abundance, and yet the productiveness of these soils is generally increased by the application of potassa in any soluble form. The reason of this is obvious: the potassa of granite is locked up in its insoluble mica and feldspar. In hornblende granite (syenite) there is an abundant supply of lime, potassa, and silica. Now, these are the chief ingredients of value in ashes, but these soils are generally very much benefited by the application of ashes alone. The syenite yields its mineral matter but slowly, in a soluble form; while the ashes supply the same ingredients, just ready for the plant.

398. Besides providing food directly for the crop, the mineral fertilizers often exert a beneficial influence upon mineral and organic substances already in the soil, and also absorb the organic food contained in the air.

Of the chief mineral manures employed in our own country, we must take some special notice. *Their forms and conditions, the best methods of applying them, and their effects,* will be the principal points to be noticed.

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more or less, mix the mass thoroughly with six or eight times, or more, its bulk of muck, or even with common soil, if need be. This makes an excellent fertilizer, worth anywhere all it costs, and more. Sulphuric acid, in carboys of 120 to 160 pounds, costs from 2 to 3 cents per pound, according to distance from the manufactory. It needs to be handled with care, as it is corrosive to the flesh and clothing."—*American Agriculturist.*

LIME.

399. Lime is found in every crop, and must, therefore, exist in every cultivated soil. And in order to be of service to the crop, it must not only be present, but must be in a suitable condition to be taken up by the roots, and made available to the growing plant. If there is not a sufficient excess of available lime present, or if it should be wanted to act upon something already in the soil, it may be applied in several different forms.

400. (*a*) Caustic Lime, prepared from limestone or oyster-shells, should be slacked before it is applied, since the pulverized condition makes it more easily spread. It is better, ordinarily, to apply it frequently in small portions, than to apply large quantities at one dressing. The quantity must be determined by the character of the soil. Every farmer should make experiments for himself, beginning with from 20 to 50 bushels per acre, uniformly spread, and increasing the quantity as he may find necessary. Recently-drained, swampy lands require larger doses.

401. *Effects.*—(1) Caustic lime combines with free organic acids in the soil, and thus sweetens sour soils. With these acids it is supposed to form soluble salts, which are valuable as food for crops. (2) It hastens the decay of vegetable fibre in the soil, and reduces it to a nutritious form—changes it to humus. (3) It sets free ammonia, which may exist in some inert condition in the soil, and thus indirectly hastens its absorption by the crop. (4) It decomposes some mineral substances already present, and makes their elements more available to plants.

402. *Cautions.*—It must not be forgotten that the too frequent application of lime, especially to clay soils, may so far exhaust the organic matter, as to cause a deficiency in this important part of every fertile soil. Its effects upon

manures containing ammonia, make it unsuitable to be mixed with such manures, or even to be applied near the same time.

403. (*b*) MILD LIME.—When caustic lime has been exposed to the air for some time, it gradually combines with carbonic acid, and loses its caustic character; it becomes mild lime. *Exp.* Pour a little dilute acid or strong vinegar upon lime which has lain a good while in the open air: a brisk effervescence will take place, showing that it has become a carbonate. It has the same composition as ordinary limestone, but is much superior to the latter, because it is reduced to an extremely fine powder, and hence more readily dissolved by rain-water containing carbonic acid gas (§ 102).

404. *Effects.*—Besides affording nutrition directly to the growing crop, it has an effect upon the stronger organic acids, similar to that of the caustic lime. These acids are capable of removing the carbonic acid, by taking its place in combination with lime; and thus the organic acids become neutral.

405. (*c*) PHOSPHATE OF LIME.—The phosphate obtained by burning bones has been alluded to (§ 204). Besides being the chief source from which the quantity of phosphoric acid in the soil is increased, it also adds to the supply of lime. When the organic matter has been burnt out of bones, they are easily reduced to a fine powder, by pounding or grinding; and may be sown by hand, or mixed with other manures. Bone-earth seldom has an immediate effect upon cereal grains. Its chemical condition seems to require some modifications, before it is well fitted to nourish such crops. Hence, the effects are often more marked upon the second or third crop, after the application is made, than upon the first. If treated with sulphuric acid, as prescribed for unburnt bones (§ 396), the action is much more prompt, and a smaller quantity will serve for a single dressing.

406. *Superphosphate of Lime.*—By mixing bone-dust and guano together, and treating the mixture with sulphuric acid, a mixture of sulphate of ammonia from the guano, and of superphosphate of lime from both the bones and the guano, is formed, which has proved to be a most energetic manure. Such mixtures are frequently sold under the name of "improved superphosphates."

Guano of inferior quality, containing a large percentage of phosphates, and but little ammonia, is now extensively employed, by mixing it intimately with some good Peruvian guano. The mixture is called "manipulated guano." There is so much room for imposition in all such artificial manures, that farmers should be cautious as to the source from whence they come. Buy only from reliable men.

407. When bones have been burnt in a close vessel, they form *bone-black*, or *animal charcoal.* In this, the animal matter has been reduced to carbon in extremely fine division. This greatly increases its absorbent power while dry; and when mixed with decaying organic manures, it takes up a large quantity of ammonia.

408. (*d*) GYPSUM.—This is a source of both lime and sulphuric acid. Its composition and properties have been so frequently alluded to already, that a very few additional remarks will be sufficient.

Effects.—(1) It furnishes both of its ingredients (lime and sulphuric acid) in a soluble form; and, as these are required by nearly all crops, its direct influence would be to supply them (one or both), if deficient in the soil, in an available form. It is especially applicable to the grasses, including corn and wheat, and to potato and tobacco crops (see Table III). (2) Its effects on most crops may be attributed, perhaps, chiefly to its property of collecting and fixing ammonia.

409. (*e*) MARL.—The term "marl" is used somewhat

indefinitely. In the valley of Virginia, as well as in many other places, the porous masses of carbonate of lime deposited by limestone springs, are called *marl*. These are known in mineralogy as *calcareous tufa*. Mixtures of carbonate of lime with clay, sand, and other impurities deposited in a loose form by water, are also called marl. When such deposits are composed largely of shells, infusoria, and organic matter, they are generally known as "shell-marl." Alkaline salts are common in shell-marl; and among the organic matter, some ammonia may generally be detected. They also contain some sulphate and phosphate of lime. The presence of such a variety of valuable ingredients, makes this species of marl a very effective fertilizer. The marls found in the tertiary strata of the tide-water region of Virginia, as well as those found in other localities, have proved very beneficial as manures. In some sections they have formed the *basis* of a system of improvement, which has done much to reclaim many exhausted farms.—(See *Ruffin's Essay on Calcareous Manures.*)

410. (*f*) Silicate of Lime.—This compound probably plays a more important part as a fertilizer, than many persons suppose. It is found to some extent in almost all soils. As one of the constituents of hornblende and trap rocks, it has been already mentioned. In the process of burning lime, some portions of it are formed by the silica (almost always present to some extent in limestones) uniting with lime.

Effect.—By the combined influence of moisture and carbonic acid, the silicate of lime is slowly changed into the carbonate, while the silica is set free in a *soluble form*, so that it can be taken up by the roots of plants. The great value of soluble silica will be perceived, when we reflect upon the extent to which it enters into the composition of the ashes of the stalks, especially of the cereal grains and hay (see Table III).

MAGNESIA.

411. Magnesia is essential to fertility in a soil; but there are very few lands which are not already supplied with an abundance of it for meeting the demands of the growing plant. In a few soils where it is deficient, it may be supplied with advantage in connection with lime. Limestones frequently contain a large per centum of carbonate of magnesia, which is reduced to caustic magnesia, just as the carbonate of lime is reduced to caustic lime, in the process of burning. This mixture of magnesia and lime must be applied more lightly than simple lime, because large quantities of caustic magnesia are injurious to the soil.

Magnesia will not serve, so well as lime, the various secondary purposes of "sweetening sour soils," of "decomposing organic and mineral compounds," etc. It is sometimes applied in the form of *phosphate* or *sulphate;* but the beneficial results from these are generally to be attributed more to the influence of the phosphoric and sulphuric acids, than the magnesia with which they are combined.

ASHES.

412. Ashes, consisting of the mineral matter derived from the soil by plants, might be expected to form one of the best fertilizers to be found; and such is really the case. The mineral bases, as they are found in ashes, are not in the same combinations which they have in the plant. Those which in the plant were combined with different organic acids, become *carbonates* by burning. Some others, too, such as the phosphates, may be considerably modified by the heat during combustion. But they are still in a favorable condition to afford nourishment to new plants.

413. The ashes used for fertilizing purposes are derived chiefly from the fuel consumed in our dwellings, and in the mechanic arts. Near the sea-coast, farmers often avail themselves of the rich mineral manure which may be procured

by burning sea-weeds. These are gathered, dried, and then burnt in shallow pits, which prevent the ashes from being blown about by the wind. Soda and chlorine, obtained from sea-water, are among the most abundant constituents of these ashes. They were formerly employed largely, as a source from which soda was prepared; but better and cheaper methods are now adopted (§ 96).

414. The average quantity of ashes produced by the various kinds of wood commonly used for fuel, is about 3 pounds from 100 pounds of well-dried wood. Where much pine is used, this average is too great, since pine yields only about *one* per cent of ashes. The quantity from sea-weeds varies to some extent with the different varieties of plant; but we may take *seventeen* per cent as about the average, which shows that these plants are very rich in mineral matter.

415. The following table gives a general view of the value of ashes, as determined by their constituents. The *first* column gives the composition of those obtained by burning a mixed fuel, consisting of about one-half oak, and the remainder beech, ash, hickory, and maple in about equal proportions. The second column gives the composition of the ashes of sea-weeds.

TABLE VII.

3000 Pounds of Dry Wood give 100 Pounds of Ashes, containing	Mixed Wood Ashes.	Sea Weed Ashes.
Potassa	9.3 lbs.	17.4 lbs.
Soda	2.5 "	27.1 "
Lime	41.2 "	7.2 "
Magnesia	6.2 "	8.0 "
Oxides of Iron and Manganese	1.6 "	0.1 "
Sulphuric Acid	1.5 "	17.0 "
Phosphoric Acid	4.3 "	3.0 "
Silica	3.2 "	1.3 "
Carbonic Acid	30.7 "	Omitted.
Chlorine	0.5 "	18.2 lbs.
Iodine	———	0.7 "

When we compare the above table with Table III, which gives us the mineral constituents of various crops, we find ashes rich in those substances most largely demanded by plants; and when we refer to Table V, we see that these substances are not always abundant in the soil. The bases—that is, the potassa, soda, lime, etc.—are chiefly found as carbonates in ashes, while smaller portions of them are combined with the phosphoric, sulphuric, and silicic acids. The chlorine is most probably combined with sodium. The salts of potassa and soda being soluble, are more apt to be lost by exposure to rain than are the salts of lime and magnesia. Some of the silica in ashes is in combination with potassa, and in a soluble condition. This soluble silica, for most soils, is one of the most valuable fertilizers which can be employed. We have already learned that its presence is necessary to the full and healthful growth of the stalks of plants; and its influence may be frequently seen on the clean, strong and healthy straw of wheat growing upon soils recently dressed with ashes. The effects of ashes upon grass and corn crops are almost always highly favorable.

416. Ashes are caustic in their character, from the presence of carbonates of potassa and soda. They also contain a large per cent of carbonate of lime. These qualities make them a most appropriate manure for sweetening sour soils, such as those which have been recently drained. They serve a good purpose, too, in hastening the decay of organic matter in compost heaps. But newly-burnt ashes should not be mixed with guano, and other manures containing ammonia, because there is generally caustic lime enough produced by the fire, to set free considerable quantities of ammonia. After ashes have been exposed for some time to the air, however, the caustic lime becomes a carbonate, and these effects will not then be produced by it.

417. *Leached ashes* are much inferior to the unleached in

their fertilizing value, a large quantity of the soluble matter having been carried off in the lye; but still they are valuable on account of having some potassa and soda left in them, and from the large quantity of lime they have retained, together with most of the phosphoric and some of the sulphuric acid and silica. They should be applied much more largely than unleached ashes, to produce a like effect.

418. The *soap-suds* used about the farm-house, contain not only the soluble matter taken out of the leached ashes in making lye, but also a considerable quantity of valuable animal matter employed in making soap. If these were carefully preserved, and thrown upon a compost-heap, which would absorb them, they would be found to reward the labor bestowed, in adding their fertilizing value to the soil. A sheltered compost-heap, formed of wood-yard scrapings, turf, weeds, and enough of vegetable mould to prevent the suds from passing through the mass too quickly, should be constructed near every wash-house, with a trough leading to it, to convey all the spent suds to the top of it.

Coal-ashes should not be neglected. They consist, it is true, chiefly of alumina and silica, and, in some varieties, lime is abundant; but all of them contain enough of the salts of potassa and soda, and of sulphates and phosphates, to make them well worth the trouble of applying them to the soil when near at hand.

419. *Ashes and Plaster.*—These make a favorite mixture with many of our best farmers. They are applied with great success to corn, by being dropped with it in the hill, or being sprinkled over it soon after it comes up. Some prefer sowing the mixture broadcast before planting, so that the rains may carry it down into all parts of the soil, where it will be found by the roots as they spread out during the growth of the crop. The gypsum thus spread out is supposed, too, to be in a more favorable condition for combining with ammonia

from the air and the soil. Sown upon clover fields and meadows, this mixture has sometimes a remarkable effect, and is, in almost every case, beneficial. It contains the elements of fertility most largely demanded by grass crops. Lime, potassa, sulphuric, and phosphoric acids, and especially soluble silica, are all taken up freely by the grasses.

A special advantage arises from mixing ashes with plaster, when the mixture is to be applied to a soil in which sulphuric acid is very deficient. The ashes, or rather the carbonate of potassa in the ashes, so acts upon the sulphate of lime, that mutual decomposition takes place if the mixture is in a moist condition. The lime and potassa exchange places, so that we have carbonate of lime instead of carbonate of potassa, and sulphate of potassa instead of sulphate of lime. This change goes on with considerable rapidity, if the mingling of the two manures is complete, and the mass is kept moist and warm.

The sulphate of potassa is much more soluble than the plaster, and is, hence, diffused through the soil at once by the rains, and made immediately available by the roots of the plant.

SALTS OF SODA.

420. *Common salt* is a very valuable fertilizer for many crops, but especially for those requiring considerable quantities of chlorine. Mixed with ashes and plaster, it has proved highly beneficial to crops of potatoes, hay, and corn. Four bushels of unleached ashes, and one bushel of plaster, with a gallon of salt, make a most valuable preparation for potatoes or grass. I have found twelve bushels of this mixture to be sufficient for an acre of potatoes planted in the ordinary way. Grass lands would require a greater or less quantity, according to the nature of the soil. Every farmer should make experiments for himself. Asparagus beds re-

quire abundant and frequent applications of salt. The most convenient way to apply it is to dissolve the salt in water, and sprinkle the solution over the bed with a common water-sprinkler.

421. *Sulphate of soda* is now a very cheap article, being produced in large quantities in the manufacture of muriatic acid (§ 80). It has been advantageously used as a fertilizer. This substance, as well as common salt, may be beneficially mixed with other fertilizers.

422. *Silicate of soda* is easily prepared by fusing sand and carbonate of soda together. If two parts of carbonate of soda are fused with one part of sand, and a little powdered charcoal, the mass is soluble in water. The solution has been applied to wheat with very marked benefit. Soluble silica is so much needed on many soils, that it is to be hoped that means will be devised for preparing it at a moderate cost.

NITRATES.

423. Nitric acid is one of the sources from which plants obtain nitrogen; hence, the nitrates have proved to be valuable as manures. The nitrates of potassa and soda have both been used with great success. Dilute solutions of these salts may be sprinkled upon the soil; or, if sprinkled over compost-heaps, they find their way to the soil in mixture with other manures.

BURNT CLAY.

424. Burning sometimes has a very remarkable influence in making a soil more productive. There are several causes which probably combine to produce this effect. (1) A part of the organic matter mingled with the soil is reduced to ashes, and thus made at once effective in providing its mineral matter in a free form to nourish the next crop. (2) Part of the organic matter is only charred, and left as finely

divided carbon in the pores of the soil, where it serves as a valuable absorbent of ammonia, carbonic acid, and water. (3) The mineral matter already in the soil is frequently improved by heat. Some substances, such as protoxide of iron, are more highly oxidized; and others are disintegrated, and rendered more soluble. (4) The mechanical condition is often improved by the soil being made more loose and porous.

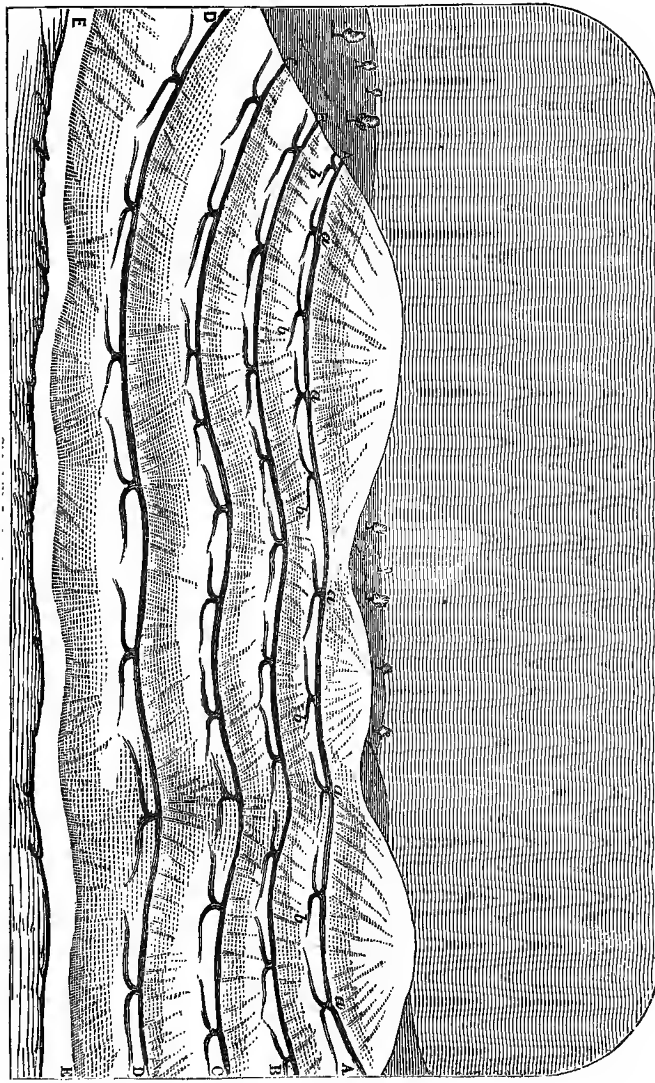
RUNNING WATER A FERTILIZER.

425. The water of springs and streams is never pure. It contains, as has been stated (§ 61), both mineral and organic matter of the proper kind, and in the proper condition to nourish a growing crop, or to add fertility to the soil through which it passes. The fertilizing matter is conveyed by the water partly in solution, and partly in minute particles, which are mechanically transported and left upon the surface. In sections of country where the land is rolling, and running streams are numerous, a portion of every farm, through which one of these streams passes, can be not only watered, but enriched by watering, if properly managed.

The purest spring-water has always portions of mineral matter from the soil and rocks through which it has passed. Decaying organic substances in the soil yield ammonia, which is also found, in some form of combination, in almost all springs. In streams which have received the water from the sewers of towns and cities, ammonia exists in very considerable quantities, and so do soluble and insoluble mineral ingredients. A careful farmer, although he may have no town or city above him to send down to his meadows, water freighted with fertility, will generally find that he has some careless neighbors up-stream, who will let him have the benefit of the "wash" from their barn-yards, hog-pens, and other like places; and not complain of his turning it into hay and grain, instead of letting it run on to the ocean, to be forever lost.

426. *Application.*—Running water can, of course, be applied only to those portions of land which are lower than the point where the water is turned out from the stream. By means of ditches conducted along the hill-sides, with just fall enough to give the necessary motion to the water, many acres of a farm may often be completely irrigated. In order to accomplish this thoroughly, with as little waste of water as possible, some attention must be given to the construction and arrangement of the ditches. The principal ditch, or conductor (*A, A,* Fig. 47), should wind around the hills nearly upon a level, so as to carry the water along the highest possible line. Openings, from 10 to 20 feet apart, must be made, as at *a, a, a,* to let out small streams from the main conductor. Small shallow channels should lead off from these openings to the right and left, nearly parallel with the main conductor; for the purpose, in the first place, of properly diffusing the water; and, in the second place, to prevent the little stream from cutting for itself a channel deeper than is wanted. These are seen at *b, b, b.* If the space to be watered extends far below the main ditch, other smaller ditches, as *B, B, C, C,* and *D, D,* should be run parallel with *A, A,* and at distances varying from 30 to 50 yards. These may vary in size as they are more or less distant from *A, A,* because a portion of the water conveyed by *A, A* will be absorbed by the soil before it reaches *B, B;* and when it reaches *C, C,* the quantity is still less. Then, these secondary conductors are not designed so much to *convey* water from one part of the meadow or field to another, as they are to *redistribute* what has run down from *A, A.* Finally, if there is not a natural channel at the base of the hill, as *E, E,* to carry off the surplus water, an artificial one should be dug for that purpose.

Fig. 47.



427. The kind of soil most suitable for irrigation is one with a porous sub-soil. The water can then penetrate to a greater depth, and surplus water can escape as it does in a drained soil. If the sub-soil is an impervious clay, a system of covered drains should be constructed beneath the surface before the ditches are made; or, if this cannot be done, and the land is to be kept in grass, it should be cultivated to the greatest possible depth with the sub-soil plow, before the grass is sown. When the soil is thus rendered porous, one portion of it may be completely saturated with water, and the stream then be turned upon another, while the former is left free to be acted upon by the air. By alternating in this way, a small stream may be made to water a large surface. If the land is under cultivation with corn, it may be watered, when necessary, by the same system; but the water should be turned out upon the soil less frequently, in this case, than in the case of a grass crop.

428. *Effects.*—The *present crop* is provided by the stream of water: (1) With an abundant supply of moisture, which is of great importance, and the land is thus made independent of drought; (2) With mineral and organic manure already in solution. *Subsequent crops* are, moreover, benefited by surplus fertility left in the soil by the water, and by decaying roots, stalks, and blades, of which some portions always remain after every crop that has been removed. After a hay-crop has been removed, the meadow should be watered, in such a way as not to allow the water to pass off through the soil, or to run freely over the surface; for, in that case, it will carry off fertilizing matter, which had better be retained. To prevent this, the quantity must be so regulated that all, or nearly all, will be absorbed, and afterwards evaporated from the surface, or thoroughly filtered before it runs off from the field; thus the fertilizing substances will be left in the soil. But if the water contains a considerable quan-

tity of organic and sedimentary substances, it should be allowed to pass freely and abundantly over the surface.

QUESTIONS ON CHAPTER XV.

§§ 379—382. What is said of *Stable Manure?* How must the urine be preserved? First method given? Second? What else must be done besides rendering ammonia involatile? If manures cannot be put into sheds, what should be done with them? What of the urine of cows, sheep, and hogs? Of their solid excrements? Is human excrement valuable? How does it compare with that of other animals? Is much of it wasted? What arrangements may be made for its preservation?

383—391. What is *Guana?* Why so rich in fertilizing matter? Its most abundant and most valuable ingredients? Where is the best guano found? Analogy between these deposits and those of coal? What of the African, Chilian, and Mexican guanos? What does Table VI represent? With what is the ammonia of guano combined? How do they become volatile? Why is the *application* of guano important? What three things are required in its economical use? What quantity is to be applied? Advantage of mixing with other manures? Most common method of applying it? When should it be diluted? First thing (*a*) to be done in preparing guano? How mixed with humus (*b*)? Use of sulphuric acid (*c*)? What effect does the acid produce? Why always to be thoroughly mingled with the soil (*d*)? What do some farmers think of the *exhausting* effects of guano? Does it really exhaust a soil? Why not? May its use exhaust some elements? Illustrate. What cases mentioned? How prevented? Best method of using guano for permanent improvement? How does it act when applied to green crops to be plowed down? What precautions necessary in buying? How tested? *Domestic* guano?

392—396. Where are *animal* substances collected? What gives them agricultural value? How preserved? What of fish? Insects? What gives value to *Bones?* How do they compare with guano? Why is their influence slow? How does sulphuric acid render bones more energetic? How is the acid used?

397, 398. Is *Mineral Manure* important? Why? Illustrate. What indirect influence does it often produce?

399—410. Why must *Lime* exist in every soil? In what condition must it be? (*a*) In what condition should *caustic* lime be applied? How much? On drained swamps? Why? First effect of caustic lime? Second? Third? Fourth? *Cautions?* (*b*) What is *mild* lime? Experiment? Its effects? (*c*) *Phosphate* of lime obtained? What does it supply? Has it an immediate effect? How is *super-phosphate* of lime prepared? What is manipulated guano? Bone black? (*d*) What does *Gypsum* provide for crops? Effects? To what crops is it especially applicable? Why? (*e*) How is the term *marl* used? What is *shell-marl?* Marls of the *tertiary* strata? (*f*) Why is *silicate* of lime important? Explain its action.

411. Is *Magnesia* valuable in soil? Why? Is it valued as a fertilizer? Why not? Will it not take the place of lime? What salts of magnesia are sometimes applied to land?

412—418. Why might we expect *Ashes* to form a good fertilizer? Are their constituents modified in burning? Chief source of ashes? On the sea-coast? Average quantity produced by wood? What does Table VII represent? What do we learn by comparing it with Tables III and V? What portions of ashes are most readily lost by exposure? Why suited for "sour soils"? Influence on organic matter? Value of leached ashes? Value of soap-suds? Why? How collected? Coal ashes?

419. How are *plaster and ashes* used together? Modes of applying them? Why especially adapted to clover and grasses? What chemical changes do they produce on each other?

420—424. What *soda* compound is first mentioned? What does common salt furnish to crops? On what crops is it most beneficial? What is said of *sulphate of soda?* How is *silicate of soda* prepared? What gives the *Nitrates* their value? Influence of burnt clay? First cause of this? Second? Third? Fourth?

425—428. Is *running water* ever pure? What substances are found in it? How does it fertilize a soil? Where do springs get their mineral and organic matter? How is the water of streams furnished with fertilizing substances? To what lands can this water be *applied?* Describe the ditching in Fig. 47. What kind of soil is best suited for irrigation? How should clay soils be prepared? How may a small stream be made to water a large surface?

CHAPTER XVI.

APPLICATION OF FERTILIZERS—PLANTING AND CULTURE OF CROPS.

429. It may be well to sum up, in review, some of the general principles and rules to be observed in applying fertilizers to the soil.

(*a*) Manures may be applied either in a *liquid* or *solid* form. The liquid form has the advantage of producing the most speedy effects, thus returning its profits most quickly to the pocket of the farmer; but, in this country, liquid manures are not much used, except on gardens and small lots. In older countries than ours, in some parts of our older States, in the vicinity of cities, and in all places where land is costly, and where a convenient and high market brings a prompt return for manure and labor, the liquid fertilizers are found frequently very economical. The manures of the solid form are most commonly applied, and have the advantages, generally, of requiring less trouble in their preparation and application, of affording a much greater variety of ingredients, and of being much more durable; and hence, requiring less frequent application.

(*b*) Solid manures should be as well pulverized as possible, so that they may be thoroughly mingled with and diffused through the soil. In this condition, a smaller quantity serves for a single application; and the farmer gets back again, in a shorter time, the capital and labor invested in the manure and the land.

(*c*) Manures of every kind should be as thoroughly incorporated with the soil as possible, so that the roots of the crop may find some portions wherever they run. If a manure is heavy, like lime or plaster, it is best to apply it on the surface after the land has been broken up. It may then be stirred into the soil, and, by its weight, it will gradually sink towards the bottom during the cultivation. Soluble ingredients, such as the alkaline salts in ashes, will soon be carried down into the earth by rain-water, even when they are applied only on the surface.

(*d*) Fermented manures have their ammonia already in a volatile form; and unless they have been composted with other substances, much of the ammonia will escape, by exposure on the surface. Hence they should be speedily covered or mingled with the soil. The tendency of all volatile matter is towards the surface. Especially is this the case in porous soils; hence guano, and other forms of manure which have passed through the process of fermentation, are frequently most effective and most durable in their influence when plowed down.

(*e*) The crop should find the required fertilizers present in the soil, and in the proper condition to be absorbed, as soon as the roots are sufficiently developed to take them up as food. Organic food is required at every period of the plant's growth, and should therefore be present at the time of planting. Of the mineral ingredients, silica and lime are taken up most abundantly during the growth of the stalk, while potassa and the phosphates enter most abundantly into the grain; but in both cases it is best to apply the fertilizers, either at or before the time of planting. Important chemical changes are often necessary, before a manure becomes fit for plant food. Bone dust, for example, has frequently, perhaps generally, a more decided effect upon a wheat crop, the second or third season after its application, than it has during the first. It doubtless undergoes, in process of time, changes in the soil, either from having a portion of its lime abstracted by lime-feeding plants, or under the influence of other substances, by which it is reduced to a more soluble, and hence more available condition. Unfermented manures applied to corn, or to a clover sod to be fallowed for wheat, generally have a better effect upon the succeeding wheat crop, than when applied directly to it at the time of sowing.

430. *Top-dressing* is more extensively practised now than it was formerly; but, like all other modes of application, it must be resorted to only under certain circumstances. There is no mode which can ever be universal in its applications; and where we find one particular method very successful in two or three experiments, there is always danger of some one drawing the general conclusion that this is, finally, to be the only method of operating. Top-dressing is doubtless favorable to grass and clover crops in the Winter and Spring Organic manures thus applied have their soluble ingredients carried down by the rain into the soil, where the roots will find them at the very beginning of their Spring growth. The unrotted portions of manure, remaining upon the surface, are soon covered by the leaves and stalks that spring up through them, and decaying, form a rich, warm mould about the roots. Top-dressing for *corn* will do well, if it be done with the newly-collected manures from the stables and barn-yards during the Winter. The urine, and other portions soluble by the Winter and Spring rains, are carried down, and become very thoroughly incorporated with the soil; while the remaining portions are turned down afterwards by the plow, and are gradually converted chiefly into humus. Manures may always be applied to the surface during the Autumn or Winter without serious loss, and frequently with decided advantage. It is always better to have stable and yard manures exposed to rains *upon the field*, than *around the barn.*

431. Mixing and Composting Manures.—When the farmer wishes to have a great variety of fertilizing ingredients provided for his crop, and applied at the same time, he may mix several kinds of manure together; but, in doing this, he must weigh carefully all the advantages and disadvantages involved.

Besides giving a variety of food to the crop, some of the most obvious advantages arising from mixing manures, are: (1) That one may render another involatile, of which we have examples in the effect of humus or gypsum in "fixing ammonia;" and (2) That one may make another more soluble, as in the case of sulphuric acid poured upon bone-dust.

432. Corresponding disadvantages are seen: (1) In a volatile substance, especially ammonia, being expelled by another, such as caustic lime; and (2) In the addition of something which may make valuable ingredients, already present, more insoluble. Sulphate of iron (copperas), for instance, added to manure containing phosphate of potassa or phosphate of ammonia, will produce the very insoluble phosphate of iron; thus rendering the phosphoric acid much less soluble than it was in its former combination. But it will only require a little reflection to avoid these difficulties.

PLANTING.

433. The general principles have been given which should govern the farmer in both the mechanical and chemical preparation of the soil. By plowing and draining, it is opened up, and ready to be acted upon by air and moisture, to receive such chemical appliances as will improve its composition, and also to be penetrated by the roots of cultivated crops. By appropriate manure, it is supplied with an abundance of all the food wanted for the nourishment of these crops.

When the ground is thus made ready, the next object of attention, before we bring the seed and the soil together, is to know that we have seed of the best kind and quality.

434. Selection of Seed. — This is a matter of the highest importance to good farming. "As a man soweth, so shall he reap," is one of the sacred proverbs, no less true in the physical than in the moral world. The farmer is apt to reap, not only the same *kind*, but also the same *quality*, as that which he has sown. A little shrivelled grain, with a poorly-developed embryo, will generally send up a weak and sickly stalk, able to bear only such grains as that from which it sprung; while, on the other hand, the vigorous germ, found in the full, plump grain, forms at once a strong foundation for a healthful future growth.

435. If the farmer has seed of the right *kind*, he may, with a little care and trouble, improve its *quality* very considerably in a few years. In wheat, the first portions that ripen are usually the best. These should be first cleared of rye, cockle, and other foreign plants; then cut as soon as ripe, and kept apart from the general crop, for seed. If this process is repeated for several years, the effect will be seen in the improved quality, and earlier ripening of the wheat.

Seed corn should be selected in the field. The largest ears, from those stalks which bear two ears, are believed by many of our best farmers to be most desirable for seed, because they are thought to be most likely to yield twin-bearing stalks for the next crop. There is good reason for this belief, from the fact that the ordinary varieties of Indian corn, when well cultivated on good soil, and not too much crowded for full development, generally yield at least two ears from every stalk; and, where only an occasional stalk has an opportunity of attaining its fullest growth, this is indicated by the production of two ears. In selecting the best ears, then, from such stalks, we have the product of the most vigorous and full growth in the crop. Those who have tried this method of selecting their seed, testify that the number of double-eared stalks can thus be greatly multiplied in a few years. It is a subject worthy of further careful experiment.

Every one who has not the proper kind of seed on his farm should at once make a change, even if he should be compelled to pay what he may regard as a very high price for seed of good quality. Changes of wheat and other grains, from one soil to another of different character, and from one climate to another, seem in many cases to prove beneficial. Wheat from the shores of the Mediterranean, and even from Central and Northern Europe, is generally more free from disease, and often escapes the ravages of insects more entirely, than the varieties which have been long cultivated in our own country. Grains transported from latitudes in which the season is short, to those in which it is much longer, ripen early, at least for a few seasons; but they finally appear to adapt their period of growth and maturity to the new climate. Our Government, through the agency of the Patent Office, is doing our agriculturists good service, by giving them an opportunity of trying various kinds of seeds from all parts of the world.

436. In determining the variety of wheat or corn to be planted, two circumstances should have their influence. (1) The *productiveness* of different varieties should be, as far as possible, ascertained. The different kinds of wheat and corn often vary in their relative products per acre, so much as to make this an important point of attention. The labor of cultivating an acre of land in a variety of corn which yields 80 bushels, is no greater than that of cultivating the same quantity of land in another variety which yields only 50 or 60 bushels; and the same is true of wheat, or any

other grain. (2) The difference in the *market value* per bushel must not be disregarded. Twenty bushels of white wheat, at $1.25, are equal in value to twenty-five bushels of red wheat, at $1.00. The *nutritive value* of corn to be used in feeding farm stock, should be estimated, in selecting the kind to be planted. Yellow corn is regarded by stock-raisers as superior to the white, in its fattening properties. For bread, the white variety, with a clear, flinty grain, is most highly esteemed.

437. The oat grain (*Avena Stativa*) degenerates, to some extent, in the Southern States, after a few years' cultivation. The stalk may still grow with all the luxuriance desired, but the grain gradually becomes less full and heavy. For this reason, Southern farmers who wish to cultivate oats, should frequently (at least once in four or five years) renew their seed by importation from a more northern latitude.

438. *Preparation of Seed for Planting.*—All kinds of seeds should be *thoroughly clear of everything* which can spring up and grow at the same time with the cultivated crop. Indian corn is easily separated from every other kind of seed, by the peculiar manner of gathering it; but not so with wheat. Everything that grows with wheat must be gathered with it; and everything that ripens about the same time, will be still represented by its seeds, when the grain is threshed. Hence the great difficulty of keeping seed-wheat clean. Spring wheat is liable to become polluted with oats, because it has the same season of growth, while oats sown with winter wheat are killed by frosts. Winter wheat is most apt to have rye, cockle, and cheat (chess) mixed with it, as these, like the wheat, are biennial, and ripen simultaneously with it.

439. In order to estimate properly the importance of having clean seed, it must be remembered that these foreign grains do not simply injure the *quality* of the flour produced

from the crop, but they also diminish the *quantity* of the grain, just to the extent of their own presence. This may not be entirely true of oats and rye, for they are not entirely worthless; but of cockle and cheat it certainly is true; for the same ground which produced a stalk of either of these plants, would have produced a stalk of wheat, if wheat had been sown in their stead.

A few bushels of wheat may be carefully picked out, head by head, and sown on a piece of *clean* and good soil; and a supply of clean seed, sufficient for the whole of the next sowing, be thus obtained.

440. STEEPING SEED-GRAIN.—A more prompt and vigorous germination, and a more rapid early growth, may be brought about, in almost all kinds of grain, by steeping the seed in suitable solutions. If the soil is then good, the early growth, thus urged forward, will continue; but steeping the seed in a solution of *one* substance, can never make up deficiency in *other* elements of fertility in the soil; nor can it compensate for *defective plowing*, or negligence in other modes of tillage.

The solutions used for steeping sometimes have the effect of destroying the eggs of insects, and the germs of injurious fungi, such as smut. Or, if these are not destroyed, their influence may be, to a great extent, counteracted by the increased vigor given to the young plant by the fertilizing salts in which the grain has been soaked.

441. Several salts may be used in the same solution, so as to give a variety of such food as the plant may require. The salts most frequently employed for this purpose are those containing potassa, soda, and ammonia, combined with such acids as are wholesome for plants. The ammonia salts, like the ammoniferous manures, are generally more powerful in their influence than the salts of the other bases. The sulphate of ammonia and sal-ammoniac are the cheapest salts

of that class; but urine may be used with like effects, on account of its ammonia, and at much less cost. Nitrate of potassa (saltpetre), nitrates and sulphates of soda and magnesia, phosphate of soda, and common salt, may all be employed in the preparation of steeping liquids. Some of these are within the reach of every farmer, and may be used at a trifling cost. The collection of urine requires only a little management, while saltpetre and common salt are found in every wayside store throughout the whole country.

442. The following receipts may be useful as general guides in preparing solutions. They are suitable for any of the cereal grains.

a. For every bushel of wheat or corn, take 4½ gallons of water, and dissolve in it one pound of saltpetre and one pound of common salt.* Pour the solution upon the grain in a tight vessel, and set it aside in a warm place to soak for 24 or 36 hours. Then drain off the surplus water (preserving it), and mix with the grain, while wet, as much plaster as will adhere to it, or, rather, as much as will keep the grains from adhering to one another in planting. About half-a-bushel of plaster is sufficient for a bushel of grain. Caustic lime, used in the same way, is believed to prevent *smut.* The water may be used a second time, for about half as much grain, by dissolving a little more saltpetre and salt in it.

b. A better solution than the preceding is formed by dissolving, in 4½ gallons of water, for each bushel of grain to be soaked, ½ lb. sulphate of ammonia, ½ lb. saltpetre, ½ lb. Epsom salts, and ½ lb. common salt; and, if phosphate of soda can be obtained, add ¼ lb. of it. Soak the grain and mix with plaster, as in the first receipt.

* A *strong* brine of salt tends to retard germination, by preventing decay in the albumen.

c. To 4½ gallons of urine, add a half-pint of sulphuric acid (oil of vitriol), ½ lb. saltpetre, ¼ lb. Epsom salts, ½ lb. common salt. The solution is to be used as before directed. In this case the sulphuric acid unites with the ammonia of the urine, and forms sulphate of ammonia. This solution is improved by standing a day or two before it is used.

Other solutions may be used, as the convenience or chemical knowledge of the farmer may suggest. A strong decoction of manure, formed by passing water through a barrel or box compactly filled with fresh stable-dung, or that collected from hen-roosts, with the addition of a little sulphuric acid, nitre, and salt to the liquid, after it has passed off, will give a solution closely resembling the one last mentioned (*c*).

When the quantity of grain to be prepared at one time is large, it may be more convenient to use a smaller amount of liquid, and apply it in a different way. The following plan will be found convenient: For every bushel of wheat provide 1½ gallons of water, and in this dissolve the salts as above given. Spread the grain upon a close floor, to the depth of 5 or 6 inches, and with a common water-sprinkler apply about one-third of the solution. Let it stand two or three hours, stirring the mass occasionally. The grain will in the meantime have absorbed most of the moisture; then sprinkle over it another third of the solution, and let it stand 24 or 36 hours. Just before it is to be sown, let the remaining third of the solution be applied; and while the grain is still wet, mix it with plaster or caustic lime, or any fertilizer you may wish to sow with it. If no pulverized fertilizer is to be used, all the liquid should be applied as soon as the grain can absorb it, so that it may stand at least 24 hours after the last portion has been applied. The grains will then be sufficiently dry upon the surface to prevent their adhering to each other in sowing.

444. Time of Planting.—This must vary widely, even

for the same crop, under variations of climate; and also, to some extent, with variations of soil and exposure, even in the same climate. It is, therefore, difficult to lay down any rules, except those of the most general character. Crops planted in Autumn, such as wheat and rye, should have time to form a good strong root, before Winter sets in. The experience of the most successful farmers in any particular section of country, is the best guide for the young farmer, at least until his own experiments have been tried sufficiently often to result in *experience.*

Cold, clay soils, and those having a northern exposure, require earlier sowing than such as are warmer, from their composition or southern exposure; for the Fall growing season is shorter in the former than it is in the latter case.

445. In the Spring, oats and Spring-wheat crops may be sown as early as the ground can be conveniently prepared. This will give the force of hands and horses an opportunity of making preparation for planting other crops, especially corn, which always demands thorough cleaning and breaking up of the soil, in order to secure a good crop. Corn should be planted late enough to escape the frosts of Spring. It is a crop which requires much light and heat to cause a rapid growth, and will, therefore, make no great progress so long as the days are short and cool. Hence, we find in the latitude of Virginia that corn, planted about the first of April, has grown very little more by the last of June, than that which was not planted till the first of May. The planting season for corn has, then, a tolerably wide range. Good crops are made from plantings ranging over the whole period between the first of April and the middle of May. Farther south the planting period is still longer.

446. The chief advantages of early planting for corn are, in the first place, that, in tobacco-growing regions, the "working" (tending) of the corn, may be as far advanced as

possible before the planting of the tobacco crop requires attention; and, in the second place, in wheat-growing regions, that the tending of the corn crop may be pretty well completed before wheat harvest begins.

447. For *potatoes* there are two favorable seasons for planting. The first, very early in the Spring; the second, late in June, or, in more southern latitudes, the first of July. The potato is not capable of bearing very hot weather while at its highest stage of growth. The weather, at that time, should be moist and mild. When potatoes are planted about the last of March or first of April, the tubers are formed chiefly during the month of June; and, although this is a warm month, the ground has not become so hot, nor usually so dry, as it is in July. Hence, they are tolerably well matured before the scorching weather of midsummer sets in. If they are planted in the early part of summer, they come up and pass through the stage of growth proper for cultivation, by the time the very hottest weather has passed. Then, if they get good rains during the latter part of August and early part of September, fine tubers are formed, and a fair crop is realized.

QUESTIONS ON CHAPTER XVI.

§ 429. In what two *forms* may manures be applied (*a*)? Advantage of the liquid form? Which form is most common? (*b*) How should solid manures be prepared? Why? (*c*) Why should manures be perfectly incorporated with the soil? How accomplished? (*d*) Should fermented manures be exposed? Tendency of all volatile matter? (*e*) How should the crop find the fertilizers in the soil? When are silica and lime taken up most abundantly? What are potassa and the phosphates? Is time required for some manures? Illustrate.

430. What of *top-dressing?* Can any mode be universally employed? To what crops and what seasons is top-dressing especially suited? Why? Why are the Fall and Winter suitable for applying organic manures?

431, 432. How may great variety be obtained in a manure? Other advantages of *mixing?* The first? The second? First disadvantage? Second?

433. Means used for reducing the soil to its proper mechanical condition? How is its chemical condition improved? When the ground has been prepared, what is the next step?

434, 435. Why is the *selection of seed* important? Effect of planting a little, shrivelled grain? How may the quality of seed be improved? In wheat? Of corn? Why do ears from stalks bearing double produce the same kind? Advantages of importing seed?

436, 437. Circumstances to be noted in determining the *variety* of seed? Productiveness? Why? Market value? Nutritive value? Why should oat-seed be frequently changed?

438, 439. First step in *preparation* of seed? Cleansing seed-wheat? Spring-wheat? Influence of clean seed upon the quality of flour? Means of procuring clean seed-wheat?

440–443. Advantage of *steeping* seed-grain? Influence on insects, &c.? Salts used in the solution? Which are most powerful in their influence? (*a*) First recipe? (*b*) Second? (*c*) Third? Other solutions?

444–447. What of *time of planting?* Of crops planted in Autumn? In Spring? Time for planting corn? Advantages of early planting? Seasons for potatoes? First? Second?

CHAPTER XVII.

INDIAN CORN (*MAIZE*).

448. Preparation of Soil.—Principles have already been given, which were designed to be of general application in reducing soils to their proper mechanical and chemical condition. A few special directions on this subject may be useful, as applicable to the culture of particular crops.

449. The most important point in the preparation of land for corn is *deep, thorough plowing*. For this, more than for any of our grain crops, the sub-soil plow is demanded—preceded by draining, where this is necessary. Corn roots run deep enough to avail themselves of the benefit of all the soil which the plow can break. The earing-season of corn, too, is a period of frequent droughts; but we have shown, in Chap. XIII., that draining and sub-soiling are the best safeguards against such contingencies.

450. The time of plowing should be determined by the quality and condition of the soil. The winter frosts are of great service to stiff clay and slaty soils; hence, the advantage of plowing them in Autumn or early Winter. When the field is covered with a clover sod, or grass which is easily killed, or with litter easily rotted, it is considered a good plan to break up with the surface-plow alone, in the Fall or Winter, so as to cover the sod or litter, and let it lie in that condition until near planting-time. It will then be sufficiently rotted to become readily mingled with the soil. The same plow should be again used, and be followed by sub-soiling. The decayed sod and litter will, during this second plowing, be partly turned up to the surface, and partly

mingled with the surface-soil, giving it both a warm and mellow character; while the sub-soil plow will open the way for the roots to run far down, in their search for food and drink.

451. There are some grasses which are not easily killed with the plow, and which form a very tenacious sod. The varieties of blue grass, common on limestone lands, are of this character. A favorite method of treating such a sod, when broken up for corn, is to turn it down during the Winter, or very early in the Spring, and, at planting-time, run the harrow or cultivator over the top, so as not to disturb the sod, but leave it with its grassy surface still more completely concealed, and pressed down upon the bottom of the furrow. The rows for planting are then opened by a small bar-share plow, run so shallow as not to turn up the sod, but only to cut through the upturned part of it. The corn is thus planted in the inverted sod. The early culture is shallow, still not breaking the sod to any considerable extent. Such preparation, when accompanied by sub-soiling, is almost certain to produce a good crop. The advantage of leaving the sod so long undisturbed, is, that it may have time for complete decay, and thus become food for the crop at the period of its most rapid growth. Alluvial, and all loose soils containing much organic matter, need not be broken until near the time for planting. Weeds and grass will not then have an opportunity of commencing their growth much in advance of the corn. Soils cannot often be made too mellow for corn, nor be kept too mellow during its growth.

452. The *distance* apart at which corn should be planted, should vary with the richness and physical properties of the soil. A very fertile soil can of course sustain a greater number of stalks than one which does not equal it in strength. But of two soils, both equally fertile, the one of stiff clay and the other of dark loam, the latter will bear closer planting than

the former, because it absorbs more freely the light and heat of the sun.

Yet in every case, there is a limit to the number of stalks to be left upon the ground; and young farmers are more apt to err in having their corn too thick, than in having it too thin. The crop demands more than simply an abundance of nutrition from the soil; it demands a full supply of both *light and heat*, with free circulation of air. Corn, more than any other grain crop, is injured by being so much crowded as to exclude the free access of light and heat from the sun, or prevent ready circulation of air.

453. Modes of Planting.—There are two modes of planting practised by the best farmers, both of which have their advantages under peculiar circumstances. By one of these modes, the ground to be planted is marked off with furrows all running in the same direction, and parallel to one another, and at the proper distance apart for the rows. If the land is level, or nearly so, the rows are generally made straight; but if the land is hilly, they are made to wind around the faces of the hills, in such a way as to be nearly horizontal. The width of the spaces between the rows varies from three and a half to five feet. The corn is then dropped into the furrows, at from one to three feet apart, and covered with the hoe or plow to a depth which should not exceed two inches, unless the soil is very dry. When the hills are so near as one foot, only one stalk should be left in each hill; and even then there will be too many stalks in the rows for any but the best lands. If the hills are two and a half or three feet apart in the rows, two stalks may be allowed to grow together. The only advantages arising from having the hills wide enough apart for two stalks, are the greater convenience in hoeing, and the more free access of light and heat to the soil. But, for the absorption of food from the

soil, there is some advantage in having the plants equally distributed in the row, each standing alone.

454. The other mode of planting differs from this, in the method of arranging the rows. The land is laid off in two directions, at right angles to each other, so that one set of furrows run lengthwise, and another set run across the field, dividing the whole into little squares. At the corners of these, where the furrows cross each other, the corn is planted. The rows must be wide enough for the plow to be conveniently run both along and across the field. In the large varieties of corn, which are almost exclusively cultivated in the Southern States, two stalks are as many as will grow to full vigor in one hill.

455. The principal advantages of this method are: (1) That the quantity to be cultivated on the field may be perfectly regulated by the width of the rows. Each square, formed by the intersections of the rows, will correspond with the space occupied by each hill of corn; or, in other words, there will be just as many corn-hills in the field as there are squares marked off by the rows, provided we reckon the margins along the fences as divided into half-squares. If, then, the rows are three feet apart each way, there will be two stalks (or one corn-hill) for every square yard of surface. If the land is tilled to the depth of a foot, each corn-hill will have the third of a cubic yard (equal to nine cubic feet) of soil to sustain it. When the soil is light, the number of stalks may be regulated to suit it, either by thinning to one stalk in each hill, or by increasing the distance between the rows, and leaving two stalks in the hills. (2) The plowing may be made more complete in the future culture of the crop, when there are two systems of rows crossing at right angles. Two successive plowings may be made to cross in the same way, and thus the soil is broken on all sides of the hills. The stirring of the soil is thus very complete and

the grass and weeds are more thoroughly eradicated than they can be by the plow running only in one direction. (3) The sun has free admission to the soil. This method cannot be conveniently practised on steep land.

456. QUANTITY OF SEED.—Each hill should have two or three times as many grains as there are stalks to be left growing. By this means, if the seed has been carefully selected and kept in a dry place, and the ground is in a good condition, the trouble of re-planting may be avoided. Another great advantage arising from an abundant application of seed is, that however perfect the grains may seem to be when planted, some will produce vigorous and healthful plants, while a few, at least, will produce only such as are feeble and sickly, and can never by any subsequent culture be made vigorous and productive. Five or six grains in a hill will almost always secure enough of the best quality to be left, while those of less promise may be pulled out. The trouble of thinning out in this case, will be amply rewarded in the future crop.

Corn is often planted by machines constructed for the purpose. These should be so made that the distance between the hills, and the quantity of seed dropped, can be regulated to suit the soil.

457. *Experiments.*—Every farmer should test the capacity of the different parts of his land for corn, by actual experiment. He should, on different parts of the same quality of soil, try the cultivation of *one*, of *one and a half*, of *two*, and of *two and a half* stalks for every square yard of surface, until he finds out the number best suited to that soil. He will then know how thick to plant his corn on different parts of his farm, and will establish rules for himself far superior to any he can find in books.

458. AFTER-CULTURE.—The points of first importance in the culture of corn, after the planting has been properly exe-

cuted, are, *first*, to keep the ground clear of everything which has the same period of growth, except the crop; and *secondly*, to stir the soil thoroughly, and to as great a depth as possible, during the early stages of the corn's growth. In clay soils on which a strong grass sod has not been turned down (§ 450), a good plan is to run a coulter, made like that of the sub-soil plow (§ 339), about twice on each side of the row, soon after the corn comes up. The middle spaces may be stirred with the shovel-plow or cultivator. The process of hoeing and thinning may then follow. After this, another deep plowing will generally be sufficient.

Many farmers, especially in the South, prefer the plan of running a small mould-board plow as near the rows as possible, at the first working, in such a way as to throw the earth off from the corn; following with the hoes, to cover again any roots that may be too much exposed. This is followed by a second use of the same plow, run in an opposite direction, so as to throw the earth back again towards the row. This method has some advantages, and is adopted in the cultivation of some other crops. In the first place, it gives free access of air to the soil about the roots of the crop, and gives the portion turned twice with the plow a complete stirring. Secondly, it destroys completely the first weeds and grass which spring up near the rows.

As corn approaches the period of tasselling, the roots spread with great rapidity, after which deep tillage will, by breaking the roots, generally result in a degree of injury greater than any benefit arising from stirring the soil. All work, after the corn has grown to the height of four or five feet, should be done with the cultivator and hoe. The land may thus be kept clean, while the roots are left free to run out on all sides in quest of food, until they form a net-work entirely across the spaces between the rows.

459. HARVESTING.—The harvesting of Indian corn has

reference to two points; (1) the preservation of the fodder, and (2) the preservation of the grain. For securing the fodder, there are two methods adopted extensively in almost all parts of our country, both of which are so familiar to every one living in a corn-growing region, that a very brief notice of each, with its advantages and disadvantages, will be all that is necessary.

(*a*) *Blading* and *topping* are performed where the securing of the fodder within the smallest compass, and in the most portable form, is desired. The blades below the ear, with the first one above, are stripped from the stalks with the hands, and placed in handfuls between stalks standing close together, until they are sufficiently cured to be tied up in small bundles, and secured in stacks or under shelter. The blades are in order for being tied, or in any way handled, only in the mornings and evenings, and on cloudy days. If they are handled in dry weather, especially if it is windy, there is always considerable loss from their breaking into fragments.

Topping consists in cutting off the portion of the stalk above the ear. The tops thus cut are allowed to lie in small heaps, until they are partially cured. They are then tied into bundles, and several of these put together so as to form shocks. In this condition they stand till they are perfectly cured; that is, until the stalk, as well as the blade part, has become dry enough to prevent moulding when placed in larger bulk. The next step is to secure them against the weather by stacking, or putting them under a shelter.

In parts of the country remote from high markets, and where provender is abundant, the blades are usually regarded as not worth gathering. The tops, being much more valuable, are frequently cut, while the blades are left ungathered.

Both blades and tops, when secured without much exposure to rain, are about equal in value to the same weight of good hay. But to secure the full forage value of tops, they must be cut into small fragments, so that the animals to which they are fed may be able to masticate them easily. I have found, when corn tops are finely cut, and mixed with a little meal, and water enough to make the meal adhere to them, that my horses consume almost every fragment, and thrive remarkably well.

After topping, the corn is left upon the stalks until it is sufficiently dry for the crib. It is then either pulled off with the shuck (husk)* still on it, and taken to the barn to be stripped and thrown into a well-ventilated crib, else shucked upon the stalks, the shucks and stalks being left together upon the ground.

(*b*) The *second* method is to cut the stalks off at the surface of the ground, as soon as the ears have become hard, and set them up in small stacks (or shocks), to be cured by the air which circulates freely through them. In this condition the crop stands till the grain is dry enough to be put into cribs. It is then shucked, generally without being pulled off the stalk. The fodder, including the shucks, is then most commonly fed to cattle without cutting. The blades, shucks, and a little of the slender part of the stalk are eaten, while the remainder is trodden down, and forms valuable litter.

(*c*) A *third* method is that of allowing the whole plant to stand untouched until the corn is ready to be gathered. Then after the crop has been removed, cattle are allowed to gather what they will of the standing fodder. In this case, the fodder is of little value.

(*d*) In the Western States, where much larger crops are cultivated than could be secured by either of the methods above given—where the market is distant, or the great abundance of corn makes the price low, and where the object is to concentrate the crop into the more portable form of beef

* "Shuck" is the word in common use in the South and South-west.

and pork, the beef cattle are turned into the field of standing corn to eat as much as they choose, and tread down at pleasure. Hogs are next made to follow and gather up the remainder. Sometimes hogs alone are allowed to gather the crop. Of course this wasteful method can only be practised where the price of corn is low in comparison with the price of labor.

460. *Advantages and Disadvantages.*—These several methods of harvesting corn have their advantages and disadvantages; and the one to be pursued must be determined upon by each farmer for himself, according to the circumstances by which he is surrounded. The method (*a*) has the advantage of securing the *fodder* in the most portable and most valuable form; and if the locality is one in which such provender commands a high price, this is no inconsiderable part of the crop. It is especially desirable in places where hay is not easily made. But it has the disadvantage of making a lighter crop of grain than either of the other plans given. The reason of this is, that the growth of the corn ceases almost entirely as soon as the blades and tops are removed. Although the grains may have become firm enough for the crop to be fully dried at gathering time, they shrink more, and will be found to be more loose upon the cob, than in the case in which the whole plant has been left standing for the same length of time, showing that it is not the more complete drying in the one case which makes the grains appear lighter than in the other; for in these two cases the opportunities for shrinkage, under the influence of drying, are the same.

461. The rule given in § 468 for cutting wheat, is not so fully applicable to corn. Wheat has its highest value before the stalk is fully ripe; but corn has not reached its highest value until the grains have become fully hardened, and glazed upon the surface. This is not generally completed

until the blades below the ear are nearly all dead, the shuck partially brown, and the upper blades beginning to die rapidly. In that state the corn may be topped without injury, or may be cut off and removed from the ground. But the value of the fodder is then greatly diminished. The bran of corn does not, like that of wheat, increase much in thickness from being allowed to stand until it is "dead ripe."

The method (*b*) has the advantage of securing the whole stalk for both fodder and litter, while the corn is well secured, provided the stacks are made small, so that the air can circulate freely, and prevent moulding. If the corn is to be immediately succeeded by a wheat crop, this method has the additional advantage of clearing the land for the plow. In fact, it is the only method by which the ground can be brought into a good condition to be seeded down with wheat. The chief disadvantage attending this plan, is the heavy labor of cutting and stacking the corn, and the inconvenience of managing the bulky mass of fodder which it gives.

The advantages of (*c*) are, first, the saving of labor, in case it can be more profitably expended on something else than the gathering of fodder; and, secondly, the securing the heaviest product of *grain* which the soil, culture, etc. could produce. The disadvantages are, first, the almost entire loss of the fodder; and, secondly, the greatly inferior value of the stalks for improving the soil, below what would result from using them for litter in the barn-yard. The latter objection to both *a* and *c* plans, may be removed by gathering the stalks after the corn has been removed, and using them as litter.

Labor-saving is the only advantage the last (*d*) method can claim. It saves the labor of gathering the crop, and leaves the manure produced in feeding spread upon the land, without the labor of hauling. Its disadvantages are too obvious to require even to be mentioned.

462. Cribbing.—The crop should be allowed to become as thoroughly dry in the field, as the season and the time required for gathering will justify. Every experienced farmer knows how readily corn becomes musty, when thrown into a large bulk in a damp condition. This often takes place around the cob, when the external condition of the ear indicated entire dryness. The cob parts with its moisture very slowly, and generally contains a great deal when the corn is cribbed. To guard against damage from this source, cribs should be well ventilated. The walls should have numerous openings for the free admission of air. The floor should be elevated at least a few inches (or, still better, a foot or two) above the ground. If the floor is made close, strips should be put across it which will hold up the corn sufficiently to allow a free circulation of air. If the body of the crib is large, poles or laths extending across from side to side, at various points, especially for the first few feet above the floor, will aid in the circulation of air, and consequent drying of the corn.

QUESTIONS ON CHAPTER XVII.

448—452. What is the most important point in *preparation of soil* for corn? Why is sub-soiling important? How is the time of plowing determined? Treatment of clover-sod? Its second plowing? Treatment of stiff grass-sod? Planting on such sod? Preparation of alluvial and sandy soils? How is the distance between corn-rows and hills determined? Danger of planting corn too thick?

453—457. First *mode of planting* mentioned? Describe it. Width of spaces? Distance between the hills? Second method? Laying off the ground? First advantage of this method? To determine the space appropriated to each hill? Second advantage? Third? How many grains to the hill? Why? Use of machines in planting corn? How should every farmer test his soil?

458. First point in after-culture of corn? Second? What if the soil is stiff sod? What, if not? Plow to be used? Hoeing and thinning? Method of turning the mould from the row? Advantages? When should deep tillage of corn cease?

459—462. The two points to be noticed in *harvesting* Indian corn? (*a*) How are blading and topping conducted? Value of blades and tops? (*b*) Process of cutting up corn? How is the fodder used? (*c*) Third method? (*d*) Method in the Western States? *Advantages* of method (*a*)? Is corn injured, like wheat, in becoming "dead-ripe"? Advantages of method (*b*)? Methods (*c* and *d*)? Condition of corn before *cribbed?* Why? Construction of cribs? Ventilated how?

CHAPTER XVIII.

WHEAT AND OATS.

463. Preparation of Soil.—Deep plowing is not so important for wheat or oats, as it is for corn, because their roots do not naturally run so deep; nor does their season of growth so frequently subject them to drought. But a point of great importance in the preparation of land for wheat especially, is that it shall be *as clean as possible* at the time of sowing. Grass and other green substances, whether they are plowed down just before sowing, or left strewed over the surface after the sowing is completed, are often injurious, and seldom beneficial, to the crop of wheat. So when straw, or litter of any kind, is spread over wheat in Autumn or early Winter, more harm than good generally results from the application. The injury is supposed, by some judicious farmers, to be owing in part to the fact that the litter serves as a harbor for chinch-bugs and other mischievous insects, and in part to the fact that the shading caused to the green crop makes it too tender near the root to stand the severities of winter so well as it would without such covering. (*Journal State Agricultural Society*, vol. ii. p. 69.)

464. When green crops or unrotted manures are plowed down for wheat, it should be done in the summer, that they may be well decayed, and ready to feed the newly-planted crop in the first stages of its growth. Clover, peas, and other leguminous plants having considerable quantities of nitrogenized matter in them (§ 370), undergo speedy decay; and may, therefore, be plowed down at a later period than would

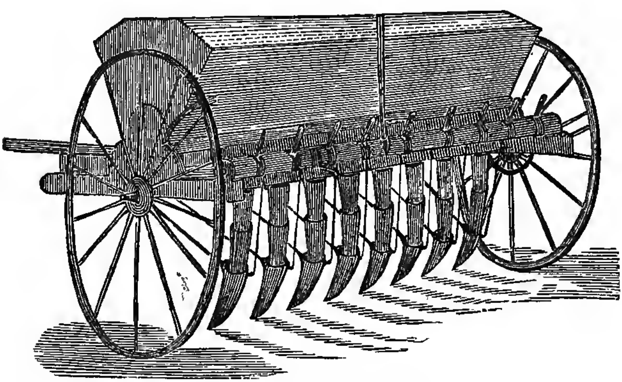
be suitable for most other crops. The time for this kind of fallowing of grass and clover-fields, must of course vary, to some extent, with variations in climate, soil, and exposure.

465. The cultivation of such crops as tobacco and potatoes, is found to be one of the best means of preparing a soil for wheat. The benefit in these cases seems to arise chiefly from the clean condition in which they leave the soil. There is also a probability, at least, that these, as well as some other crops, leave the soil in a favorable *chemical* condition for wheat. The rotation of wheat after corn is regarded, by our best Valley farmers, as affording but a doubtful chance for a good crop. The chances after oats are regarded as much more favorable, especially if the oat stubble is turned down early, that it may rot, while the scattered grains left upon the ground may spring up, and be destroyed during the seeding of the wheat.

466. MANURING.—Some farmers put off the application of their stable and yard manures to wheat, until winter or spring. When this is done, they are usually but poorly compensated for their labor. Winter wheat has two periods of growth: the first in Autumn, and the second during the following Spring and Summer. The vigor of the crop, in its second period, generally depends very much upon the healthful development of those parts of the roots, which are natural to the first, or Autumn period. If, then, manure is incorporated with the soil at the time of sowing, the impulse given to the wheat plants in Autumn is almost certain to continue until the crop is matured—unless some *physical* cause come in to prevent it, such as drought, or the depredations of insects. But when manure is spread upon feeble wheat in Winter or Spring, it comes too late. The basis of a good crop is not there. As well might you expect to make a great ox from a stinted calf, as to make a good crop in such a case as this.

467. Modes of planting Wheat.—There are two plans pursued very largely in the planting of wheat. (1) The old method of sowing broadcast with the hand is still kept up on nearly all of the small farms, as well as many of the larger ones, throughout the Union, but especially in the South. The slovenly method of sowing the grain among the standing corn crop, and covering it with shovel-plows or cultivators, is fast passing out of favor. The custom of breaking up the ground, whether fallow or corn and oat stubble, &c., with the large plow, then sowing and covering with the harrow, cultivator, or shovel-plow, is still extensively prevalent, and is well suited to many soils, particularly the tenacious clays, which retain the roots of wheat firmly, during the frosts of winter. (2) *Drilling* has, within a few years past, been rapidly gaining favor among our progressive agriculturalists. The majority of those who have tried this method would be entirely unwilling to give it up. The annexed figure (48,)

Fig. 48.



will assist those who have not seen the "drill," to form a tolerably correct idea of its mode of operation. The drawing is taken from the "Southern Planter," and represents Bickford and Huffman's Iron-cylinder Drill. This instrument has "attachments" for sowing guano and grass seed. A glance at the machine will enable any one to see that the lower part of each of the tubes, which extend downward from the axle to the ground, will open a small furrow as it moves forward. Through an opening near the bottom of the tube, and immediately behind it, the grain is discharged so as to fall into the open furrow. Then, as the machine moves forward, the soil falls into the furrow behind the tube, and covers the grain which has been deposited there. A contrivance within regulates the quantity discharged. Without attempting any further description of this apparatus, let us see what are some of the most important results of its operation.

(*a*) The quantity of seed may be regulated to suit the quality of the soil, the climate, and the time of sowing. Some soils bear heavier seeding than others. In climates where the winters are severe, some of the plants almost always perish, and for this some allowance must be made in determining the quantity of seed applied. So northern exposures require more seed than those inclining to the south and east. Late sowing, if it be near the beginning of Winter, requires an increase of seed, because the roots, not having time to gain much vigor before Winter, will send up fewer stalks in the Spring than they would have done, if more time had been allowed for their first stage of growth; hence, a greater number of roots will be required to yield a full crop.

(*b*) A smaller quantity of seed is required than is used on the same soil in broadcast sowing, partly from the uniformity with which they are distributed, and partly from the increased vigor given to the plants by the admission of light and air between the rows. These circumstances cause the roots to send up a large number of stalks. The drill is supposed to save about one-third of the seed. On a farm of even moderate size, this saving would very soon amount to the cost of the machine.

(*c*) The depth is uniform, and may be suited to the soil. Heavy soils require more shallow planting than light, porous soils. The covering, too, is complete, the grains never being left exposed on the surface, as is often the case where the plow or harrow has been used. The crop stands the winter frosts better, from having the roots of the different plants interwoven, and so matted together, as to prevent one from being thrown out by the freezing of the soil, without the mass being elevated together. This advantage is seen especially in light and porous soils, from which wheat is so often entirely frozen out.

(*d*) The plants shade the soil less completely in drills than they do when more uniformly dispersed over the ground. The effect in this case is similar to that mentioned in connection with the planting of corn. Two stalks of corn growing in the same hill, throw a shadow upon the ground very little larger than that of a single stalk standing alone. So, if the stalks of wheat are confined to narrow spaces, and even crowded in those spaces, the soil in which they grow gets the benefit of more light and heat, and of a more free circulation of air, than it could if the same number of stalks were more uniformly spread over the surface. The result is a more vigorous growth, and consequently a better crop.

(*e*) Small quantities of such fertilizers as guano, plaster, ashes, &c., can be applied more directly to the wheat, and with more uniformity by the proper kind of "attachment" to the drill, than in any other way. The economy of fertilizers is hence very great, when they are applied in this way.

Every one who farms on a sufficiently-large scale should have this valuable implement, and, more especially, if his soil is not such as to hold wheat strongly in winter. The cost (from $80 to $100,) may possibly deter one who farms on a very limited scale, but this obstacle may be very readily overcome by two or three, who have small farms near together, uniting in the purchase of a drill which will, if carefully used, serve all of them for many years.

468. Harvesting.—The time of wheat-harvest must be determined by the condition of the grain. The cutting should be done before the crop appears fully ripe. As soon as the grains have passed out of the "milk state"—that is, as soon as the inner part has become firm, but is still soft enough to yield readily to the thumb-nail when pressed into it—the crop has its greatest value. The straw is then of a greenish-yellow, and there is still a green tinge about the head. If the wheat is allowed to stand two or three days after it reaches this stage, the straw and head assume a brown appearance—the crop has become dead ripe. The grain and straw have then both become less valuable. A portion of the starch of the grain has been converted into bran; and, according to the testimony of the best millers, it will not make so much nor so good flour, as that which has been cut when less perfectly ripe. When cut in that condition which gives the best grain, the straw has more starch, and more albuminous matter in it, and is therefore more nutritious, than it would be if allowed to become dead ripe.

Long exposure to rains has an injurious effect on both grain and straw. The dark color thus produced is owing to partial decay on the surface. When this takes place on the surface of the grain, the decayed particles become mingled with the flour in grinding, and give it a dark shade. At the same time, repeated wetting and drying destroys the nutritive substances in the straw. Wheat should, therefore, be placed under shelter or carefully stacked, as soon as it has become sufficiently dry to prevent moulding, or heating in bulk.

OATS.

469. Soil.—The best chance for a good oat crop is to sow it upon corn or wheat stubble of the previous year. A freshly-turned sod seldom yields a full crop of this grain; but any land of tolerable fertility, which has been under cultivation the previous year, will produce a fair crop of oats.

470. Planting.—The land should be plowed up in the Spring, or latter part of the Winter, and the sowing be done as early in the Spring as the weather will permit. It is a grain sufficiently hardy to endure quite severe frosts after it has come up in the Spring. Some varieties may be sown in the Fall, and will not only live through the Winter, but come forward more rapidly in the Spring, and ripen earlier than the ordinary oats. These are called "Winter oats." Their early progress often enables them to escape droughts, by which the spring varieties are cut short. This gives them an advantage in localities where early droughts are common.

QUESTIONS ON CHAPTER XVIII.

§§ 463—466. Is deep plowing important in *preparation of soil* for wheat and oats? Why not? What point is of great importance? Effect of straw or litter spread over wheat in Winter? The cause? When should green crops be plowed down? What crops prepare land well for wheat? Why? What of rotation of wheat after corn? What of manuring wheat in Winter? When should manure be applied to wheat? Why?

467. *First mode of planting?* How conducted? Second mode? Describe the *drill.* Advantages from its use? (*a*) Quantity of seed regulated? (*b*) Economy in seed? (*c*) Depth? Protection against frost? (*d*) Admission of light? (*e*) Economy in fertilizers?

468. Time of *harvesting?* When is the grain fit for cutting? Injury from standing too long? Explain this. Effect of long exposure to rain?

469, 470. Best preparation of soil for *Oats?* Season for sowing? Winter oats?

CHAPTER XIX.

POTATOES.

471. Soil.—The potato will grow upon almost any soil, with good management and a favorable season; but a loose, moist, and cool soil is most suitable. Well-drained swamps sometimes produce the potato with great luxuriance of growth. North-lying slopes of loose rich mould, gravelly and sandy loams, etc., are all favorable to the production of this important crop.

472. Preparation.—The ground should be prepared by a thorough plowing in the Autumn or Winter. But if the land has a clay sub-soil, this should not be turned up to the surface; it should, however, be well broken with the sub-soil plow. In the Spring, at the time selected for planting, manure should be applied either immediately before planting, or in the drills with the potatoes. If manure is abundant, the best method of applying it is to spread it broadcast over the soil, and stir it completely into the loose mould, to the depth of four or five inches, by plowing and cross-plowing as many times as may be necessary. If manure is not abundant, it is more economical to use it in the drills for covering the tubers at the time of planting.

473. Manures.—The best manure for potatoes is fresh stable, or hog-pen scrapings, mixed with a large portion of broken straw, leaves, or other litter.* From ten to twenty tons per acre, as the soil is more or less fertile, should be

* The horses and hogs can be made to do the mixing.

applied, in case it is spread upon the surface. A smaller quantity will be sufficient when applied in the drills. When only a light application of this kind of manure can be afforded, a little guano may be mixed with it, very much to the advantage of the crop, especially on light, thin soils.

474. Planting.—In our southern climates, the great enemy of the potato crop is the hot sun, and particularly when accompanied by drought. Our planting should, therefore, have special reference to protection against excessive heat. The best means of accomplishing this is by *mulching*. If the manure has been previously stirred into the soil, the crop should then be planted in drills, at distances varying from one to two feet from each other, according to the soil and variety of potato. The stronger soils will bear closer planting than those of less fertility; and those varieties of the potato which produce their tubers within a small space around the base of the stems, as we see in the Mercer variety, may be planted much more thickly than such as the Long Red, which sends its tubers off to a considerable distance.

475. After the soil has been thoroughly prepared, I have found, in my own experiments, that the most convenient method of planting is to open a furrow along one side of the ground (along the lower side, if not level) with a shovel-plow or small bar-share, and drop the tubers in this furrow, at distances varying from eight to twelve inches. Then, with the same plow, another furrow is run close to the row thus prepared, and the soil thrown upon the potatoes, so as to cover them about two inches deep. If the soil and variety of potato will allow of very close planting, another row of tubers may be dropped in this second furrow, and the soil from a third be thrown over upon it; the third may then be supplied with potatoes, and be covered with the soil from a fourth, and so the operation be continued till all the ground

is planted. If the soil is not very fertile, or the potatoes of the spreading varieties, the planting should be done only in every second or third furrow, as the judgment of the planter may dictate. When this process of planting has been completed, a large harrow may be passed over the ground, so as to leave it with a smooth and even surface. It will be well to sow a mixture of ashes, plaster, and salt over the ground, either before or after harrowing. The mixture should consist of four bushels of leached or two of unleached ashes, with one bushel of plaster, and one gallon of salt; and should be applied at the rate of ten or fifteen bushels per acre. Then the whole surface is to be covered to the depth of six or eight inches with broken straw, forest leaves, or some other form of litter. This covering (mulching) protects the crop against the severe heat of the sun, prevents rapid evaporation, and thus secures both a cool and moist soil. Besides this, it prevents the growth of weeds, while the potato-shoots readily find their way to the surface. The shading of the ground hastens the decay of the manure which has been applied, thus increasing its efficiency, and also promotes other beneficial changes in the soil. Potatoes planted in this way require no subsequent culture. If a few weeds find their way through the mulching litter, they can be readily pulled up by hand. At digging-time the tubers will be found very near the surface, and many of them even lying upon the surface of the soil.

When potatoes are cultivated in the ordinary way, in drills three or four feet apart, such manure as that recommended above should be spread upon the tubers in the drills, so as nearly to fill the furrow, then a light covering of soil be added.

476. Culture.—If the methods of planting are adopted which require future culture, all plowing and hoeing should be done during the early stage of growth. No working,

which will disturb the roots, should be done after the flower buds begin to make their appearance; because the period has then come for the rapid growth of the tubers, and they should not be disturbed. If weeds still prove troublesome, they may be removed by very shallow hoeing, and by hand Deep covering at the time of planting, or heavy earthing in future culture, are injurious to the crop, especially in heavy clay soils, or in very damp localities.

477. The flower-buds of the potato should be plucked off as soon as they make their appearance. The nutrition, expended in the production of seeds, is almost identical in kind with that which promotes the growth of tubers. Hence, if seeds are produced, it must be at the expense of food which would otherwise nourish the tubers. The plucking of the flower-buds prevents this abstracting of starch, gluten, &c., from the crop. Topping the vines, when they are too rank, has sometimes a like effect.

478. Digging.—As soon as the tops of the potatoes die, it indicates full maturity of the tubers, and the crop should then be gathered. For if the weather should become warm and moist, there is danger of a second growth, which makes the potato watery, from the conversion of a portion of its starch into dextrine. The same injury results, as is well known to arise from the "sprouting" of potatoes in the Spring. After being dug, they should be dried in the open air, and laid away in a cool, dry cellar. If they are to be buried in the earth, a dry and elevated spot should be selected for this purpose, and so prepared that the water cannot collect and stand in the bottom of the bed. They should not be buried until near the beginning of Winter, as there is then but little danger of heating, and consequent rotting under the influence of warm weather. Before the weather becomes warm enough in the Spring for the sprouting of the tubers to commence, they should be taken up,

and returned to the cool, dry cellar. If they are damp when taken from the ground, they should be spread out where they will be exposed to the sun for a few hours. They may be kept in good condition for eating much longer, by being spread on a dry floor in a cool situation, than in any other way—the great object being to prevent *germination.*

479. SELECTIONS FOR PLANTING.—Those designed for seed may be conveniently selected, either at the time the crop is laid up in the Fall, or when spread out in the Spring. For planting, those tubers of *medium size* are best, because their buds (eyes) are generally more vigorous than those of the very large or very small ones. The object in planting this, as well as all other crops, should be to secure plants which are healthy and vigorous at the very beginning of their growth.

It is well known that the part of the potato tuber, most remote from the point where it is attached to the root, has a greater number of eyes than any other part. These eyes are less vigorous than those more sparsely scattered over the parts nearer the root-end, and will consequently give more feeble plants. A single tuber, of average size, has too many eyes for a single hill, and should, therefore, be cut in two. In doing this, attention should be given to what has just been said about the eyes. The tuber should be so split as to have some of the best buds on each piece. This is done by dividing lengthwise, or from the root-end through to the opposite part.

480. DEGENERATING.—Potatoes are found to degenerate in the hands of a great many farmers, and hence an impression prevails extensively that the same variety *naturally* deteriorates, when cultivated in the same soil and climate for several successive years. This is true to some extent, if it is planted too frequently on the same land, even when the best modes of culture are pursued. It is also true when,

year after year, the little worthless tubers are selected for planting; and when careless preparation of soil, careless planting, and careless culture, are bestowed upon the feeble plants which spring from little, half-developed tubers. Corn, wheat, rye, and every other kind of crop, degenerates under similar treatment. Let any farmer try the rules and principles above given *carefully*, for a few years in succession, and it is most probable that he will find the quality of his crop *advancing* gradually, instead of retrograding. Such, at least, has been the writer's own experience.

QUESTIONS ON CHAPTER XIX.

§ 471–473. Best soil for *Potatoes?* How should the soil be prepared? Application of manure? If manure is abundant, how applied? Best manure for potatoes? Quantity?

474, 475. Thing to be guarded against in *planting* in southern climates? Best means? Distance of rows and hills? Convenient methods of planting? If the soil is not fertile, how should the distance be regulated? Application of ashes, plaster, and salt? Advantages of *mulching?* Ordinary mode of planting?

476, 477. When should the *culture* of potatoes be performed? Why? Effect of plucking off the flower-buds?

478, When should *digging* commence? What injury from second growth? Suitable locality for burying potatoes? Proper time for burying? When should they be taken up? How treated? Why?

479, 480. When should selections be made for seed? Which tubers are best for seed? Why? In what part of the tuber are eyes most numerous? Where most vigorous? Why should tubers be cut? How? Why do potatoes so often appear to degenerate? How may this be prevented?

CHAPTER XX.

HAY CROPS.

481. Clover.—From the three divisions of its leaf, clover is called "Trifolium." There are several varieties cultivated in different countries, but the best for our climate is the common red clover (*Trifolium pratense*). This is a biennial plant. If sown early in the Spring, and not too much shaded by other crops, it produces a few blossoms the first season. When allowed to grow the next year to full maturity, without cutting, it dies; but if it is cut or pastured, so as to prevent it from coming to full maturity, it lives through a third or even a fourth summer, and retains vigor enough to produce a tolerably fair crop. But its heaviest product is always in the second season after sowing.

482. Some farmers believe that red clover is, by a mysterious process, converted, by close pasturage, into another species called "white clover," from the color of its bloom. There is no doubt that the red clover soon disappears from a closely-pastured field, and that white clover (*Trifolium repens*,) springs up in its place; but this is easily explained, without the necessity of supposing the change, above mentioned, to take place. Red clover is naturally biennial, and, if left to its full course of development, will die at the end of the second season; and by artificial cutting or cropping by cattle, can seldom be made to grow well longer than to the end of the third or fourth season. White clover, on the other hand, is *perennial*. Its seeds are almost always mixed to some extent with those of the red variety, and when sown together, the latter, being of a much more rapid growth, and

a much larger plant, takes possession of the ground, while the smaller white variety is too much shaded to be distinguishable beside its more prosperous companion. But the short-lived red crop soon runs its course and dies, while the white, more tenacious of life, remains in possession of the field, with more room to display itself as the prominent owner of the soil.

483. Soil.—Clover grows best on clay loams, having a good supply of lime, in some available form; but almost any soil (not swampy) may be made to produce a good crop, by frequent application of ashes and gypsum. The roots of clover run deep (§ 353), and hence require a deeply-broken soil. The sub-soil should be well broken in the cultivation of some preceding crop, when it cannot be done at the time of sowing the crop with which the clover is mixed. If, for example, corn is to precede oats, and clover is to be sown with the oats, a good sub-soiling for the corn crop will also be of great service to the clover, since the strong roots of clover will penetrate even a stiff clay sub-soil, if it has been well broken within a year or two. It is then less apt to be frozen out in Winter, than it is when cultivated on a soil less deeply broken.

484. Sowing.—The Spring is undoubtedly the best season for securing a good stand of clover, while March and April are most probably the safest months for sowing it, in our latitude. It may be successfully sown upon wheat or rye, but there is more certainty of getting it to stand well with oats—the ground being in a better condition for the seed to become covered, and for the roots to get a good hold upon the soil.

485. When sown on a field of wheat, if the surface is a loose mould, a large harrow should be passed over the soil, about the last of March or early in April, and about six quarts of seed per acre sown immediately afterwards. If the

surface is somewhat hard, the clover may be sown before the harrowing is done, as there is then no danger of covering many of the seeds too deep; and the slight covering given by the harrow on suoh a soil, will protect the young plant from injury in the rapid drying of such surfaces. To secure uniformity in sowing, the seed should be mixed with something which will increase the bulk. The seed for an acre may be thoroughly mixed with a bushel of ashes and a half bushel of plaster. The quantity to be applied can then be easily regulated by the hand, as in sowing wheat, while the ashes and plaster will fertilize both wheat and clover. The harrowing, which is to precede or follow the sowing, will not injure the wheat; but is thought by many persons to be of service to it. The wheat-gleaner, now so extensively used, is a good instrument for covering clover-seed, if the surface is not too hard.

486. If clover is to be sown with an oat crop in the Spring, the seed should be prepared as above directed, and then applied immediately *after* the last harrowing of oats. The harrow passing over the ground, after the clover-seed has been applied, would cover it too deep. The first rain that falls will cover it sufficiently.

487. Cutting, etc.—If the clover crop is designed for hay, it should be cut at the period of its growth at which it has the greatest nutritive value. This occurs when about one-third or one-half of the heads have commenced turning brown. After this period, the sugar and starch which abound in the green stalks are rapidly converted into woody fibre, while the proteine matter speedily disappears. The first crop of the season is most valuable for hay, but the second, and sometimes even the third, may be cut for this purpose. The cutting should be so managed as to form long and regular swaths, for the convenience of hay-making.

488. The leaves of clover are very abundant, and consti-

tute a very valuable part of the hay; but when the hay is dry, they are very *brittle*, and liable to be wasted in making and stacking the crop. To prevent this loss, as far as possible, is an important point. It is best done by letting the swath lie until the top is tolerably well cured, and then turning it over with a fork, without any additional tossing. The hay may be safely packed away in mows, or stacked, before it is entirely cured, if a layer of dry straw a few inches thick is spread over the mow or stack for every foot in depth of hay. The straw tends to absorb the moisture of the hay, and also to admit the air. If there is much greenness in the hay when put up, a little salt spread over it will not only assist in preserving it, but will make it more palatable to stock. The straw used in packing will be greatly improved in flavor by contact with the clover. (See Mr. Ruffin's method, § 506.)

489. GATHERING SEED.—The second crop is generally best for seed; because, in the first place, the heads are usually better filled than those of the first crop; and, in the second place, because it is more clear of weeds and other foreign plants. The first mowing clears the soil of everything, and the second growth of clover springs up with great rapidity, and is matured before almost every other plant found associated with it. The crop is thus cleaner, and being less thickly set upon the ground, it has a more favorable opportunity of bringing its seed to maturity, than the first crop had.

490. If there is no grass in the field which will eradicate the clover, it may be made to produce crops of hay for several years in succession. This is done by running a sharp coulter, or a sub-soil plow, through the clover very early in the Spring, so as to loosen all the soil, and give the seed left upon the land the preceding Fall, an opportunity to germinate and take root. The new plants thus produced will take

the places of the old ones as they die out. If the soil is a loose loam, harrowing and rolling will answer the purpose better than coultering.

491. Grasses.—We have not room for specific directions for the cultivation of all the grasses used in hay-making. Some general remarks on two or three of them must serve our present purpose.

Timothy (*Phleum pratense*).—This is sometimes called "cat's-tail," and in some of our Northern States, "Herd's grass." It is a perennial, and makes hay of fine quality, when cut at the proper season; and where the soil suits it, the crop is generally abundant.

The Soil best adapted to timothy is a rich clay loam, moist, but not swampy. Alluvial meadow lands, free from stagnant water, and drained swamps, well subdued by the cultivation of a few grain crops, generally produce fine yields of this grass. Uplands, too, and more especially northern slopes of good clay loam, yield fine timothy, unless visited by severe drought in the early part of Summer.

Sowing.—Timothy may be sown either in early Autumn or in the Spring. One of the surest methods of getting a good stand of this grass, is to sow it with rye in the latter part of August. It then has time to get a tolerably strong root before Winter sets in, and it is, moreover, sheltered by the rye against the severity of frosts. If sown in the Spring, it may be put in with wheat, or with the oat crop. About a half-bushel of seed should be put upon an acre, to insure a sufficiently thick stand. The seed may be mixed with ashes and plaster, as before recommended for clover, and should be but slightly covered. As an ordinary harrow would cover many of them too deep to germinate, a very light brush-harrowing is quite sufficient; or, the method recommended for clover will also do well for this grass. A gallon of clover-seed per acre, added to the timothy, will make the first and second crops much heavier than the grass alone will produce. Then the clover, being a biennial plant, and the timothy perennial, the former will disappear gradually from the spaces it has filled, while the latter will spread out, and soon cover the whole ground.

492. *Harvesting.*—Timothy has its highest nutritive value when the first heads begin to turn brown. A large part of the crop is at this time in bloom. The stalks are then succulent, and contain their largest quantity of starch, sugar, gum, and albumen. The hay should be cured as rapidly as possible, and without rain. By having the weaker hands engaged in tedding immediately behind the mowers, and then in turning, as soon as the top becomes tolerably well cured, it may be prepared in a few hours to be put up in small hay-cocks, where it will soon become sufficiently cured for the stack or the mow. It should be sprinkled with salt (5 or 6 quarts to the ton) when packed away.

The after-crop of timothy makes a pasture of very superior quality, for cattle, sheep, or horses. This grass also adds to the fertility of the land, partly by the decay of its abundant crop of blades about the root, and partly by the gradual decay and reproduction of its bulbous roots.

493. Orchard Grass.—This grass will grow upon almost any soil which is not swampy. It may be sown in the Spring with clover, which it eradicates after one or two seasons. It has a very strong root, and is not easily overcome by other grasses: it is, hence, very suitable for lots designed to be kept in grass for a long time. It starts early in Spring, and continues green quite late in Autumn; and is, therefore, valuable for early and late pasture. *As a hay crop,* it holds no very high place generally. When harvested for hay, it should be cut in full bloom; because the hay has then its highest value, and the maturing of the seed, which is exhausting to the soil, is prevented.

The sub-soil plow, when run beneath the sod of this grass once in two or three years, is of service, especially if the process is followed up by a top-dressing of stable or yard manures. *Ashes* and *plaster* should be used freely and frequently on all grass lands. The grasses demand an abundant supply of lime and potassa (see Table III).

494. PASTURE. — For permanent pastures, limestone soils are most suitable; and where they are level, and at all swampy, draining is wanted, to make them yield a crop which is good in either quantity or quality. The most durable and nutritious grasses for pasture are what are called "Blue-grasses." The Kentucky Blue-grass should, most probably, stand first on the list, and should be introduced into every limestone region. The common "Spear-grass," or greensward, is another species of the same genus, and forms fine pasture.

The proper care of pasture lands is too much overlooked by many of our farmers. Worthless briars and weeds are too often seen to occupy much of the best soil, where a little timely attention and labor would have secured a rich green sod of sweet and nutritious grass. Top-dressing with mineral and other fertilizers, will often be found as profitable on pastures, as upon cultivated crops.

In those sections of country where the perennial grasses will not thrive, more attention should be given to the introduction of the *annuals* and *biennials*, to be cut for hay. The annual meadow-grass and biennial rye-grass, with other varieties, have been cultivated where those of more permanent character will not readily take root. The different varieties of *millet*, *oats* cut in full bloom, and *corn* sown broad-cast, or thickly drilled, all make good substitutes for hay, on lands where the best hay grasses and clover are not easily or abundantly produced.

EXPERIMENTS.—Every farmer should make repeated experiments on his own lands, with various kinds of grass, that he may determine which are best adapted to his soil. Then it should be an established rule: (1) *Never to allow a field to be out of clover, or some kind of grass, when it is not occupied by other crops;* (2) *Never to miss an opportunity of fallowing with clover or grass sod. It is the cheapest way of enriching a soil.*

QUESTIONS ON CHAPTER XX.

481. Why is *Clover* called Trifolium? Best variety for our climate? What is a biennial plant? Its growth the first season? The second? When does it produce its heaviest crop?

482, 483. What do some believe in regard to the change of red into white clover? How explained? Best *soil* for clover? How may any soil be made to produce it? Why is deep plowing important?

484, 485, 486. Best season for *sowing* clover? On what crops may it be sown? How treated when sown on wheat? How is the sowing rendered uniform? If clover is sown on oats, should it be harrowed? Why not?

487, 488. When should clover be *cut for hay?* Why? Which crop is most valuable? Why do the leaves of clover require especial care? Does it bear tossing? How may straw and salt be used for hay?

489, 490. Best crop for *seed?* Why? Why clear of weeds? How may clover be made to produce good crops for several years in succession? How to be treated if the soil is loose?

491, 492. What is *Timothy* sometimes called? Why called a perennial? What *soils* best adapted to it? Seasons for *sowing?* With what crops may it be sown? How much seed per acre? How prepared? What of mixing clover-seed with it? When should timothy be *cut?* Why? How cured? For what is the after-crop valuable? How does it enrich the soil?

493, 494. Soils adapted to *orchard grass?* When sown? For what lots is it suitable? Its value for pasture? As a hay crop? When cut? Why? How should it be treated occasionally? Lands best suited for *pasture?* How treated if they are level and swampy? Best grasses for pasture? Examples? How should pasture lands generally be treated? What may be substituted for perennial grasses? How should every farmer test his own lands? What established rules should be observed everywhere?

CHAPTER XXI.

BEANS AND PEAS.

495. VALUE.—There is a large class of plants which have their seeds enclosed in a sort of bivalve pericarp, usually called a "pod." These are called "leguminous" plants. The different kinds of *bean* and *pea* are examples of this class. The varieties of *clover* are also leguminous, having their seeds enclosed in *pods*. Red clover has usually one seed in every pod, but some kinds of white clover have several together in the same pod.

496. This whole class of plants is remarkable for the quantity of *nitrogen* they contain. The nitrogen is chiefly found as one of the constituent elements of a proteine body, which we have called "legumen" (§ 157). All the proteine compounds have been spoken of as possessing a high nutritive value, and as forming a most important ingredient of animal food. They bear a relation to animal nutrition somewhat similar to the relation of ammonia to plant nutrition. The legumen of beans and peas is so abundant as to place them above both wheat and corn in nutritive value. On this point more will be said hereafter. The stalks of these plants also abound in proteine matter, and in that respect resemble clover hay in composition and value, and hence make excellent rough forage for stock.

497. We have learned that, when proteine substances undergo decay (§ 159), *ammonia* is always one of the products. This has also been mentioned as the most valuable ingredient in organic fertilizers. If, then, bean and pea crops are plowed into the soil at the proper period of growth—that is, at the

period when they contain the greatest amount of proteine matter — considerable quantities of that most important fertilizer, ammonia, are generated in the soil. Clover was once regarded as almost the only suitable crop to be employed as green manure, but experience has shown that other leguminous plants have a similar value; and, in some climates and soils, certain varieties of beans and peas seem to be even superior to clover for the purpose of fallowing.

498. Varieties. — Different latitudes require different varieties. Those only which have a comparatively short period of growth, are adapted to the Northern States. Such are the China Bean, Horse Bean, and the different varieties of Field Pea. Those which require a longer season and more hot sun, are confined chiefly to the Southern States. There is a species of *bean* cultivated extensively in some of the older Southern States, of which there are a good many varieties. All the varieties are embraced under the general names of "Cornfield Pea" and "Southern Pea." Mr. Edmund Ruffin, Sr., in his valuable Essay on this crop (for which a premium was awarded by the Virginia Agricultural Society, 1854), enumerates *nine* varieties. (1) "The buff-colored pea, usually called either the *cow* or *clay pea.*" (2) "The Bass (red) pea, used extensively on the Lower Roanoke, in N. C." (3) "The *black-eye pea,* of several varieties, was formerly most generally known, and indeed was almost the only kind cultivated." (4) "The early black pea has perfectly black and large seeds." (5) "The mottled or shinney pea, which has been so much celebrated in latter years, differs in some respects from all others. The seed are of a light brownish color, thickly streaked or mottled with deeper brown." (6) "Large black or Tory (late) pea." (7) "Small black and late pea." (8) "Green-eye white pea." (9) "The small green or bush pea" — sometimes called "Chickasaw" and "Oregon Pea." But these are by no

means all the names applied to the varieties of "Southern Pea; for the same variety passes under different names in different sections of the same State. "This kind only, of all enumerated and described here, seems to be a true *pea;* and, therefore, is not of the same species with all the other kinds here termed varieties of the Southern Pea."

499. CLIMATE.—The different species of bean have the quality of gradually adapting themselves to different latitudes, at least to some extent. If the pods which first come to maturity are always selected for seed, the time of ripening may be made to occur several weeks earlier, after a few years' culture. At present, the Southern Pea is not much cultivated north of 37° 45′, nor will many varieties come to maturity so far north as this, in an ordinary season. But with proper attention several of them might, most probably, be adapted gradually to still higher latitudes. Their great value, for both forage and manure, would certainly justify a fair experiment on this point.

500. Some of the earlier kinds, such as the "Early Black" [(4), above] and the "Shinney" (5), are thought to be best adapted to the climate of Virginia; taking into consideration the time of maturing, and their productive value for feeding and fallowing. For table use some of the lighter colors are generally preferred, such as the "Black-eye" and "Green-eye White Pea." In more southern latitudes, the "Shinney," "Clay," and "Bass," are among the varieties preferred, and most extensively cultivated.

501. SOIL.—Crops of this class will grow well on almost any kind of land not deficient in lime. The best soil for beans is a warm, sandy loam, of *medium* fertility. A very rich soil produces a most luxuriant growth of vines, especially in the "Southern Pea;" but the quantity of seed is then but small. On medium quality of soil the crop of vines is not so heavy, but the grain crop very abundant, provided

the culture and season have been favorable. The *very poor* soil will generally produce a crop sufficient, when turned under, to add considerably to its fertility. This is proverbially true in the culture of the Southern Pea. Land in lower Virginia, which "will not produce Black-eye Peas," is regarded as in rather a hopeless condition. South of 37°, almost any soil may be restored to fertility from the most exhausted condition, by cultivating the pea, with the application of some form of *lime;* either *marl, caustic lime, gypsum,* or *ashes,* attended with proper rotation, and as frequent fallowing as possible.

502. Plowing, for bean and pea crop, should be deep and thorough. The roots penetrate a well-broken soil to a great depth; and as the plant gathers mineral substances largely through its roots, especially lime and potassa, with sulphuric and phosphoric acids, these will be transferred from the lower to the higher parts of the soil, and be left by the decaying crop in a good condition to form the food of succeeding crops of grain, tobacco, cotton, etc.

503. PLANTING.—The methods adopted for planting may vary with the object to be attained. If the crop is cultivated for its grain and forage, the largest yield can be obtained by cultivating in rows, varying in distance according to the kind of bean or pea to be planted. The varieties which grow erect (bush-beans) may be planted in rows two or three feet apart. Those which spread their vines, like the Southern Pea, should be in rows from three to four and a half feet. The seed may be drilled in the rows, or planted in separate hills. If the object is to prepare a crop for fallow, the land should be well prepared, and the crop sown broadcast, and covered with the harrow or cultivator.

504. The Southern Pea has been cultivated in the Southern Atlantic States from time immemorial. Some of the methods

pursued in Virginia, and the States farther south, are the following:

1st. "The oldest and still most extended culture [in Virginia], is to plant the peas after and among corn. When the corn is mostly about 8 or 10 inches high, and has been just plowed and hoed, peas are planted, either in the narrow intervals between the stations of corn, if in drills; or otherwise, in a plowed furrow, the last made by the plow in the middle of the wide intervals between the corn rows. In either case, usually 10 or 15 peas are dropped together, and come up and grow in a cluster. So many seeds are put together, for the young plants to better force their passage through the earth. But some experienced cultivators of North Carolina think that 5 or 6 plants together, produce better than a greater number. One more plowing is all that is afterwards given to the corn — which, at very little more trouble, is all the culture required for the peas.

"2d. The next most extensive, though, in Virginia, a very recent mode of pea-culture, is also as a secondary crop amongst corn, but made by sowing broadcast, when giving the last horse-tillage, and covering the seeds more or less perfectly by that tillage process. This costs but the seed and the labor of sowing. The crop all goes for manure, and is seldom ripe enough (in Virginia) for good manure.

"3d. The third mode, and, as I think, the cheapest and best, to raise the pea-crop for manuring, is to sow the seed broadcast, on a separate field, or without corn."—*Edmund Ruffin's Essay, Va. S. Ag. Soc.*

"In sowing peas broadcast as a fallow crop, in preparation for wheat or other crops, the land should be broken up in the Winter deeply, and about the first week in June (in our latitude), the peas sowed at the rate of one bushel or five pecks to the acre, and either harrowed in with a heavy harrow, or plowed in with single plows, according to the state of the land."—*P. M. Edmondston, of North Carolina.*

4th. "In planting as a separate crop, break up the land, if possible, in Winter; and at the time of planting (which in this latitude is best during the first fifteen days of June), run off the land in rows 4, 4½, or 5 feet distant, either by running one furrow, or listing with three furrows, according to the condition of the land. If it is grassy, it should be listed—drop the peas from two to three feet distant in the row, from ten to fifteen peas in a hill, and cover with the hoe, harrow, plow, or cultivator with the front hoe removed. After the peas have made two or three of the second leaves, run the bar of the plow as near as possible, throwing the earth from them, as in the first working of corn, and, if necessary, throw out the middle and run over them with the hoe, cutting out the grass and weeds, and a little after the vines have commenced to run, plow again, throwing the earth to them. This is all the cultivation necessary; and on fertile land, with favorable seasons, it will give a good return for the labor spent—say an average of sixteen or twenty bushels to the acre, which, at seventy-five cents per bushel, will equal twelve or fifteen bushels of wheat, at one dollar per bushel. This method of planting will take about one peck and a half, or three half-pecks, to the acre."—*Idem.*

This last method is best when the peas are to be gathered, not only because the mode of culture brings a better crop, but because of the greater convenience of gathering. It has the further advantage of leaving the land in a condition free of grass and weeds, and hence in a better state of preparation for the succeeding crop. Some farmers prefer it even for fallows, because of the greater certainty of getting a good stand of peas when planted in this way.

When peas are planted with corn, they do not seem to interfere, to any great extent, with the growth of the corn crop; because the latter is well matured before the peas reach their stage of most rapid growth, provided they are not planted before the corn approaches the time of tasselling.

505. Gathering.—When the pods are ripe, or enough of them to provide as much seed as is wanted, they are picked off by hand; and when sufficiently dry, are threshed out with flails or sticks, or are run through a threshing machine. If the greater part of the crop is intended for manure, it should be plowed down as soon as the gathering is finished. The seeds are believed to have a higher fertilizing value than the vines, if they come to maturity; but by this time the vines have lost part of their value. The question as to the proper time for plowing down resolves itself into this form: "When will the seeds and vines together, generate the greatest amount of ammonia in the soil?"

Chemistry would reply,—"When nearly all the seeds have become *firm* in the pods, but not dry." At this time the most forward pods will be dry, but the vines will still retain much of their greenness. Consequently, the *seed portion* of the crop will now contain nearly its maximum quantity of ammoniferous matter, while the *vine portion* will not yet have lost much of what belonged to it. This is the *theory* which science would present to the inquirer, independent of experiment, and based only upon the well-known character and composition of bean and pea crops generally, at the different stages of their growth. The *experiments* of the most successful pea-growers of the South confirm these simple deductions of science.

506. If the vines are to be used as forage, they may be cut off close to the ground with sharp hoes, or still better with short stout scythes, and cured like clover hay. The curing is a somewhat difficult process. Mr. Ruffin remarks, that "at maturity of growth they should be pulled up, if planted in clusters (or perhaps cut by the scythe, if broad-

cast?), and put up in tall and slender shocks, supported by a small stake set in the ground, to remain till cured enough to stack, or to be put away in a house." *Clover* may be cured in the same way.

507. Mr. Edmondston, of North Carolina, says: "As an article of forage or fodder, there is none superior to the pea-vine. Horses and cattle will eat it with avidity, and in preference to any other kind of fodder. The difficulty of saving these vines has constituted the chief objection to their use. The writer believes that they can easily be saved, by cutting them off close to the ground with sharp hoes, in the month of September; and then, having first provided forks and poles, plant the former in the ground in a straight line, and so place the poles upon the forks, that a common-sized man can clasp his hands over the poles [*i. e.*, they must be about 6 feet above the ground]. Place rails, with one end resting upon the ground, the other upon the pole, about 6 or 8 inches apart, after the manner of a top-stack or fodder-house, as it is called, leaving both ends open, and upon these rails throw the vines, until they are about one foot deep; throw over all some straw or grass, and a good supply of the best fodder for milch cows, or any other kind of stock, will be obtained."

508. The Black-eye, and other early varieties of this pea, grow well in the valley counties of Virginia south of Augusta, at least well enough to give a good fallow; and it is probable that they could soon be acclimated still farther north, at least until a sufficient growth could be attained to make them well worthy of attention as a fallow crop. They grow well on both the clay and sandy soils of the south-western part of the valley; and in cases where soils are too poor to produce clover, the pea may be cultivated and turned down, until the soil is rendered sufficiently fertile for the improvement to be continued with clover. Another valuable

purpose might be served by attention to this crop. There are cases in which farmers fail to get a stand of clover; sometimes this occurs repeatedly for several years, until the land suffers seriously for want of a fallow crop. When such failures occur (and they are not unfrequent), a pea crop might be sown, and the land fallowed the next season. The Southern Pea could thus be made a valuable auxiliary to clover in enriching our lighter soils, and in rendering our stiff clays more mellow, as well as more fertile.

509. The *wheat drill* may be used in planting peas. The quantity of seed can thus be regulated with accuracy; and in cases where the drills are thought to be too close, every alternate tube may be closed up, and the drills will then be double the width of those of wheat.

QUESTIONS ON CHAPTER XXI.

§§ 495, 496, 497. What are *leguminous* plants? Examples? What valuable element do they contain in large quantities? What proteine body is found in them? What of the stalks? Product of the decay of proteine bodies? What if bean and pea crops are plowed down at the proper season? What was once regarded as almost the only crop suitable for *fallowing?*

498. *Varieties* for different latitudes? What suited to the Northern States? What extensively cultivated in the Southern States? Varieties of the *Southern Pea?"*

499, 500. What is said of adapting themselves to *climate?* How may they be rendered earlier? Present limit of the Southern Pea? Which varieties are best adapted to the climate of Virginia? Which variety best adapted to table use? Which to culture in the States farther south?

501, 502. What *soil* best adapted to beans and peas? Influence of a very rich soil? What of the crop on poor soils? Where may the Southern Pea be especially available in restoring poor soils? What mineral manures does the crop require? What kind of plowing does this crop demand? Why? How does the crop fertilize the soil?

503, 504. *Modes of Planting.*—If cultivated for grain and forage, what should be the mode of planting? If the crop is to be plowed down for fallow, how may it be cultivated? First method given as practised in the Southern States? Second method? Method practised in North Carolina for fallow crop? Describe the fourth method. Why is this last method best where the peas are to be gathered? Why do they interfere so little with the corn among which they are planted?

505—509. *Mode of Gathering.*—If the crop is intended chiefly for manure, when should it be plowed down? Value of the seeds as a fertilizer? What question decides the time for plowing down? How does chemistry settle this question? How does experiment settle it? How are the vines collected for forage? How cured? Their value as forage? Chief objection to their use? Method of curing given by Mr. Edmondston, of North Carolina? What varieties grow in the valley of Virginia? Of what crop may they prove an auxiliary? What instrument may be used in planting peas?

CHAPTER XXII.

TOBACCO.

510. THIS important Southern crop is becoming more and more widely cultivated, and the prospect of continued high prices is inducing many of our farmers to turn their attention to its culture, in portions of Virginia and other States, both north and south of us, where, in former times, people have grown up to manhood without ever having seen a growing crop of tobacco. While so many new hands are thus engaging in its culture, it becomes important to have the leading points and principles involved in its management collected and set forth in a concise, systematic, and accessible form. The following discussion of this subject is the result, first, of the writer's personal observations of the methods pursued by some of the most successful planters in Virginia and Kentucky; secondly, of information gathered from those familiar with the business; and thirdly, of gleanings from books and agricultural journals — especially the "Southern Planter."

511. CLIMATE. — Tobacco requires a long summer season to bring it to maturity. Hence, so far as our own country is concerned, the *best* tobacco can be cultivated only in the Southern States. *Elevation* has an influence somewhat similar to increase of latitude, not in the varying length of days, but in the lateness of Spring, and the early appearance of the cool nights and frosts of Autumn. This makes the culture of tobacco uncertain in the high and mountainous parts of Western Virginia, while a like risk is not felt in

the same latitude further east, where the elevation is not so great.

A variety, called the "Connecticut Seed-leaf," is beginning to be cultivated in considerable quantities in New England, and at present commands a good price. It requires a shorter season than the kinds cultivated farther south.

512. Soil.—Tobacco will grow upon almost any good soil, when well prepared by thorough tillage, but that best adapted to its culture is a rich, dry loam, newly cleared and brought under cultivation. Although the light clay and sand loams, well manured, are the most reliable for making the finest qualities of tobacco, yet the clay soils—even the stiff clays of the limestone formation of the Valley of Virginia—produce excellent crops, but they require free applications of rich organic manures to render them sufficiently porous. The sandy loam, which has been drifted down from the mountain-gorges, along the northwest side of the valley, is well adapted to the growth of tobacco.

513. Varieties.—"Owing to the great diversity of climate and soil in Virginia, a corresponding change is produced in the grades of tobacco raised throughout the State, yet she produces more valuable tobacco than any other State in the Union. The Orinoko and the Prior for manufacturing, and the White Stem and Big Frederick for shipping, both in strips and stems, are the most profitable to the planter of all the various kinds raised. Having had twenty years' experience in cultivating and manufacturing, and the last five years in selling the article, I am clearly of the opinion that, on all lands suitable, the Orinoko is decidedly preferable for manufacturing, from the fact that it is the only kind that is sweet by nature, if ripe. It should be sun-cured, or as much so as the season and circumstances will admit. If thoroughly ripe it is much easier to be cured of the right color (I know of no object in nature that is

nearer that color than the land-terrapin, which, doubtless, is familiar to every planter), and it stands manufacturing better. If cut before being ripe, it chews bitter, its color is forced, and it will not hold it. The Prior is a good kind to cultivate on all mountainous lands, as it stands the wind better than any other kind, being tough. For shipping purposes, I give the preference to the White Stem. It can be grown large and rich, is smooth and tough when cured, and loses less weight in the curing than any other kind."—*W. H. Brown*, "*Southern Planter*," Jan., 1854.

514. PLANT-BEDS.—The climate, the soil, and the variety to be cultivated, being all favorably determined, the first and one of the most important ends to be attained, in order to insure success, is to secure an *abundance of good plants.* To do this, the planter must look well to the preparation of his plant-beds. Of these he should have several, sown at different periods, or one very large one, divided into several parts, to be sown at different times. He will thus secure a succession of plants, and can then avail himself of the most favorable season for "planting out." The condition of weather for the germination and growth may be very unfavorable after the planting of one bed, but more favorable for one planted earlier or later. To meet all the contingencies that may arise, and still secure an abundance of plants, enough of ground should be sown to produce (if all portions do well,) a large excess over what the crop to be raised will require.

515. PREPARATION OF BEDS.—The general practice is to burn the surface of the beds before planting. A warm and dry locality, exposed to the sun, and well protected against cold winds, is most suitable. A southern or south-eastern exposure should be selected, if possible, having a loose, rich soil. It should be well cleared of roots, stones, and every thing that might interfere with a proper tillage of the sur-

face, or with the subsequent growth of the young plants. The burning process is then conducted by covering the bed entirely, or in part, with brush or logs previously collected, and igniting them at a time when they are dry enough to burn freely. The fuel should not be allowed to lie flat upon the ground while burning, but should be sustained upon cross logs placed beneath it. The whole bed need not be covered with fuel at one time; because, when one portion has been subjected to the fire for an hour or two, the burning fuel may be removed to another portion, and thus the several parts be burnt in succession. Some important effects are produced by this roasting process. In the first place, any seeds of grass, weeds, &c., which may be in the soil, ready to spring up with the plants, are entirely or partially destroyed; and secondly, the condition of the soil is improved by burning (§ 424), and by the quantity of ashes left upon it. Beds should generally be burnt just before they are sown; though, in some soils, it is better to burn and expose to frost a few weeks before planting. As soon as the surface is cool, *guano,* or some finely-pulverized manure *rich in ammonia,* and *clear of seeds of every kind,* should be freely applied, and the surface then be finely chopped up with the hoe, and smoothly raked. It will then be ready for the seed. "About two table-spoonsful of seed for every 100 square yards will be sufficient, and not too much. The seed are mixed with old ashes, and, to sow them regularly, it is best to sow one half over the bed, and the other half across the first sowing. It is then trodden, and thickly covered with brush." * The object of the covering with brush is to protect the young and tender plants against frost and sudden changes of weather, and at the same time to admit the air, and the light and heat of the sun. The covering is removed

* Wm. H. Jones, "Southern Planter" for November, 1854.

when there is no longer danger of frost. One bed, at least, should be sown during the Winter, and others betimes in the Spring, so as to multiply the chances for an early supply of plants. Then, for later plants, another sowing should be made at a more advanced period in the Spring.

Plants have been successfully grown by the application of guano abundantly, without the labor and expense of burning. —(*See "Journal V. S. Agricultural Society,"* Vol. II., pp. 69, 70.)

516. The fly is the great enemy of plant-beds. Various remedies have been tried for this evil, but none, perhaps, have succeeded better than the sprinkling of dry, fresh ashes, or newly-slacked lime, over the leaves of the young plants, by means of a sieve, or with the hand, as soon as the fly begins its depredations.

An occasional application of guano and plaster, during the growth of the young plants, has the effect generally of pushing them forward, so that they spring up rapidly in spite of the fly.

All weeds and grass should be pulled out of plant-beds as soon as they begin to make their appearance. To render the process of weeding convenient, and also to facilitate the drawing of plants, the beds are frequently divided into smaller secondary beds, four or five feet wide, with narrow walks between them.

517. Preparation of Soil.—This is a point of the very first importance in making a crop of tobacco. The soil must be both *rich and mellow*. If the land is *newly cleared*, all the undergrowth must be well grubbed out, and everything be burnt upon the land, or removed from the surface, which would impede the culture of the crop. This should be followed by two or three thorough coulterings, with strong teams, so as to break up as completely as possible all roots left in the soil. Hands should follow the coulter to cut out

and remove all the broken and exposed roots. The soil should be thoroughly plowed, and then listed and hilled in the best way, which the number of stumps present, and the general character of the surface will permit. Sometimes the hilling has to be done altogether with hoes, on account of the steepness or roughness of the ground. Such is often the case on the steep lands of those counties lying along the base of the Blue Ridge, and in many other places. At other times the soil may be first thrown up into beds or lists, and these be divided into hills with the hoes.

New land is generally the best for tobacco. But in the best tobacco-growing sections, the land is nearly all cleared, except so much as is required to be kept in timber for fencing and fuel. The preparation of *old land* is here the matter of most importance. The point to be attained is to get a rich soil, deep and well pulverized. Tobacco requires an abundant supply of ammonia, as well as mineral matter, especially lime and potassa, with phosphoric and sulphuric acids. Hence, guano and rich stable or hog-pen manures, lime, ashes, plaster, and the phosphates, are all valuable fertilizers for this crop, unless they are already present abundantly in the soil. It has been shown that ammonia is not generally abundant in soils that have been frequently cultivated without manure; hence, old land usually requires an application of some form of ammoniferous manure, to secure a full crop of tobacco. A good clover or pea fallow may be plowed down in the Fall, and manured well and re-plowed in the Spring, with sub-soiling, where the land requires it; then, if necessary, in order to get it fully pulverized, let it be stirred with shovel-plows, and well harrowed. This will mingle the manure thoroughly with the soil, as well as reduce the soil itself to the desired condition. If manure is not abundant, some guano should be mixed with it, and a smaller quantity will then answer the purpose. All *wet* lands must be *well drained* for tobacco.

518. LISTING* AND HILLING.—Listing here consists in throwing up small parallel ridges with the mould-board plow, at proper distances for the rows of tobacco. These ridges are often called "lists." The distance between the tops of these—or, in other words, the distance between the rows of tobacco—should be from 3½ to 4½ feet, varying with the soil and variety cultivated. The width should always be sufficient to allow the hands to pass between the rows, when the crop is fully grown, without danger of breaking the leaves. To secure uniformity of distance between the lists, it is best to lay off the ground first with single furrows, at the required distance, and upon each one of these, as a central line, throw up the soil equally from both sides, with the mould-board plow, until all the soil has been thrown out from the middle of the intervening spaces. The lists may then be divided into sections, out of which the hills are to be formed. The hills should be about 3 feet apart in the rows. This distance can be regulated, with considerable uniformity, by running a shovel-plow across the lists at right angles, making cross-furrows three feet apart. The sections into which the lists, or ridges, are thus divided, are then heaped up in the form of sharply-peaked, conical hills, thus to remain until they are to receive the plants.

519. The hilling serves several important purposes: (1) It elevates the plant, so as to prevent the points of its lowest leaves from reaching the ground so readily, and becoming soiled. (2) On soils which retain much water in wet sea-

* "*Listing*," in Southern agriculture, denotes: (1) The dividing of land into narrow strips by furrows, as in preparing it for planting corn. (2) The same term is used to indicate the process of throwing the surface soil up into small parallel ridges, out of which the tobacco hills are afterwards formed.

sons, the plants are kept with a large portion of their roots above the water which settles along the furrows. But if wet seasons continue long, the crop is always injured, notwithstanding the elevation of the hills. (3) The air has more free circulation beneath the leaves when they become large, if the plants are thus elevated.

520. Planting.—The season best suited for field planting, in Virginia, is from about the middle of May till about the middle of June, or later, in the southern part of the State. The process of planting can be carried on only when there is a considerable quantity of moisture in the hills, else just before there is a certain prospect of immediate rain; that is, just before or just after a rain. The hills are prepared to receive the plants, by having their conical tops cut off with the hoe, and the flat surface thus formed, pressed down or struck with the lower face of the same instrument, so as to form a compact soil to receive the roots of the plant. While this operation is performed by one set of hands, others should be engaged in setting the plants. A careful man should draw the plants from the bed, which can be done with the hand alone, if the soil of the bed is loose and moist; but if the bed has become somewhat hard, as often happens where there is much clay in the soil, the aid of a sharp flat instrument to pass under the roots may be necessary, as it is important to guard against bruising either the top or root of the young and tender plant.

Some of the weaker hands take the plants in baskets, and, following those engaged in flattening the hills, drop a plant at each hill; while others follow with sharpened sticks or pegs, with which they make holes in the centres of the hills, to receive the roots. Care should be taken to have the root extend straight downward in the hole, and not doubled back upon itself: it is then more certain to grow, and to grow well. The plant should be inserted low enough to have all the root completely covered, but not so low as to let the bud be below the surface. After the root has been inserted in the hill, the soil is firmly pressed around it. If the ground is not very moist, or if the sun is very hot, at the time of planting, a leaf of some kind, or a little handful of broken straw or chaff, should be laid over each plant till it has taken root.

521. The same ground should be passed over at every good planting season, for the purpose of *replanting*. Some plants of the first setting will have died, while others will have been destroyed by cut-worms. To secure a plant to every hill, then, the replanting may have to be repeated several times.

522. Another method of planting, differing a little from that just described, is said to be pursued by a very intelligent and successful planter in Buckingham county. His land is prepared and listed in the method just given; but instead of making hills, he lets the ridges (lists) stand as they are thrown up by the plow, until he is ready to plant The tops of the lists are then flattened, and at the same time compressed, by running a one-horse roller along them from end to end. The roller is made sufficiently long to rest upon two lists at the same time, while the horse that draws it walks between. There is, moreover, an attachment to the roller for marking off the stations for the plants, at a uniform distance. This consists of pegs projecting from the surface of the roller, and so situated that each one will make a hole for a plant at every revolution; while those at the same end are just as far apart on the surface of the roller, as the plants are to be distant in the rows. If the diameter of the roller is near *two feet*, the circumference will be about *six*. Now two pegs, placed on opposite sides of a roller of that size, would, during its revolutions, mark off spaces of three feet each; that is, two spaces for every revolution. Each end

of the machine may thus be made to flatten the top of a list, and at the same time leave holes prepared to receive the plant. The difficulty of making a single peg always strike the centre of the list as it comes around, may be obviated by having several pegs near together, in a line running lengthwise. Some one of these will be certain to leave a hole near enough the middle of the list for the plant. The plants are next dropped and set by hands following the roller.

523. This method has the advantage of substituting *cheap* horse-labor for more expensive hand-labor; but it may have more than compensating disadvantages. In rough or stumpy land, it would be impracticable. It omits the neat hoe-dressing applied in hilling. The plants are in rows in only one direction, and, consequently, cross-plowing cannot be done. Still, the plan is worthy of a fair trial, and on many fields may greatly economize labor. The substitution of horses or mules for men, is a point at which all farmers should aim, wherever such substitutions can be made. The hire of a first-class hand for one year, would buy a good mule; while the expense of keeping the hand one year would feed the mule for two years. Then in many operations the mule, with a little *management*, can be made to do the work of two or three good hands.

524. Culture.—The two leading objects to be kept in view in the culture of tobacco, are the same as those mentioned in connection with the culture of corn: (1) All weeds and grass must be kept down; and (2) the ground must be kept mellow and well aired. The culture should be commenced as soon after planting as possible, and kept up constantly until the plants are too large for its continuance. Within a week or two after planting, the soil on the surface of the hills may become crusted, especially in clay soils; also, grass and weeds may begin to make their first appear-

ance. In either case the hoe should be applied, to scrape down the surfaces of the hills. A clean, loose surface will thus be formed around the plants. This should be followed by a deep plowing, which should be made so close to the rows as to cut down a considerable portion of the hills, the mould being thrown out into the spaces between the rows. Guano, or a mixture of guano and salt, should then be applied. By a subsequent plowing within a week or two, the soil should be thrown up again to the rows, and the hills again dressed up with the hoes. The kind of plow used must be determined by the character and condition of the soil. To a firm soil, the coulter should be first applied to as great a depth as possible; then the shovel, or small mould-board, for throwing the earth to and from the hills. In short, the best means should be adopted for accomplishing the two objects above mentioned.

525. Priming and Topping.—When the plant has grown to the height of two or three feet, a round bud will make its appearance in the centre of the plant. This is the *flower-bud*, and is called the "button" in some parts of Virginia. At this period of growth, some of the lower leaves should be pulled off, so as to leave the stalk naked for five or six inches above the ground. The stripping of these lower leaves is called "priming." At the same time that the priming is done, the flower-bud is broken or nipped off with the thumb and finger. If the plant is sufficiently large, it may be topped before the flower-bud appears, by nipping out the central leaf-bud. "There is great difference of opinion as to the proper height of topping. From 8 to 20 leaves are recommended—the latter for manufacturing. If the tobacco is pretty forward and the land rich, at first, prime off just enough of leaves to hill up the tobacco well, and top to 12 or 14 leaves. Continue to top to 12 leaves until 1st of August, then top to 10 until middle of August, and from that

time until 1st of September top to 8, afterwards to 6."* If the topping were omitted, the flower-bud would soon be developed into a branching top, full of clusters of flowers, from which the seeds are afterwards produced.

526. SUCKERING.—Soon after the topping is done, the axillary buds at the bases of the leaves begin to grow rapidly, and, if let alone, form branches of the main stalk. They are called "suckers," and must be broken out as soon as they are large enough to be caught with the thumb and finger. This process has to be repeated from time to time, as new suckers make their appearance. Meantime the green worm will have commenced its ravages, and must be carefully picked off and destroyed; otherwise, it will soon disfigure and greatly injure the crop.

527. The *philosophy* of priming, topping, and suckering is easily understood when we refer back to what has already been said (Chap. XI) on the physiology of plants. All parts of the plant are designed to aid in its mature growth, and ultimate production of seeds. As the period approaches for maturing the seeds, nearly all the vital energy of the various organs seems to be directed towards, and expended upon them. If the first flower-bud is removed, the natural vigor of the plant is not destroyed, but only diverted towards the leaves and axillary buds, strengthening the former, and causing the latter to spring up as suckers. But when the suckers are removed, the whole vigor of the plant is concentrated in the remaining leaves. A choice of the most perfect leaves is made by "priming off" those nearest the earth, and which not only would not themselves attain a vigorous growth, but would exclude the air and light too much from the middle leaves of the plants, which are always the most vigorous. The number of leaves left in topping is determined in part

* Southern Planter, Nov. 1854.

by the apparent strength of the plant, and in part by the length of time it has for maturing its leaves. The more forward plants have a longer season of growth after topping, and can hence bear a greater number of leaves; while the later ones must be topped lower.

528. CUTTING.—The maturity of the plant, and consequent fitness for cutting, is indicated by the points and edges of the leaves curling downward, the leaf becoming thick and brittle, and its surface assuming a yellowish spotted (piebald) appearance in some varieties, and on some soils, especially new land; and a fine glossy appearance in others. At this stage, the plant contains more of those ingredients which subsequently give value to it, than at any period either earlier or later. It should then be cut, and not till then, unless it is becoming fired,* or is in immediate danger from frost. The cutting consists in splitting the stalk with a sharp, thin-bladed knife, down nearly to the lowest leaf, and then cutting it off just below this leaf. As the plants are cut, they are inverted between the hills, and allowed to remain in that position a few hours, until they are sufficiently wilted to be handled without being broken. They are then collected and placed (8 or 10 together) upon sticks, and hung upon scaffolds in the open air, or in the tobacco barn.

529. CURING.—The process of curing is a matter of the highest importance. On it depends, to a very great extent, the market value of the crop. It should, therefore, be attended to with great care. The modes adopted vary somewhat with the end for which the crop is designed. "Tobacco for manufacturing purposes should be exposed to the air on scaffolds; and if ripe and sun-cured, it will have that

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* The "Black Fire" is a disease which is often very destructive to the tobacco crop. It produces decayed spots over the leaves. A mixture of *common salt* with guano is recommended as a preventive —*Southern Planter*, May, 1858.

sweet, aromatic flavor so peculiar to good tobacco. * * * After cutting, it should be carried to the scaffolds and hung, about 8 plants to the stick, and closed on the scaffolds for the purpose of sweating, by which process the green color is expelled, and the tobacco becomes yellow, which is far preferable."* It should then be removed to the barn, to be fully cured by firing. "If time will allow, and the weather is not threatening, I prefer housing the tobacco without scaffolding. It will yellow as well, crowded in the barn, as on the scaffold; and all danger of injury from rain is avoided, as well as the loss of some from the effects of the sun. * * * It is carried from the field, crowded as closely as possible on the tiers, and permitted to remain from 6 to 8 days, or longer, until it is yellowed sufficiently; then it should be opened, and the sticks arranged in the barn for firing. The sticks should be placed from 6 to 8 inches apart, and may be placed a little closer in the roof than in the body of the barn."†

530. CHEMISTRY.—During the process of curing, tobacco undergoes important chemical changes. Its peculiar properties are owing to the presence of several remarkable compounds, of which one called "nicotine," and another called "nicotianine," are most important. *Nicotine* is an alkaline substance, and has the form of an oily liquid when separated from other compounds. In its concentrated form, it is a most deadly poison; but when taken in the dilute condition in which it reaches the stomach in chewing, or the lungs in smoking "the weed," its effects are greatly modified. The quantity of nicotine varies in the different qualities of tobacco cultivated in the same region, and still more does it vary in that cultivated in different countries. The Havana has about 2 per cent of nicotine, hence its mildness. Virginia (best manufacturing) tobacco has 5 or 6 per cent,

* T. D. Edmunds.

† Wm. H. Jones, of Mecklenburg.

while the stronger varieties have about 7 per cent. The French tobacco has from 3 to 8 per cent of nicotine, according to the region in which it grows. *Nicotianine* is a more volatile substance than nicotine, and is more odoriferous. The pleasant odor of good tobacco is due to this compound chiefly.

531. The nicotine and nicotianine do not exist in the green leaf, but are formed during the curing of the tobacco, from substances already in the plant in variable quantities. If the leaves are dried very rapidly, these compounds are not fully formed; and if the heat is raised too high in firing, they may both disappear to some extent, by being either volatilized or decomposed. They both contain nitrogen, and, like all other compounds containing that element, are readily decomposed. Hence the firing should be commenced at a low temperature, which should be gradually increased, and may be advantageously suspended at night. The temperature should never rise above 120°.

532. Tobacco-barns should be closely planked, or in some way made close, having windows for ventilation, which may be opened or closed at pleasure. Smaller, and hence safer fires, will be sufficient in such houses. Curing yellow tobacco with *charcoal* at a high temperature, kept up day and night, is recommended.*

"It is best to fire all grades of *shipping* tobacco, and cure it a dark nutmeg color. * * From 24 to 36 hours after cutting, if the tobacco is ripe—if not, from 36 to 48 hours, according to the weather—seems to be about the right time to commence firing. Begin with small fires, and bring the tobacco to a proper state, and then increase the fires." †

533. STRIPPING, &c.—After the tobacco has been fully

* See Southern Planter, Oct. 1858.

† Wm. H. Brown, Richmond.

cured, the next step is to strip the leaves from the stalks, and tie them up in little bundles ("hands,") to be pressed ("prized,") into hogsheads for market. The two points requiring most attention in stripping are, first, to have the tobacco in proper "order;" and, secondly, to assort carefully, so as to separate the different qualities.

534. The tobacco is in "order" when the leaf, or rather the blade of the leaf, is sufficiently moist to be pliant, and yet the stems dry enough to break off readily from the stalk. This condition can be secured only in the beginning of a spell of damp weather. After the weather has continued damp for some little time, the moisture penetrates the stems, as well as the thinner parts of the leaves, making them too tough to be easily broken from the stalks, and rendering them liable to mould when wrapped together, or when the tobacco is laid down "in bulk." If the stems have thus become pliant, the tobacco is in "too high order," and must be thoroughly dried, and allowed to come in order again before the stripping can be done.

535. A large quantity may be kept in order for stripping, by packing it down when in the proper condition, upon an elevated platform extended along one side of the barn. This is called "bulking." The tops of the plants must be lapped over each other in the middle of the pile, the lower end of the stalks being turned outward. The whole mass must then be covered up with straw, or something else, which will preserve it in order until it can be conveniently stripped, which is generally at times when the weather is unfavorable for out-door work.

536. The business of *assorting* requires both care and judgment. It should, therefore, be the business of the most experienced and trustworthy hands. It is accomplished chiefly during the process of stripping, but may be made more complete by the hands engaged in tying, attending

properly to the sorting out of such leaves as do not properly belong to the quality upon which they are engaged. The number of grades or qualities must be determined by the purpose for which the crop is designed. Where the only object is to make the dark shipping tobacco, the best leaves are assorted, according to size and quality, into first and second quality of "leaf;" while the lower leaves of the stalks, together with any others that may be injured or ragged, form first and second qualities of "lugs."

If the crop is designed for the manufacturer, the color, as well as other qualities, must be taken into account. The dark and yellow colors must be first separated into two general classes, and then each of these again assorted according to their several "qualities."

537. When the assorting and tying have been completed, the bundles should be "bulked down," unless the stems are found to contain so much moisture as to be in danger of moulding. It should then be hung up on the sticks, and dried. It is always thoroughly dried before prizing. Then, at the first favorable time before prizing, it should be again packed down in bulk. The bundles should be carefully straightened in packing down; and, when it is afterwards transferred to the hogsheads, the same, or still greater care, should be taken to have every leaf straight, and in its proper place. The hogsheads usually contain about 1300 or 1400 pounds.

The price of tobacco depends very much upon *the skill with which it has been cured*, and *the care bestowed upon the assorting, tying, and subsequent handling.*

QUESTIONS ON CHAPTER XXII.

§ 510, 511. What is said of the extension of the culture of *Tobacco?* What *climate* is best suited to this crop? Why? Influence of elevation?

512. *Soil* best adapted to tobacco? What of the clay soils? What of the drift deposits in the valley?

513. What gives rise to *variety* of grades in tobacco? Variety best for manufacturing? For shipping? To what lands is the Prior adapted?

514–516. Why do *Plant-beds* require special attention? How is a succession of plants to be secured? Why important? The general practice in the *preparation* of beds? Locality selected? Preparation of the ground? How is the *burning* conducted? Effects of burning? When should beds be burned? What is said of the application of guano? How are the seed prepared? How planted? Time of planting? Growing of plants without burning? Great enemy of plant-beds? Remedy? What application should be made dnring the growth of the plants? Attention to weeding?

517, 518. What is especially required in the *preparation of the soil?* How is new ground to be managed? How is the hilling performed? Preparation of old land? What fertilizers are especially required by tobacco? What fallow-crops make a good preparation for tobacco? How must wet lands be treated? What is meant by *listing* tobacco land? Proper distance between the rows? How is uniformity of distance secured? Distance between the hills?

519. *Hilling?* First purpose served by hills? Second? Third?

520. *Planting season?* How are the hills prepared to receive the plants? Describe the process of planting.

521, 522. What of *replanting?* What method of planting without hilling is described? Detail the process. Advantage of this method?

524. Leading objects to be observed in *culture* of tobacco? When commenced? How conducted?

525–527. When are *priming* and *topping* commenced? What is *priming?* What is *topping?* What determines the number of leaves to be left? What renders *suckering* necessary? How performed? Explain the philosophy of pruning, topping, and suckering.

528, 529. When is the plant fit for *cutting?* How indicated? Why is it then most valuable? How is the cutting performed? What is next to be done? Why is the process of curing a matter of great importance? How is manufacturing-tobacco cured?

530–532. What *chemical* changes take place in the curing of tobacco? What substances are formed in the tobacco? The properties of these? Quantity of *Nicotine* in different varieties? Influence of drying the leaves very rapidly? Effects of too high temperature? Advantage of closely-planked barns? Curing with charcoal? How should *shipping* tobacco be fired?

533–537. In what does the *stripping* of tobacco consist? Two points to be observed? When is tobacco "in order"? When should it be laid down in bulk? How may a large quantity be kept in order? What does the business of assorting require? What points decide the quality of tobacco? What process follows stripping and tying? On what does the price of tobacco very much depend?

CHAPTER XXIII.

COTTON.

538. The following remarks on the planting and culture of cotton are compiled chiefly from the "Cotton Planter's Manual" (J. A. Turner). All the leading points to be observed in the management of this great Southern crop are believed to be here presented. Modifications, of course, must be made to suit differences in soil, climate, &c. Those who wish to investigate the subject fully are referred to the valuable "Manual" above mentioned, and to Southern Agricultural Journals.

539. Kind of Soil.—"The first inquiry which presents itself is, to know what are the peculiarities of those soils which suit the growth and maturity of cotton. Experience is, perhaps, the safest and most reliable test, in the settlement of this question—and it is now pretty universally conceded, that our best cotton lands are those which are of deep and soft mold, a sort of medium between the sandy and spongy, and those soils which are hard and close—those which are penetrated by the warming rays of the sun, imbibing readily the stimulating gases of the atmosphere, and which allow the excess of rain-water to settle so deep into the earth, as to lie at a harmless distance below the roots of the young plant. These are the properties of soil needful to the vigorous growth and early maturity of the cotton plant; and the knowledge of this fact is of great, and perhaps I might add, indispensable importance, to its successful cultivation. For though we may not find, and indeed it is very improbable that we should often find, all these essentials in

the selection of a farm, yet by the aid of the plow, the hoe, and the spade, and the incorporation of foreign substances, we may remedy many defects, and supply many of the peculiar demands of this plant.

540. PREPARATION OF SOIL.—"The best and most important part of the work in cotton making, consists in a judicious and proper preparation of the soil for planting. It is difficult to say, in all cases, and in the varied condition in which lands are found, and the diversity of soils, what the process of preparation should be; but we lay down general principles for our government, and results to be obtained, and leave the planters to the selection of the best means at command for their accomplishment. All lands for cotton ought, before the crop is planted, to be broken deep, close, and soft; and this to be done long enough before planting to allow the rains gently to settle them. It is the most common and perhaps the best plan, to prepare all lands intended for cotton, in beds made by the turning-plow; and in flat and wet lands, sometimes an additional elevation ought to be given, by drawing up the beds with the hoe. I think, in this work, we have often followed too much the example of our neighbor, and have looked too little to reason, in the indiscriminate bedding and high elevation of all lands. I am the advocate of deep, soft beds, made by very thorough and close plowing, but cannot consent to the necessity or benefit of elevating much lands which are warm and dry, and which are not subject to inundations from excessive rains. For the convenience of culture, I would have the young cotton stand on a slight elevation; but when the condition of the land did not require it, I would not give it more."—*Col. Chambers's Essay*, pp. 11–13.)

541. MANURES.—"Every kind of compost, green crops turned in, cotton-seed, and even naked leaves listed and left to rot, improve this crop. When planted on cotton-seed,

and sometimes on strong stable manure, it is more difficult to retain a stand, owing, probably, to the over-stimulus of these strong manures. So, on leaves, unless well-rotted, the cotton will long continue to die, in consequence of the leaves decaying away, and exposing the root too much to sun and rain. These difficulties may be avoided by a little pains; and by no means justify the opinion entertained by some, that cotton should never be planted on freshly-manured land. The only question is the cost of the manure. A great deal may be made on every plantation, without much trouble or expense, by keeping the stables and stable-yard, hog and cow-pens, well supplied with leaves and straw; and also from pens of corn-cobs, sweepings from negro and fowl-house yards, and rank weeds that spring up about them, collected together, and left to rot. Whenever the business is carried further, and a regular force is detached to make manure at all seasons, and entirely left out from the crop, it becomes the owner to enter into a close calculation of the cost and profits. In many agricultural operations, such a course the experience of all countries has proved to be profitable; but these operations partake more of the farming and gardening, than planting character; and whether the same method will do for the extensive planting of short-staple cotton, remains, in the opinion of your Committee, yet to be tested. If anything like an average of past prices can be maintained, it is certain that more can be made by planting largely than by making manure as a crop. If, however, prices continue to fall, and the growing of cotton be confined to a few rich spots—those susceptible of high manuring—then our whole system must be changed, our crops must be curtailed, and, staple-labor losing its past value, the comparative value of a cotton and manure crop will preponderate in favor of the latter. As a substitute for manuring on a large scale, resting and rotation of crops is resorted to. In our right level land, the practice of resting cannot be too highly recommended; and, by a judicious course, such as resting two, and planting two, or at most three years, our lands may not only be kept up forever, but absolutely improved. From rotation of crops, but little is done for cotton. After small grain — whether from the exhausting nature of that crop, on light lands, or because the stubble keeps the ground rough and porous—cotton will not do well. After corn it is difficult to tend, as, from our usual manner of cultivating corn, grass is always left in full possession of the field. It does best after cotton, or after a year's rest. Rest is the grand restorer, and the rotation chiefly required in the cultivation of cotton."—*Gov. Hammond's Report*, p. 27.

542. APPLICATION OF MANURES.—Dr. Cloud, after various experiments, says: "I determined upon a new mode of application entirely, which consisted in spreading all the manure used broadcast. This was done by hauling the manure out on the land, and depositing it in heap rows, say thirty feet apart, and the heaps thirty feet apart in the rows, with ten bushels of manure in each heap. The cotton-rows being first laid, the manure was spread broadcast, and the land bedded out. On or about the 10th of April, the cotton-seeds were planted after a spacer, by which the hills are regulated precisely as desired. The result was a perfect stand, with the cotton healthy, and all of the same age. There is no difficulty in understanding the difference here in favor of broadcasting the manure, and in bedding out the rows. It is not deposited a half-gallon in a place, but is incorporated evenly throughout all the soil. The consequence is, that however rich the manure may be in alkaline matter, its thorough incorporation with the soil, so quickly and effectually dilutes it, as to render it entirely innoxious to young cotton. There was no part of the experiment that gave me so much satisfaction as this. Every planter knows

the value of a first uniform and perfect stand. I use the term perfect, because, by the use of the spacer, I approximate nearer a perfect stand than it is possible to accomplish by any other process."—*Dr. Cloud's Experiments*, p. 72.

543. PLANTING.—"The *distance* to be given is the next inquiry to be considered. This is a very important object, and one upon which we are very dependent for success; and yet it must be varied very much by circumstances, some of which are beyond our knowledge or control. The general principle may be stated, and then our best judgment must guide us in its application.

"When the crop is at maturity, the branches of the stalks ought slightly to interlock every way. We cannot, therefore, do better in planting, than make an estimate of the probable average to which the weed will grow, dependent, of course, upon the vicissitudes of the seasons. It would, therefore, be vain to attempt to be more specific in directions, which must be varied always to suit the varied character of the soil. This whole question, then, is to be settled upon the principle already stated. The planting should be in drills, chiefly because of the difficulty of obtaining good stands in hills; and I would add, for the information of those who may be without experience, that in the common medium lands of the country, these rows ought ordinarily to be about five feet apart, and the stalks in the drill should be thinned, so as to stand from fifteen to twenty inches from each other. The width of the rows, and the distance in the drill, may be increased upon better lands; and in some cases of very thin lands, it may fall a little below the distances designated. I do not regard it as a matter of indispensable importrnce, but should decidedly prefer that the rows should run in such direction as to give the plant the largest benefit of the sun, from early morn to its setting. The cotton is decidedly a sun plant.

544. The Mode of Planting.—"Here we have many plans, all setting up claims to some peculiar merit. With the preparation which I have indicated, it would hardly be necessary to stop to discuss the relative merits of these modes, or seek to do more for the accomplishment of our purpose than to select some one, which we know to answer well. I therefore advise the use of some small and very narrow plow for the opening furrow. This should be run in the centre of the bed, opening a straight furrow of uniform size and depth. In this the seed should be strewed by some careful hand, scattering them uniformly along the furrow, just thick enough to secure a good stand the whole length of the row. These I would cover with a board, made of some hard wood, an inch or an inch and a half thick, about eight inches broad, and thirty inches long, beveled on the lower edge so as to make it sharp, slightly notched in the middle so as to straddle the row, with a hole bored in the centre one inch from the upper edge, and screwed on the foot of a common shovel or scooter-plow stock. This wooden scraper and coverer, when drawn over the row, covers the seed nicely, leaving a slight elevation to prevent the settling of water, and dresses the whole surface of the bed neatly for the space of fifteen inches on each side of the drill. Thus all clods or obstructions are removed, and a clean space is left wide enough for the passage of the plow in the first working between the young cotton and the rough land. This is an advantage of much importance with a crop so tender and small as cotton at this stage.

545. Culture.—"As soon as the young cotton is up to a good stand, and the third and fourth leaves begin to appear, the operation may commence. In lands which are smooth and soft, I incline to the opinion, that the hoes should precede the plows, chopping into bunches, passing very rapidly on, and let a careful plow-man follow on each side of the

drill, throwing a little light dirt into the spaces made by the hoe, and a little also about the roots of the cotton, *covering, and leaving covered*, all small grass which may have sprung up. This is, indeed, the merit claimed for the operation that, after the hoes have passed, the plows come on and effectually cover and destroy the coat of young grass then up. This is known to practical planters to be the crop of grass which escapes the hoe, and does mischief to the cotton. But when the land is so rough as to endanger the covering of the cotton with the plow, the operation must be reversed, and the hoes follow the plows. All that is now proposed to be done is a very rapid superficial working, reducing the crop to bunches, soon to pass over and return again, for a more careful operation. This should be done as soon as possible, as will be indicated by the necessities of the case. The grass and the weeds must be kept down, and the stand of cotton reduced. At this first working, unless in lands already very soft, I should advise the siding to be close, and to be done with some plow which would break and loosen the earth deep about the roots of the young plant. Others may theorize as they choose, but with a plant sending out a tap-root, upon which it so much relies, and striking so deep into the earth, as that of cotton, I shall insist upon its accommodation, by providing a soft, deep, mellow bed, into which these roots may penetrate.

546. "In the second working, the plows should in all cases go before the hoes, and in all lands at all tenacious or hard, let the work be deep and close again, and the middle of the rows also be well broken up at this time. Now the hoes have an important and delicate duty to perform. The cotton is to be reduced nearly to a stand, though it is now rather early to be fully reduced. It is, perhaps, best to leave two stalks where one is intended to grow. The young stalk is very tender, and easily injured by bruises and skins

from rough and careless work, and it is much better to aid a little sometimes with the hand in thinning, than to spoil a good stand by bruises from the hoe. The cut-worm and the louse are charged with many sins, which ought to be put down to careless working at this critical stage of the crop. The distance to be given I have before stated, and, in the first operation of bunching, this ought to be looked to, and the spaces regulated accordingly. At this second passing over, the hoes must return a little soft dirt to the foot of the stalk, leaving it clean and supported. If this work is well done, the weed will grow on, without any necessity for further attention for some twenty days or three weeks, when the plow should return again. At this time, some plow should be used next the cotton, which will tumble the soft earth about the root, covering the small young grass which may have sprung up since the last working, but the plowing should be less close, and shallower than the former working.

547. "The hoes have much to do in the culture of this crop, and must be prepared to devote pretty much all their time to it, constantly passing over, and perfecting that which cannot be done with the plows, by thinning out surplus stalks, cleaning away remaining bunches of grass, stirring about the roots of the plant, and, if need be, adding a little earth to them. It is difficult, in a treatise of this sort, to say how often, and in what manner, this crop should always be worked, when the character of the seasons, and the difference in the land, must have necessarily so much to do in settling this question. The general rule must be, to keep the earth loose and well stirred; the early workings to be deep and close; and as the crop comes on, and the fruit begins to appear, let these workings be less close, and shallower, keeping the soil soft and clean. It is of great importance to work this crop late, and it should not cease until the branches lock, or the cotton begins to open. I do not con-

sider that it is necessary to pile the earth in large quantities about the roots of the cotton, but think the tendency of all the workings should be to increase the quantity.

548. SELECTION OF SEED.—"The selection of seed is an interest not to be disregarded. We have been humbugged a great deal by dealers and speculators in this article, yet we would greatly err to conclude that no improvement could be made. We should, however, save ourselves from this sort of imposition, and improve our own seed, by going into the field, and picking each year from some of the best-formed and best-bearing stalks, and thus keep up the improvement. Great benefits may often be derived by changes of seed in the same neighborhood, from differences of soil, and occasional changes from a distant and different climate, may be made to great advantage.

549. PICKING.—"The picking of cotton should commence just as soon as the hands can be at all profitably employed—say as soon as forty or fifty pounds to the hand can be gathered. It is of great importance, not only to the success of the work, but to the complexion and character of the staple, to keep well up with this work, so that, as far as possible, it may be saved without exposure to rain. The embarrassments to picking when once behind, and a storm or heavy rain shall intervene, mingling it with the leaf, and tangling in the burr, are just as great as to get behind in the cultivation of the crop, when much additional labor will be required to accomplish the same object.

"In the early pickings, when the seeds are green, some sunning is indispensably necessary; but, after some maturity and dryness, very little will be required. This must be determined very much by circumstances; but dew or rain-water should always be removed by drying upon the scaffold, before the cotton is bulked in the house. With proper care and attention, great improvement may be given to the complexion of the staple by a little heating in the bulk, extracting the oil from the seed, and imparting a slight cream to the color. This process, however, must be conducted with great caution and care, lest the heating proceed too far, and injury be done. It is easily checked by stirring and exposure to the air. It is an advantage to all cotton to lie in the bulk before ginning, and we doubtless often lose much of this benefit for want of sufficient house-room. Indeed, I think it a very common error in our plantation arrangements, not to build houses for this special object. The cotton, when ginned, ought to be so dry that the seed will crack when pressed between the teeth. It is often ginned wetter, but just as often the cotton samples blue. A gin should be used which will neither cut nor nap the cotton, but send out the fibre straight and smooth, so that when the samples are drawn, they will have the appearance of having been carded. This is greatly promoted by the largely increased number of brushes now added by the best manufacturers.

550. PACKING.—"The packing should be in square bales; and, without reference to freight, or any of these mere incidental influences, I think the weight of the bale should be fixed at about four hundred or four hundred and twenty-five pounds—to be in two breadths of wide bagging, pressed until the side-seams are well closed, or a little lapped, and then secured with six good ropes, the heads neatly sewed in; so that, when complete, and turned out of the press, no cotton should be seen exposed. These packages should be nearly square, for the greater beauty of the bales, but, still more, for the greater convenience with which they may be handled and shipped, saving the necessity for tearing the bags, and giving a better guarantee that they will reach a distant market in good order."—*Col. Chambers's Essay*, pp. 16–20.

551. *Remark.*—I do not pretend to endorse every position taken, and opinion expressed, in the above compilation. The writers are intelligent and responsible men, and have had personal experience in the matters about which they write. I have never lived in a cotton-growing region; and, therefore, have had but little opportunity of personal observation in the culture of this important crop. But, in addition to what has been given, I will venture a *suggestion*, based upon my general knowledge of the cultivation of the soil. One of the writers quoted speaks of *rest*, as "the grand restorer, and the rotation chiefly required in the cultivation of cotton." Now I venture to suggest a *pea fallow*, with gypsum and ashes, as probably much superior to "rest" for any soil. "Rest" can never restore to land what the crops are every year carrying away; and unless the rest is *employed* in the production of something which will collect organic fertility from the air, and improve the chemical condition of the mineral matter, which needs elaboration, it can certainly do but little for the *ultimate* improvement of the land.

QUESTIONS ON CHAPTER XXIII.

§ 538, 539. Is the proper *culture of Cotton* the same for all localities? *Soil* best adapted to this crop? Why?

540—542. What of *preparation of soil?* How should the soil be broken up? Why should cotton be planted on beds? Kind of *manures* suited to cotton? How is the cost of manure to be attended to? Modes of *applying* manure?

543, 544. How is the *distance of planting* determined? How should the planting be conducted? Width of the rows and distance in the drill? *Mode of planting* given?

545—548. First step in the *culture* of the crop? Use of the plow? When should the hoe follow the plow? Why should more stalks be left at the first thinning than are intended to grow? How long should the culture continue? Why is the *selection of seed* important?

549. When should the *picking* of cotton commence? When is sunning necessary? Influence of having the cotton well cured? What should be the condition of cotton when ginned? What kind of gin should be used? Why?

550, 551. In what kind of *bales* should cotton be *packed?* Weight of the bales? Why should the bales be square? Suggestion given as to *fallowing* for cotton?

CHAPTER XXIV.

ROTATION OF CROPS.

552. By "rotation of crops" we denote *the cultivation of different kinds of crops upon the same field, in a uniform order of succession.* This requires a systematic division of the land, as well as a systematic order of culture. For example, if corn, oats, wheat, and clover are the crops to be cultivated every year upon a farm, there must be at least one field, or one division of a field, for each. Then, if they are to be cultivated by a regular system of "rotation," they must succeed each other in the same order, on each of the several divisions of land. Thus, let A, B, C, and D represent the four fields, of which we will suppose, for the *first year*, A to be in clover, B in wheat, C in oats, and D in corn. The *second year* we may plant corn on the clover-sod of A, and, having sown clover-seed the first year on the wheat in B, we now have clover the second year on B. We sow wheat on the oat stubble of C, and oats on the corn stubble of D. The *third* year A is to be in oats, B in corn, C in clover, and D in wheat. The *fourth year* A is in wheat, B in oats, C in corn, and D in clover. In the fifth year we return again to the same order with which we set out on the first year, namely, A in clover, B in wheat, C in oats, D in corn; and so the order during the sixth, seventh, and eighth years, would be the same as that of the second, third, and fourth. Thus, these four crops may be made to follow each other in the same order, over a system of fields, for any number of years. This will serve as an example of a "rotation" of

four crops, or a four-field (or four-shift) system. Other systems of rotation will be given hereafter.

553. The leading object of any system of rotation should be, *to realize the highest profit from our land, and, at the same time, to preserve or increase its fertility.*

A fertile soil may contain a large excess of some of its ingredients. It may contain a great deal more lime, or potassa, or phosphoric acid, than would be exhausted by many years of constant cultivation. This surplus fertility can, of course, yield no profit to its owner, until it takes part in the production of crops; meanwhile, it must be as unemployed capital. The object, then, should be to make it productive as soon as possible, but under such management as will still retain enough of each element to secure constant fertility. Every crop taken from the land will carry away some portions of the fertilizing matter of the soil, especially those kinds which naturally promote its growth. But the same crop will take largely of some of these substances, and but little, comparatively, of others. The grain crops will remove potassa and phosphoric acid abundantly, while they take away less of lime and sulphuric acid. The leguminous crops, on the other hand, such as peas and clover, carry away lime and sulphuric acid much more freely than do the grain crops, while they require less of potassa and phosphoric acid than is required by the grains.

554. Again, while the grain crops exhaust the ammonia of the soil very rapidly, they absorb none directly from the air; but the leguminous plants are known to collect nitrogen (most probably in the form of *ammonia* *) directly from the air, and hence require less of this important fertilizer from the soil. On the contrary, such crops increase the quantity

* Some chemists think that these plants absorb *pure* nitrogen, and assimilate it; but this is not fully proved.

of ammonia, whenever they are turned down, and allowed to decay in the soil.

We see, then, that one class of plants will rapidly exhaust one set of *mineral* ingredients, while another class will exhaust a different set with equal rapidity. If one class of these crops were cultivated exclusively, it would, by and by, render the soil deficient in some of its elements, while others, required in less quantities, would still be present in excess. But if other kinds of crops were cultivated in rotation with these, then all the various elements would be consumed in somewhat uniform proportions. We see, too, that while the grains are exhausting the *ammonia* from some of our fields, the peas and clover are increasing the supply on others, and preparing them to nourish succeeding grain crops. They also digest mineral matter, and, as they decay, yield it as mineral food for the grain.

555. The *physical*, as well as the chemical, condition of the soil, may be benefited by proper rotation. In the cultivation of corn and tobacco, the land is kept clean, and deeply and frequently stirred, while, in the cultivation of wheat, no stirring is done after the crop has been planted. Then, in such a system of rotation as gives a crop to be turned down very frequently, there is a constant accumulation of humus, derived from the carbonic acid and moisture of the air, and incorporated into the soil, which tends to improve the majority of lands. The physical condition must be such as to enable the chemical changes, which promote fertility of soil and growth of crops, to go on freely; and also to bring about the most favorable connection between the plant and the soil.

556. Hence, any good system of rotation will have reference: (1) To the chemical condition of the soil — to the proper *preservation*, and yet *gradual consumption*, of its *mineral elements*, and to the restoration of the supply of

humus and *ammonia;* and, (2) To keeping the land in the best possible physical condition, by the varying culture adapted to the different crops.

557. CAUTION.—It must be remembered that while rotation may enrich a soil, if properly managed, so far as humus and ammonia are concerned, it can never increase the quantity of any mineral element present; but, on the contrary, every crop which is carried from the field, must carry some mineral fertilizers with it. These cannot be restored by plowing down clover and peas. The condition of the mineral matter already present, may be improved by these crops, and thus fitted for future use; but the *quantity* cannot be increased. Hence, the application of manures must accompany any system of rotation.

558. ORDER OF ROTATION.—The order in which any series of crops, embraced in a system of rotation, must succeed one another, may vary with variations of soil; but they should generally follow each other in such succession, *that the one may leave the soil in good order for the next which is to follow.* Tobacco or clover fallow leaves the land in good order for wheat, while the cultivation of wheat leaves it in a good condition for clover. But clover cannot conveniently succeed either corn or tobacco, because neither the season of culture, nor the condition in which these crops leave the surface, make their tillage a suitable preparation for clover.

559. The rotation adopted in different sections of country, must vary to suit the kind of products chiefly cultivated. Every section has one or more leading crops. These are the chief sources to which the farmer must look for his profits. In some places, corn is almost the sole grain to which attention is given; and, together with clover and grass, constitutes the whole product of the soil. In other places, tobacco is the chief object of attention; in others wheat, or wheat and corn with clover. Cotton, in some parts of the South, is the

leading crop, and all others are secondary to it. The system of rotation of one region, then, may not suit another having a different climate, and producing different crops, any more than the same time of planting will suit all places alike. Having the general principles here furnished before him, and some examples to be given hereafter, the planter must exercise his own *common sense*, aided by experience and *close observation*, in coming to a decision as to what system will best suit his climate, soil, and leading products. The crop which yields the highest return, in the form of *clear profit*, should be most highly favored in the rotation pursued.

560. MANURING.—Every farmer should not only have his regular system of rotation in cropping, but should also have engrafted upon this a system of manuring. In this he should look, *first*, to a speedy and abundant return for his capital and labor; *secondly*, to the permanent improvement of his land. If manures yield the greatest profit when applied to corn, let the corn be the chief crop to which they are to be applied; or if they are most profitable on corn to be followed by wheat, let them still be applied to the corn. Or if they pay better on wheat directly applied, or on wheat with the succeeding clover crop, let that point decide the question as to how they are to be used; and so, if they may be more profitably applied to tobacco, or cotton, let them go in that direction.

In some cases, it is best to *multiply* the quantity of manure by employing it first in the cultivation of clover, and then plowing down the clover as fallow. This may be advantageously done for either corn or wheat. The fertility of the manure (if applied in Winter or Spring) is taken up by the clover, and the quantity greatly increased from the air; while the mineral matter of the soil is also becoming incorporated with it. This crop afterwards turned down, gives far more fertilizing matter to the soil than would be afforded by the manure which it has consumed during its growth. The shading influence of the clover also tends to hasten the decomposition of any surplus portions of manure, left unfermented upon the surface of the field. Such manuring must then be followed by such a succession of crops as will make it "pay best." The systems given below will serve as a general guide on this point.

561. Division of Land.—Before any complete system of rotation can be successfully carried out, the farm must be divided into fields, or sections of fields, nearly equal. These must correspond in number with the number of years embraced in the rotation. Where the same crop is cultivated year after year for a long time, on the same soil, as may be done successfully in some cases, it is not a rotation at all. But we sometimes see two crops grown the same year on the same land, the one to be gathered, and the other to be turned down for manure. Corn and the Southern Pea may be so cultivated, where the summer season is long.* The peas are planted at the last working of the corn, and afterwards plowed down to enrich the soil for the next corn corp. This is the simplest form of rotation; but, as it embraces only one year, it requires only one field. If the two crops required two years for their growth, as in the alternate culture of wheat and clover, or of tobacco and peas, two divisions of land would be necessary. So, if the rotation includes any number, as four or five crops, each requiring one season for itself, there must be four or five fields. These are called "two-field, three-field, four-field rotations," etc., according to the number of fields or divisions included.

The number of crops is not necessarily equal to the number of fields. The same crop may appear more than once in

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* Journal Va. State Ag. Society, vol. ii. p. 165.

the series, as seen in Mr. Ruffin's "six-field rotation," given below.

562. A tabular view of several systems of rotation will now be given. These may serve as illustrations of what has been said, and may be useful as guides to the young farmer in arranging his own system.

The divisions of land, or fields, are indicated by the letters (A, B, C, etc.) at the tops of the columns containing the names of the crops. The successive years embraced in the rotation, in each case, are indicated by the numbers (1st, 2d, 3d, etc.) in the left-hand column.

TWO-FIELD ROTATION (*a*).

CROPS.—*Wheat and Clover.*

Years.	Field A.	Field B.
1st	Wheat,	Clover.
2d	Clover,	Wheat.

TWO-FIELD ROTATION (*b*).

CROPS.—*Cotton and Peas.*

Years.	Field A.	Field B.
1st	Cotton,	Peas.
2d	Peas,	Cotton.

These are very simple systems of rotation. The former (*a*) I have seen practised with success for a number of years together. The method of manuring in this case is to apply plaster and ashes to the clover, and the organic manures to the wheat when sown. The second system (*b*) is frequently adopted in some cotton-growing sections. Plaster and ashes may be applied to the peas—organic manures to the cotton.

THREE-FIELD ROTATION (*a*).

CROPS.—*Corn, Wheat, Clover.*

Years.	A.	B.	C.
1st	Corn,	Clover,	Wheat.
2d......	Wheat,	Corn,	Clover.
3d......	Clover,	Wheat,	Corn.

THREE-FIELD ROTATION (*b*).

CROPS.—*Tobacco, Wheat, Clover.*

Years.	A.	B.	C.
1st...	Tobacco,	Clover,	Wheat.
2d ...	Wheat,	Tobacco,	Clover.
3d ...	Clover,	Wheat,	Tobacco.

Each crop in both of these systems, it will be seen, has taken the round of all the fields. Manures may be applied very successfully as a top-dressing to the clover in Winter or Spring.

FOUR-FIELD ROTATION (*a*).

CROPS.—*Corn, Oats, Wheat, Clover.*

Years.	A.	B.	C.	D.
1st	Corn,	Clover,	Wheat,	Oats.
2d....................	Oats,	Corn,	Clover,	Wheat.
3d....................	Wheat,	Oats,	Corn,	Clover.
4th..................	Clover,	Wheat,	Oats,	Corn.

FOUR-FIELD ROTATION (*b*).

3 CROPS.—*Corn, Wheat, Clover.*

Years.	A.	B.	C.	D.
1st	Corn and Tobacco,	Clover,	Clover,	Wheat.
2d............	Wheat,	Corn and Tobacco,	Clover,	Clover.
3d............	Clover,	Wheat,	Corn and Tobacco,	Clover.
4th...........	Clover,	Clover,	Wheat,	Corn and Tobacco.

In the rotation (*a*) above, corn is planted on a clover sod. The corn leaves the land in fine condition for oats, while the latter on many soils is regarded as affording a good preparation for wheat. In the second case (*b*), it will be seen that each field lies in clover two years in succession. The clover should be cut at least once the first year, to secure a good crop the second year (§ 487). Manures, both organic and inorganic, should be applied at least once in every circuit of the rotation (*a*). The rotation (*b*) will improve any soil capable of producing clover, provided the fields are not pastured, if only mineral manures, such as ashes, plaster, and bone-dust, are applied. The growth of clover alone will give organic matter in large and yearly-increasing quantities. Where much pasturing is necessary, a greater number of fields must be embraced in the system.

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FIVE-FIELD ROTATION OF EASTERN VIRGINIA.

CROPS. — *Corn and Peas, Wheat, Clover, Wheat, Pasture.*

Years.	A.	B.	C.	D.	E.
1st.	Corn and Pea-fallow	Pasture....	Wheat......	Clover......	Wheat
2d.	Wheat	Corn and Pea-fallow	Pasture....	Wheat......	Clover
3d.	Clover......	Wheat......	Corn and Pea-fallow	Pasture....	Wheat
4th.	Wheat......	Clover......	Wheat......	Corn and Pea-fallow	Pasture
5th.	Pasture....	Wheat......	Clover......	Wheat......	Corn and Pea-fallow

This system gives one field in corn every year, upon which, at the last plowing, peas are sown broadcast, to be fallowed for wheat. Two fields are cultivated in wheat every year: one in clover, for cutting or fallow, or for both, and another in clover or grass, for pasture. As wheat is here the leading crop, unfermented manures should be applied to the clover to be fallowed; fermented manures, such as guano, to the wheat directly. This rotation is well adapted to a wheat-growing region far enough south for the growth of the southern pea.* *Tobacco* may be brought into this system, in connection with corn, as preparatory for wheat.

SIX-FIELD ROTATION (*Mr. Ruffin's*).

CROPS.—*Corn, Peas (broadcast), Wheat on Pea-fallow, Clover, Wheat on Clover-fallow, Pasture.*

Years.	A.	B.	C.	D.	E.	F.
1st...	Corn ...	Pasture	Wheat.	Clover..	Wheat.	Peas
2d ...	Peas ...	Corn ...	Pasture	Wheat.	Clover..	Wheat
3d ...	Wheat.	Peas ...	Corn ...	Pasture	Wheat.	Clover
4th..	Clover..	Wheat.	Peas ...	Corn ...	Pasture	Wheat
5th..	Wheat.	Clover..	Wheat.	Peas ...	Corn ...	Pasture
6th..	Pasture	Wheat.	Clover..	Wheat.	Peas ...	Corn

Journal of Virginia State Agricultural Society, vol. ii., p. 184.

This system differs from the five-field system given above, in allowing the pea crop the benefit of an entire field, and a full season of growth. It has been well tested, and is found highly improving to the wheat-growing farms of Eastern Virginia.

Various other systems of rotation are in use in different regions of our own and other countries. These have been given as specimens, *suggestive* to the young farmer.

563. SECONDARY ROTATIONS. — On every farm there are some smaller lots, set apart to be cultivated in such crops as could not be brought under the general system of rotation adapted to the main body of the farm. Such are the lots appropriated to potatoes, cabbage, &c. These, as well as the larger fields, should be cultivated according to the principles here laid down. Cabbage, potatoes, wheat, and clover, make a good series for a rotation.

A lot of the richest loamy soil, which can be conveniently set apart for this purpose, and of sufficient size to meet the wants of the farm, should be surrounded by a close, strong fence, proof against pigs, as well as larger animals. It should then be divided into four sections, A, B, C, and D, about equal to each other. The first year, let A be deeply broken up and sub-soiled (drained, if necessary), well dressed with manure, stirred thoroughly, and planted in cabbage, which is a highly nutritious vegetable, and very much relished by laboring men. If B cannot be conveniently brought under clover, let peas or some other fertilizing crop be substituted, as preparatory to cabbage the second year. Let C be sown with wheat, and D be cultivated in potatoes. This will introduce the rotation, which may then be kept up as represented in the following table:

Years.	A.	B.	C.	D.
1st...	Cabbage	Clover or Peas	Wheat	Potatoes
2d ...	Potatoes	Cabbage	Clover	Wheat
3d ...	Wheat	Potatoes........	Cabbage	Clover
4th ..	Clover or Peas	Wheat	Potatoes	Cabbage

The first crop of clover may be cut off every season, and either be fed green, or made into hay. The second growth should be left on the ground, and turned down in the Autumn or Winter.

564. Gardens.—The same principles which have been applied to field rotation are equally applicable to garden culture. The plots should here be arranged under a few general divisions. Each of these should then be sub-divided, and appropriated to plants of the same general character. Those that are cultivated on one of these leading divisions ought to be transferred to another the next season; then let plants of a somewhat different class succeed them. Thus the garden rotation may be kept up by *groups*, instead of single crops. Such root vegetables as beets, parsnips, and salsify, may be thrown into one group, and cultivated on contiguous beds; the different varieties of beans and peas naturally constitute another group; and so, by general similarity, by time of planting, or by some other circumstance, a convenient classification may be made, upon which a system of rotation can be based.

QUESTIONS ON CHAPTER XXIV.

§ 552. What is meant by "rotation of crops?" What is said of the division of the land? Explain the example given for illustration.

553. What should be the leading object of any system of rotation? How does the rotation of crops make the elements of fertility more profitable?

554. How does rotation affect tho ammonia of the soil? Whence

do crops get their nitrogen? What would be the effect of the long-continued cultivation of any one crop?

555. How may rotation improve the physical condition of the soil?

556. To what two points must a system of rotation have special reference, as far as regards the soil?

557. Can the humus and ammonia of the soil be increased by proper rotation of crops? Can the mineral fertilizers be increased in the same way? Why?

558. Is the same order of rotation suited to all soils? Why not?

559. Is the same system of rotation adapted to all sections of the country? What is said of leading crops? What must guide the farmer in deciding what system will best suit his purposes?

560. Is rotation in manuring important? What points require special attention? How may the quantity of manure be multiplied? How does clover increase the efficiency of manure?

561. How should the land be divided before introducing a rotation of crops? Under what circumstances may no division of land be necessary? What determines the number of divisions required in any case?

562. Of what use are the tabular statements given in this section? Explain the "two-field rotation." The "three-field rotation." The "four-field rotation." The "five-field rotation." The "six-field rotation."

563. What is said of secondary rotations? What illustration is given?

564. How may the principles of rotation be introduced into gardens?

CHAPTER XXV.

VALUE OF CROPS AS FOOD.

565. The leading object of the cultivation of the grain, grass, and root crops, is to provide food for man and beast. The value of any one of these products, then, must be determined by the extent to which it fulfils the end of its culture. This must depend upon its proximate composition (§ 133); that is, upon the quantity of nutritive matter which it contains. It has been stated, in Chapter VI., that the animal kingdom is dependent, either directly or indirectly, upon the vegetable kingdom for its subsistence. The proximate constituents which give value to plants have been described in the same chapter. Then, in Chapter VIII., we studied the proximate constituents of animal bodies. These latter are derived from the vegetable compounds, under the influence of vitality controlling the processes of digestion, respiration, secretion, &c.

566. The ingredients of plants which serve valuable purposes as food, are *starch*, *sugar*, *gum*, *proteine matter*, *oil*, *woody fibre*, *water*, and *salts*.

567. *Starch* is the most abundant element in grain crops, forming about one-half of the weight of the most common cereal grains; but in these the proportion varies to some considerable extent. Even in the same species of grain, the quantity of starch differs in accordance with the circumstances of climate, soil, and culture. The estimated quantities given must, therefore, be regarded as only the *mean* of a great variety of samples, serving merely as an approximation to the true proportion in any particular case. *Wheat* con-

tains from 40 to 50 per cent of starch, according to the variety, influence of climate, &c. *Corn* varies less widely in its proportion of starch, ranging from 40 to 45 per cent. The white, soft varieties of both wheat and corn abound most in starch. *Rye, oats, buckwheat,* and *beans,* do not vary widely from corn, nor from one another, in their percentum of this element. *Rice* surpasses all the ordinary grains in the quantity of starch it contains, having about 70 per cent. *Potatoes,* in the condition in which they are taken from the ground, have about 15 per cent. of pure starch; and even *hay* contains from 3 to 5 per cent.

568. *Gum* and *Sugar* are very similar to each other, and very similar to starch, in their nutritive value, as we shall learn presently (§ 576). They are found in nearly all of our cultivated crops, in quantities varying from 2 to 15 per cent. *Hay,* cut in good time, has more of these substances than we find in any of the ordinary grains, except rye.

569. *Proteine compounds* have been described (§ 154) as composed in part of nitrogen. They resemble most of the muscular and membranous organs of animals, and constitute the elements of food which nourish these parts of the animal body. As the greater part of the solid portion of the animal is made up of proteine matter, it may be regarded as consisting of the *concentrated proteine* of the food consumed during its growth. Hence we see the importance of this kind of food, in building up the animal system.

570. *Beans* and *peas* contain more proteine matter than is found in any other of our common crops. It exists here in a form called "legumen" (§ 157), and in quantity as high as 25 per cent. The cereals have from 10 to 20 per cent of this kind of matter, chiefly in the form of *gluten* (§ 155). It is most abundant on the inner surface of the bran, and is taken out largely with it, in the preparation of flour. This gives to wheat bran a nutritive value greater than its

appearance would indicate. This important kind of matter is also found in grass, hay, and to some extent in straw. Green clover, and clover hay, also hay made of pea-vines, owe much of their value to the presence of proteine matter. *Cabbage* contains not a little of it, and is hence quite nutritious. Of all the grain crops in ordinary use, none contain so little of this important element as rice.

571. *Oil* is found to exist in some form in almost every plant, and in almost all parts of every plant. In passing through the digestive organs, the vegetable oils undergo such modifications as convert them into the varieties of fat peculiar to different animals. Those grains which abound most in oily matter, within certain limits, are best fitted for food, where *fattening* is the leading object. Some seeds, such as those of flax, hemp, and cotton, contain too much oil to be fed alone. These seeds are ground into meal, and have their oil pressed out by machinery, for use in the arts. The cakes which are left,still contain enough of oil, together with their starch, gluten, etc. to make them valuable as articles of food for stock. *Indian corn* has a larger quantity of oil in it, than is found in any other of the cereal grains, having from 8 to 10 per cent. *Oats*, which have about 5 or 6 per cent, come next in order. *Wheat* and *rye* contain 2 or 3 per cent of oil, while *rice* and *buckwheat* have not more than 1. The oily matter in good hay ranges from 2 to 4 per cent, and it is by no means wanting in straw which has been cut in good time.

572. *Woody fibre*, when dried, is chiefly indigestible, and yet it serves an important purpose in promoting the digestion of other constituents of food, with which it is mingled. Its presence makes the mass of food porous, so as to be easily penetrated by the fluids of the digestive organs. It also keeps the stomach and intestines properly distended (§ 631, *b*). *Hay* and *straw* are composed to a great extent of woody fibre. In the grain crops, the bran contains most of the fibre.

573. *Water* is a constituent of the dryest articles of food. The ripest grain, and the dryest straw and hay, have seldom less than from 8 to 12 per cent of water in them, under ordinary circumstances. *Potatoes* contain about 75 per cent of water, while turnips, and other root crops of a similar kind, have as much as 85, and sometimes even more.

574. The *mineral elements* contained in food crops, are not to be disregarded in estimating their value. The animal system demands mineral as well as organic elements, to promote its growth and healthy development. The bones must be provided with phosphate of lime, and the fluids of the body with salts of soda and potassa. These, with other mineral substances found in the animal body, must have their origin in the food consumed. By referring back to Table III, it will be seen that the ashes of the grain crops contain most largely the phosphates and alkaline salts,—just the minerals chiefly demanded by the animal.

575. The following Table gives about the average composition of the crops most extensively used as articles of animal food; but as they vary in composition under changes of climate, and from other causes, the numbers here given must be regarded as giving only the *general average* in each case.

TABLE VIII.—VEGETABLE FOOD.

In 100 lbs.	Wheat.	Corn.	Rye.	Oats.	Buckwheat.	Peas.	Rice.	Potato.	Cabbage.	Meadow Hay.	Clover Hay.	Wheat Straw.	Pea Hay.
Starch	48	45	41	30	45	40	72	15	2	3	3	1	4
Gum and Sugar.	9	8	14	5	5	5	4	1½	3	12	13	7	10
Proteine Matter.	17	18	13	11	10	25	6	2	3	7	9	2	12
Oily Matter	2	9	3	5	1	3	1	½	½	3	4	2	2
Vegetable Fibre..	10	9	15	33*	26*	10	4	5	2	50	45	70	52
Water	12	12	12	13	11	14	12	74	88	15	16	12	15
Minerals in Ashes	2	2	2	3	2	3	1	1	1½	9	10	6	5
	100	100	100	100	100	100	100	100	100	100	100	100	100

* The chaffy husk of oats, and the black husk of buckwheat, are both composed chiefly of fibre.

In the foregoing Table, equal quantities (by weight) of the several crops are compared, and we are thus enabled to estimate the quantity of each of the proximate elements consumed with a given weight (say 100 lbs.) of each kind of food. If, for example, a horse consumes 100 lbs. of corn, he consumes of starch 45 lbs.; of gum and sugar, 8; of proteine matter, 18; of oil, 9. But in 100 lbs. of clover hay he eats only about 3 of starch; of gum and sugar, 13; of proteine matter, 9; of oil, 4. If 100 lbs. of potatoes were consumed, the corresponding quantity of starch would be five times as great as in the hay, but the quantity of other nutritive substances would be greatly less. The water, which constitutes the greater part of the weight of potatoes, has no money value, because it is easily obtained from other sources. So, we place a low estimate upon woody fibre, because of its abundance, though it is important in forage.

576. Of the substances which give to articles of food their chief value, we place the *proteine compounds first;* because they do most towards building up the animal system—they are most nutritious. In fact, they are often spoken of as constituting *the nutritious part* of food. They are certainly more largely appropriated in the nourishment and growth of animals, than are any other forms of food; but the oily portions, which may be regarded as next in importance in feeding, certainly deserve to be regarded as *nutritious;* for on these, to a great extent, the *fattening* of animals is dependent. *Starch, gum,* and *sugar* may be classed together, since they serve a like purpose in sustaining animal life. After undergoing digestion, they are all thrown into the veins, where they become a constituent part of the blood, to be consumed during respiration (§ 611). These are sometimes called "respiratory food," because they are chiefly consumed by the oxygen conveyed to the blood in breathing. They are not less essential to animal life than other forms of diet;

yet, from their abundance in vegetable products, they are not estimated at so high a value as the proteine and oily parts of plants.

577. To estimate the value of the crop grown upon a given piece of ground, we must not simply take into account the relative quantities of these three kinds of food (the nutritive, the fattening, and the respiratory) contained in a given weight of the crop, but the quantities contained in the whole product of the land. A hundred pounds of potatoes contain only about one-eighth as much proteine matter as the same weight of corn, one-ninth as much oily substance, and one-third as much starch. This shows that a given weight of potatoes is far inferior in value to the same weight of corn. But when we come to compare the products of an *acre* of land cultivated in corn, with the products of an acre cultivated in potatoes, the case stands very differently. In order to institute such a comparison, we may suppose that an acre which would yield 60 bushels, or about 3500 lbs. of corn, would, if properly cultivated, yield 400 bushels, or 20,000 lbs. of potatoes. Now, 3500 lbs. of corn contain, according to the preceding table (Table VIII), 630 lbs. of proteine, 315 lbs. of oil, and 1855 lbs. of starch, sugar, and gum; while 20,000 lbs. of potatoes contain 400 lbs. of proteine substance, 100 lbs. of oil, and 3300 lbs. of starch, sugar, and gum. If, then, we estimate the feeding value of these crops by the quantities of their proteine and oily substances alone, the corn has greatly the advantage, but if we bring the starch, etc. into the account, the potatoes again surpass the corn.

578. Let us now assume some relative value per pound, which may be attached to each of these three kinds of food. Suppose the starch, etc. in corn or potatoes to be worth one cent per pound for feeding stock, while the proteine and oily substances are worth three cents per pound. Then the acre

of corn will give starch, sugar, and gum, worth $18.55; proteine and oily matter, worth $28.35; total, $46.90, exclusive of the value of the fodder. The acre of potatoes will give starch, etc., worth $33.00; proteine and oily matter, worth $15.00; total, $48.00. Under the suppositions here made, the products are nearly equal; but the labor required by the potato crop is greater than that required by the corn, and for this due allowance must be made.

579. In order to compare at a glance the forage value of the *probable* products of an acre of several common crops, with reference to the three classes of food we have been considering, let us arrange them in tabular form. In the first column we place the probable average products in bushels and pounds; in the second, third, and fourth, the quantities of the three classes of food in each crop; and, lastly, the money value under the suppositions just made. *Wheat* is not included, because it is especially appropriated to man, and hence has a higher value than could be assigned it as forage. This Table must not be regarded as giving accurate estimates, but simply as indicating the proper method of comparing crops, so as to determine their relative value in feeding.

TABLE IX.—FORAGE VALUE OF SOME CROPS.

One Acre, producing			Starch, Sugar, & Gum.	Prote'e Matter.	Oil.	Money value (?).
Corn,	30 bus.	= 1,750 lbs.	927	315	158	$23.46
Oats,	40 "	= 1,300 "	455	143	65	10.79
Peas,	20 "	= 1,200 "	540	300	36	15.48
Potatoes,	200 "	= 10,000 "	1650	200	50	24.00
Cabbage,	10 tons.	= 20,000 "	1000	600	100	31.00
Clover Hay,	1½ "	= 3,000 "	480	270	120	16.50
Pea Hay,	1½ "	= 3,000 "	420	360	60	16.80

If the *peas* and the *pea hay* above given are both the product of the same acre of ground, as may be the case, the sum of their values is $32.28. When the fodder of corn and the straw of oats are preserved, these must be added to the grain crops.

In order to understand clearly the relation of the animal kingdom to the vegetable, and to comprehend the principles which should regulate the application of crops to feeding, and which should guide us in the general management of animals, we must direct our attention for a little while to some of the leading points of "Animal Physiology."

QUESTIONS ON CHAPTER XXV.

§ 565. What is the leading object of the cultivation of the soil? How is the value of a crop determined? What is meant by the "proximate composition of plants" (133)? Whence do animals generally get nourishment?

566. What ingredients of plants are valuable for food?

567. Which is the most abundant proximate element in the grain crops? Of what is starch composed? Is the proportion of starch constant in the same grain? What per cent. is found in wheat? In corn, rye, oats, &c.? In rice? In potatoes? In hay?

568. To what are gum and sugar similar in oomposition? Are they abundant?

569. What are proteine compounds (154)? Why are they important in the nutrition of animals?

570. What is here said of beans and peas? What is "legumen" (157)? How much of it in beans and peas? What is "gluten" (155)? Where found? Why is cabbage nutritious?

571. Is oil widely diffused? How does it become valuable in feeding? Do any grains contain too much oil to be fed alone? What per cent. of oil in the several grains?

572. Is woody fibre digestible? Why then has it any value? What crops are composed largely of this substance?

573. What is said of water in articles of food, and of its value?

574. Why are the mineral constituents of food not to be disregarded? What do you learn on this subject from Table III.?

575. What is given in Table VIII.? How are the several crops here compared? If equal weights of different articles have been

given to an animal, do they always afford equal amounts of nutritious matter? How is this illustrated?

576. What compounds stand first, in estimating the value of articles of food? Why are these placed first? What stands next in value? Why? Why are starch, gum, and sugar, classed together? What part do they perform? Why are they not as highly valued as proteine and oily compounds?

577. How can we fairly estimate the value of the products of a given quantity of land? What examples are given?

578. How may the value in money of different crops be determined? Illustrate.

579. What is the object of Table IX.? Why is wheat not included? For what reason should we now give some attention to "Animal Physiology"

CHAPTER XXVI.

ANIMAL PHYSIOLOGY.

580. ANIMAL PHYSIOLOGY treats of the functions performed by the various organs of animals. But in order to get a clear view of the offices fulfilled by these organs, we must examine their structure to some extent. We here have a very wide field, of which we can look only into a very limited portion. As every man should have some knowledge of the structure and functions of the organs of his own body, that he may know how to preserve them and promote their healthful action, so the farmer should have not only this knowledge with regard to himself and the members of his household, but also with regard to the different kinds of animals which stock his farm.

There is a close analogy between the organs of man and those of the lower animals. We shall frequently refer to this resemblance, and shall make use of the organs of man's body as *types* of the most perfect structure.

581. THE SKIN.—All the animals of which we shall speak have their bodies enveloped in a tough, elastic, external covering, which consists of two distinct layers. That which forms the outer surface is called the "cuticle;" * and that which lies next to the flesh is called the "true skin" (*cutis vera*).

582. The *cuticle* is generally very thin, and almost transparent. It has no blood-vessels or nerves, and may be removed from the surface without pain. On the palms of

* Also called "Epidermis."

the hands and soles of the feet it is made thick and strong, so as to protect these parts of the body, which are exposed to most constant friction and pressure. With a sharp knife or razor, thin shavings of cuticle may be cut from the front part of the hand, without exposing either nerves or veins. But if the whole thickness of the cuticle is removed, so as to expose the outer surface of the cutis vera, a smarting pain is felt, from the contact of the air with the nerves which are then laid bare. (See Fig. 49.)

The cuticle has various openings in it called "pores," through which the perspiration from the true skin passes out to the surface. There are other openings also, through which oily secretions are thrown off. The number of pores in the cuticle is immensely great. Wilson says, "2800 might be taken as a fair average of the number of pores in the square inch" of the human body.

The lower surface of the cuticle consists of a colored layer. The coloring matter is secreted under the influence of the light and heat of the sun. In this respect there is an analogy between the animal and vegetable kingdom. It has been shown (§ 179,) that the leaves of plants require the light of the sun to develop their coloring principle; so we find the human skin varying in color, in the same individual, very much in proportion to its exposure to the sun-light. The activity of the skin's secretions is promoted by light. If the light is too much excluded, the health of the animal body, like that of the plant, is impaired. The dark races of men doubtless derive their peculiarities of color, *in part*, from long-continued exposure to the sun, for generation after generation, until color, like other peculiarities, becomes hereditary.

The cuticle is continually *growing*, and, as new layers are formed beneath, the outer surface becomes dry and scaly, and gradually disappears. Where the skin is naked, the scaly portions are removed by ordinary friction as fast as they are formed ; but where the surface is covered with hair, they accumulate and form *scurf*. The healthy action of the skin of *all* animals is promoted by the frequent removal of this accumulation. *Washing with soap* softens and removes the surplus dead cuticle from the skin, and with it particles of dirt which have become imbedded in it.

583. The *cutis vera* (true skin) is composed of two layers; the outer one consisting of very minute bundles of fibres, so closely interwoven as to give it quite a compact structure. It is pervaded by a great number of veins and arteries which circulate the blood through it, and convey the necessary nourishment both for it and the cuticle. These veins and arteries are also accompanied by nerves, which make this layer of the skin very *sensitive*. Where the veins and arteries meet, they form little projections or elevations, called "papillæ," which make the surface of the skin uneven. The papillæ may be distinctly seen as little, red, conical elevations on the surface of the tongue. This layer is called the "sensitive, or papillary tissue" (Fig. 49). The inner layer of the true skin is much thicker, and more coarsely fibrous in its structure. Its veins, arteries, and nerves, are numerous, but fewer in number, though larger, than those of the sensitive layer. In this, the *oil-glands* of the skin are imbedded, and are connected with the surface by tubes passing up through the cuticle. These oil tubes usually open in pairs into the sheaths of the hair, and thus provide the natural oil which gives the hair its beautiful glossy appearance. The *perspiratory* glands are also situated in this part of the cutis vera. They separate impurities from the blood, and throw them out with the perspiration through the cuticle at the pores.

584. There are cells in the lower part of the true skin filled with fat. Such cells form what is called "adipose tis-

sue." The following figure, from Cutter's Anatomy and Physiology, will aid the student in getting a clear idea of the relative situation of the parts of the skin, as described above. It represents a vertical section of the skin, through its whole thickness, but greatly *magnified.*

FIG. 49.

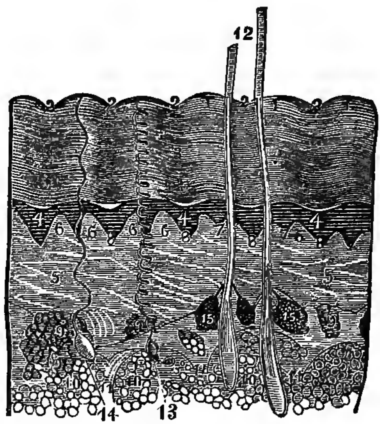


Fig. 49.—1, 1, The lines, or ridges of the cuticle, cut perpendicularly. 2, 2, 2, 2, 2, The furrows, or wrinkles of the same. 3, The cuticle. 4, 4, 4, The colored layer of the cuticle. 5, 5, The cutis vera. 6, 6, 6, 6, 6, The papillæ. 7, 7, Small furrows between the papillæ. 8, 8, 8, 8, The deeper furrows between each couple of the papillæ. 9, 9, Cells filled with fat. 10, 10, 10, The adipose layer, with numerous fat vesicles. 11, 11, 11, Cellular fibres of the adipose tissue. 12, Two hairs. 13, A perspiratory gland, with its spiral duct. 14, Another perspiratory gland, with a duct less spiral. 15, 15, Oil-glands with ducts opening into the sheath of the hair (12).

585. FUNCTIONS OF THE SKIN.—The leading office of the skin is to protect the surface of the body. For this purpose, it is most admirably adapted by our beneficent Creator, being made both tough and elastic—resisting all ordinary forces in the form of blows and friction, yet yielding to slight pressure, and to the bending of every joint. The cuticle is made

without nerves, that it may cover the more sensitive layer beneath; and yet it lies so closely in contact with the web-work of nerves on which it rests, that almost the slightest touch, even a breath of air, makes known its presence through these little nervous channels; the sensation, however, is made pleasant by the intervening of the cuticle, while it would be extremely painful if this layer were removed. When injured or broken, the cuticle is renewed very rapidly, while the bruised surface beneath throws out, in the mean time, liquid matter which, drying, leaves a scab over the surface as a temporary protection.

The cuticle is constantly worn away by friction, but it as constantly grows again; and when the amount of friction or pressure becomes greater than usual, and is rapidly applied, it is sometimes worn off, so as to expose the sensitive layer below, and sometimes only loosened from its contact with this layer, causing the secretion of fluid matter beneath, giving rise to blisters. Such effects are seen upon the hands of one who undertakes more severe manual labor than he has been accustomed to perform, and upon the shoulders of young horses when first put into harness. But if care is taken to apply the increased pressure and friction gradually, no great inconvenience is felt, because the cuticle has the property of increasing in thickness, whenever the protection of the other layers requires it; provided time enough is allowed for the necessary change to take place.

586. The sensitive layer, by its abundant supply of nerves, acts an important part in giving warning whenever an external body comes in contact with any part of the system. If the *mind* were not thus made conscious of the presence and action of outward forces, the body might be seriously injured, before the necessary means could be adopted for its protection.

587. The *pores* serve as outlets for the perspiration, which

is constantly secreted from the blood, and carries out in solution, surplus matter, both mineral and organic. This process is constantly going on. If the temperature of the body is much increased by exercise or warm clothing, the perspiration collects more rapidly than it is evaporated, and forms drops upon the surface if naked, or moistens the hair or other covering of the skin. At ordinary temperatures, the perspiration is not thrown out more rapidly than it is evaporated from the surface; but still it goes on. It is then called "insensible perspiration."

Experiment.—Insert your hand into a dry, clean jar of clear glass, having wrapped your handkerchief, or something of the kind, around your wrist, so as to close the mouth of the jar. In a short time, the inner surface of the glass will be covered with a film of moisture. This is the insensible perspiration made sensible, by being collected as fast as it escapes from the pores of the skin.

Perspiration is necessary to health in both man and beast, hence anything tending to check it, is apt to result in injury. The impurities, instead of being thrown out, are retained by the blood, and inflammatory diseases are the consequence. Sudden chilling of the body, after free exercise, is always dangerous. Any one who remains at rest in the cold air, after taking violent exercise, should at once increase his quantity of clothing. The practice of leaving a horse exposed to a cold wind after brisk exercise, is very pernicious; but to ride him into a deep pond to cool him off, while he is sweating freely, is still worse. The pores of the skin are suddenly closed, and inflammation, and frequently congestion in some part of the body, is a very common result.

The safest plan for both man and horse, is to rub the skin briskly as it cools off, protecting it at the same time from cool currents of air. Or if this cannot be conveniently done, the man should throw a cloak over himself, and a blanket over his horse.

588. The oily secretions from the skin protect it against sudden changes, to some extent, by forming a non-conducting film over the surface. They also diminish friction between the cuticle, and the bodies with which it comes in contact, and thus prevent it from being abraded so often as it would be, if the surface were more dry and harsh.

Cleanliness promotes the healthy action of the skin. Children and servants should be required to bathe frequently, and rub briskly afterwards. A foul skin and foul clothing are fruitful sources of disease. Horses, cows, and even *hogs*, should have clean, dry beds; otherwise, they will be liable to cutaneous diseases.

589. The peculiar structure of the skins of animals, gives them their value in the manufacture of *leather*. The cuticle forms the grain of the leather, while the true skin forms the main body, and the stronger part of the material. Its peculiar net-work of fibres gives it both toughness and elasticity. For the chemistry of tanning leather, see § 196.

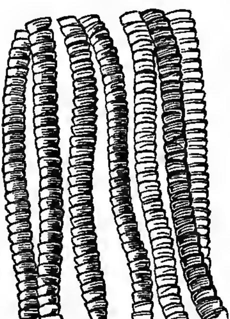
590. Appendages of the Skin.—Hairs, feathers, nails, claws, hoofs, and horns, may be regarded as appendages to the skin (§ 201).

Hairs have their origin in the true skin, and spring from a bulb-like root (Fig. 49). They have neither veins nor nerves, and hence have no vitality in themselves. They grow at the root only; and the upper part is thrust out by the increase of length at the lower extremity. A hair consists of three parts: 1. The *cuticle*, or external scaly covering; 2. A horny, cylindrical tube, having a fibrous structure; 3. A *pith* of cellular structure, forming the central axis of hair. These parts may be seen very distinctly in the tubular part of an ordinary feather. The tough external covering (the cuticle) may be scraped off with a knife—the horny part is then laid bare; then within this is the pith, or medulla, full of cells which are visible to the naked eye.

The cells in the centre of a hair are generally filled with air, but they readily absorb water, and various kinds of liquid solutions. The whole hair may be impregnated with water, or with a colored solution. The dyeing of wool consists in thus conveying coloring substances into the cells of the fibres of wool, where it fixes itself, or is fixed by the action of some other substance. Sometimes the color is developed by chemical changes produced within the fibre, by first dipping the material to be colored into one solution; then transferring it to another, which will form some colored compound with the first.

The surface of hair is not smooth, as might be supposed from simply viewing it with the unaided eye. The microscope shows that the outer coating is made up of numerous scales, which generally overlap one another. In the case of wool and fur, these are especially remarkable. Fig. 50 shows fibres of fine wool, as they appear when magnified by the microscope. The little scaly rings adhere to each other, and the fibres, as they are worked together in the process of felting, or in carding, spinning, weaving, etc. form a cohesive, yet porous mass. If the surfaces were destitute of these scaly projections, the fibres of wool and fur would be far less valuable for the purposes to which they are applied.

Fig. 50.



591. The *nails* of man, and the *claws* and *hoofs* of other animals, may be regarded as portions of the cuticle, contrived by an all-wise Providence for the defence of those parts of

the hands and feet most exposed to injury. They are endowed with the property of perpetual growth; so that, as the extremities are worn away by use, new portions are thrust forward to take the place of what is removed.

ORGANS OF MOTION.

592. Bones. — The bones have no power of producing motion, but they form the framework of the body. They give it strength, and determine the general outline of its figure. They are, moreover, the instruments of motion, through which the muscles carry on their operations.

The composition of the bone has been given (§ 204), as consisting of a solid mineral portion, chiefly phosphate of lime, and a softer organic portion, composed of gelatinous matter. The bones are surrounded by a strong fibrous membrane, called the "periosteum." To this the tendons and ligaments are attached, and thus the bones are connected with the muscles and with each other. The periosteum covers all parts of the bones, except the extremities, where two bones come together to form a joint, and the crowns of the teeth, which are coated by a hard bony substance called "enamel." This covering of the bones is provided with arteries and veins, and through it the bones get their nourishment. It is also supplied with minute nerves, but is not very sensitive, unless inflamed by disease.

593. The outer portion of the bony substance is usually very compact and hard, and forms a strong wall, varying in thickness in different bones, and in different parts of the same bone. In the slender part, called the "shaft," it is thicker than at the projections near the joints. The inner part of the bone is porous, and comparatively soft. The middle part of the longer ones is tubular, and filled with a peculiar oily substance called "marrow."

594. Wherever two bones meet to form a joint, the ends

of both are covered with a very strong, elastic cushion, called "cartilage," or "gristle," which yields to any sudden pressure, and again expands to its ordinary form. This prevents the hard parts of the bones from coming in contact, and thus preserves the joints from injury. The surfaces of the cartilage are extremely smooth, and move upon each other with but little friction. The friction is also still further diminished by a liquid secreted around the joint, and most perfectly adapted to the purpose for which it is intended.

FIG. 51.

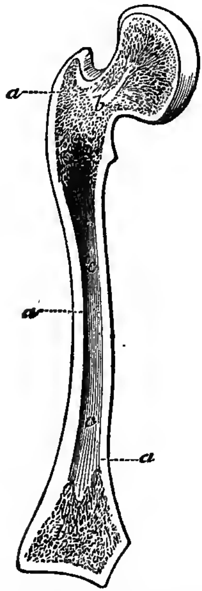


FIG. 52.

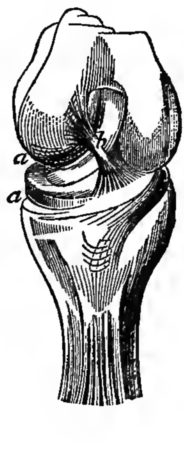


Fig. 51 is a section of a man's thigh-bone (femur)—*a, a, a*, the compact wall within the periosteum; *b, b*, the cellular or porous part within; *c*, the marrow. This structure gives the bone a remarkable combination of lightness and strength.

Fig. 52 represents a joint, with the rounded extremity of one bone fitting the hollow extremity of the other, and each part coated at the end with cartilage, *a*, *a*.

595. The joints are held together by strong ligaments (*b*, Fig. 52), attached to the convex part of the one bone, and the concave part of the other. There is also a membrane which covers the joint externally, and over this, ligaments of a strong fibrous structure extend from bone to bone.

Some bones are connected by cartilage alone, without joints, as seen where the ribs are attached to the breastbone. In such cases, considerable elasticity, with only a limited motion, is required, as in the expansion and contraction of the chest in breathing.

596. FUNCTIONS OF THE BONES.—These are, *first*, to give the requisite stiffness and strength to the various parts of the animal; *secondly*, by means of joints, cartilages, etc. to give facility and freedom of motion; *thirdly*, to protect other organs, as in the case of the brain, which has around it a strong and elastic wall, composed of the several bones of the skull; or the eye, which has its socket within a bony cavity; or the organs within the chest, surrounded by a most graceful framework, which yields readily to the action of these organs, and yet serves as a strong defence against external injuries.

597. In domestic animals generally, *slender bones* are desirable, provided the size in other respects is not too small; for, if we desire a combination of strength and activity, as in a well-formed horse, we shall not find it in large bones. The strength of a bone is by no means proportional to its size. In an animal of slender, graceful limbs, the bones are more compactly formed, and are found to be often stronger than those of another, of the same size in body, but having thicker and more unwieldy limbs. *Again*, if we value the

animal for food, the bones must be subtracted. Every one must have observed the wide difference in the quantity of bone found in different beeves of the same size. Those having slender legs and well-rounded muscles, have small bones throughout. The same is true of hogs and sheep.

MUSCLES.

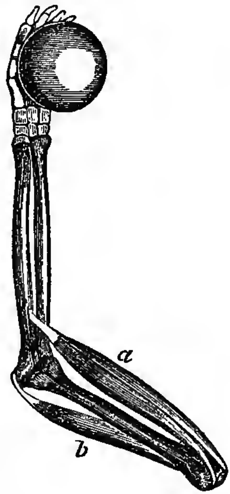
598. Surrounding the bones, and attached to them on all sides, are the *muscles.* They consist of bundles of fibres, varying widely in form and size, encased in sheaths, or coverings of membrane. They constitute the lean flesh of the body, give it symmetry of form, and are the true organs of motion. The muscles are attached to the periosteum of the bones by *tendons,* or cord-like extremities. The union between these and the surface of the bone is very strong.

Under the stimulating influence of the nerves, the muscles have the power of contracting, in such a way as to diminish their length, and of again relaxing when the stimulus ceases to operate. The *will,* acting through the medium of the nerves, can stimulate any particular set of muscles, and cause alternate contraction and relaxation.

599. FUNCTIONS.—The most important office of the muscles is to produce motion. This is done by their contractile force. By contraction they draw after them the bones to which they are attached. In bending the elbow, or in closing the hand, it will be seen that the middle part or "swell" of the muscle is enlarged. This is done at the expense of its length; and the extremities being thus brought more nearly together, motion of the bones to which they are attached must follow. By grasping the arm above the elbow with the opposite hand, and then bending the elbow, a very considerable enlargement of the muscles in the upper part of the arm will be perceived. These are the muscles employed in moving the lower part of the arm. In

closing one hand, while the arm between the elbow and wrist is held in the grasp of the other, a similar enlargement will be felt there. The accompanying figure (Fig. 53) shows how the muscles are attached to the bones, above and below the elbow. By contracting the muscle *a*, the elbow is bent; and by relaxing this, and at the same time contracting *b*, the arm is again straightened. The muscles are thus arranged in *pairs*. Every muscle which is employed to bend a joint, has its antagonist on the opposite side employed again to straighten it. There is thus a pair of muscles for every motion, and for every variety of motion, performed by every organ of the body.

FIG. 53.



The stimulating influence of the nerves upon the muscles cannot continue indefinitely. The duration is about inversely proportioned to the force exerted. Violent muscular effort can be of only short duration, while moderate exertion may continue much longer without weariness. But the power of endurance in the muscles may be greatly increased by *habit*. When a man first begins to perform some severe labor, to which he has not been accustomed for some time, he finds his power of endurance much less on the first day, than it is after several days spent at the same work.

600. The muscles may be permanently injured by too *violent* use, or by too *long-continued* action without rest. Hence we find both men and horses often weakened, or stiffened for life, by too severe, or too long-continued use of particular muscles.

If different sets of muscles are brought into action alternately, they partially relieve one another. A change of position gives relief, when we become weary of any posture in which we have continued for some time. Sitting affords relief to one who has been long standing, while standing equally relieves one who has been long sitting. The change of position brings a fresh set of muscles into play. So an animal, wearied with ascending a hill, is relieved by descending. So long as a horse is driven upon a level road, the same muscles are perpetually at work; but when he comes to a gentle ascent or descent, it affords him relief. Hence horses can make long journeys over a gently undulating country, with more ease than over a level plain.

601. The muscles of young animals are much less compact and strong than those of animals fully matured. They are consequently more easily injured. Boys and young horses often have both their strength and activity seriously impaired, by being over-worked. Muscular strength is *increased* by exercise within certain limits; but in young animals there is danger of exceeding these limits when they are subjected to severe labor, as in plowing with young horses or oxen. By *moderate* use the blood is made to circulate freely through the muscles, and thus supply increased nutriment, which adds to their compactness and strength.

ADIPOSE TISSUE.

602. The adipose tissue has the form of little cells or sacks. These are filled to a greater or less extent with *fat*. They are most abundant immediately beneath the skin, around the kidneys, and in other places where fat is found to be accumulated. The cells of this tissue, in a healthy animal, are rapidly filled up when the animal is abundantly fed on substances well supplied with fattening food (§ 571). But if the supply of this kind of food is withheld, they are

just as rapidly exhausted of what is already accumulated. The fat is exhausted to supply the blood with the proper elements to keep up the process of breathing (§ 631). During sickness, when the digestive organs are diseased, and the proper supply of food cannot be conveyed to the blood through the stomach, the fat is withdrawn from the adipose tissue, and the whole system becomes emaciated.

This tissue, when filled, serves as a species of wadding to the muscles, giving them symmetry of form. In young persons there is an abundant supply of fat on the lower surface of the skin, giving every part of the body a smooth, rounded appearance; but in old age this supply is greatly diminished, and the skin becomes wrinkled. Corpulent persons have an unnatural accumulation of this tissue in almost all parts of the body.

603. Animals in process of fattening should never be allowed to become very hungry; because, at that moment, the blood begins to abstract food from the adipose tissue. This loss must be supplied by extra feeding. If man were as prudent in the selection of his food as the lower orders of animals are, there would be fewer lean, sickly-looking faces seen around us. Governed by that instinct with which their Creator has endowed them, brute animals select first those kinds of food which are most wholesome; and if these are abundant, the less wholesome are altogether rejected. Man, on the other hand, controlled more by a vitiated or morbid appetite, than by the high intelligence with which he has been created, rejects the plain cold bread, the simple well-roasted beef, the nicely-boiled ham, the plainly-cooked potatoes and fruit; and in their stead must have his hot rolls and biscuit, his highly-spiced meats, his hotly-seasoned vegetables, his most indigestible pastries, his custards, and cakes, and candies. Then it is a wonder if he is not constrained to take a glass of brandy, to help out his digestive powers.

If we were to feed our cattle as imprudently as we do ourselves, our farms would be but poorly stocked.

GLANDS.

604. These are soft, porous organs of various shapes, situated in different parts of the animal body, "in some cases extremely minute, and in others large like the kidneys and liver. There are two classes of glands — one for the modification of the fluids which pass through them, as the mesenteric and lymphatic glands (§ 610); and the other for the secretion of fluids which are either useful in the animal economy, or require to be rejected from the body;" of such are the liver and kidneys. The term *secretion* literally means *separation;* but as here used, it denotes both separation of fluids from the blood, and modifications, to a greater or less degree, during the process of separation. The first class of glands above mentioned do not properly secrete, but rather transmit fluids, under a slightly modified form.

ORGANS OF DIGESTION.

605. Digestion consists in, *first*, reducing the food to small particles, suitable to be acted on by the fluids with which it is mingled in the stomach and intestines; and *secondly*, dissolving out the nutritive portions, and preparing them to pass into the organs of circulation, where they form the elements of the blood.

The organs of digestion are *the mouth, the stomach, the intestines*, and *the lacteals*. These are all lined with a membranous coating, in some respects similar to the skin, and connected with it where both come together, as on the margins of the lips, nostrils, &c. This lining is called the "mucous membrane," because it secretes a slimy fluid called "mucus," which keeps the digestive and other organs moist, and protects them against injuries.

606. The office of the mouth is to masticate the food, and mingle it with saliva. While the tongue, the palate, and the cheeks hold the food, and toss it from side to side, the teeth grind it to fragments; and, in the meantime, the salivary glands, situated in different parts of the mouth, secrete saliva, which first moistens the food, thus assisting the teeth in reducing it to the proper condition, and secondly becomes incorporated with it, and, passing into the stomach, seems to aid in the other processes of digestion.

Food should be *perfectly chewed*, and *thoroughly mingled with saliva*, before it passes into the stomach. Slow and imperfect digestion (dyspepsia,) is one of the consequences of not giving the teeth and the salivary glands time to perform their offices fully. Horses and cows, when fed on concentrated forms of food, such as corn or meal, are apt to swallow it hastily without sufficient mastication. This is easily prevented, by mixing the meal with cut hay or straw, moistened with water. The food is then consumed more slowly, and the amount of chewing and salivation greatly increased.

607. The *Stomach* is a large membranous sack, situated in the left side of the chest. It is composed of three layers. (1) The external, or serous coating, is very tough and strong, yet more or less elastic in different animals. (2) The middle coating is composed of muscular fibres, arranged in two layers. In one of these the fibres run longitudinally, in the other they cross these at right angles, running circularly around the stomach; thus, together forming a sort of webwork. (3) The inner coating is the mucous membrane, which is arranged in folds, forming a soft and spongy lining to this organ. Lying in the surface of the mucous membrane, next to the middle, or muscular coating, are a set of tubes opening into the stomach, for the secretion of *mucus;* and near these, a multitude of little glands, also communicating with the inner surface. By these glands the gastric

juice (§ 209) is secreted, and passed into the cavity within, there to be mingled with the masticated food.

The tube through which the food descends from the mouth is called the "œsophagus." It opens into the top of the stomach, towards the left side. The outlet by which the food passes from the stomach is at the right extremity, opening into the upper part of the intestines, called the "duodenum." Figure 54 (from Cutter,) gives a good general view of a section of the human stomach.

Fig. 54.

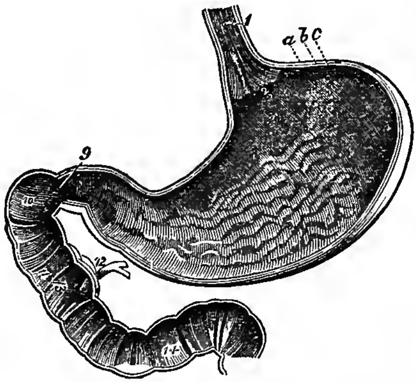


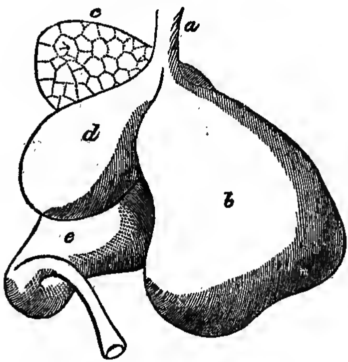
Fig. 54.—The inner surface of the stomach and duodenum. 1. The lower portion of the œsophagus. 2. The opening through which the food is passed into the stomach. 8. The stomach. 9. The opening through which the food passes out of the stomach into the duodenum, or upper portion of the small intestine. 10, 11, 14. The duodenum. 12, 13. Ducts through which the bile and pancreatic fluid pass into it. *a*, *b*, c. The three coats of the stomach.

608. In what are called "ruminating" (cud-chewing) animals, as the cow, sheep, camel, &c., the structure of the stomach is peculiar and complicated. These animals live chiefly upon grass and herbage, which they collect with great rapidity where the supply is sufficient; but while engaged in

gathering their food, they do but little chewing. It is simply crushed and moistened sufficiently in the mouth to render it pliant, that it may be swallowed. The real mastication is a subsequent process, which will be presently described.

The stomach of one of these animals has four apartments, sometimes called the "four stomachs." Fig. 55 will give a

FIG. 55.



general idea of one of these organs. The first division, *b*, is a large sack, called the "paunch," and serves as a sort of store-room, into which the supply of food is first collected, through the œsophagus, *a*, and in which it is steeped for some time in a watery fluid entirely different from the gastric juice. By the contractile force of this part of the stomach, a portion of the crude mass of food is pressed into the second apartment, *c*, which is small, and is lined with a set of little honey-comb cells. Here the fibres of food are worked up into a ball, and when the animal ceases to collect, and retires, or lies down to chew its food, this ball (cud, or quid,) is thrown up into the mouth, where the teeth and saliva reduce it to the proper condition to be returned to another apartment of the stomach, *d*. The process of forming the cud goes on quite rapidly in *c*. When the masticated food returns to enter *d*, there is a membranous valve by which *b* and *c* are closed. This third apartment is an oblong bag, lined with a folded membrane, called the "many-plies." In it the food is compressed, and has its surplus moisture removed. From this it passes gradually into the fourth apartment (*e*), which is the stomach proper. Here it first meets with the gastric juice, and here the process of digestion proper first begins.

When a cow is fed on whole grain or meal *alone*, it passes directly into the third stomach (*d*), without returning to be subjected to a second chewing; and much of it (especially the whole grain,) passes through the intestines entirely undigested. But if meal is fed in mixture with cut hay or straw, a large part of it passes with the fibrous food through all the apartments of the stomach, is chewed with the cud, and is consequently better fitted for complete digestion, and for accomplishing its part in the nutrition of the animal (§ 642).

The second stomach (*c*) of the camel is supplied with very large cells, covered with a muscular membrane, by which the animal can open and close these cells at pleasure. In these a large supply of water is laid up for use as it may be wanted. The animal may thus carry with it a supply sufficient for many days. Thus our Creator has adapted this faithful beast of burden, in this, as well as many other respects, to the important purpose which it serves in countries where large sandy deserts abound.

609. The *Intestines* (bowels) form what is called the "alimentary canal," so called because here the *nutritious* portions of the food are separated from the refuse part. There are two general divisions of the intestines — the *small intestines*, and the *colon*. The small intestines are subdivided into

(1) the *duodenum*, which is the part into which the food first passes from the stomach. Into it the ducts from the liver and pancreas open, and discharge the bile and pancreatic fluid. It extends from the stomach across to the right side of the abdomen, beneath the liver (Fig. 56); thence it

FIG. 56.

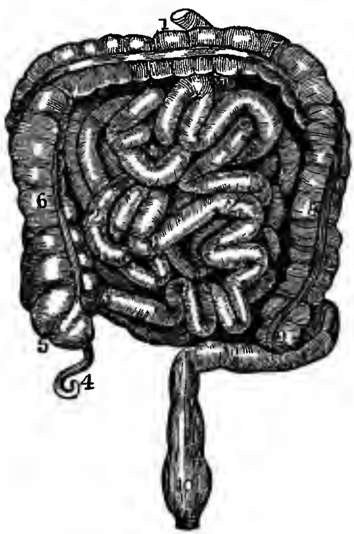


Fig. 56.—1, 1. The duodenum, 2, 2. The small intestine. 3. The junction of the small intestine with the colon. 4. The appendix vermiformis. 5. The cœcum. 6. The ascending colon. 7. The transverse colon. 8. The descending colon. 9. The sigmoid flexure of the colon. 10. The rectum.

descends to the lower part of the abdomen, where it becomes of a pinkish color, and is then called (2) the *jejunum*. The remaining part of the small intestines is (3) the *ileum*, which is of different lengths in different animals, and is coiled up in the middle part of the abdomen. The *colon* is the large part of the intestines. It is connected with the small intestine near the bottom of the abdomen, on the right side, whence it ascends as high as the lower part of the stomach; then passing across in front of the duodenum to the left side, it again descends to the lower part of the body, where it is connected with the *rectum* (10).

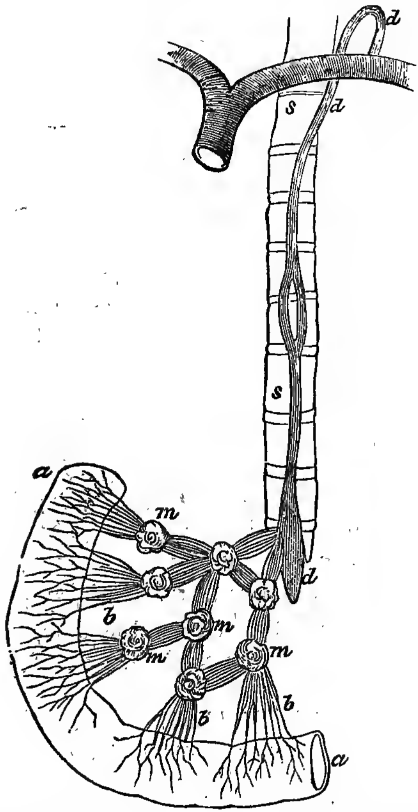
The structure of the intestines is so much like that of the stomach in its general features, that a definite description of its different layers will be unnecessary. The mucous membrane, which lines every part of it, lies in folds, so that the food passes readily over them, as it is transferred from point to point along the alimentary canal, by the muscular action of the intestines.

610. There are numerous little tubes opening into the intestines, through which that part of the food which has been prepared for the formation of new blood, is absorbed and carried into the organs of circulation. These little vessels are called "lacteals" (*lac*, milk), from the milky appearance of the fluid which they absorb from the bowels. They pass through a set of organs called mesenteric glands, and at each successive gland the *number* of lacteals is diminished, while the *size* is increased. They at length terminate in a larger vessel, called the "thoracic duct." In Fig. 57, *a*, *a*, is a portion of the smaller intestine; *b*, *b*, *b*, are lacteals; *m*, *m*, *m*, are mesenteric glands; *d*, *d*, the thoracic duct, which conveys the new blood, called "chyle," to the veins. The lacteals and thoracic duct may be regarded as connecting links between the digesting and the circulating organs. In the figure, *s*, *s*, is the spinal column.

611. Functions of the Digestive Organs.—When the food reaches the stomach, properly masticated and mixed with saliva, the glands which supply the gastric juice are stimulated to secrete that fluid freely—the muscular coat of the stomach is at the same time excited to activity, and, by its contractions and expansions, the food is kept in mo-

tion, until it becomes thoroughly mingled with the gastric juice. The proteine or albuminous portions of the food are thus first coagulated, then dissolved (§ 209), while the oily

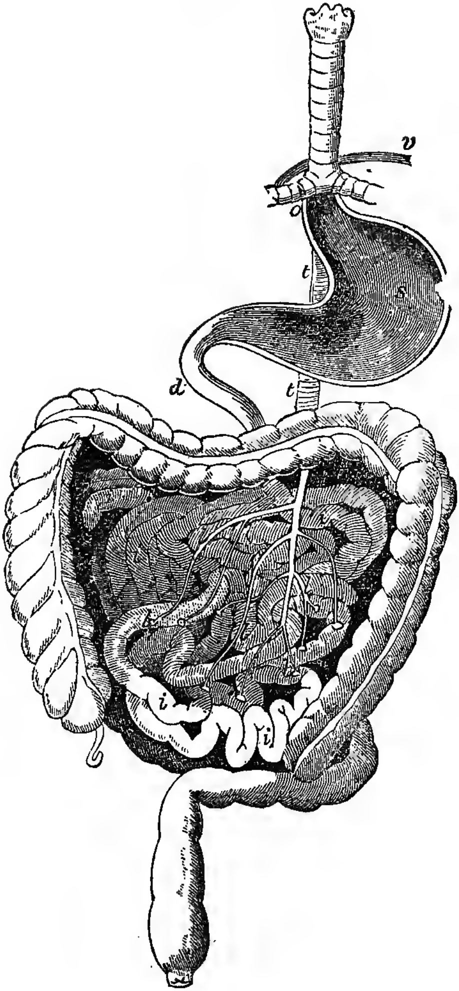
Fig. 57.



matter, starch, and other portions are reduced to minute particles, but not changed chemically. When the food has been thus acted upon by the stomach and gastric juice, it forms a gray, semi-fluid mass called "chyme." It is then passed into the duodenum, where it meets with the pancreatic fluid (§ 210) and the bile. These are mingled with it, and at once dissolve the starch, converting it into dextrine and sugar, and so far dissolve the oily portions of the chyme, as to cause them to give a milky appearance to the solution, forming an emulsion. In this condition the food is called "chyle." It then consists of the milky portion, to be converted into blood, and the indigestible part, to be carried off through the intestines. As the chyle passes along the intestinal canal, the milky portion is absorbed by the lacteals, and, after passing through the mesenteric glands, is thrown into the thoracic duct, and by it carried up near the spine to the lower part of the neck, where it is discharged into a large vein, and mingled with the blood. Fig. 58 will enable the reader to trace out the course of the food through the whole process of digestion. *O* is the œsophagus, through which the food enters the stomach; *s*, where it is mingled with the gastric fluid, and converted into *chyme.* It next enters the duodenum, *d*, where it meets and mingles with the pancreatic fluid and bile, and becomes changed into *chyle.* Thence it passes along the smaller intestines, *i*, *i*, *i*, where it comes in contact with the open mouths of the lacteal tubes, *l*, *l*, by which it is carried through the mesenteric glands, and being there slightly modified, is discharged into the thoracic duct, *t*, *t*, and by it conveyed up to a point near the neck, where it is poured into the large vein, *v*, and becomes a portion of the blood.

Every farmer may soon make himself familiar with all the organs of domestic animals, by close observation, whenever he has an opportunity.

FIG. 58.

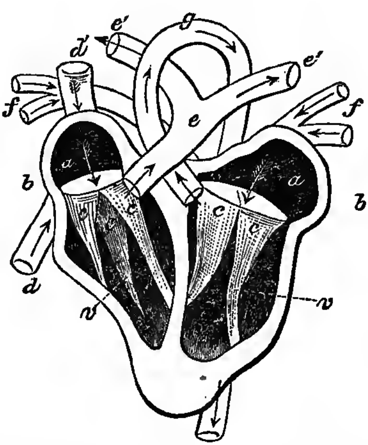


ORGANS OF CIRCULATION.

612. Having traced the nutritious part of the food through the process of digestion, by which it is prepared to pass as a portion of the blood through another set of organs, we must now follow it still further, and see how it is affected in this new channel. In order to understand the changes which take place during the circulation of the blood, we must first know something about the *organs* through which this circulation is carried on. These organs are the *heart*, the *arteries*, the *veins*, and the *capillaries*.

613. *The heart* is a strong muscular organ, situated in the left side of the chest. The general outline of its form, in

FIG. 59.



most animals, is that of a cone, having its base turned toward the head. It is hollow, having the cavity within divided into four apartments, two on each side. It may, in fact, be regarded as a double organ, with its two parts separated by a strong membrane. Each of these parts has two cavities, one for receiving and one for throwing out the blood. Those which receive the blood are called "auricles," and those which send it off again are called "ventricles." The two cavities which lie next to the right side are called the "right auricle" and "right ventricle;" those on the left side the "left auricle" and "left ventricle." Fig. 59 will give some idea of the general structure of the human heart. Conceive the front of the heart to be turned towards us, and a vertical section to be formed by cutting in front of the middle of it. Then *a*, on the left of the figure, will be the right auricle, and *v* the right ventricle; *a'* and *v'* will be the left auricle and ventricle respectively. Between the cavities on each side are openings (*b*, *b*) extending through conical bag-like valves (*c*, *c*, *c*), which open towards the ventricles, allowing the blood to flow in that direction; but when any pressure is exerted, tending to drive it back into the auricle, these valves at once close, and resist its passage in that direction. On the right side there are three of these valves; on the left only two. They differ slightly in structure, but we shall not stop to consider that point. It will be seen, from the structure of the heart, that the blood can flow in only one direction through either side of it; that is, from the auricle to the ventricle.

614. The muscular walls which surround the cavities of the heart have the property of contracting and again relaxing, so as to *diminish and enlarge* the cavity alternately. And this operation goes on in such order, that, when an auricle is contracted, the corresponding ventricle is enlarged. All the veins from parts of the body below the heart, meet in one common vein (*d*), while those from above meet in another (*d'*); and these discharge the blood flowing from the veins, into the right auricle. Where they are connected with this auricle, there are valves, opening towards the heart, and allowing blood to flow in that direction, but resisting its pas-

sage back again towards the veins. When the right auricle, then, is enlarged, the blood from the veins flows freely into it; when it again contracts, the pressure closes the valves of the veins, but opens those of the ventricle; and at the same moment the ventricle is relaxed, and allows the blood to flow into it. The moment it is full, it contracts and drives the blood out through the pulmonary artery (*e*), whose branches (*e′*, *e′*) lead to the lungs. The arrows show the direction of the current.

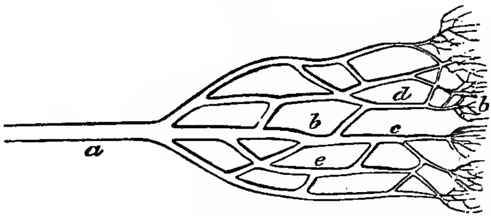
As the blood returns from the lungs through the pulmonary veins (*f*, *f*,) the stream flows into the left auricle (*a*). When this is filled, it contracts; the valves at the extremities of *f*, *f*, are closed, preventing the current from returning towards the lungs, while the ventricle (*v′*) is open to receive it. As soon as *v′* is thus filled, it contracts, and drives the blood out through the large artery (*g*), the branches of which convey it off towards the different parts of the body.

615. *The arteries* are strong cylindrical tubes, which convey the blood from the heart to every portion of the body. They consist of three coats; the outer one firm and tough, the middle one fibrous and elastic, the inner one thin and very smooth. The first gives them strength, and prevents injuries; the second permits expansion and contraction of the internal cavity; the third affords a smooth channel for the flowing stream.

616. There are *valves* at various points in the arteries, all opening out *from* the heart, allowing the blood to flow only in that direction. The divisions and sub-divisions of the arteries are almost innumerable, running to every point of every organ throughout the whole body. Besides these branches, there are numerous cross-connections, which multiply as the branches increase in number and diminish in size, the whole forming a sort of net-work. This is a most

wise provision to prevent obstructions of the current, as it flows towards any point of the body. Let *a* (Fig. 60), repre-

FIG. 60.



sent an artery, with its branches and cross-connections. If the portion of the current flowing from *b* to *b* meets with an obstruction from pressure, or any other cause, at *c*, instead of stopping, it finds a cross-channel, and turns aside towards *d*; meanwhile, *b* gets its supply from a branch below *c*, by another cross-channel coming up from *e*. Without these connecting arteries between the continuous branches, there would often be interruptions in the circulation towards some parts of the body.

The arteries are chiefly imbedded beneath the muscles and tendons, and, in exposed parts of the body, lie close to the bones. Here we have another display of the wisdom and skill of the Divine Builder of the animal structure. The arteries having their valves opening from the heart, allow the blood to flow freely in that direction; hence, if an artery is ruptured or severed, the blood gushes from the opening with all that force given to it by the heart in driving it towards the extremities. These organs, therefore, require protection.

617. *Veins* are the tubes through which the blood flows back from every part of the body to the auricles of the heart. They also convey the waste matter from all the different points at which they meet the extremities of the arteries.

This refuse matter consists of such particles as have served the purpose for which they were designed, have become worn out, lost their vitality, and are now taken up and thrown into the veins by a set of *absorbent* vessels, called "lymphatics," situated at the extremities of the minute branches of the veins; besides this, the blood of the veins is charged with carbonic acid gas, to be conveyed to the lungs, and there discharged. These additions to the blood, after it leaves the arteries, make a larger channel now necessary. The veins are therefore made more capacious than the arteries.

The veins are provided with *valves* opening towards the heart, allowing an easy flow in that direction, but resisting motion the other way. Hence the blood in these can only flow *toward*, and not from the heart. If, then, a vein is cut, there is no outlet formed directly from the heart. The blood must flow to the minute extremities of the arteries; and there, passing through little tubes, called "capillaries," into the veins, run on till it reaches the opening by which it comes to the surface. But, as the veins have none of that strong pressure upon them which the pulsations of the heart exert upon the arteries, a very slight bandage is usually sufficient to close an orifice, and cause the stream to pass on in its proper course.

618. The *capillaries* are very minute tubes, or vessels, connected at one end with the extremities of the arteries, and at the other with the origins of the veins. They thus form a sort of connecting link between these two channels of the blood. The capillaries are too small to be seen without the aid of the microscope; and are so numerous, that the point of a needle cannot be inserted into the flesh anywhere, so as to avoid wounding some of them. They are found at every point in the body—in the skin, the bones, the muscles, the digestive organs; in the coats of the veins

and arteries themselves, and, in short, wherever growth takes place.

The office of these little vessels is to elaborate the elements of nutrition brought from the digestive organs. Those belonging to any particular part of the body have the power of taking from the arterial blood just the kind of matter required by that part, and of giving it the proper form. Those, for example, situated in the bones, have the power of secreting and depositing phosphate of lime, cartilage, etc., while those in the muscles secrete only such material as is suited to the nourishment of these organs; and so of those in every other place. If the capillaries are in a healthy condition, and the blood is supplied with the proper variety of food, they secrete with unerring certainty the kind of matter wanted, and in exactly the right form and quantity for the situation they occupy.

ORGANS OF RESPIRATION.

619. The *breathing* organs are the *windpipe* (trachea), and its branches, called "bronchial tubes," and the *lungs*.

The trachea, or windpipe, passes down in the front part of the neck into the chest, where it separates into two branches, called "bronchia," which pass to the lungs on the right and left. These branches are each again subdivided into numerous smaller branches running to every part of the lungs, and ending in little *air-cells* (see Fig. 61). They convey the air from the mouth to the lungs in its pure condition, and bring it back deprived of a part of its oxygen, and charged with carbonic gas and watery vapor from the blood.

620. These, like the digestive organs, are lined with mucous membrane. When this membrane becomes temporarily inflamed, it constitutes a "cold," and generally causes hoarse-

ness of voice and coughing. When it becomes more generally and permanently diseased, it becomes "bronchitis."

621. The *lungs* are two large, spongy organs, situated on the right and left of the chest. They are formed (1) of the air-cells at the extremities of the bronchial tubes, surrounded by the tissue which separates them from one another; (2) of a net-work of capillary tubes surrounding these cells, and in contact with their lining membrane; then (3) the whole mass of the organ is pervaded in every part by arteries, which bring the impure venous blood from the right ventricle of the heart, and pour it into the capillaries to be oxidized through the porous membrane, which separates them from the air-cells. It is also pervaded by a corresponding number of veins, which receive from these capillaries the blood charged with oxygen, and convey it back to the left auricle of the heart.

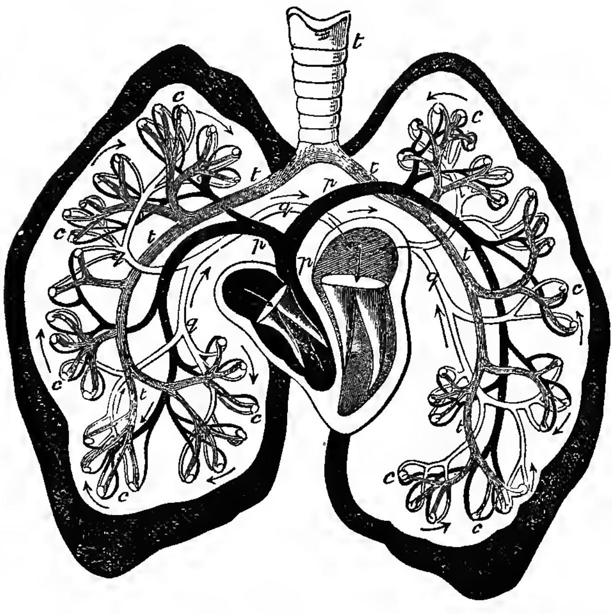
622. The lungs and heart are separated from the digestive organs by a strong membrane, extending entirely across the body, and attached to the inner lining of the ribs. This is called the "diaphragm," and helps to sustain the lungs. The ribs surround the lungs at the sides, and the sternum, or breast-bone, in front. The ribs and breast-bone are provided with a set of external muscles by which they are drawn upward and outward, so as to enlarge the chest. This tends to produce a *vacuum* around the lungs, by removing external pressure. Then the pressure of the atmosphere from without causes a current of air towards the lungs, through the windpipe, filling and expanding the air-cells and tubes. When the muscles of the ribs and sternum are relaxed, these bones again return to their natural position, exerting at the same time so much pressure upon the lungs, as to force out again the air which had just entered. This motion of the ribs is also accompanied by an upward and downward motion of the diaphragm, which aids in the inhalation and exhala-

tion of air. Thus the process of *breathing* is kept up by muscular force, which is involuntarily exerted upon the walls surrounding the chest.

623. Each of the lungs is sub-divided into lobes. Of these the right lung has *three*, while the left has but *two*. The right lung is much larger than the left; this difference seeming to have been designed to make room on that side for the heart.

624. It will be interesting to trace a little more definitely the circulation of the blood through the lungs, with the aid

FIG. 61.



of a figured illustration. Fig. 61 gives an ideal section of the heart, the lungs, and the several vessels by which the blood and air are brought together. The auricles and ventricles are here represented as in Fig. 59. Leading from the right ventricle is the pulmonary artery (*p, p, p*), branching off, first into two large divisions leading to the two lungs, and then into innumerable subdivisions leading to the capillaries around the air-cells (*c, c, c*). The pulmonary arteries are represented by dark-colored lines, because the blood they convey is the impure, dark-colored blood, brought from various parts of the body by the general system of veins. The pulmonary veins (*q, q, q,*) convey the lighter, oxygenated blood back to the heart, and pour it into the left auricle. The trachea and bronchial tubes (*t, t, t,*) convey the air into the cells, where it is separated from the blood only by a very thin membrane, which has such a structure as to allow gases and water to pass through it readily, but resists the passage of the blood.

625. SUMMARY.—If we could watch the blood of an animal from the moment the chyle is thrown into it by the thoracic duct (§ 611), until it returns again to the same point, we should observe some most remarkable and interesting phenomena. It has been seen by physiologists at every point in its circulation, and its various changes most minutely examined with the help of the microscope. Let us follow it.

As the dark current flows past the mouth of the thoracic duct, the new elements of nutrition mingle with it, and all are received by the right auricle of the heart. Here it undergoes no change, but passes directly into the right ventricle, from which it is driven along the pulmonary artery (still dark in color), into the lungs, where the capillaries spread it over the outer surface of the air-cells. So soon as it comes in contact with the membrane which surrounds these cells, and which has one side exposed to the air, its carbonic gas, and a portion of its water, are rapidly transmitted into the air-cells, while oxygen is transmitted with equal rapidity from them in the opposite direction, and absorbed by the blood. So the breath returns from the lungs charged with carbonic acid and watery vapor, while the blood returns towards the heart charged with oxygen.

626. *Pure air* and *freedom of motion* are both essential to the healthful action of the lungs. Unwholesome gases not unfrequently find their way to the blood through the air-cells of these organs during respiration. A large number of animals, confined in a close room, soon vitiate the air with the carbonic acid of their breath, to such an extent as to cause death (§ 63). If the lungs are confined by external pressure, from tight clothing, or any kind of tight bandage, they are unable to expand sufficiently to inhale the requisite quantity of air. Hence the blood is not properly oxydized, and consequent injury to health follows.

The most marked change which is found to have taken place in the blood, while passing through the lungs, is its change of color, resulting from the absorption of oxygen gas. The color is now a bright crimson. In this condition we find it passing into the left auricle of the heart; thence it is driven into the left ventricle, from which it is forced out to every part of the body, through the arteries into the capillaries. Here we find it performing the important office of *nutrition*. With the help of the oxygen brought from the lungs, its proteine constituents undergo those slight modifications, which adapt them in one case to building up the skin, in another to building up the muscle, in others the various forms of tissue. In the bones we find it leaving some of its proteine matter in the form of cartilage, and its phosphate and carbonate of lime, as the hard minerals of the animal frame-work. The oily portions of the food are deposited in the adipose tissue. Thus the *nutritious* portions of the blood are disposed of.

If now we observe the starch, sugar, and gum, we find them disposed of in a different way. As they pass through the capillaries they are rapidly consumed. The greater part of the oxygen from the lungs combines with their carbon, forming carbonic acid, and generating *heat* in every part of the body, while their hydrogen and oxygen are liberated in the form of water. Here we find combustion going on, similar to that which takes place in the open air when wood is burnt (§ 65), and *animal heat* thus constantly kept up. These products of combustion (carbonic acid and water,) now pass into the veins, and are carried to the lungs.

627. From every point to which the blood has carried fresh nutriment, we see it conveying away the old, worn out material, that has performed its full service. This is now to be discharged through various organs constructed for that purpose. We have already seen the carbonic acid, and a portion of water thrown out through the lungs. Other substances, in the form of excretions, disappear at various other points. The decomposed proteine substances are separated from the blood, chiefly by the kidneys, and are discharged as a part of the urine. Several mineral salts are also thrown out at the same time (§ 215), and with these a large quantity of water. Through the pores of the skin, water, some salts, and organic matter, are discharged as perspiration. The skin also carries on the process of respiration to some extent —absorbing oxygen, and exhaling carbonic acid, but only on a limited scale.

These various processes are not completed to their full extent, during any one round of circulation. For example, the blood cannot all pass through the kidneys at every round, to discharge its urinary matter; nor can it all reach the skin, to throw off at once what belongs to the perspiration. But in the numerous and rapid circuits it makes day after day, all the matter it holds, whether for *nutrition* or *excretion*, finds its destined place.

628. *Water, Sugar, Alcohol, &c.*—Much of the water taken into the stomach is rapidly taken up by the absorbent vessels of the coats of the digestive organs, and thrown at once into the blood, without passing with the chyle through the thoracic duct. An immediate effect of this is seen in the increase of perspiration, produced on a warm day, by a free draught of water. "The *sugar* contained in the food, or formed from the starch, appears to be in great part absorbed by the coats of the stomach and small intestines, in the same way as water and saline fluids, and thus finds its way into the veins without passing through the chyle-duct. It is directly oxydized in the circulation, and in a few hours after its ingestion disappears entirely from the blood. *Alcohol* is absorbed in the same way, and oxydized in the circulation, being converted into water and carbonic acid."—(*Silliman, Jr.*) Hence, if food and alcohol be taken into the stomach at the same time, the alcohol will reach the brain through the blood, and produce intoxication, long before the food has passed out of the stomach. The oxydation of alcohol in the blood produces large quantities of carbonic acid and water, and this combustion, which goes on rapidly, gives rise to an unnatural degree of heat.

629. Respiration of Plants and Animals.—The effect of the combined influence of the breathing processes in animals and plants on the condition of the atmosphere, has been mentioned (§§ 65, 625). These two classes of organic beings exert a remarkable compensating influence, in preserving the proper proportions of oxygen and carbonic acid in the atmosphere. In the structure and arrangement of an "Aquarium," we have another beautiful and instructive example of a similar compensation in water.

An aquarium is properly an artificial pond, in which aquatic plants are cultivated. It is also used as the habitation of fish and other water animals, kept for amusement or use.

FIG. 62.

Aquatic plants require the water in which they grow to be supplied constantly with a certain amount of carbonic acid, to be absorbed by their leaves. Fish, on the other hand, require a constant supply of oxygen in the water they inhabit, and a constant removal of carbonic acid. Fish breathe the oxygen, dissolved in water, through their *gills*, which serve for them the same purpose as lungs in land animals. When they are confined to a small portion of water, they soon die, unless the water is renewed from time to time, or its gases in some way fitted for their respiration.

If the object is to rear fresh-water fish, the aquarium must be supplied with fresh water; and, to avoid the necessity of changing it frequently, fresh-water plants must be cultivated in it, so as to absorb by their growth the carbonic acid and other impurities, and at the same time renew the exhausted supply of oxygen. If salt-water fish are to inhabit the aquarium, sea-water, or water of similar quality, with plants naturally adapted to it, must be provided.

Besides the artificial pond in the garden or the lawn, the aquarium has of late assumed another form, and become a fashionable household ornament. In the form of a very large glass vase, like that in Fig. 62, it has found its way into the parlor and the hall. Here we have the little fresh or salt-water lake, with its rocks, its soil, its plants, and its finny inhabitants, all grouped in miniature, to amuse and instruct us.

QUESTIONS ON CHAPTER XXVI.

§ 580. Of what does Animal Physiology treat? Why should every man have some knowledge of this subject? What animal is here taken as the type of most perfect structure?

581. With what are animals generally covered? Of what two general divisions does the skin consist?

582. Describe the cuticle. On what parts of the human body is this peculiarly thick and strong? If the cuticle is broken or removed, what is the consequence? What are pores? What is said of their number? Of what does the lower surface of the cuticle

consist? What effect do light and heat have upon this colored layer? How is the cuticle renewed? What are the effects of washing with soap?

583. Give the structure of the cutis vera. What are the peculiarities of its outer layer? What renders it sensitive? What are papillæ? Describe the inner layer of the true skin? What glands are situated here? How are they connected with the hairs? What office is performed by the perspiratory glands?

584. What is the adipose tissue? Describe Fig. 49?

585. What is the leading office of the skin? How is it peculiarly adapted to the purposes it serves? What is the effect of too much friction or pressure upon the cuticle?

586. What part does the sensitive layer perform?

587. What is the office of the pores? The effect of increase of temperature? What is insensible perspiration? What experiment illustrates it? The effect of checking perspiration? What care is necessary? What precautions may be adopted for both man and horse?

588. Use of the oily secretions? Effect of cleanliness?

589. For what are skins valuable? Why? Give the chemistry of tanning (196).

590. Appendages of the skin? Of what composed (201)? Describe a hair. Of what does wool-dyeing consist? Are the surfaces of hairs smooth? Describe fibres of wool.

591. Use of nails, claws, and hoofs? Advantages of their perpetual growth?

592. Office of bones? Their composition? Describe the periosteum.

593. Parts of the solid mass of the bone? Marrow?

594. How are the bones protected where they meet in joints? How is friction diminished? Describe Figs. 51 and 52?

595. How are joints held together? How are bones connected where there are no joints? Example?

596. What are the chief functions of bones? Examples of bones protecting other organs?

597. Why are slender bones desirable?

598. How are the *muscles* situated? Their construction? How attached to the bones? How do they become active?

599. What is the most important office of the muscles? How

performed? Explain Fig. 53. Why arranged in pairs? Can the same muscle act perpetually? Influence of habit?

600. Effect of too violent action? How does change of position afford relief? Illustrations?

601. Character of muscles of young animals? Effect of moderate exercise?

602. Describe the *adipose tissue.* Where situated? What becomes of the fat of animals, when not well fed? When sick? Influence of adipose tissue on form?

603. Why should fattening animals not be allowed to become hungry? How do the lower animals select food? How does man?

604. What are *glands?* Their size? Meaning of secretion?

605. In what does *digestion* consist? Organs of digestion? How lined? Use of mucus?

606. What is the office of the mouth? Of the salivary glands? To what condition should the food be reduced before passing into the stomach? How may horses and cows be made to masticate meal properly?

607. How is the *stomach* situated? Describe its three coats? What is the œsophagus? The duodenum? Describe Fig. 54.

608. What is said of the stomachs of ruminating animals? Illustration. What if a cow is fed on whole grain or meal alone? Advantage of mixing meal with cut hay or straw? What is peculiar about the second stomach of the camel?

609. What is the alimentary canal? Why so called? Its two general divisions? Subdivisions of the small intestines? Of the colon? Illustration. Structure of the intestines?

610. What are the lacteals? Thoracic duct? Explain Fig. 57.

611. Influence of food upon the stomach? What portions of food are dissolved in the stomach? What is chyme? What changes take place in the duodenum? What is chyle? How is the chyle conveyed to the blood? Object of Fig. 58? Explain it.

612, 613. What are the *organs of circulation?* Describe the heart. What are auricles and ventricles? Describe Fig. 59.

614. Explain the contracting and expanding of the auricles and ventricles? With which cavities of the heart are the veins connected? With which are the arteries connected?

615. Describe the *arteries.* Uses of their several coats.

616. How are the valves of the arteries arranged? What does

Fig. 60 illustrate? Why are the principal arteries placed beneath the muscles and tendons?

617. What are *veins?* What vessels are connected with the minute branches of the veins? How are the valves in the veins constructed?

618. What are the capillaries? What of their size? In what parts of the body are they found? Their office?

619, 620. What are the *organs of respiration?* Situation and divisions of the windpipe? Their office? How lined? What diseases mentioned?

621. Describe the lungs. How are the arteries and veins connected with the lungs?

622. How are the lungs and heart separated from the digestive organs? How surrounded on the sides? How is the chest expanded and contracted?

623. Divisions of the lungs?

624. Trace the circulation of the blood through the lungs, in Fig. 61.

625. If we could watch the blood throughout its course, what would we observe? What does the current receive from the thoracic duct? Any change in passing through the heart? What change in the lungs?

626. Influence of impure air? Most marked change in the blood in passing through the lungs? Through which side of the heart does the blood pass after it leaves the lungs? What takes place in the capillaries? How are starch, sugar, and gum disposed of? How is animal heat kept up? What are the products of combustion (65)?

627. What is carried off by the blood from different parts of the body? How disposed of? Are these various processes completed during every round of circulation?

628. How is water often transmitted to the blood? How illustrated? What of sugar and alcohol?

629. What is the *compensating influence* between plants and animals? What is an aquarium? How do the plants and fish together preserve the purity of water?

CHAPTER XXVII.

SELECTION AND PREPARATION OF FOOD.

630. We have learned from the last two chapters, that food is disposed of in several different ways:

1. *In nutrition* — that is, in promoting the growth of the various organs, as in young animals; in replacing the worn-out material of these organs, and in supplying the various fluids secreted in different parts of the body, among which we may include the *milk* of female animals.

2. *In fattening* — that is, in filling the adipose tissue with the peculiar fat of the animal under consideration.

3. *In respiration* — supplying to the blood such elements as are oxidized, and converted at once into carbonic acid and water, and thus keeping up the heat of the animal system.

631. To these several points we should give attention, in determining the *kinds* and *variety* of food to be given, whether to man or beast. There are several other circumstances not to be overlooked in connection with this subject, of which the following may be mentioned:

(*a*) Whatever may be the primary object in view, whether to promote growth, increase strength, to produce milk, or to fatten, the food must have a sufficiency of starch, sugar, or similar compounds, to supply the demands of the respiratory process. Animal heat must be kept up; and if the requisite quantity of respiratory food is not supplied through the digestive organs, the fat will be withdrawn from the adipose tissue, and the animal must become *lean*. More heating food is required, too, in *cold*, than in warm weather. Animals then breathe more rapidly, in order to keep up the proper degree of warmth; and if food is deficient, there is a rapid falling-off in their condition. Hence we find stock not so easily kept up in Winter as in Summer. Difference of climate has an influence on the kind of food which the system demands, as we see illustrated in the case of men from our own country, spending a winter amongst the snow and ice of the Polar regions. Dr. Kane, in his "Arctic Explorations," says: "There are few among us who do not relish a slice of *raw blubber*, or a chunk of frozen walrus beef. The liver of a walrus, eaten with little slices of his fat,—of a verity it is a delicious morsel; * * * * and, as a powerful and condensed heat-making and anti-scorbutic food, it has no rival."

(*b*) The digestive organs are capable of great distention and contraction. If the food is very much concentrated, it nearly all disappears during its passage through the intestines. These organs then become so much contracted as to be brought to a state of *constipation*, which is always unfavorable to health. The stomach, too, acts with less energy in such a case, than it does when distended by a portion of insoluble food. *Fibrous food*, in some form, is necessary for nearly all animals, but especially for those whose natural food is grass and grain, such as the horse and cow. Fine flour and meat, *alone*, do not constitute a wholesome diet for man, especially in warm climates, or in Summer. The bowels require both distention and friction from fibrous matter. This may be supplied by leaving the *bran* in flour, or by eating vegetables and ripe fruits. A horse fed on grain alone, never thrives well; he requires the addition of hay or straw. Some kinds of grain, like oats, have a husk, which provides a considerable supply of woody fibre.

632. *Food for growing animals* must be highly *nutritious*. Every part of the system has to be built up. The muscles, the tendons, the skin, and various membranes and fluids,

require for their increase an abundant supply of *proteine matter*. The adipose tissue is to be provided with *oily substances* for forming fat. The bones, which at first are composed chiefly of organic matter (§ 204), are to be solidified with *phosphate of lime* from the food. The fluids of the body all require for their perfection the soluble salts of potassa and soda. Besides all these, *respiration* must be provided for. What a variety of properties, then, must the food adapted to the young animal possess! But in the sweet and wholesome food which God himself has provided for his tender creatures, we have a most perfect standard. *Milk* contains all that the wants of the young animal demand, until it is capable of chewing and digesting other forms of food. *Caseine* of milk is readily converted into fibrine and gelatine, by the digestive and circulating organs. *Butter* provides fat for the adipose tissue. The bones, too, find here their special mineral, as if provided in anticipation of their wants (§ 204). The other mineral salts necessary for other parts of the body, are also found here. Then the *fuel* consumed to keep up the animal heat, is furnished as *lactose* (sugar of milk). Could we find a more perfect adaptation of means to an end, than we have in the composition of milk?

As soon as the young animal is capable of taking other forms of nourishment, we should provide it with such as most nearly resemble milk in composition. Of the different kinds of grains, no one has a composition so nearly resembling milk as beans or peas (see Table VIII). Bean meal is, therefore, one of the best kinds of food for calves, colts, and pigs, as science would tell us, and as numerous experiments have proved. But to adapt it to their yet feeble digestive powers, it should be *boiled*. *Grass* and *clover* are among Nature's own provisions for this same purpose. *Steamed* hay has been found to be well adapted to this kind of feeding. *Wheat-bran* mixed with a little corn meal, and boiled, forms an excellent food for calves and pigs.

633. *Milch cows* require food containing an abundance of substances convertible into the elements of milk. Hence their food should not differ widely in character from that given to young animals. It may differ chiefly in being adapted to a dissimilar condition of the digestive organs. Food in a less digestible form may be given to the full-grown animal. Such animals require more fibrous matter in their food, than is required by the young. Bean and pea meal, wheat-bran, clover and pea hay, cabbage, carrots, beets, etc., are good articles of food for cows. The quantity of butter may be somewhat increased by mixing a little corn meal with the cow food. If there are not enough of oily substances in the food to provide butter for the milk, the adipose tissue is exhausted to supply the deficiency; hence the difficulty of keeping animals fat while giving milk.

634. *Strength* is required, especially in those animals employed in labor. The strength and activity of an animal reside chiefly in the muscles; it is hence of the highest importance to have these organs well developed and well sustained. It has been shown (§ 600) that the muscles are exhausted by long-continued exercise. If the increase of waste thus produced is not provided for by proper food, exhaustion and weakness must be the result. Such animals, then, should have food containing an abundance of *nutritive* matter.

635. Exercise, and consequent waste of the muscles, render more abundant supplies of nutrition from the blood necessary; and, in order to meet this necessity, the increased activity has the effect of making the circulation of blood more rapid. The rapid circulation demands rapid and free *respiration*, and thus increases the consumption of *respiratory food*. This must be supplied through the digestive organs,

else the fat from the adipose tissue will be demanded to meet the deficiency, and the horse or ox will become "poor."

636. Hence, a proper combination of nutritive and respiratory elements must be contained in food, to adapt it to the wants of animals subjected to severe exercise. But whilst the muscles of one part of the body are actively employed, those in other parts are often subject to a corresponding inactivity; hence the muscles of the digestive organs are less active, at the moment action is going on in other parts of the body, than they are while the body is at rest. In the mean time, the fluids from these organs have been rapidly absorbed and carried to the blood. Especially is this the case in the intestines. A frequent consequence of this is constipation of the bowels, from more than ordinary exercise. After the exercise has ceased, or while it is suspended, the digestive process is restored with increased rapidity; but the bowels have meantime, probably, become too much contracted for their activity to be soon restored, and inflammation and diarrhœa are often the result. To guard against this evil, a considerable quantity of insoluble fibrous matter should be mingled with the food, so as to keep the digestive apparatus properly distended and stimulated. If the exercise is such as to agitate the bowels considerably, diarrhœa, instead of constipation, may result.

The above principles point to a mixture of grain and hay, as affording probably the best combination of those properties which adapt food to the use of work-animals. We find in these the requisite amount of proteine compounds, for keeping up the muscular strength; of starch, gum, and sugar, for supplying fuel for respiration; of oil, to prevent the exhaustion of fat; and of vegetable fibre, to prevent constipation, and aid digestion. The perfection of horse provender is, perhaps, found in good clover or timothy hay, and corn-meal — the hay being cut up and mixed with the meal, and water enough added to make the latter adhere.

637. An occasional change of food is promotive of health, provided only wholesome food be always given. The addition of a little wheat-bran to the provender of horses, or even a few potatoes, beets, or pumpkins cut into fragments, and mixed with their usual food, improve their health by cleansing the mucous membrane of the intestines. The effects will be seen in a more soft and pliant condition of the skin, and in the improved, glossy appearance of the hair.

There is a close connection and strong sympathy between the skin and the mucous membrane, and whatever promotes or impairs the health of the one, has a corresponding effect upon the other. Sudden changes of temperature, which impair or weaken the action of the skin, sometimes result in inflammation of the mucous membrane of the nostrils, trachea, and lungs (§ 620); and at other times the stomach and bowels become similarly diseased from the same cause. On the other hand, food which fails to promote healthful action in the mucous membrane of the digestive organs, causes frequent eruptions on the skin, or unnatural secretions in other parts of the body.

638. If the object we have in view is to *fatten* an animal with the greatest possible rapidity, the chief point in which his food should differ from that of the growing animal, should be in the relative quantity of oily matter contained in it. While it should be adapted to sustain, and even increase, the muscular and membranous parts of the body, it should be more especially adapted to the filling up of the adipose tissue (§ 602). It should, therefore, contain as much oil as is consistent with healthful digestion.

By referring to Table VIII., it will be seen that *corn* is more abundantly supplied with oily matter than any other of the grains commonly used in feeding. Next to it the oat crop is most prominent. There are some other grains, such as flax-seed and rape-seed, which abound still more in oil; but, as heretofore stated, they contain far too much to be either wholesome or palatable when fed alone; but they are sometimes advantageously mixed with forms of food which are deficient in oil. The grasses, whether eaten green or as hay, have oil enough to make them highly valuable for fattening stock. The reader is referred back to § 571.

Having selected the proper kind of food, the next important object is to give it such preparation as will best adapt it to the animal by which it is to be consumed.

PREPARATION OF FOOD.

639. There are some important general principles involved in the preparation of food, which demand our attention. Economy in feeding requires not only the right kind of food, but also such preparation as will give that food its greatest value. It must be in such condition that the animals to be fed will relish it — that they will consume it entirely without waste — and that it shall all be digested, and thus fitted for the purposes it is intended to serve. We often see provender rejected by cattle, because its condition is that of coarse, dry, hard stalks, or straw, difficult to masticate, and often insipid when eaten alone. Again we see the choice portions of hay picked out by horses, and the remainder pulled down and trodden under their feet. Then we often find whole grain passed through animals, as may be seen in the droppings of cattle when fed on unground corn, or of horses, when fed on unground oats. To avoid such waste we must give attention to the most economical means of reducing provender to the best condition.

The means best adapted to the preparation of food are *cutting*, *grinding*, *mixing*, *boiling* or *steaming*, and *fermenting*.

640. *Cutting* aids both mastication and digestion. Portions of the coarser kinds of dry provender, such as straw, fodder, and hay, are often rejected, as above stated, on account of the difficulty of chewing them; and while the more tender parts are selected, others equally nutritious are trodden down and wasted. But if the whole mass is cut into small fragments, a great part of the difficulty of mastication is removed, and the consumption is more complete.

In connection with the question of cutting such substances as straw and fodder, another question of importance arises: "Will it pay" to expend the necessary labor? This must be decided by the circumstances of the case. If the farmer has a great deal more straw and fodder than his stock can consume, and wishes to use the excess as litter for absorbing liquid manure, he may not find any economy in cutting. And even in the case of feeding hay, if the supply is abundant, and the price low, as is frequently the case in the grass-growing regions of Western Virginia, it may be more economical to feed it whole with considerable waste, than to expend on it the labor necessary to cut it up. But in sections of country where such provender is scarce, or where there is a sufficient demand for it to keep up the price, good "cutters" may be among the most economical implements about the farm, and they are no less important in towns and cities where horses and cows are fed at considerable cost.

If a farmer is near to a good market, at which he is certain of realizing a liberal price for his straw, hay, and fodder, his object should be to secure a large surplus of these articles. In order to do this he must feed economically at home — he must prepare whatever part is thrown to his farm-stock in such a way that it shall be entirely consumed. Then, in towns and cities where provender is costly, it is equally important to make every particle effective as far as it can be done. In such cases, all long forage should be well cut.

641. *Grinding* sustains very much the same relation to grain, that cutting does to long forage; but, as grain is more readily transported than other products of the farm, economy in its use becomes more generally important. Grinding is thought by many experienced feeders to add from 20 to 30 per cent. to the nutritive value of grain when fed to hogs or horses, and from 40 to 50 per cent. when fed to cows. The cow masticates grain much less completely than either the hog or the horse. In Autumn, before corn has become hard, there is but little advantage in grinding for hogs.

642. *Mixing* may be added to cutting and grinding with great advantage. When horses or cows are fed on any kind of long forage (hay, straw, fodder, or even shucks), together with meal or bran, the former should be finely cut, and the latter mixed with it—water enough being added to moisten the whole mass. There will then the double advantage arise, (1) of having the whole completely eaten up, without waste; and (2) more perfectly masticated and digested, than if fed separately. A similar advantage arises from cutting beets, turnips, pumpkins, etc. and mixing them with meal.

643. In localities remote from the sea-shore, where vegetation affords too little of the salts of *soda*, to supply the demands of the animal fluids, common salt should be mixed with the food, or else a supply of it kept in a sheltered place, so that stock can get it when they want it. It may be conveniently mingled with food, and at the same time rendered more acceptable to stock, by being sprinkled over hay and straw as they are stacked or packed away in barns. There is generally moisture enough present to absorb the salt completely. From four to six quarts on a ton of hay will greatly improve its quality, and aid in its preservation. A small quantity of salt is beneficial to hogs, if given regularly; but large doses are very poisonous.

644. *Boiling* and *steaming* render substances generally

more soluble, and in that way promote digestion. Steaming has been profitably applied to hay, when fed to young animals, and to sheep, whether old or young. Green grass is more valuable than the hay made from it. In making hay there are changes produced in the stalks and blades, partly physical and partly chemical. Among these changes is the greater insolubility of the fibre. This makes it more indigestible. Steaming reduces it back to a condition somewhat similar to that of green grass. Boiling may be applied to grain, either whole or when ground. It renders the starch more soluble; and if, in the case of meal, a slight fermentation is produced before boiling, a large portion of the starch will be changed to *dextrine*. This is one of the steps in the progress of digestion, already made. When whole grain has been boiled, it is more easily masticated, as well as more easily and completely digested. *Roots* should generally be boiled or steamed.

If our object is to make food perform its office as rapidly as possible—that is, if we wish it to cause rapid growth and rapid fattening—the most digestible condition is the best. In such cases, if the animals are kept comfortable and quiet, there is but little waste of food. Boiling is especially adapted to hogs, and almost indispensable to the thrifty growth of young pigs.

For horses and work-oxen, the boiling of meal is a disadvantage. The digestion then goes on too rapidly. If the grain is ground, and mixed with cut hay or straw, the digestion is made complete, but goes on more slowly. In this way the digestive organs are not so quickly left inactive, and the sensation of hunger is not so soon produced.

645. *Fermenting* meal and bran has an effect in some respects similar to that produced by boiling. Starch is changed to dextrine, and a portion of it even to sugar. This is a more economical method of preparing food than boiling, since

it requires no fuel, and but little labor. A very good method is to have two barrels or tubs, of sufficient size each to hold the material for one day's feeding. In summer, let them be set outside of the kitchen, in such a place that the slop may be conveniently thrown into them. In the morning of one day, have the meal for the next day's feeding thrown into one of the barrels, and require all the kitchen slops of that day to be poured upon it. By the next morning it will be sufficiently fermented to commence dealing it out to the hogs. At this time the other barrel should be supplied with meal, to be drenched with slop for the next day. By thus preparing in one barrel, every day, the meal for the following day, a supply of fermented food may be kept constantly on hand. During cold weather, the fermentation will not take place in the open air. The vessels should then be placed so near the kitchen fire, as to secure a temperature above 60° F.

Care must be taken not to allow the fermentation to progress too far. If the food becomes very sour, it contains too much acetic acid to be either palatable or wholesome. To avoid this, the whole of the contents of the barrel should be fed out on the day for which it was prepared. But there is a limit to the quantity of slop a given number of hogs will drink in a day. Care must be taken, then, not to have an excess collected. The proper limit may soon be ascertained, a corresponding mark made upon the barrel. If the quantity collected is not sufficient, water must be added. Hogs require a good supply of liquid food (§ 381).

Sugar, by a simple chemical change, may be converted into oily matter. The capillaries of the adipose tissue seem to have the power of producing this change, or at least of secreting more fat from the blood than was contained in the food, provided sugar is present. If, then, the fermentation is allowed to proceed just far enough to increase the quantity of sugar, without continuing long enough for this sugar to be converted into alcohol and acetic acid, the fattening property of the food is increased.

QUESTIONS ON CHAPTER XXVII.

§ 630. What are the several ways in which food is disposed of? Explain each.

631. If food is deficient in respiratory substances, what is the consequence? Why do animals require more of such food in cold, than in warm weather? Illustration from Dr. Kane? What cause of constipation is here mentioned? How prevented?

632. What properties must food for growing animals possess? What form of food has these properties in the highest degree? What is the composition of milk (204)? What kinds of food most resemble milk in composition?

633. What kind of food do milch cows require? Examples mentioned? Why is it difficult to keep animals fat while giving milk?

634. In what do the strength and activity of animals chiefly reside? How are the muscles exhausted? What kind of food should laboring animals have?

635. What influence has exercise on the demand for respiratory food? If this is not supplied, what is the consequence?

636. What is frequently the influence of exercise on the digestive organs? How prevented? What mixture forms the best combination of food for work-animals? Why? The most perfect food for a horse?

637. What are the advantages of change of food? How are the effects shown? What connection between the skin and mucous membrane? Effects of sudden changes of temperature?

638. If we wish to fatten an animal, what should be the quality of the food? Which ordinary grain crop contains most oily matter? What of flaxseed, etc.? The grasses?

639. What does economy in feeding require? In what does proper preparation of food consist? How is the food of cattle and horses often wasted? Means best adapted to preparation of food?

640. Advantages of cutting? Is cutting hay, etc., always economical? How does convenience of market render cutting of food important?

641. What are the advantages of grinding? Why especially important for cows?

642. What two purposes are served by mixing food?

643. When should salt be given to animals? How may it be mingled with their food?

644. What is said of *boiling* and *steaming?* The effect upon hay? Upon grain? Why is boiling grain or meal especially adapted to hogs? Should the food of horses and work-oxen be boiled?

645. Effects of *fermenting* food? What method is here recommended for hog food? Effects of too much fermentation? Into what may sugar be converted by the digestive process?

CHAPTER XXVIII.

SELECTION AND CARE OF STOCK.

646. On these points we have room for only a few general principles, and some of their applications. For more definite instruction, the student must resort to books which treat especially of these subjects.

In the selection of stock, several important facts should be kept in mind. In the *first* place, it costs no more to rear or fatten an animal of the best quality, than one of inferior quality. But, on the contrary, it generally requires much less food for the best stock, than for that of inferior grade; while the ultimate value of the former far surpasses that of the latter. *Secondly*, the proportion of the most valuable parts varies widely in animals of different structure. Any one may see, without very close observation, how much larger the bones of one beef-ox are than those of another, whose weight is the same. A like difference may be seen in hogs. *Thirdly*, it must be remembered that the *muscle* and the *fat* determine the true value of any animal intended for slaughter. The hide is not to be disregarded, but is of secondary importance.

647. All kinds of stock whose destiny is the slaughter-house, should have (1) compactly-formed muscles, round and regular in their structure. The flesh in such cases has a finer texture than it has in animals with irregular, loosely-built muscle. (2) Their bones should be comparatively slender. The bone is valueless as food, but requires a large quantity of nutritious matter to promote its growth. (3)

Animals of compact structure, with slender bones, not only require less food during their growth, but are more easily fattened than those of heavy frame and flat muscle.

648. If *strength* is the object sought in our selections, it must be remembered that this is found chiefly in the muscles, not in the bones (§ 599). A bone of medium size, enveloped in well-formed muscles and tendons, is much more efficient than one of larger size, with muscles and tendons loosely constructed. But the qualities which give great strength are to be learned more from *observation*, than from any written description.

649. *The activity* of a horse or other animal is determined from the structure of the bones, by the manner in which they are connected with one another at the joints; by the general figure they give to the whole frame; then by the structure of the muscles and tendons, and the character of their connections with the bones. The bones of an active animal are always slender, and the joints so formed as to give great freedom of motion. The general form of the body is round, and the shoulders high. The muscles are not only firm, but also symmetrical in form, and so attached to the bones as to give the legs a tapering figure.

650. Care of Stock.—Farmers lose as much by careless treatment of stock, as they do from carelessness in anything else. Hundreds of dollars are often lost in this way, which might readily have been saved by a little timely attention. Young animals, which require more attention than all others, are most frequently neglected both as to shelter and food. Many in this way are lost, and many others so much stunted as never to regain their full vigor. If, on the contrary, young animals are well protected against inclement weather, and provided with plenty of appropriate food, they soon gain sufficient vigor to enable them to bear the severities of Winter without danger of being lost, or of becoming so much

enfeebled as never to recover full strength. Every farmer will find it to his interest to give special attention to his colts, calves, and pigs.

651. Horses.—Stables should be *well lighted,* and *well ventilated.* The eyes of horses, as well as people, are very much weakened by being kept in the dark; and then, when brought out suddenly into the full light of day, irritation of those delicate organs is the result. Such treatment, often repeated, frequently ends in *blindness.* Besides securing the health of the eyes, light seems also to do much to promote the general vigor of the animal system. *Pure, fresh air* is not less important for any animal, than wholesome food. The lungs are capable of transmitting other gases, besides oxygen, to the blood. They are also delicate organs, and liable to irritation from the inhalation of impure air. If stables are not well aired, the horses necessarily breathe ammonia and other effluvia, in mixture with the confined atmosphere in which they live. But ventilation should be so managed that the horses will not be exposed to direct currents of air. Openings on opposite sides, higher than their heads, will generally give a sufficiently free circulation. These should be long, and not many inches deep.

652. The *temperature* of stables is not to be disregarded. They should be neither very warm nor very cold. If they are very warm, the horses become severely chilled when brought out in cold weather. If very cold, the waste of animal heat requires a largely-increased consumption of respiratory food. All animals inhale air more freely in cold than in warm weather. This is necessary so as to increase the oxidation of the blood, that a more rapid combustion may go on in the body, and an increased quantity of heat be produced (§ 627). The practice of making stables in the cellars of barns, is very objectionable. They are generally

dark, close, and too warm. If the front is made of open lathing, it does much to remove these objections.

653. The use of *tight girths*, either in riding or working, confines the ribs, and thus prevents the full and free action of the lungs. The oxidation of the blood being thus diminished, circulation is to some extent impeded, the injurious effects of which will be readily inferred from what has been heretofore stated. Loose girthing around the body is sufficient to keep a saddle securely in place, if a second girth is put around the horse's breast.

654. *Kindness* does more to bring animals completely under the control of man, than any and all other means together; and, of all animals, the horse is one of the most sensitive to kind treatment. When colts are treated with a kind hand from the very commencement of life, if dealt with *gently* when first trained to the saddle or the harness, they seldom give their owners much trouble, and are ever afterwards more safe and more useful.

655. CATTLE.—Dry, clean sheds, well littered, and opening toward the south, make the best protection for horned cattle in winter. In cold, wet weather, it may be well to confine them to their shelters, or stable them, but generally, in fair weather, they do better if they have the use of an open lot, supplied with corn-stalks, or straw, to keep down the mud.

When cattle are to be fattened, they should be kept as quiet as possible. If allowed to run at large, they take too much exercise, and thus cause a waste of both muscle and fat. They should therefore be confined to a limited area, but should be made entirely comfortable, so that they may not become restless to escape from their confinement. This plan, of course, cannot be pursued when cattle run on pasture while fattening.

656. HOGS.—These are the most neglected of all domestic animals in our Southern States. Many a poor hog never

knows what it is to enjoy a comfortable shelter during the whole of his precarious life. But, when we consider the fact that scarcely any animal is more sensitive to extremes of either heat or cold, we see at once the importance of having him provided with comfortable shelter against the hot suns of summer, and the cold winds and rains of winter. Every farmer has observed how his hogs pant, when confined in the hot sun; and how they shiver, when exposed to cold, bleak winds, and driving rains and snows.

Under all circumstances, hogs should have a dry bed, frequently provided with fresh, clean litter, in cold weather. If they are confined to a pen in summer, the best bed they can have is a clean, dry floor of plank. Their bedding has much to do with the healthful condition of their skin, and consequently with the health of the animals themselves.

657. SHEEP.—The quantity of wool produced by sheep depends very much upon the care and attention they receive. Open sheds, facing the south, are the most suitable shelters for them in winter. Regular feeding generally finds its reward in the increased weight of both fleece and mutton.

658. BAD HABITS.—The most troublesome of these is the habit of jumping over, or breaking through fences. Such a habit is more easily *prevented* than *cured.* Bad fences are the cause — good fences are sometimes the cure, but always the preventive. If a farmer tempts his stock to commit depredations, by neglecting his fences and gates, he has no right to complain of their propensities.

Good enclosures are economical. Almost every rickety fence on a farm is the cause of more loss of time and crops, in a few years, than would renew or repair it many times. If your fences are always kept in good order, your stock will never learn that it is possible to break into the corn or wheat fields.

QUESTIONS ON CHAPTER XXVIII.

§ 646. What is the first reason given to show the importance of selecting the best quality of stock? Second reason? Third reason?

647. What qualities should be possessed by all kinds of stock intended for the slaughter-house?

648, 649. In selecting animals for strength, what should be especially observed? What determines the activity of an animal?

650. What is said of loss from *careless treatment* of stock? At what period of life do animals require special care?

651. How should stables be constructed? Why well lighted? Why well ventilated?

652. How should the temperature of stables be regulated? Why? What objection to stables in cellars of barns?

653. Effects of tight girths?

654. Advantages of kindness? How may horses be easily broken?

655. What kind of sheds should be provided for cattle? Why should they be kept quiet while fattening?

656. Which of our domestic animals are most neglected? Why do hogs require care at all seasons?

657. What is said of the care of sheep?

658. Why are good fences and good gates economical?

CONCLUDING WORDS.

In all parts of the brief outline here given, the author has aimed to be as concise as was consistent with clearness. Much that has been said was intended as merely suggestive. The leading design has been to present the great principles of Science closely connected with Agriculture, and to show how those principles are involved in the daily business of the farm.

It is hoped that the young farmer will find some things so presented to his mind, as to inspire him with new ardor in his honorable profession; and, at the same time, enable him to pursue it with unwonted pleasure. No profession can ever give much mental pleasure or satisfaction to the man engaged in it, unless he has, first, a clear view of the principles which form the basis of his operations; and, secondly, a distinct understanding of the relation between these principles and his own practice.

The life of the agriculturalist, as well as that of men in other pursuits, may have its toils, its trials, its perplexities, and its disappointments; but it has, at the same time, rare sources of pleasure and comfort. In the first place, it is the most independent of all departments of industry. It is true there is a mutual dependence pervading all the classes of society, but none have to rely so little upon the capricious patronage of their fellow-men as the successful cultivators of the soil. Hence, they are less seldom tempted to resort to trickery and deception, than men in some other professions, in order to secure the favorable consideration of "the public"

Again, every farmer may feel that he is a member of that class upon whom a country like ours is chiefly dependent for its wealth and prosperity. The farming interests lie at the foundation of our national greatness. A paralysis in this department would evidently result in a paralysis of every industrial and commercial pursuit throughout this broad land. The farmers nourish and enrich the nation.

The land-holders of our country, too, are the conservators of the purest patriotism. They are always the most stable and reliable citizens of this, and every other land. No other class of the people have their interests so closely and completely identified with the general and permanent interests of every part of the country — none can be more warmly attached to their native soil — and none are found more ready at all times to raise the strong arm of resistance against every invasion of rights, from whatever source it may come; and yet, no class of our citizens are so conciliatory and conservative in all times of great political excitement. Such considerations give a dignity and importance to agricultural pursuits which few other professions can claim.

Besides these more general relations of the farmer to society, which should cause him to feel no ordinary degree of satisfaction in the pursuit of his honorable calling, he has around him the more closely-associated interests of his own little "republic" at home, in which he can ever find much to alleviate any vexations which may arise to mar his comfort. A well-tilled farm, with its appurtenances all skilfully arranged, and in good order — with its close, strong fences, its deeply-plowed fields, and its well-selected, well-fed, and comfortably-sheltered stock — presents to the mind of any man of taste, a most pleasing object of regard. How much, then, must that pleasure be heightened, when he can say: "All these are my own!" If, in addition to this, the happy owner can look over his broad fields, and view every step taken in their improvement and culture, with the light of Science before his mind — if he can trace each effect back to its true cause — how much more elevated still must be his pleasure, and how much more complete his satisfaction!

There is yet a higher view, which the intelligent tiller of the soil may take of all that he sees around him. When he beholds in the light and heat of the sun, in the air he breathes, and in the fertilizing shower, exhaustless sources of life and joy — when he has learned how nicely the balances of Nature have been adjusted in all her departments — his thoughts must often rise in gratitude to the all-wise Author of these beautiful and benevolent arrangements. In every breeze that sweeps across his fields — in every shower that waters the thirsty land — in the growth of every plant upon his soil — in every shaking leaf, and in every blooming flower by the wayside — Science has taught him to see, and seeing, to adore, the hand of Omnipotence.

APPENDIX.

APPARATUS AND CHEMICALS.

THE list of apparatus and chemical substances given below, will be sufficient for all the important experiments mentioned in this work. They can be bought in Baltimore, Philadelphia, or New York, from dealers in such articles, at about the prices given in connection with each.

APPARATUS.

	Beaker glasses — nest of 5, from 1 to 8 oz.	$0.75
1	Bell-glass receiver — quart size	.50
	Bottles — 1 thin gas generator — pint	.35
	" ½ doz. wide mouths — quart	.50
	Crucibles — nest Hessian	.10
	Corks — 50, of assorted sizes	.50
2	Flasks, round bottoms — one 6 oz. and one 8 oz	.25
1	Funnel, glass — ½ pint	.20
2	Funnel tubes	.30
1	Small clay furnace	.75
2	Stoppered retorts — one half-pint and one 4 oz.	.75
1	Retort stand — common iron	1.00
1	doz. Test-tubes — assorted sizes	.50
1	Spirit-lamp — common	.50
2	Tubes with bulb (air-thermometer)	.25
1	lb. Glass tubes — various sizes	.75
1	Thermometer — common 12 inch	1.00

Common saucers may be used for evaporating dishes, and tea-cups and tumblers for various purposes.

CHEMICALS.

Acids — Acetic	4 oz.	$0.12
" Hydrochloric (Muriatic)	8 "	.10
" Nitric (white fuming)	1 lb.	.25
" Oxalic	2 oz.	.10
" Sulphuric (Oil of Vitriol)	2 lb.	.12
Alcohol (common)	½ gallon,	.50
Alum	½ lb.	.06
Ammonia Water (Spirit of Hartshorn)	½ pint,	.10
Antimony, powdered	1 oz.	.10
Barium, Chloride of	1 "	.10
Copper turnings	4 "	.25
" Sulphate of (Blue Vitriol)	4 "	.08
Ether, Sulphuric	4 "	.20
Fluor-spar, powdered	2 "	.06
Iodine	⅛ "	.10
Lead, Acetate of (Sugar of Lead)	¼ lb.	.10
Litmus Paper, for testing acids	1 sheet,	.06
" " Red	1 "	.06
Manganese, Black Oxide of	1 lb.	.10
Phosphorus	½ oz.	.15
Potassa, fused (in sticks)	1 "	.12
" Carbonate of (Salts of Tartar)	½ lb.	.15
" Nitrate of (Saltpetre), refined	½ "	.08
" Chlorate of (for oxygen gas)	½ "	.25
" Bitartrate (Cream of Tartar)	½ "	.25
Soda, Sup. Carbonate (common)	½ "	.05
Zinc (granulated)	1 "	.25
Marble Powder	2 "	.05
Mercury	1 oz.	.10
Tin Foil	1 "	.10

The quantities given above will be sufficient, if economically used, to repeat the experiments two or three times, in each case. Distilled water should always be employed in dissolving chemical substances. With a retort, and large bottle as a receiver (Fig. 7), a sufficient quantity of water may be distilled in a short time. The clay furnace, mentioned above, may be used for heating flasks and retorts instead of the lamp — charcoal being used as fuel.

The experimenter may soon learn to bend tubes to any shape, by holding them in the flame of a spirit-lamp until the glass becomes soft; then, with the aid of a rat-tail file, he can easily fit them into corks, and thus attach them to the necks of bottles and flasks.

TABLES.

The following tables may often be useful to farmers for reference.

Money.—The "prices current" of foreign markets are frequently quoted in newspapers, in accordance with foreign currencies. In reducing these to their value in our own coin, the tables here given will be convenient.

ENGLISH MONEY.

4 farthings	make	1 penny	=	$\$0.02\frac{1}{60}$
12 pence	"	1 shilling	=	$0.24\frac{1}{5}$
20 shillings (a sovereign)	"	1 pound	=	4.84
21 shillings	"	1 guinea	=	5.10
5 shillings	"	1 crown	=	1.21

FRENCH MONEY.

1 franc	equal to	$\$0.18\frac{3}{5}$
5 franc-piece	"	0.93
1 crown	"	1.10
1 Napoleon (20 francs)	"	3.85

OTHER FOREIGN MONEY.

1 florin (Austria)	equal to	$0.48
1 rupee (Bombay)	"	0.50
1 thaler (Prussia)	"	0.73
1 ruble (Russia)	"	0.75
1 ducat (Germany)	"	$2.23\frac{1}{2}$
1 ducat (Holland)	"	$2.27\frac{1}{2}$
1 doubloon (Mexico)	"	$5.53\frac{1}{2}$

Weights.—*Avoirdupois Weight* is used in all business transactions. The old *long ton* of 2240 lbs. has generally passed out of use in this country, except at Custom Houses.

TABLE OF AVOIRDUPOIS WEIGHTS.

16 drams	make	1 ounce (oz.)
16 ounces	"	1 pound (lb.)
25 pounds	"	1 quarter (qr.)
4 quarters (100 lbs.)	"	1 hundred (cwt.)
20 hundred-weight (2000 lbs.)	"	1 ton (T)
56 pounds of butter	"	1 firkin.
56 pounds of hay	"	1 truss.
14 pounds (an English weight)	"	1 stone.
100 pounds of fish	"	1 quintal.
196 pounds of flour	"	1 barrel.
200 pounds of beef or pork	"	1 barrel.
560 pounds of wheat	"	1 quarter (English).
60 pounds of wheat	"	1 bushel (U. States).
70 pounds of wheat	"	1 bushel (England).

MEASURES.—The standard of *dry measure* in the United States is the Winchester bushel, containing 2150$\frac{2}{5}$ cubic inches. A circular vessel 18$\frac{1}{2}$ inches in diameter, and 8 inches deep, holds a bushel.

The English bushel now in use holds 2218$\frac{2}{5}$ cubic inches.

DRY MEASURE.

2 pints	make	1 quart.
8 quarts	"	1 peck.
4 pecks	"	1 bushel.
5 bushels of corn (South)	"	1 barrel.
8 bushels of wheat (England)	"	1 quarter.

Liquid Measure.—The *wine gallon* is the standard by which liquids are generally bought and sold. It contains 231 cubic inches.

COMMON LIQUID MEASURE.

4 gills	make	1 pint.
2 pints	"	1 quart.
4 quarts	"	1 gallon.
42 gallons	"	1 tierce.
31$\frac{1}{2}$ gallons	"	1 barrel.
63 gallons	"	1 hogshead.

LONG MEASURE.

12 inches	make	1 foot.
3 feet	"	1 yard.
5½ yards (16½ feet)	"	1 rod or pole.
40 rods (220 yds.)	"	1 furlong.
8 furlongs (1760 yds.)	"	1 mile.

4 inches	make	1 hand.
6 feet	"	1 fathom.
4 poles (66 feet)	"	1 chain.
80 chains	"	1 mile.
3 miles	"	1 league.

LAND AND SQUARE MEASURE.

144 square inches (12 × 12)	make	1 square foot.
9 square feet	"	1 square yard.
30¼ square yards	"	1 perch.
40 perches	"	1 rood.
4 roods	"	1 acre.
16 perches	"	1 square chain.
10 square chains	"	1 acre.
640 acres	"	1 square mile.

SOLID MEASURE.

1728 cubic inches (12 × 12 × 12)	make	1 cubic foot.
27 cubic feet	"	1 cubic yard.
28 cubic feet (8 ft. long, 4 ft. high, and 4 ft. wide)	"	1 cord.
24¾ cubic feet of stone (16½ ft. long, 1½ ft. wide, and 1 ft. high)	"	1 solid perch.

A FEW SIMPLE AND USEFUL RULES.

I. *To calculate Simple Interest, at 6 per cent.*—Multiply the *dollars* by *half* the number of months, and the result will be the *interest in cents.* For odd days, multiply the *dollars* by the *whole* number of days, and divide by 60—the result will be *interest in cents.*

For any *other rate* of interest, as 7 or 8 per cent, multiply the *dollars* by the *rate per cent*—the result will be the interest for *one year in cents.* This divided by 12, is the interest for *one month.* The interest for one month divided by 30, gives the interest for *one day*. From these, the interest for longer periods may be calculated.

II. *To determine how many* BUSHELS *a given Space will hold.*—Multiply together the length, width, and depth, measured in *feet*. This gives the contents in *cubic feet*. Then multiply the number of cubic feet by 4, and divide the product by 5 — the result will be the number of *bushels* required; at least with sufficiently close approximation for ordinary purposes.

Illustration. — A garner 8 feet long, 5 feet wide, and 6 feet deep, contains $(8 \times 5 \times 6 =)$ 240 cubic feet; and will hold $\left(\frac{4 \times 240}{5} =\right)$ 192 bushels, very nearly.

III. *To determine the Contents of a Circular Vessel or Cistern in Gallons.* — Multiply the *diameter* (measured in feet) by $3\frac{1}{7}$, and this product by *one-fourth* of the diameter—this will give the area of the bottom, which, multiplied by the depth (in feet), gives the contents in *cubic feet*. To reduce this to gallons, multiply by $7\frac{1}{2}$. (A cubic foot holds about $7\frac{1}{2}$ gallons.)

Illustration.—A cistern of 8 feet in diameter and 12 feet in depth, contains $(8 \times 3\frac{1}{7} \times 2 \times 12 =)$ 602 cubic feet, and $(602 \times 7\frac{1}{2} =)$ 4515 *gallons*, nearly.

To determine the contents of the same cistern in bushels (see Rule II), multiply the cubic feet by 4, and divide by 5. Thus, $\frac{602 \times 4}{5} = 481\frac{3}{5}$ bushels.

If the cistern is narrower at the bottom than it is at the top, the diameters at top and bottom should both be measured, their lengths added together, and the sum divided by 2. This will give the mean diameter, which may be used as in the preceding example, with a tolerably accurate result, provided the upper and lower diameters do not differ much in length; but if they differ widely, the result will be too great.

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