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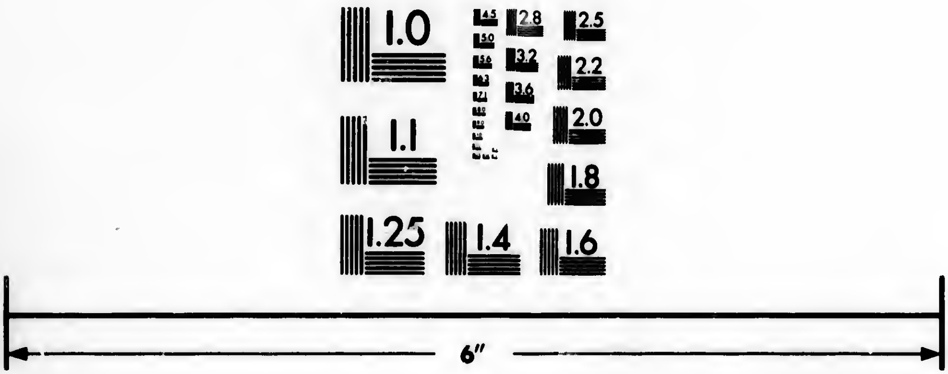

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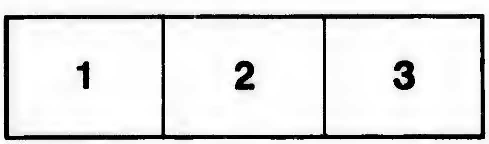

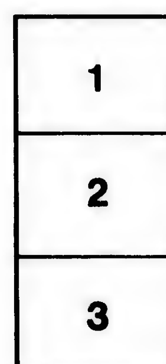

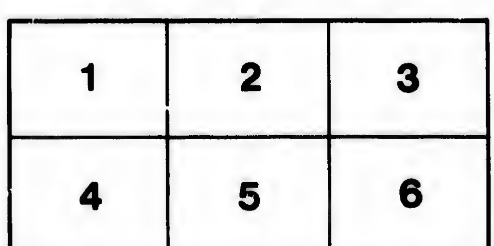

THE CHEMISTRY OF COMMON THINGS.

NOVA SCOTIA SCHOOL SERIES.

THE

CHEMISTRY OF COMMON THINGS.

BY

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Preface.

THIS little treatise on the Chemistry of Common Things is intended to be read by the more advanced pupils in schools and educational institutions, as also by others who desire to obtain a general and popular knowledge of the chemical relations of the world around us.

The teacher may illustrate the subject of reading by a few experiments and the exhibition of some specimens of rocks and minerals. The woodcuts which are introduced into the work will serve as a guide in the illustrations, and to some extent will supply the place of actual experiments.

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THE

CHEMISTRY OF COMMON THINGS.

INTRODUCTION.

CHAPTER I.

THE CHEMISTRY OF THE WORLD AROUND US.

1. The events of every-day life may be little observed by us, but still they are wonderful. Strange things are taking place every day in town and country, which, from their daily and hourly occurrence, have become so familiar to us, that the greater number of old as well as of young people have ceased to wonder at them. When a child first learns to observe and remember anything correctly, it may give expression to much surprise when a tree puts forth its leaves, or a rose-bush unfolds its flowers; but the momentary thought about the birth of the leaves or the pretty little roses, in most instances, soon dies out for want of culture.

2. Were an inhabitant of some other world, differently constituted from our globe, to land on the Earth some bright summer morning, and inspect our homes, he would probably feel puzzled to understand how people inclosed in bodies of flesh and blood could be profited by partaking of oat-

meal and milk or bread and tea. If the stranger sojourned here for a year or more, he would, amongst other things, hardly fail to observe that a tree, with its roots fixed in a sandy soil, and its leaves dangling in the thin air, could, as each summer's sun beat upon it, shoot higher and higher, putting out more branches and leaves; and that a young animal, let loose for a number of months in a grass plot, could, by eating grass, add to its flesh, blood, and bones.

3. The occurrence of these, and other events of a like startling nature, would give our visitor from the Stars abundance of matter to think about, if he were inclined to be thoughtful at all. Did the tree flourish simply because it drew up into its interior a quantity of sand or clay, or the young animal grow heavier merely because it stored up in some internal cavities a quantity of grass, then no mystery would for a moment overhang either example. But the tree accumulates woody matter, and no true wood appears within its reach; and the body of the animal is being constantly augmented by successive quantities of flesh, and blood, and bones, and neither of these are directly partaken of.

4. Though plants and animals appear different, they are made up of the same substances. The blade of grass, as it grows in our fields, looks very unlike the ox which feeds upon it. In colour, shape, texture, and, indeed, in all that which marks the external aspect of the grass and the animal, the one stands in striking contrast to the other. But however unmistakable the difference may be in their general outward appearance, yet the moment the investigation is directed to their chemical constitution, it is observed that the ultimate substances, of which each plant and each animal are made up, are identical.

5. From the same quarry, stones may be taken which at one time go to build a palace, and at another time a cottage.

So far as the general aspect of the dwellings is concerned, the one appears different from the other, but in the stones and the lime they are the same. And so in the plant and the animal kingdoms. The little particles of matter of which each plant and each animal are made up, have been obtained from the same great reservoirs of matter—the thin air or atmosphere, and the solid earth or soil; and though in look different, yet in the materials of which the many thousand plants and animals are built up, they are at one.

6. When a tree, or, what comes to the same thing, a piece of wood or coal, is burned, the greater part passes off as gas, and a very little of a grayish substance is left, which is generally called the ash. This is well seen in the burning of wood or coal in our fire-places. And, again, if a piece of an animal, such as a slice of meat, be thrown on a bright fire, it begins to char, and in greater part burns away, leaving a small quantity of ash behind. These experiments teach us, that when a plant or an animal is burned, it almost entirely becomes gas, which curls up the chimney and escapes into the air, whilst, at the same time, there is left behind a few ashes which cannot be burned.

7. All animals are dependent on plants for the food necessary to sustain their existence. It is true the lion feeds on other animals, and therefore he does not directly make use of plants as food; but the animals which he partakes of derive their sustenance from plants, and when he devours them, they hand that over to him. Herbivorous (grass-consuming) animals, therefore, obtain their nourishment from plants at first hand; and carnivorous (flesh-devouring) ones do so at second hand, or after it has passed through the system of the plant-eating animal.

8. Plants, on the other hand, derive their food from the air and the soil. The quantity of matter which they obtain

from each of these sources is inversely that which would appear at first probable. The earth, in which the roots of a plant are fixed, is so solid, stable, and abundant, and the air in which the leaves flutter is so flighty and thin a medium, that nothing is more natural than to suppose that, besides affording the plant anchorage ground, the soil may supply the larger part of the matters necessary for building up the plant structure—but such is not the case.

9. The whole of that matter which passes off as gas when a plant is burned, has been obtained at one time or another from the atmosphere; whilst the very small portion left as ash is all which has been derived from the soil. The atmosphere, therefore, is not only the region into which the noxious gases and the smoke from our fires pass, but it is likewise the great feeding-ground from which plants procure the greater portion of their food.

10. The atmosphere and the soil are, indeed, the great store-houses out of which matter is lent to the plant and the animal. Every one knows that a book consists of so many pages, each page of a number of words, and each word of one or more letters. At the first, the types which print these letters are lying in boxes, from which the compositor lifts them, and thereafter arranges them into words. Now, the plants and the animals on this world may be said to constitute the great book of living beings. Each individual is like a page, made up of a number of little pieces, which in their turn consist of still smaller parts or atoms. The atmosphere and the soil are the places where all these atoms are kept when they are not in use.

11. While a plant is growing, it draws in from the air and the ground a multitude of little atoms, which it builds up within its structure in many different forms. When the plant is ripe, and is partaken of as food by the animal, the

latter takes possession of the atoms, and these become part of the animal frame. And just as the compositor, when the printing of the book is finished, takes all the type letters down again, and throws each one into the box it came from, so, when the plant and the animal die and rot, or are burned, all the atoms which compose them are separated; the part which came from the air returns to the same region, and that which was taken from the soil is bequeathed back again to it.

12. Agriculture, or the art of producing food, is the most primitive as well as the most necessary vocation. Whatever appertains to the direct production of food for man must be considered the most essential of all practical information. At the same time, it must be remembered that what relates to food is not the only thing which man need think of, even when his thoughts are turned solely to earthly matters. The hard rock and the unwieldy clay have locked up within their stony grasp, treasures of gold, silver, copper, lead, iron, mercury, and many other things, which cannot be used as food; but which in the hands of man have been turned to good account, and have been made the means, at least, of procuring that most necessary of all things—namely, *food*. In this way the useful arts and manufactures become a necessity, opening, as they do, the door by which millions of men can pass through this life with ease and comfort to themselves and others.

13. The daily growth of a plant or an animal is, doubtless, a wonderful thing; but the hard rock and the thin air afford us, likewise, much cause for astonishment. The plant spins wood out of air and clay, and the animal manufactures flesh out of grass; but these events are not a whit more strange than that a candle or a coal-fire burns, a piece of iron rusts, an egg rots, or gunpowder explodes. Were we not accus-

tomed to such changes, we would not only be surprised at their occurrence, but would, doubtless, feel alarmed at the appearance of many of them.

14. In the kindling of an ordinary fire, the paper burns, and disappears as gas; the sticks then commence to sparkle, crackle, and vanish; and the *black* coals begin to send forth *white* flame, become *red* hot, and, ghost-like, glide slowly from our sight. These, and a thousand other changes in stone and gas, are going on around us every day, and yet we scarce give them a moment's thought

15. The various simple substances or elements which constitute the atmosphere and the soil, and which at times appear in the plant and the animal, form the alphabet of chemistry. The number of elements contained in the A, B, C of chemistry, is sixty-five. About twenty of these elements are everywhere to be found, and enter into the composition of plants and animals, whilst the remaining forty-five elements occur only here and there in small quantity.

16. In the English alphabet there are twenty-four letters, by assorting which in different ways, many hundreds of words are made up. And so in regard to the chemical alphabet. The sixty-five elements in it can be united together in very many ways, and yield thousands of different substances—gases, liquids, and solids;—all of which are, doubtless, serviceable to man, directly or indirectly. Some are useful as food, and thereby give him strength and life; others can be cemented together into a house, and thereby afford him shelter; whilst others assist him much in his daily avocations.

17. When we wish to learn a language correctly, we must commence at its alphabet; and learning letter by letter, afterwards proceed to form these letters into words, and words into sentences, and sentences into paragraphs. And

so, in the study of chemistry, we must first learn something about the more simple substances or elements which compose the Earth's crust; and thereafter we will be in a position to understand how these can be united together to produce complex substances, such as are found in minerals, and in plants and animals.

PART I.

THE ATMOSPHERE AND ITS RELATION TO PLANTS AND ANIMALS.

CHAPTER II.

CONSTITUENTS OF THE ATMOSPHERE.

18. THE atmosphere which surrounds the Earth is composed of millions of atoms of matter in a gaseous condition. These minute particles of air or gas are invisible to us, but nevertheless they fill up, not only the valleys, but ascend far above the highest mountains, and form a mantle or covering which entirely envelops the globe, and its plants and animals.

19. The lower stratum of the atmosphere which we reside in is pressed upon by the higher portions, and is comparatively heavy; but as we ascend into the upper regions of the air, either in a balloon or by climbing a mountain, part of the air is left below, and that which remains above, being subjected to less pressure, is more and more expanded, and becomes thin and rare.

20. The total thickness or height of the atmosphere is about 45 miles; but one-half of the whole is situated within $2\frac{3}{4}$ miles of the level of the sea; three-fourths of the whole lie within $5\frac{1}{2}$ miles; and the further we recede from the sea the air becomes the more attenuated, till at a distance of 30

miles it is so much expanded and rare, that less than 100th part of the entire atmosphere is left to occupy the remaining 15 miles of thickness.

21. The pressure which the air exerts on the globe and everything contained thereon is from 14 to 15 pounds on every square inch of surface; which is equal in weight to a covering of water to the height of 32 feet, or a coating of quicksilver about 30 inches in depth. The atmospheric pressure is exerted equally on every side, and accordingly is not perceptible to touch; but an ordinary-sized man, presenting about 2000 square inches of surface, must be subjected to a pressure of 30,000 pounds, or nearly 15 tons. This enormous weight is easily borne by us, owing to the uniformity of the pressure; whilst its withdrawal to a greater or less extent would lead to loss of blood, and to the disunion and destruction of the animal frame.

22. The temperature of the atmosphere is greatest at the surface of the earth, and becomes colder as we ascend, in the proportion of about 1° F. for every 352 feet in the lower regions, and less at greater heights. In all countries possessing a mountainous character, the freezing-point is reached at a greater or less distance from the sea-level. Thus, even at 0° latitude (the Equator), the level of everlasting snow is 15,207 feet; and this gradually descends, till at 60° latitude the snow-level is less than 4000 feet above the sea. The Andes, in South America, which rise to a height of 21,000 feet, are always covered with snow for a considerable distance from the top.

23. It is impossible to see the little particles of matter of which the atmosphere is composed; but it is highly probable that each minute atom of gas does not touch its neighbour atom, and that a certain space intervenes between each. Thus the various gases may be represented by signs as in

Fig. 1, where the asterisks * stands for particles of oxygen

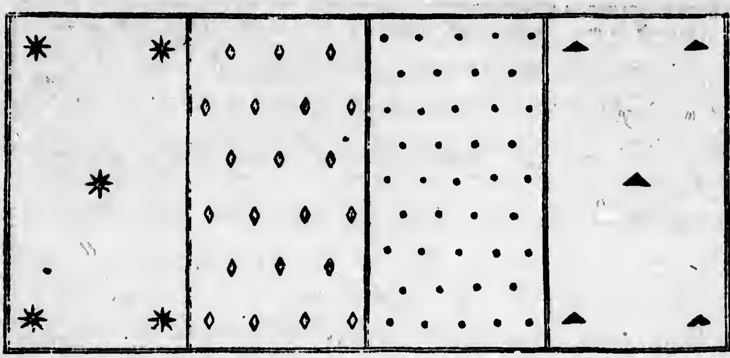


Fig. 1. (Dalton.)

gas, the minute diamonds ◇ for atoms of nitrogen, the periods • for water vapour, and the pigmy pyramids ▲ for atoms of carbonic acid, and where in either case the gaseous particles are represented as separated from each other by a greater or less space.

24. If we could, by the aid of a powerful microscope, be able to observe the particles of the various gases as they are mingled together in the air, they would probably present the appearance which the artist seeks to depict when he is painting a snow-storm, and where every little flake of snow appears here and there as a white dot on the canvas; or that observed in Fig. 2, where the atoms of the various gases are represented by different signs. We may thus obtain some conception of the manner in which all the particles of the gases are present in the atmosphere, though they are so small that they cannot be made visible to the eye, and consequently cannot be seen.

25. The atmosphere has been shown by the chemist to be a mixture of many different gases and vapours, which are not in a state of union; but the particles are merely

mechanically mingled, as small pieces of coal and sand

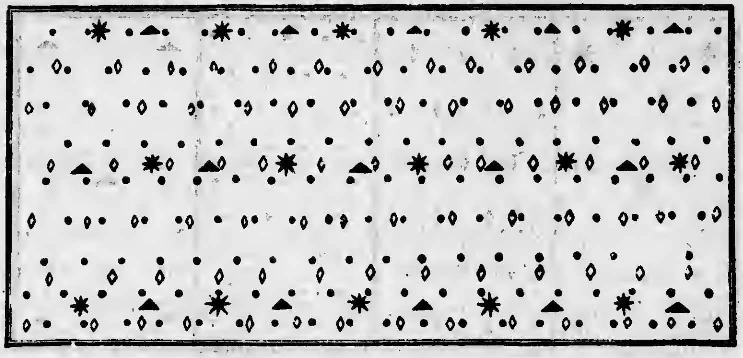


FIG. 2. (DALTON.)

would be were they shaken together. The more important constituents of the atmosphere are given in the following table:—

PRINCIPAL CONSTITUENTS OF THE ATMOSPHERE.

Oxygen,
Nitrogen,
Carbonic acid,
Water vapour,
Ammonia,
Nitric acid, and
Ozone.

26. The two gases, oxygen and nitrogen, constitute by far the greater bulk and weight of the air; whilst the carbonic acid, ammonia, nitric acid, ozone, and water vapour, are present in much smaller quantity. Other substances, such as the fragrant perfumes from sweet-scented flowers, the badly-smelling gases evolved from putrifying matter, and miasma generated in damp places, are known to pass

into the air; but the proportion of these is so small, and their durability probably so short, that they have only been discovered as constituents of the great atmosphere by the most delicate tests in the immediate neighbourhood of their production.

27. In all countries the atmosphere possesses the same composition. It has been examined in Paris and in London, and has been brought from high alpine hills, and been collected at a height of 21,000 feet in a balloon; and leaving out of consideration the less abundant gases, the oxygen and nitrogen are present in the proportion of nearly one volume of oxygen to four volumes of nitrogen, forming five volumes of atmospheric air. The proportion of these gases in the air is in 100 parts:—

By volume—

21 of oxygen,
79 of nitrogen.

And by weight—

23 of oxygen,
77 of nitrogen.

OXYGEN.

28. This gas is one of the most important elements in the whole earth. It is not only present in the atmosphere to the extent of one-fifth of its entire bulk, but it forms eight out of every nine parts by weight of all water, is a constituent of the stones of which our house walls are built and streets paved, and of the clay of our fields and the sand of the sea-shore. Indeed, oxygen is so universally distributed in large quantity in every region of the world, that it is estimated that nearly one-half of the whole globe is composed of it, either in a gaseous, liquid, or solid condition.

29. The presence of oxygen in the atmosphere can be easily demonstrated in the ordinary phenomenon of the rusting of a piece of iron. When the iron is left exposed to the air, it soon gets coated over with a red powder; and if allowed to rust long enough, the hard tough iron disappears, and in its place there remains a quantity of red ochre or rust. During the process of rusting, the little atoms of iron seize the oxygen of the air as it floats over them, and combine therewith to form the red powder, which is thus composed of iron and oxygen.

30. The most convenient method for the preparation of oxygen is to heat a mixture of chlorate of potash and black oxide of manganese. The apparatus required is a glass flask provided with a good cork and a glass delivery tube, and a pneumatic trough with a shelf and several glass jars. (Fig. 3.)

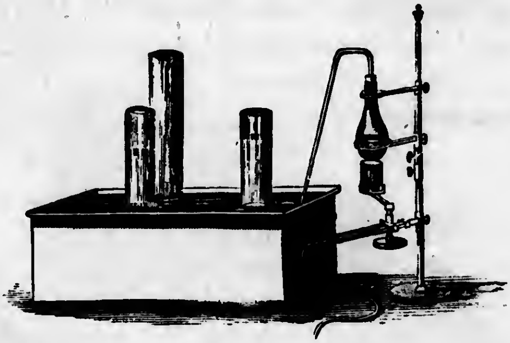


Fig. 3.

31. Four parts of chlorate of potash and one part of black oxide of manganese are mixed together and introduced into the flask; and then heat is applied. The oxygen gas quickly comes away, and, escaping from the end of the bent tube, can be received in the jars filled with water, and standing on the shelf of the trough. The gas rises into the jars and displaces the water.

32. Oxygen is a transparent, colourless, odourless, and tasteless gas, and in these respects is not distinguishable from ordinary air. It is heavier than atmospheric air in

the proportion of 1105 to 1000. It is not combustible, but is a great supporter of combustion. Thus a splinter of wood which has been ignited and blown out, so as to leave only a red tip, is immediately rekindled on being thrust into a jar of oxygen. (Fig. 4.) A candle with merely a red wick, when plunged into a jar containing oxygen (Fig. 5), is relighted in the same manner, and thereafter burns most vividly.

FIG. 4.

FIG. 5.

33. Again, a piece of sulphur placed in a small spoon, heated till it takes fire, and then introduced into a globe of oxygen (Fig. 6), burns with a beautiful blue flame; and phosphorus, when set fire to under a bell jar containing the gas (Fig. 7), gives rise to the evolution of light of the most dazzling nature.

FIG. 6.

FIG. 7.

34. Indeed, so great is the power of oxygen to support combustion, that a coil of fine iron wire, which has been tipped with burning sulphur and introduced into a jar con-

taining the gas (Fig. 8), immediately passes into vivid combustion, and the burning iron falls in white hot globules into a metal tray placed beneath. It is the presence of oxygen in the atmosphere, to the extent of one-fifth of its volume, which enables our candles, gas jets, and coals to burn; and the other constituents of the air dilute the oxygen to that point at which the combustion can proceed at the ordinary rate.

FIG. 8.

35. As a supporter of respiration, or the breathing of animals, oxygen is likewise of vast importance; and were its presence withdrawn from the air for several moments, every animal would die. Indeed, oxygen is air-food to the animal, and is being constantly inhaled or breathed into the living system. Land animals obtain the supply of oxygen which they require through the operations of the lungs, which thus serve the office of carriers of air into the animal frame. Oxygen is soluble in water to the extent of 3½ volumes in 100 volumes of water; and it thus becomes of great importance to fish and other animals inhabiting fresh and salt water, which receive their air-food dissolved in the water which surrounds them, and which in many cases they pass through their gills.

NITROGEN.

36. Every five gallons of atmospheric air contain four gallons of nitrogen, which is thus the most abundant constituent of the gaseous envelope. It is generally prepared by removing the oxygen from a confined portion of air. This is most easily accomplished by burning a piece of phosphorus on a small stand under a glass bell jar containing ordinary

air. The open end of the jar rests on a plate containing water. (Fig. 9.) The phosphorus in burning combines with the oxygen of the air, forming a white substance resembling snow, and called phosphoric acid, which quickly dissolves in the water, whilst the latter rises in the jar to supply the vacant place. When the phosphorus exhausts the oxygen, and thus extinguishes itself, the nitrogen gas remaining in the jar will become transparent in a short time, and will then occupy four-fifths of the original volume of the vessel.

FIG. 9.

37. Nitrogen is a colourless and transparent gas, with no taste and no odour. It is not combustible, neither is it a supporter of combustion, as may be observed by inverting the jar in which it was prepared, and plunging a lighted candle therein, when it will be immediately extinguished, owing to the want of oxygen. It is a general rule that a gas which will not allow a candle to burn in it will not admit of an animal to live in it, and nitrogen is no exception to this rule. It is a non-supporter of respiration, and animals introduced into pure nitrogen almost immediately die.

38. The very large proportion of nitrogen in the atmosphere at once tells us that it cannot be directly a poisonous agent; and the death of animals introduced into the pure gas is due rather to the absence of the oxygen or air-food. The principal offices fulfilled by nitrogen in the atmosphere appear to be the proper dilution of the oxygen to that point when it can support combustion and respiration, without active destruction of material, whilst at the same time it imparts that bulk to the entire atmosphere which is necessary for

the production of strong currents of wind, which are alike useful in navigation and in carrying away smoky and poisonous gases.

CARBONIC ACID.

39. This gas is present in the free atmosphere in the small proportion of one part in every 2,500, or four volumes in 10,000 of air. It may be recognised as a constituent of the atmosphere by exposing some clear lime water in an open vessel, such as a tumbler or saucer. The lime water may be prepared by adding water to slaked lime (same as is used in making mortar); and after settling, a clear solution of lime is obtained. On exposing this liquid to the action of the air, the lime combines with the carbonic acid, forming carbonate of lime or chalk, which appears as a white film or skin on the surface of the water. This test is regarded as one of the best methods of showing the presence of carbonic acid in the atmosphere.

40. In the preparation of the gas in a state of purity for experimental purposes, recourse may be had to chalk, or, what is chemically the same thing, marble, which is found in masses like ordinary stone at and near the surface of the earth. When the marble is acted upon by an acid such as sulphuric acid or hydrochloric acid, much gas is evolved with effervescence, which consists of carbonic acid.

41. The apparatus required for the preparation of the gas is a double necked gas bottle (Fig. 10), fitted with a funnel tube for pouring in liquid, and a delivery tube for the escape of the carbonic acid gas. Chips of marble are placed in the bottle, the tubes are inserted, and thereafter some water and sufficient

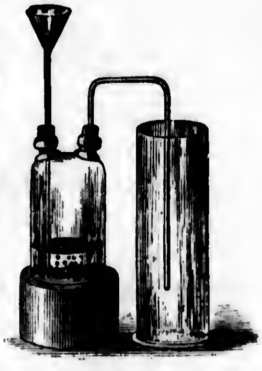


Fig. 10.

hydrochloric acid are added to cause the disengagement of the gas with effervescence. The delivery tube conducts the escaping gas to the lower part of the jar which is placed to receive it. As the gas continues to flow from the bottle, it chases out the air originally present in the jar, and in a short time the vessel becomes completely filled with carbonic acid.

42. The great weight of this gas, as compared with ordinary air, admits of a jar being filled with it by the above process of displacement, but it may also be prepared and received over water. The apparatus required for this mode of collecting the gas consists of a gas bottle, with a delivery tube leading the gas to a pneumatic trough, where it is passed into jars which have been previously filled with water. (Fig. 11.) On the large scale, carbonic acid is

FIG. 11.

liberated in leaden vessels, from chalk or whiting and sulphuric acid, and is used for charging soda water, lemonade, and other aërated or effervescing waters.

43. Carbonic acid is a transparent, colourless gas, with an

agreeable, acidulous taste, as observed in the effervescing liquid known as soda water. When a bottle containing soda water is opened (Fig. 12), the gas which escapes in bubbles or bells is carbonic acid. It is soluble to the extent of its own volume in cold water, and hence there is some loss in preparing the gas at the pneumatic trough. A stream of the gas on being passed through water coloured with blue litmus or purple cabbage, exhibits faint acid properties.

FIG. 12.

44. When the gas from the generating bottle (Fig. 10) is allowed to flow through lime water contained in a wine glass or tumbler, it first causes the formation of a milky liquid due to the formation of carbonate of lime or chalk, and thereafter it dissolves the precipitate and yields a clear sparkling liquid, which agrees with many natural *hard waters* in containing chalk dissolved in excess of carbonic acid.

45. A lighted candle introduced into a vessel containing carbonic acid, is immediately extinguished, and the gas itself refuses to burn. In the same manner, a lighted taper, flaming sulphur, and burning phosphorus, are put out when introduced into the gas. Carbonic acid, therefore, is neither combustible nor is it a supporter of ordinary combustion. A piece of magnesium wire or ribbon, however, when lighted and plunged into a jar of carbonic acid, will burn as readily there as in ordinary air.

46. The density of the gas is half again as much as air, being 1524, whilst air is 1000; which signifies, that a vessel which, when filled with air, would hold in the proportion of 1 pound, would, when filled with carbonic acid, contain $1\frac{1}{2}$ pound. The weight of the gas is so great, that it can

be poured out of a vessel like ordinary water; so that if a candle be placed on a table, and a jar of carbonic acid have its mouth inclined over it (Fig. 13), the gas flows down and extinguishes the light.

FIG. 13.

47. Carbonic acid is a powerful poison, and an animal immersed in the gas is almost instantly killed by suffocation. Even a mixture of 100 parts of air and 5 parts of carbonic acid, which allows a candle to burn feebly in it, will prove poisonous when breathed by an animal. Such an impure atmosphere may be readily formed by burning a candle under a glass jar, when carbonic acid is evolved during the combustion of the candle in quantity sufficient to extinguish the light in a few minutes.

48. Although the action of carbonic acid on the life of an animal and on the light of a candle is apparently the same as that exerted by nitrogen, yet the cause of the extinguishment is not the same in both cases. This will be more easily understood if it is remembered that a man will die if he gets no food, just as certainly as if arsenic had been mixed with food and given to him. In the first instance, the man will succumb to exhaustion consequent on starvation; and in the latter case, the poison will prove the instrument of death.

49. Nitrogen, when it is breathed alone, kills a man, because whilst he is breathing it, he is kept from inhaling the oxygen necessary for the continuance of life; and thus he is, strictly speaking, starved to death. Carbonic acid, on the other hand, has a positively prejudicial action on the animal system, and even when mixed with a large proportion of air, will kill any animal which breathes it.

50. There is thus floating about in the atmosphere a small

quantity of a gas which is a poison to us. The meagreness of its amount compared with that of the oxygen is our safeguard. The proportion of carbonic acid in the air being only one part in 2500, whilst that of oxygen is one in five, it follows that the oxygen is present in the atmosphere to an extent 500 times greater than that of the carbonic acid. Notwithstanding its poisonous powers, carbonic acid is a gas which has most important functions to perform in the economy of nature, as will afterwards appear more evident.

51. Carbonic acid differs from the gases previously considered in being *compound*, and not *simple*, as oxygen and nitrogen are. The meaning of these terms will be observed from the statement, that two substances can be obtained from carbonic acid, and therefore it is compound, or is composed of more than one kind of matter; whilst oxygen and nitrogen, when subjected to the action of any of the forces, have not been shown to contain respectively more than one sort of element, and are therefore simple.

FIG. 14.

52. The substances which enter into the composition of carbonic acid are carbon (pure charcoal) and oxygen. If a piece of charcoal be attached to a wire, set fire to, and plunged into a globe or bottle containing oxygen gas (Fig. 14),

it burns very quickly, and rapidly disappears, passing into the condition of carbonic acid gas, which remains in the vessel.

53. In order to show that by the combustion of charcoal in oxygen, the two substances unite, and produce carbonic acid, some clear lime-water may be poured into the globe, and the whole well shaken, when the liquid will become milky in appearance, owing to the formation of carbonate of lime or chalk, and thus prove that carbonic acid had been formed. What occurs in the small vessel, where a fragment of charcoal is consumed, takes place on the large scale when coals and wood are burned in our grates, as also during the combustion of coal gas, candles, &c.

54. The quantity of carbonic acid evolved by the burning of fuel must be very great, though no certain data are in existence from which the amount may be calculated. The quantity of coal consumed in Britain in a single year amounts to about 80,000,000 tons; and the combustion of this quantity of coal would alone yield 200,000,000 tons of carbonic acid. How much greater must be the quantity of this gas evolved during the respiration of all animals, the combustion of candles, wood, &c.! During fermentation as well as the natural decay of plants and animals, carbonic acid also passes into the air; and the same gas is constantly issuing from fissures in the earth's crust, as in the Grotto del Cane in Italy, in the Poison Valley of Java, and generally in all volcanic districts.

WATER VAPOUR.

55. However clear and cloudless the sky may be, water vapour is always present in the atmosphere. The proportion of water in the air varies according to the season of the year

and the state of the weather. The average amount may be stated to be from one part to one and a half in every 100 parts of air. As it descends to the earth at intervals, in the form of rain, snow, and hail, it is necessary that the amount in the atmosphere be kept up.

56. The appearance of a cloud in the sky reminds us occasionally of the water in the air. And the descent of rain, snow, or hail, conclusively proves that the atmosphere has much water vapour in store, which it parts with in the shower of rain, the storm of hail, and the numberless beautiful flakes of snow, which present many different crystalline forms (Fig. 15).

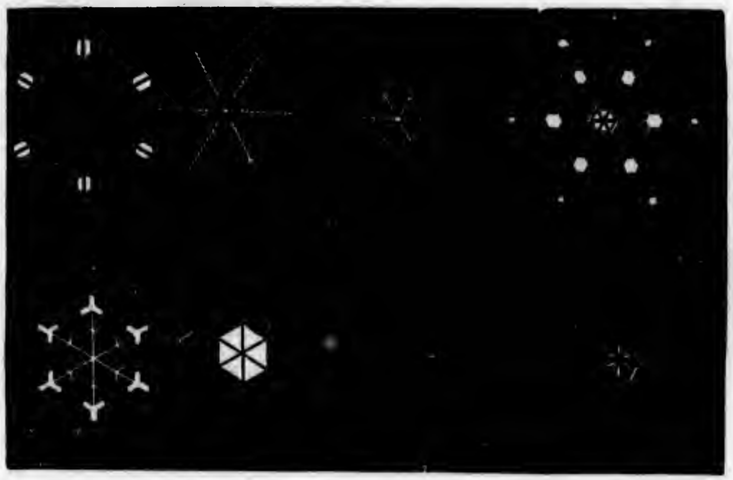


FIG. 15.

57. The rain which falls on the streets and the roofs of houses is soon dissipated in vapour, when the shower passes over and the sun again shines brightly. And though not so obvious, yet it is equally certain, that from the surface of

every lake, every river, and every part of the ocean, there is a quantity of water constantly rising in vapour. The entire surface of the globe is estimated at about 200,000,000 of English square miles. The land covers 50,000,000 of that space, and the sea rules over about 150,000,000. So large a surface cannot fail to send much water into the air.

58. Even a block of ice, cold though it be, gives off a small quantity of gaseous water at ordinary temperatures; and, as a consequence, slowly decreases in weight and size. Heat greatly assists evaporation, and, when applied to a vessel containing water, the quantity which passes into vapour increases as the liquid gets warmer, till, as is well known in the process of *boiling*, the water rapidly passes into steam.

59. Although what is popularly called steam appears as a white cloud, yet true steam is never seen as such. When water is boiled in a thin glass flask (Fig. 16), it will be observed that so long as the steam remains in the upper part of the flask it is as clear and transparent as ordinary air is; but after it is projected a little distance into the cold air immediately above, it gets cooled down, and condensing, forms itself into a multitude of minute bladder-like particles, which may be called *water-dust*, and then becomes a little cloud.

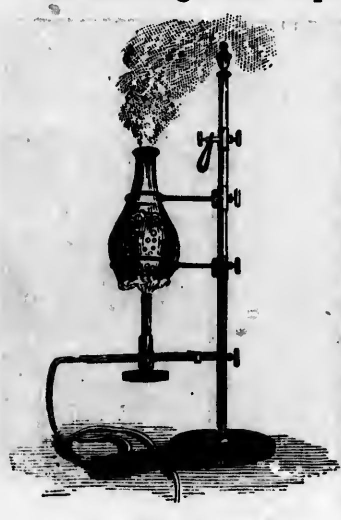


FIG. 16.

60. What is thus seen on the small scale, in and near a glass flask, takes place on the largest scale in our atmosphere. When the sky is destitute of the merest speck of a cloud, as in one of our bright summer days or clear moonlight nights,

water exists in the air as true vapour, and is as invisible as the steam in the upper part of the flask; but the moment a colder wind blows in amongst the air containing much gaseous water, the formerly invisible vapour appears as a cloud.

61. Clouds, therefore, are condensed water vapour, the particles of which may be supposed to be made up of little bladders, each inclosing air, like a minute soap-bell, or a little bag. Winds can waft these clouds to and fro, till, through changes in the electrical state of the atmosphere or otherwise, the little water bags get broken up and run into each other, and multitudes agglutinate together and form a drop of rain.

62. From whatever source water is procured—whether from the ocean, shower, spring, river, or lake—it is always the same. It is true that water from the sea has a different taste from that of rain water; but the difference does not lie in the water, but in the substances dissolved in it. If two tumblers be filled with water from the same vessel, and a portion of sugar be placed in the one, whilst some salt is added to the other, it will soon become apparent, on tasting the liquids, that the one contains sweet water, and the other salt water.

63. It is the same as if two houses were built of similar materials, and the one was tenanted by a sugar merchant, who stocked it with loaves of sugar, whilst the other was occupied by a salt merchant, who filled the rooms with parcels of salt. Some people would be inclined to call the one a *sugar house*, and the other a *salt house;* yet it will be apparent that the houses themselves are similar, and that they are quite separate from the sugar and the salt stored in them. Indeed these substances may be carried away, leaving the houses as good as ever. So in regard to the water in the tumblers. It came originally from the same vessel, and still remains water, although sugar and salt may be dissolved in its atoms or rooms.

64. Water containing sugar or salt can be purified from such on the small scale, by placing it in a glass retort (Fig. 17) and applying heat, when the water rises in steam, and passes down the tube to the receiver; whilst all the sugar or salt is left in the bulb of the retort. In this way sea water or hard spring water can be separated from the salts contained therein.

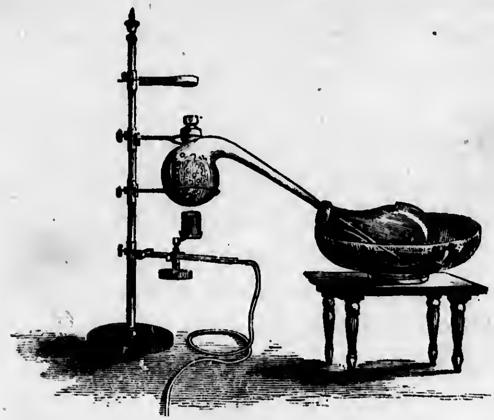


FIG. 17.

65. On the large scale, where much water requires to be distilled, a copper vessel (Fig. 18) may be employed, which

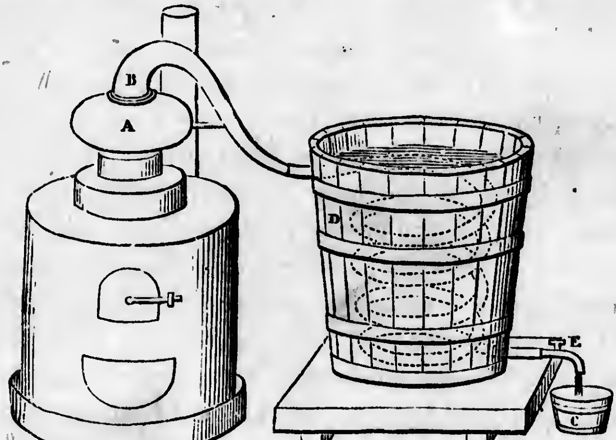


FIG. 18.

is placed in a furnace, and the water present in the still being heated, rises in vapour, and passes by the head (A, B) through a worm of tubing surrounded by cold water in a tub (D); and being condensed, the distilled water flows from the other end of the worm (E) into a vessel (C) placed below for its reception.

66. About eighty years ago it was first satisfactorily shown that pure water was not a simple substance, as was formerly believed, but was made of two gases, oxygen and hydrogen. Water can be taken and resolved entirely into oxygen and hydrogen; and these, in their turn, can be united so as to form water. Oxygen has been already discussed, and requires no further comment at this time.

HYDROGEN.

67. Hydrogen can be obtained from water in many different ways. When a number of little pieces of potassium are thrown on water contained in a basin or large plate, the potassium acts on the water, sets free its hydrogen, and at the same time kindles it. This is by far the prettiest method of preparing the gas. A less expensive process is to pass steam through a red-hot gun barrel. This is accomplished by placing the centre of the iron tube in a choffer containing burning charcoal. When the water vapour passes through the red-hot barrel it is broken up; its oxygen is retained by the iron, and its hydrogen is allowed to pass on and escape by a tube placed at the further end of the gun barrel.

68. The most convenient process for preparing hydrogen on the small scale, is to act on water with iron or zinc, and sulphuric acid. Instead of raising iron to a red heat and passing water vapour through it—which is a troublesome process—a gas bottle may be employed, in which iron filings, water, and a little sulphuric acid are placed. Zinc, in the granulated condition, is preferable to iron filings. The hy-

drogen is a gas, and, passing through the delivery tube, may be collected in jars at the pneumatic trough (Fig. 19).

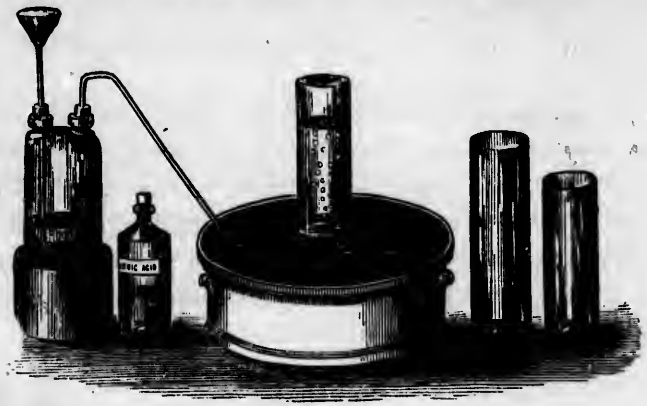


FIG. 19.

69. Hydrogen is a highly combustible gas, burning with a pale blue flame, tinged with yellow. This flame may be observed either by burning the hydrogen from a glass jet placed in the gas bottle (Fig. 20), or by setting fire to a jar full of hydrogen gas (Fig. 21). Care must be taken that no air is mingled with the hydrogen in either vessel, or an explosion will occur.

FIG. 20.

FIG. 21.

70. The flame of hydrogen has very little illuminating power, but it gives out an intense heat; and when this heat is received on a piece of lime, it raises the lime to a white heat, and gives rise to the lime-ball light, or Drummond light,

which is so intense that it has been seen from a distance of 112 miles. Though this gas burns itself, it will not allow any other combustible to burn in it. This may be illustrated by pushing a lighted candle up into a jar containing the gas, when the hydrogen will be set fire to, but the candle will be extinguished.

71. Hydrogen is the lightest substance known, being $14\frac{1}{2}$ times lighter than air, 16 times lighter than oxygen, and 11,000 times lighter than water. Taking air as 1000, the same bulk of hydrogen would weigh little more than 69. Its lightness may be seen by filling two jars with the gas (Fig. 22), and placing the one with its open end upwards, and the other with its mouth downwards, uncovering both of them at the same time. In less than a minute it will be found, by applying a light, that all the hydrogen has disappeared from the first jar, whereas the other jar will still be full of the gas.

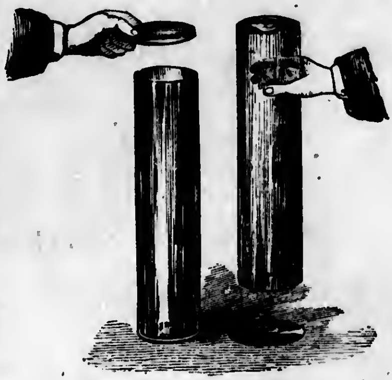


FIG. 22.

72. A prettier arrangement for exhibiting the lightness of the hydrogen is to employ a large bell-jar (Fig. 23), filled with hydrogen, and pass up into it a small vessel containing air. The moment the small glass pail passes into the light gas, the

FIG. 23.

whole of the common air in it falls like water through the much lighter hydrogen; and on withdrawing the small jar and bringing it over a light, it will be found by the resulting slight explosion that the combustible gas hydrogen must have entered the jar. This experiment may be repeated a number of times; but care must be taken that the large bell-jar is not brought near the light.

73. The property of lightness enables hydrogen to be used with advantage in filling balloons. The readiness with which this gas will raise a small balloon may be observed by arranging that the hydrogen generated in the gas bottle (Fig. 24) be passed through a tube containing fragments of chloride of calcium, to dry the gas, and then allowing the dried gas to fill a small balloon made of goldbeaters' skin. When distended with the gas, and released, the balloon will rise to the ceiling of the room. Several of the large gas balloons constructed in the earlier attempts at navigating the air were rendered buoyant by means of this gas; but coal gas can now be had so much more cheaply and readily, that hydrogen has ceased to be used for the purpose of raising large balloons.

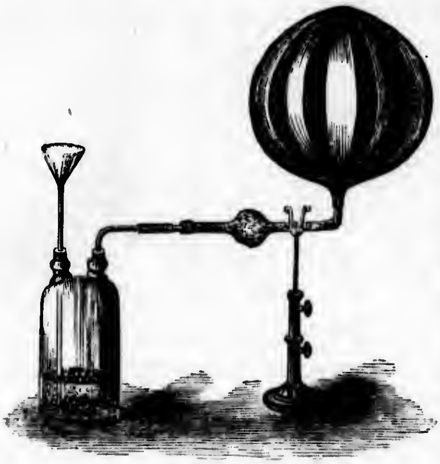


FIG. 24.

74. It is curious, therefore, to notice that water—which, when converted into steam and pent up in the boilers of our steam packets, can carry us from port to port in spite of wind or weather; or stored up in the locomotive engine, can make

us fly on iron bands from place to place—is the same substance which can supply us with the best, though not the cheapest, known gas for filling balloons, and enabling us to navigate the air.

75. When hydrogen burns, it combines with the oxygen of the air, and so produces water. This may be observed by holding a dry tumbler with its mouth downwards over a jet of burning hydrogen (Fig. 25), when the interior of the glass will become quickly bedewed with the water formed during the burning of the hydrogen. It is absolutely necessary for the proper combustion of hydrogen that air be supplied; for, if a jar of the gas be set fire to (Fig. 26), and then the cover be immediately placed over it so as to exclude the air, the hydrogen will go out, for the same reason that a candle ceases to burn when an extinguisher is put over it.

FIG. 25.

FIG. 26.

76. Though hydrogen burns quietly when a jet or a jar full of the gas is set fire to, yet when mixed previously with air or oxygen and then set fire to, it gives rise to a violent explosion. A mixture of two parts of hydrogen and five parts of air by volume, or still more so, two parts of hydrogen and one part of oxygen, introduced into a small thick jar, or into a soda-water bottle, and set fire to, burns instantly with a loud report or explosion.

77. An agreeable way of hearing minute explosions, succeeding each other so rapidly as to produce a continuous sound

or note, is to burn a small jet of the hydrogen as it is generated from a gas bottle (Fig. 27), and place over the burning jet different lengths of glass tubes of various sizes, when a chemical harmonicon will be formed, and musical notes be produced, the pitch and quality of which are determined by the diameter, thickness, and length of the tubes held over the flame.

Fig. 27.

78. Sounds produced in an atmosphere of hydrogen are extremely feeble as compared with the same sounds in air. Thus if a bell be struck or rung, or a speaking toy be squeezed in a bell-jar containing hydrogen (Fig. 28), the sounds will be very faintly heard; but if the jar be thereafter held with its mouth upwards till the hydrogen escapes and the air takes its place, the sounds from the bell and the toy will be much more distinctly heard.

Fig. 28.

AMMONIA AND NITRIC ACID.

79. These substances are present in the atmosphere in very small quantity, as compared with the amount of either of the gases already considered. Nevertheless, they perform very important functions in relation to the life of plants. Both consist in part of nitrogen. The ammonia is popularly known under the name of hartshorn, and the nitric acid as aquafortis.

80. It has long been observed that in stables and from

manure heaps, hartshorn is given off and carried into the air; but although its odour distinctly marks its passage into that region, yet the quantity is so small that the air does not directly yield evidence of its presence. It is likewise known that every lightning spark as it passes through the air compels some of the nitrogen and oxygen previously existing as separate gases to combine and form nitric acid; but it is only recently that traces of that substance have been found in the atmosphere, by an indirect process of examination.

81. The search for ammonia and nitric acid in the air is somewhat tedious, because these are present there in very small quantity, compared with the whole bulk of the air. In looking for ammonia and nitric acid in the air, it is really like seeking for a needle in a stack of hay. But, just as a powerful magnet can pull even a needle out of hay, so by other means the ammonia and the nitric acid can be taken out of the air.

82. Were a barrel filled with powdered coal and sand, with a little sugar sprinkled here and there through the mixture, it would be a difficult matter to recognise a sweetish taste when a small quantity was placed in the mouth; but if water be poured over the whole, and a small opening made at the bottom of the barrel, the water as it sinks through the mixture will leave the coal and sand unacted on, whilst it dissolves out the sugar; and, in proof of this action, the liquid will taste sweet as it passes from the barrel. Our air is a great mixture of oxygen and nitrogen, with a sprinkling of other gases. When rain passes through the atmosphere, the ammonia and nitric acid are dissolved and carried by it to the earth, just as sugar can be dissolved out of and carried through sand and coal.

83. Ammonia can be observed in rain water, or in liquified snow, by adding a little acid to retain the ammonia—which

is liable to escape—and evaporating down twenty or more gallons to dryness, when a saline residue will be left, possessing little or no odour. If to this substance there be added some lime, in the condition in which it is used for building houses, and a little water, a strong odour of hartshorn will be given off. This is abundant proof of the presence of hartshorn, or ammonia. When a piece of red litmus paper is moistened with water and then suspended so that the escaping ammonia may act upon it, the red colour will be changed to blue; and yellow turmeric paper similarly treated will be altered to a brown red colour.

84. Ammonia is produced in large quantity during the distillation of coals in gas-works, and is separated from the coal gas on being passed through a series of iron pipes called the coolers or condensers. Soot contains a considerable quantity of ammonia; and when animal substances, such as hoofs, horns, and bones (but not fat), are heated in iron cylinders, vapours are evolved which, when purified, yield ammonia. Smelling salts are a compound of ammonia, and may serve as a guide from which to learn and recognise its characteristic odour.

85. Nitric acid may be separated from rain water by adding a little soda and evaporating a large quantity down to dryness, when the nitric acid remains in combination with the soda in the residue. In India, Egypt, and some other warm countries, nitre appears like hoar frost on the surface of the ground; and if the earth be scraped off and washed with water, the nitre is separated from the greater part of the sand and clay.

86. The impure material thus obtained, and which is called rough Indian nitre, can be afterwards purified by re-solution in water, and again boiling down, till when cold, pure white crystals separate. This nitre, also known as saltpetre, is

made up of nitric acid and potass. A compound of nitric acid and soda, known as cubical nitre, or Chili saltpetre, is found in very large quantity in South America.

87. Nitric acid may readily be separated from the nitrate of potash or nitrate of soda by placing either of these in a retort (Fig. 29), adding thereafter some sulphuric acid, and heating the mixture, when the nitric acid is liberated, and passes over as vapour into the receiving flask where it is condensed and collected as a liquid.

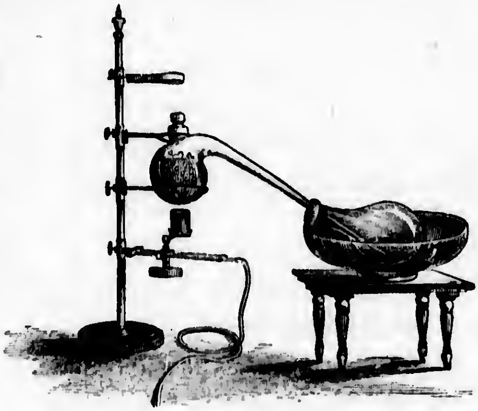


FIG. 29.

88. Nitric acid is a very corrosive substance, and has a powerful action upon copper, mercury, iron, zinc, lead, and other metals, as well as upon most animal and vegetable materials. It cannot safely be tasted unless it has been mingled with a large quantity of water; and, even then, the sour taste of the acid will be very decided.

89. Besides occurring in the conditions and places referred to, nitric acid is formed when animal matter is in a state of decay, in cellars and other places. The use of nitre in the preparation of gunpowder, every 100 parts of which contain 75 parts of nitre, renders it a necessary commodity in all wars and revolutions. Hence, towards the close of last century, when France was surrounded by enemies, and when nitre could not be obtained from Britain or elsewhere, it was prepared from animal refuse of all kinds mixed with lime.

On being allowed to stand for some time, a nitrate of lime is formed; and this, when mixed with potashes, produces nitrate of potash, or nitre.

90. It was formerly stated that nitric acid was produced when a lightning spark passes through the air. This action does not appear to depend on the heat of the spark, for in an ordinary iron blast furnace many tons of air are daily forced through layers of matter at a white heat, and yet the nitrogen does not escape from the furnace in the form of nitric acid, but is principally liberated as free nitrogen.

OZONE.

91. When electrical sparks are passed through air or oxygen, a peculiar substance called ozone is developed, which is generally regarded as an active state of the element oxygen. As a lightning-flash is just a large electric spark, it follows that during every thunder-storm, ozone will be developed in the atmosphere.

92. It is not necessary that the electricity actually spark through the atmospheric air or oxygen gas in order that it may generate ozone, as the mere passage of the electricity round a tube or other vessel containing these gases will cause its development; and hence a more or less highly electrified condition of the atmosphere, even where no lightning is visible or takes place, enables ozone to be formed.

93. The same substance is produced when phosphorus is placed in a bottle of air, with just sufficient water to cover the phosphorus about one-half, and keep it from taking fire; and ozone is also developed when a little ether is diffused through atmospheric air contained in a jar, and a heated glass rod is cautiously introduced.

94. The properties of ozone are, that it possesses a peculiar odour, long known as the electrical odour observed when fric-

tional machines were being worked, but which is often likened to weak chlorine. It is a powerful bleaching agent, destroying the majority of vegetable dyes; and is a great disinfectant, causing the destruction of the deleterious gases which are given off from decaying plant and animal matter.

95. The proportion of ozone present in the atmosphere is variable. It is abundant in country districts, but is scarcely recognisable in town localities, whilst a larger proportion is found in the atmosphere in winter than in summer time. The bleaching property which the atmosphere exerts on clothes exposed to the air is considered to be due to the ozone present there.

96. Ozone does not appear to be of much importance directly, either to plants or animals; but indirectly, it is of great service to the animal creation, from the readiness with which it purifies the air of noxious gases. In the act of destroying these gases, the ozone combines therewith, and oxidizes, or slowly burns them. It is the great natural disinfectant, or purifier of the air.

CONCLUDING REMARKS ON THE ATMOSPHERE.

97. The substances mentioned in the foregoing pages, namely, oxygen, nitrogen, carbonic acid, water vapour, ammonia, nitric acid, and ozone, are the principal constituents of the atmosphere; and they are in thorough gaseous intermixture with each other. They constitute the aerial covering of the globe, which encircles continents and seas, mountains and valleys, to the height of about 45 miles.

98. This thickness appears at first to be very great; but when it is considered in conjunction with the immense diameter of the earth, which is about 8000 miles, it becomes insignificant, and is no more in proportion than the thickness of a sheet of writing paper placed over an ordinary school globe.

99. The probable total weight, as well as the relative amount of the oxygen, nitrogen, carbonic acid, and water vapour in the atmosphere, may be gleaned from the following table:—

	Weight in tons.
Oxygen gas, ...	1,233,010,020,000,000
Nitrogen gas, . . .	3,994,592,925,000,000
Carbonic acid gas, . . .	5,287,305,000,000
Water vapour, . . .	54,459,750,000,000
Weight of atmosphere, . .	5,287,350,000,000,000

100. These figures are so great that we fail to deduce from them any definite idea of the magnitude of the atmosphere; but some notion may be gained from the statement, that this great weight is equivalent to that which would be felt if the air were taken away and an envelope of water thirty-two feet in height put in its place, or if the air were annihilated and a casing of mercury thirty inches in thickness were fitted over the earth's surface. Were a monster pair of scales made, in one pan of which all the air could be placed, and in the other its weight in lead, the air would take a globe or ball of lead sixty miles in diameter to balance it.

CHAPTER III.

THE PLANT, AND WHAT IT FEEDS ON.

101. The food of all plants is derived, in greater part, from the atmosphere which envelops the leaves, and in smaller quantity, from the soil in which the roots are fixed. The atmospheric food mainly consists of carbonic acid, water vapour, ammonia, and nitric acid; whilst the saline food is principally composed of certain salts present in all fertile soils. No distinct line of separation of the two sources of the food of plants can be made; for, doubtless, water and the other constituents generally derived from the atmosphere are also taken into the system of the plant by the roots.

102. The gases obtained by the plant from the atmosphere, and the saline matters abstracted from the earth, are employed in various ways in the production of numerous compound substances. In some instances all the food elements appear to assist in the formation of complex substances in the manufactory situated within each plant; whilst at other times a few elements only are required. The more simple instances are the formation of starch, gum, sugar, and oils; and in the production of which, the plant need only be regarded as being supplied with carbonic acid and water. As previously stated, these substances are not simple, but compound,—carbonic acid consisting of carbon and oxygen, whilst water is composed of hydrogen and oxygen.

103. That carbonic acid is made up of carbon and oxygen is clearly shown by burning a piece of carbon (charcoal) in a

globe containing oxygen gas (Fig. 30), when the charcoal combines with the oxygen and becomes carbonic acid gas. If a small plant, or some fresh and healthy leaves, be introduced into the vessel in which a portion of carbonic acid has thus been produced (Fig. 31), and the whole exposed to sunshine for a short time, it is found that the carbonic acid quickly vanishes. What occurs in this globe will appear more evident if the apparatus be altered in shape.

Fig. 30.

Fig. 31.

104. Instead of a globe, take a glass tube (Fig. 32), place

Fig. 32.

the plant or the fresh leaves in it, and while exposed to the bright rays of the sun, pass a stream of air containing carbonic acid through the tube, in the direction of the arrows; when it will be found that though this gas is present in the air as it flows at the one end, yet, as it passes out at the other extremity, no carbonic acid will be observed, whilst at the same time there is an increase in the quantity of oxygen gas.

105. The plant has the power of breaking up carbonic acid, retaining the carbon, and setting the oxygen free. When wood is burned, all the charcoal in it combines with the oxygen of the air, and forms carbonic acid; and as this

gas is the largest product of the burning, it may be roughly stated that a stream or current of the gases evolved from burning wood is mainly composed of carbonic acid. The globe and tube experiments (Figs. 30, 31, and 32), when viewed in this light, possess a peculiar interest; for the gas from burned wood (carbonic acid), acted on by the plant or the fresh leaves, has all the woody matter or carbon retained by the plant, and built up in its leaves or branches; whilst the oxygen of the air which burned it, is once again set free. It will be observed that it is not necessary that a whole plant be employed, as a few leaves recently cut off, and which are still fresh, will act in the same manner.

106. The charcoal, or coal burned in our grates, is reproduced in the plants growing in our fields and forests. Coals and wood take fire, and burn, and fly away as gas. Everything betokens to the unaided eye that they have been destroyed; but such is not the case. In this there is seen one of the many circles round which all matter courses. The oxygen of the atmosphere passes through burning wood, and appears as carbonic acid; which in its turn is acted on by plants, deprived of its carbon, and thereafter becomes once again oxygen. Wood to wood, and gas to gas, everything returns from whence it came.

107. Carbonic acid is very thinly distributed through the air; but its total quantity is very great. As the air blows against the leaves of a tree or a flower, a lichen or a wheat-stalk, the carbonic acid is imbibed, the carbon in it retained, and the oxygen discharged. And thus the oak tree, with its 7,000,000 leaves dangling like tongues in the air, and the smallest blade of grass, hold out their nets and catch carbonic acid—food to them—as it floats past their homes. This gas also enters the plant by its roots. Rain, by dissolving it, no doubt carries it in by this road; but the prin-

cipal supply is derived from the leaves, which withdraw it directly from the atmosphere.

108. The rapidity with which gases can pass into a plant by its leaves varies according to the thickness of the epidermis or skin of the leaf, and the number of small openings in it. These openings are called *stomata*, and are generally more abundant on the lower side of the leaf than on the upper. If a thin slice of an ordinary leaf be placed under the microscope, in such a way that we look along the edge of the leaf, it is observed that the upper surface is much more thickly built together, and has fewer openings or stomata, than the lower, which is more porous, and has numerous openings. It is through these little doors or mouths, as they may be called, that carbonic acid and other gases enter the leaves of the plant.

109. Water is necessary for the preservation of plants as well as animals. In dry seasons the withered appearance of the crops betokens parched ground, and a consequent scarcity of water. The quantity of this liquid evaporated from the leaves of plants is very considerable. An ordinary sized cabbage sends off into the air from 19 to 25 ounces each day. As the leaf gets dry it sucks up, like a sponge, more water; and this tends to cause a circulation of the fluid from the roots to the leaves. It is partly a phenomenon of the same kind as noticed in an oil lamp, where, when the oil, moistening the wick, has been burned away, more rises from the reservoir beneath to supply its place.

110. This can, however, only be considered one of several forces at work in causing the circulation of liquids in plants. Whilst carbonic acid enters the plant principally by its leaves, and to a much smaller extent by the roots, water, on the other hand, is imbibed in greater part by the roots, though a considerable amount is likewise absorbed by the leaves.

Ammonia and nitric acid pass into the plant both by the leaves and by the roots; and the saline substances derived from the soil, and which are equally important to the life of the plant, are drawn in by the roots.

111. The movement of the juice or sap in a plant is best noticed in a tree, such as the ash or maple, during the spring months. The fluid ascends through the wood from under the bark, and passes up the branches and twigs till it comes to the leaves; and then it descends between the wood and the bark, and in its passage is in part stored up in the plant, and in part rejected by the roots. It will thus be noticed that all the gaseous materials entering the plant are at one time or other brought to the leaves, and are there acted upon by heat, light, and other forces.

CHAPTER IV.

THE PLANT, AND WHAT IT YIELDS US.

I.—THE STARCH GROUP.

112. THE substances which are derived by the plant from the atmosphere and the soil are manufactured into new substances, very unlike what they were originally. The proportion in which carbon unites with oxygen to form carbonic acid is one atom of carbon to two atoms of oxygen; whilst the proportion in which hydrogen and oxygen go to produce water is one atom of each. Thus:—

$$\text{Carbonic acid is composed of} \ldots \begin{cases} \text{Carbon.} \\ \text{Oxygen.} \\ \text{Oxygen.} \end{cases}$$

and

$$\text{Water is composed of} \ldots\ldots\ldots\ldots \begin{cases} \text{Hydrogen.} \\ \text{Oxygen.} \end{cases}$$

As these substances pass through the leaves, two atoms of oxygen are by degrees given off by the plant, and escape into the air, leaving behind the carbon to be united with more or less of the hydrogen and oxygen obtainable from water.

113. This movement supplies the materials for the elaboration of many substances, amongst which are included starch, sugar, gum, woody fibre, oils and fat, resins and balsams, all of which agree in being composed of the three elements—carbon, hydrogen, and oxygen; in other words, of carbon and the elements of water. The presence of carbon in wood may be readily observed by heating it strongly,

when the wood chars; or by placing a piece of clean wood in oil of vitriol, when the carbon or charcoal is separated from the hydrogen and oxygen, and the wood becomes black.

114. It is very difficult at first to understand how it is possible for a piece of white sugar to contain black charcoal; but this can be shown by withdrawing a part of the water and leaving the carbon. The most homely way of doing so is to heat a piece of sugar before the fire, and very quickly it will lose its hydrogen and oxygen in the form of water, and will blacken or char from the charcoal being left on the surface.

115. This change is better seen when a strong hot solution of sugar is placed in a cup or thin tumbler, and concentrated oil of vitriol cautiously poured on it, when the sugar blackens, froths up, and often runs over the sides of the vessel. When the whole gets cooled, the coaly matter can be lifted out of the vessel in pieces of considerable size, and will satisfy every one of the large quantity of charcoal in sugar.

STARCH.

116. Starch is present in large quantity in all plants used for food, and to a less extent in nearly every other plant. Many varieties of starch are found in commerce, which have been obtained from different sources. Common starch is procured from wheat and other cereals; potato starch from the tubers of the potato; arrow-root from the roots of *maranta arundinacea;* sago from the stem and pith of the sago palm; Oswego and Chicago corn food from the Indian corn; rice starch from rice; and besides these there are tapioca, tous les mois, salep, &c.

117. These varieties of starch, although they may differ from each other in external appearance, are yet the same in

chemical properties and composition. The microscope is of great assistance in determining what variety of starch any sample may contain, as each kind has a size and shape of granule peculiar to itself; and thus potato starch can be readily distinguished from wheat starch, arrow-root, &c. These granules of starch are inclosed in numberless cells or little bags in the various plants; each cell containing a multitude of granules inclosed together.

118. Water does not sensibly act on starch in the cold, but when it is heated it forms a kind of jelly, which is well known in the dressing of linen; but which, however, cannot be strictly termed a solution. In the process of heating, the starch granules are broken up. Each starch particle is like a very small onion with a great many coats; and when hot water is added to it, these become rent. A grain or two of gelatinous starch, in a tumbler of water, can be easily recognised by the addition of iodine dissolved in alcohol, when a blue colour is acquired by the liquid, owing to the formation of iodide of starch.

119. Starch is generally prepared from potatoes or wheat flour. To prepare starch on the small scale, the simplest method is to reduce some potatoes to a fine pulp, by rubbing them against an ordinary grater; and after adding water, throw the pulpy mass thus procured on a piece of cloth, stretched over the mouth of a basin (Fig. 33). The water passes through the cloth, carrying with it the starch; and by allowing the liquid to remain at rest for several hours, the starch will settle to the bottom of the vessel, when the water may be poured off.

Fig. 33.

120. Starch from wheat flour may be obtained by placing a portion of the wheaten flour in a piece of cloth, and alternately dipping it in a vessel of water, and pressing the liquid out between the fingers (Fig. 34). Shortly the whole of the starch will pass through the cloth, and be received in the water.

FIG. 34.

121. In the preparation of starch from wheat on the large scale, several processes may be adopted; but the plan generally followed in Great Britain is to take the grain coarsely ground and mix it with water sufficient to wet it thoroughly. On standing for some days, the dough-like mass becomes sour, and in part ferments or rots. The whole is then mixed with more water, and placed in a larger vat, where the souring proceeds, and a deposit containing starch and bran settles to the bottom. This deposit is placed in a kind of basket, where, on being washed by a stream of water, all the starch is carried into a settling vat, and the bran is left in the basket. The starch thus obtained is not quite pure, but by repeated washing and straining through fine sieves, the impurities are got rid of, and the addition of a little blue ultramarine brings up a better white colour.

122. The wheat starch is then dried in boxes with perforated bottoms lined with cloth; and when solid enough to be handled, these large blocks are cut into pieces about six inches square, inclosed in paper, and strongly heated, when the starch splits up into the little columnar pieces which are well known as the ordinary condition in which wheaten starch is to be had to purchase.

123. The other varieties of starch are prepared from their respective plants by processes similar to those followed in the

preparation of potato starch or wheaten starch, and do not, therefore, require special notice. Sago and tapioca have the form of minute pellets given to them by being placed in a moist state on perforated hot plates or cullenders, and being forced through the perforations.

GUM.

124. Gum exudes from many plants in the condition of a thick and sticky juice. There are two families of gums,—viz., the *true gums*, and the *gum resins*. The latter are composed of a resin united with an oil, such as turpentine, which can be separated from it. The gum resins are not even softened when thrown into water, whereas all true gums either dissolve or soften when treated with that liquid.

125. The true gum best known in this country is gum arabic, which is exuded by a species of acacia, growing in Arabia, Senegal, Upper Egypt, India, &c. It is procured in pieces up to the size of a small apple; and when broken exhibits a fracture like glass. The colour runs from white to dark yellow. It is soluble in water, giving a clear and thick solution, from which alcohol precipitates pure white gum or arabin. The gums exuded by our fruit trees—the cherry, plum, apricot, peach, &c.—differ a little from gum arabic, but in many respects they are the same.

SUGAR.

126. Sugar is present in the sap or juice of the majority of plants. It is now so largely consumed that its manufacture is an important branch of commerce. The juices of the greater number of plants owe their sweetness to the presence of sugar. The plant which supplies the greater portion of the sugar used in Britain is a very tall grass, called the sugar cane. To denote the source of the variety of sugar

used by us, the name of *cane sugar* is generally applied to it. It is the sugar of the stems of plants.

127. The cane plant grows to an average height of fifteen feet, with a stalk about two or three inches thick. It arrives at maturity in little more than a year, when it is cut down and passed between heavy rollers, which press out the greater part of the sweet juice. The quantity of sugar in this juice is 17 to 20 parts in every 100 parts, the remainder being principally water.

128. Several impurities accompany the sugar, which are got rid of by a long and tedious process, and the sweet liquid, on being boiled down, deposits crystals of sugar in the condition in which they are seen in what is called raw, brown, or Muscovado sugar, and at the same time yields the dark-coloured and thick liquid known as *molasses*. When this liquid is evaporated further it gives another crop of brown crystals, from which *treacle* drains away.

129. The form characteristic of loaf-sugar is communicated by filling moulds with refined sugar in grains, and pouring over these a very strong solution of pure sugar, when the latter sinking through the grains, carries before it all the brown-coloured liquid, which flows away by an aperture in the lower part of the mould into a vessel placed to receive it, and is known as *golden syrup*. The purest sugar is thus alone left behind; and, on cooling, the whole forms a solid mass, which may be detached from the mould. When pure, cane sugar is white and brittle; when smartly broken into pieces, minute electric sparks are to be seen; and when two lumps are rubbed together in a dark room, a pale phosphorescent light is visible.

130. Sugar candy, barley sugar, and tablet are varieties of cane sugar. Sugar dissolves readily in water as well as in watery infusions such as tea and coffee. Boiling water dis-

solves more sugar than cold water does. When a strong hot solution is allowed to cool, much is deposited in large crystals, constituting *candy sugar*. The insertion of threads into the syrup facilitates the formation of these crystals.

131. A hot saturated solution of sugar assumes, on cooling, the well-known granular appearance characteristic of tablet; and when heated till little or no water is left, and then thrown on a marble or metal plate, the sugar solidifies with the glassy aspect exhibited by *barley* sugar. What is called "black man" in the west of Scotland, and "jib" or "gundy" in the east, is a strong solution of sugar in water, which has been partially burned or destroyed. These different forms in which sugar is presented to us are often rendered more attractive by the addition of spices.

132. In the East Indies a large and gradually increasing quantity of cane sugar is derived by the natives from the date-tree. The stem of the tree is pierced, and a tube being inserted, the sweet liquid flows slowly into vessels placed to receive it; and thereafter is boiled down and thrown into earthen vessels, in which it solidifies, and is brought by the natives into market for sale.

133. In the United States and Canada, sugar is largely extracted from the maple tree. During February and March a considerable quantity of sweet juice is present in the maple tree, which the inhabitants of North America readily withdraw, by boring holes in the tree, when the juice flows out. This saccharine liquid is treated in a similar manner to that stated above in reference to the sugar cane.

134. Maple sugar was first brought into extensive use by the Quakers of North America, who did not wish even indirectly to encourage slave labour, which was so largely employed in the cultivation of the sugar cane. The amount of

maple sugar used is considerable, being about one-eighth of the total quantity of sugar consumed in North America.

135. On the Continent, sugar is obtained from beetroot. As a source of sugar, beetroot came into extensive use during the reign of Napoleon I., who ordered the blockade of the continental ports in order to ruin the colonial trade of Great Britain. Till that time, the continental people were dependent on our colonies for a large portion of their sugar, and it became necessary that sugar should be supplied in some other way to keep up with the demand. Accordingly, great exertions were made to derive sugar from beetroot economically, which were ultimately successful.

136. The four kinds of sugar referred to, namely, cane, maple, date, and beetroot sugars, are in no way different from each other, and the chemist speaks of them all under the name of *cane sugar.* The properties of this variety of sugar are, that it dissolves in one-third of its weight of cold water, and more largely in hot water, but is with difficulty soluble in alcohol. When a water solution is mixed with oil of vitriol, and heat applied, the whole becomes black, and separates more or less charcoal, according to the quantity of sugar employed in the experiment.

137. Grapes and honey owe their sweetness to the presence of sugar, but it is not the same as cane sugar. The sugar obtained from fruits such as the grape and currant is the same as that present in honey, but differs from cane sugar. It has received the distinctive title of *grape sugar*, whether it be obtained from grapes or honey. It is the sugar present in the fruits of plants. It is much less sweet than ordinary sugar, about three spoonfuls of grape sugar being required to sweeten tea to the extent that one spoonful of cane sugar will do.

138 Grape sugar dissolves to the extent of one part in

one and a half of cold water, and in less of hot water. It is readily soluble in alcohol. When acted on by sulphuric acid, it does not char like cane sugar. Its most characteristic properties are, that when heated with caustic potash solution, it yields a dark brown or black liquid; and mixed with a little sulphate of copper, potash added, and heat applied, grape sugar causes the precipitation of red oxide of copper.

139. There are many other sugars, but they scarcely call for notice. *Sugar of milk*, or *lactine*, is prepared from the whey of milk; *manna sugar*, or *mannite*, is obtained from the root of the dandelion and other plants; and *liquorice*, or *Spanish juice*, is procured from the creeping underground stem of a plant called *glycyrrhiza glabra*, and is principally imported from Spain.

LIGNIN OR WOODY FIBRE.

140. Wood is largely present in forest trees, and to a less extent in nearly every other plant, and is a substance which is so well known, that little requires to be said about it. The chemist calls it *lignin*, and in the mouth of the botanist it is spoken of under the name of *woody fibre;* which term includes all the different kinds of wood divested of colouring and other foreign matters. The cabinet-maker classifies woods by the name of the tree from which they have been derived, such as mahogany, oak, fir, &c.

141. Linen, cotton, and paper are different varieties of wood. Although wood generally appears in mass as a stiff, rigid material, yet in many cases it can be obtained as a soft, pliable, and tenacious substance, which can be made use of for many purposes. For instance, the flax plant supplies us with linen and cambric; the cotton plant produces cotton for our wants; and the hemp plant gives us cordage and canvas.

142. Woody fibre can thus be worked into cloth and

made into dresses; and when these garments fall into rags and tatters, the woody matter or lignin in them is still useful in making paper. So true is it that paper is simply wood, that now-a-days straw, hay, clover, esparto fibre or Spanish grass, and even the wood of some trees are turned into writing and packing papers.

143. Whilst *modern* wood is employed in a multitude of ways, *ancient* wood or coal is made use of likewise. Coal owes its origin to the remains of plants which flourished many thousands of years ago, and which have undergone changes in the interior of the earth. It is therefore a form of fossil wood, and is ever ready to give us heat when placed in our fire-places, and light when its vapour is kindled at our gas jets.

CONCLUDING REMARKS ON THE STARCH GROUP.

144. Starch, gum, sugar, and woody fibre are unlike each other, and yet they are formed of the very same substances in nearly similar proportions. Though no one presumes to say that he distinctly understands how four substances may appear different, and yet have the same composition, yet it is generally supposed, that by an alteration in the arrangement of the little particles of matter constituting any material, many substances may be formed, every one of which may be very different in external appearance.

145. This fact may be likened to what often occurs in the English language, where the same letters can produce words of various meanings. For instance, the letters A R T, arranged as they are here printed, give us *art;* when the position of the letters is altered, we get *rat;* and again, *tar;* and doubling the number of the letters, we obtain *Tartar*. Now, just as three letters can compose various words, each of which conveys a fresh idea from either of the others, so by a different arrange-

ment of the three elements, carbon, hydrogen, and oxygen, we obtain starch, gum, sugar, wood, and many other substances. Just as ART can be changed into TAR, so starch may be transformed into sugar, or any of the other substances named.

146. If a seed of wheat be examined, it is found to be made up in greater part of starch. When placed in the ground and moistened, the seed softens, and the starch becomes a kind of gum called *dextrin;* in course of time this gum—dextrin—changes into sugar, and the seed becomes sweet to the taste; and finally, as the pigmy wheat stalk rises above ground, the sugar is lodged in the stem as wood.

147. This is seen more or less in all plants. The maple tree during the autumn months has stored up within it a quantity of starch, which remains fixed during the winter; but when spring sets in, the starch changes rapidly into gum dextrin, and afterwards into sugar; and it is when this change occurs that the sweet juice is drawn from the tree, and the sugar is extracted from it. If the sugar were not withdrawn at this stage, it would pass up the tree, and would soon be converted into a branch or a leaf.

148. The same remark applies to the extraction of the sugar from the cane and the beetroot. If the right time be not observed, and the plants be allowed to continue their growth, the sugar becomes wood. In the ripening of an ear of corn, at first a sweetish liquid is present; but when fully ripe, this sweet substance has been converted into starch, which is stored up in the seed. And again, in an unripe apple, starch is abundant; but when the apple has ripened and is in a fit state to be eaten, the starch has in part become sugar.

149. What is thus accomplished in the plant, and by natural means, can also be carried on out of the plant, and by artificial processes. Starch, by heat and other agents, is

converted into a gum largely sold under the name of *British gum*, and used by calico printers instead of ordinary gum. By the addition of 10 parts of sulphuric acid, and 1000 of water to 500 of starch, and heating the mixture, the starch passes into grape sugar. Large quantities of potato starch are in this way made into sugar. Even woody fibre, such as old linen, when acted on by sulphuric acid, becomes sugar as sweet as that got from honey or the grape.

150. The possibility of these changes will be rendered apparent from the following table, which gives the composition of the members of the starch group:—

Starch	$C_{12} H_{10} O_{10}$
Dextrin	$C_{12} H_{10} O_{10}$
Gum	$C_{12} H_{11} O_{11}$
Cane sugar	$C_{12} H_{11} O_{11}$
Grape sugar	$C_{12} H_{14} O_{14}$
Woody fibre	$C_{12} H_{10} O_{10}$

151. The above table gives the relative quantities of carbon, hydrogen, and oxygen in each of the substances named. It will be noticed that the carbon in all is the same, and that a slight variation in the hydrogen and oxygen—in other words, in the elements of water—is only necessary to supply the material for the conversion of any one of these substances into any other. Thus starch, dextrin, and woody fibre contain 12 atoms of carbon in combination with 10 atoms of hydrogen and 10 atoms of oxygen; and gum and cane sugar consist of 12 atoms of carbon and 11 atoms of each of hydrogen and oxygen.

VEGETABLE OILS, ETC.

152. Vegetable oils are found in all the higher plants, and the seed is the part in which the largest quantity is usually to be found. The oils divide themselves into two classes;

the *fixed* or *fatty* oils, which cannot be distilled without decomposition, and leave a greasy stain on paper; and the *volatile* or *essential* oils, which are capable of distillation, and when they moisten paper, dry up, and leave no greasy mark.

153. Fixed oils may be liquid or solid; and what is liquid in one country may be solid in another. Palm oil is in Africa, the country of its birth, a liquid oil; but when brought to this colder region, it has become a solid, like butter. Cocoa-nut oil in the cold air of winter is solid, like lard; but when taken into a hot room, it becomes liquid like water. Liquid oils which in this country never freeze, will do so if taken to the cold climate of the polar regions.

154. The fixed oils include the greater number of the important commercial oils, such as olive, almond, linseed, rape seed, castor, coco-nut, and palm oils. These oils are obtained by crushing the fruit or seed between heavy rollers, or other bruising arrangements, by means of which the oil is expressed in a rough state, and is afterwards purified.

155. Some oils, such as linseed oil, dry up in a day or two, when a thin surface is exposed to the air, and they are therefore called drying oils; whereas almond, castor, and many other oils never dry up, or at most only partially do so when the oil decays. This class of oils is largely used in the manufacture of soaps and candles.

156. The volatile or essential oils are prepared by distilling the substance containing them with water. The operation is conducted in a still (Fig. 35, A), connected with a worm (B, E), immersed in a tub of cold water (D). The sweetly scented flowers are placed in the still by the head, which is movable, and water is added to them. When the latter is boiled, the steam rises, carries with it the oil, and passing along the worm, falls in drops from the end of the tube (E) into a vessel (C) placed below.

157. The volatile oils comprehend the greater number of the rarer and more costly oils, such as bergamot, lavender, spearmint, cinnamon, and clove oils, some of which are extracted from plants by special processes. Camphor and tur-

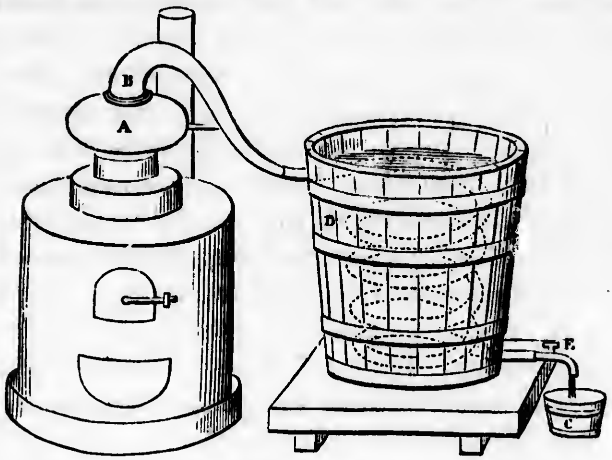


FIG. 35.

pentine likewise belong to this class. Camphor is solid at ordinary temperatures.

158. Fir trees give out when the bark is cut a glutinous, sticky substance, which is called a *balsam*. When this balsam is heated with water in the still, a volatile oil passes over, well known as that of turpentine, and ordinary *resin* is left in the still.

159. Sealing-wax is made up of a resin called shellac, a little turpentine, and some vermilion. Gamboge is a natural mixture of a resin and a gum. Amber is a resin which has exuded from a tree, and which, from old age and pressure, has been slightly altered. It has generally imbedded within it a number of insects; some perfect in form, and appearing with distended wings as in the act of flying; others have their legs and wings detached from their bodies but lying

beside them, plainly telling us what a vain struggle the insects had for life before they were embalmed in the amber.

160. Caoutchouc or *India-rubber* and gutta-percha, are prepared from the sap of trees growing in warm countries. Caoutchouc is the hardened juice of the syringe tree of South America, from whence the largest quantity is procured; although a considerable supply is now obtained from the East Indies, Java, and the neighbouring countries.

161. Gutta-percha is derived from a forest tree growing abundantly in Borneo and other countries near that island. The demand for this article is so great, that instead of simply tapping the tree as in the receiving of India-rubber, and allowing the sap to pass from the tree by degrees, the gutta-percha tree is at once cut down and the juice extracted by powerful pressure. When boiled to get rid of a little water, the juice on cooling becomes solid, and is then sent into the market.

162. The fixed, and many of the volatile oils, contain the same chemical substances as starch. The elements, carbon, hydrogen, and oxygen, which compose the fixed oils, such as olive oil, are the same as those in starch, but the quantity of oxygen is much less. The essential oils contain still less oxygen, as instanced by camphor; whilst others, such as turpentine and bergamot, have none. Caoutchouc and gutta-percha contain only carbon and hydrogen.

163. The plant manufactures the oils and resins out of carbonic acid and water. It will be evident that as starch, gum, sugar, and wood can be formed by the plant from carbonic acid and water, then the oils, &c., can also be so. Moreover, starch and its companion substances no doubt pass into oil in the plant, by giving off a part or the whole of their oxygen.

164. Though starch, gum, sugar, wood, and oil, are found

in plants, yet none of these substances can be directly absorbed or made use of by the plant in which we find them. In the cultivation of the sugar cane, it would not materially increase the quantity of sugar in the plant, to moisten the ground in which its roots are placed with a solution of sugar. The plant cannot take in sugar as sugar, starch as starch, gum as gum, wood as wood, or oil as oil. If these are to be useful at all they must first decay or rot, and the gases evolved may be drawn in by the leaves and roots, and thus made useful.

165. It must, therefore, be kept in recollection that starch, gum, sugar, wood, and oil are formed by the plant from carbonic acid and water; and that these substances the plant receives, directly or indirectly, from the atmosphere and strictly feeds upon. When once, however, any one of the actual group of substances has been produced in the vegetable organism, the plant can change it into any other or into oil; sugar, for instance, may become starch, gum, wood, and these in their turn may pass into each other or into oil.

CHAPTER V.

THE PLANT, AND WHAT IT YIELDS US.

II.—THE ALBUMEN GROUP.

166. In all plants there is found a greater or less amount of complex substances, which are respectively named albumen, glutin or vegetable fibrin, and legumin or vegetable casein. These contain carbon, hydrogen, oxygen, and nitrogen, with minute and variable proportions of sulphur and phosphorus.

167. In the construction of these substances by the plant, it is requisite that it be supplied with carbonic acid and water vapour, which afford the carbon, hydrogen, and oxygen; along with compounds of ammonia or nitric acid which yield the nitrogen, and with certain saline matters which afford the sulphur and phosphorus.

ALBUMEN.

168. Albumen is found in the majority of plants, especially in the liquids and juices, but it may be experimentally obtained from potatoes, turnips, &c. When potatoes are grated down to a pulp, water added, and the whole strained through a cloth filter (Fig. 36), a milky liquid is obtained in the vessel, which settles after standing for some hours, and leaves a liquid above which is tolerably clear.

Fig. 36.

169. If this liquid be boiled, a white substance separates with a stringy appearance, very like that observed floating in hot water when an egg has been broken in the process of boiling. This white matter obtained from potatoes, and called albumen, does not only look like white of egg, but, so far as chemistry is concerned, the two are identical, being made up of the same elements, and having the same properties. Turnips, cauliflower, &c., yield a marked quantity of albumen; and, indeed, the juice of the stems of plants, including even trees, and the fruits of all plants, such as grapes, always contain a small amount of albumen or white-of-egg matter.

GLUTIN OR VEGETABLE FIBRIN.

170. Glutin or vegetable fibrin is present largely in the seeds of wheat, barley, corn, &c. If some wheat flour be tied up in a piece of cloth, and alternately drenched or soaked in water and pressed between the fingers (Fig. 37), it will be found that in a short time all the starch is washed out of the flour, and a sticky, adhesive subtance is left in the cloth, which can be drawn out to a certain extent like India-rubber. This is known by the name of vegetable fibrin or glutin. It is found in large quantity in the seeds of plants, and in smaller quantity in all the other parts of the vegetable structure. Fibrin derived from wheat flour is almost identical with that present in washed flesh.

FIG. 37.

LEGUMIN OR VEGETABLE CASEIN.

171. Legumin, or vegetable casein, may be derived from pease, lentils, beans, and other leguminous plants. When

pease-meal is stirred up with water, the yellowish white powder, which at first floats about in the liquid, gradually sinks and leaves a clear liquid above; which, when a little rennet is added and the whole boiled down to dryness, leaves a grayish white solid, presenting the characteristic odour and taste of cheese.

172. It is called legumin or vegetable casein, and so like is it to ordinary cheese procured from milk, that the Chinese prepare and sell cheeses made from pease. This kind of cheese is a great favourite with the lower classes in China, and is purchased in the streets of Canton under the name of taofoo. This casein or cheese matter is not restricted to pease, but can be obtained from almost every other plant.

CONCLUDING REMARKS ON THE ALBUMEN GROUP.

173. The three substances, albumen, fibrin, and casein, are, therefore, present in greater or less quantity in all plants; and they possess the same chemical composition, and any one of them is convertible into any other. Fibrin and casein are insoluble in water, whereas albumen is easily soluble in that liquid.

174. The juice of a plant stalk such as the wheat, contains albumen which gradually travels up to the little seed vessels, and in these the albumen changes into fibrin, and as such is stored up. In the pea, the juice of the stalk also contains albumen, but when it reaches the pods, it passes in great part into casein.

175. And, again, when a wheat seed or pea is placed in the ground, and a small plant begins to make its appearance, in the former instance the fibrin, and in the latter the casein, becomes in part albumen; which, being soluble in water, is easily carried up the young stalk of the plant.

176. The foregoing observations on the food of plants,

and the mode in which they construct and manufacture materials for the use of the animal, have reference to the distribution of those atoms of matter which are obtained from the great storehouse of gaseous matter, namely, the atmosphere. In an after division of this book, it will be observed that the elements which constitute the earth or soil in which the roots of a plant are fixed, also perform a most necessary part in the nourishment and support of plants, and, in short, that the plant draws food not only from the atmosphere, but likewise from the second great storehouse of raw material, namely, the earth or soil.

177. Indeed, it ought distinctly to be remembered that a plant cannot live merely on the gases it derives from the atmosphere, but must also obtain saline matter from the soil. And though in the starch group of compounds there is no saline matter present, and in the albumen group there is only a minute amount, yet the plant cannot form either of these classes of compounds without being supplied with the saline food from the soil.

CHAPTER VI.

THE ANIMAL, AND WHAT IT FEEDS ON.

178. The food of the animal requires to supply three kinds of material: first, *combustible* or *coaly* substances, which can be burned in the living organism; second, *flesh-forming* ingredients, which are useful in supplying the material for replenishing the wear and tear of the animal system; and third, *saline* matter: and, considering that many animals require to increase their size and weight, the food must supply extra material, which becomes lodged in the animal structure.

179. No one part of the food of the animal can be dispensed with. Whatever diet be indulged in, it must be capable of yielding heat-producing, flesh-forming, and saline materials. The earth-worm eats earth, and extracts therefrom parts of plants capable of nourishing it. The hippopotamus roots up plants in the beds of African rivers, and feeds on these. The giraffe dines on leaves. The reindeer lives for the greater part of the year on lichens. Two hundred different kinds of caterpillars feast on the oak tree, and fifty varieties of insects on the much-despised nettle. Our oxen, sheep, horses, &c., subsist on grass; and other animals, such as the lion, the carrion crow, &c., live on their less powerful neighbours.

180. Fresh-water and marine animals are herbivorous and carnivorous, as the land kinds are. Many species of fish live on sea-weed, whereas sharks, whales, &c., live on fish and

other marine animals. A single sea-weed is the birth-place and home—ay, even the world—of myriads of shell-fish, and other minute denizens of the ocean. The forests of the land, with their thousands of plumed occupants, and their millions of other tenants, do not house a tithe of those countless hordes of animals, sheltered and fed by the forests of deep sea-weed.

181. The food of man embraces a multitude of substances. In our own country we partake of a heterogeneous mixture of bread, beef, potatoes, porridge, tea, coffee, &c., &c. In giving beef and potatoes a prominent place in our diet, we have selected one of the best and most suitable forms in which nourishment can be obtained. In the north polar regions, dried fish supplies the place of bread, and large quantities of blubber are consumed. The very children delight in chewing blubber, and have a decided distaste for sugar and other sweets.

182. The South Sea Islanders have their bread-fruit tree, which, when cooked, tastes like wheaten bread. The fruit can be obtained ripe from the tree for eight months in the year, and the remaining four months it keeps well in pits, as our potatoes do. A man and his family can be supported on the produce of ten trees. Besides being used as food, the wood of the tree is employed in making canoes, furniture, and clothing.

183. Again, there is a tribe on the banks of the Orinoco who live on the palm tree in every sense of the word. Hammocks are slung from the trees, and boarding is laid from one palm to another. The natives are born on the trees, and they eat the fruit of the trees, and are thus fed by them; besides which, they are housed on the trees, clothed by them, and buried on them. In short, the trees, with their human freight, form a city on stilts. The Hindoo depends mainly

upon two important plants, which yield him rice for food and cotton for clothing.

THE HEAT-PRODUCING CONSTITUENTS OF FOOD.

184. One portion of the food of the animal supplies coal, to keep up the animal warmth. In order to understand the production of animal heat, we must recall to recollection what takes place when charcoal is burned in air. When such is going on, the charcoal combines with the oxygen of the air, begins to disappear, and forms a gas called carbonic acid, containing both the charcoal and the oxygen.

185. This can be proved by conducting the combustion of the charcoal in a glass bottle (Fig. 38), and adding some lime-water to the resultant gases. The formation of carbonate of lime or chalk, which communicates a milky appearance to the liquid, is sufficient evidence of carbonic acid having been produced. The same gas may be observed as being given off during the burning of a candle, a gas jet, and the coal in our grates.

Fig. 38.

186. Air, in its passage through the body of the animal, is changed in a similar manner to that contained in the jar where charcoal is burned. Ordinary air, as we inspire it, contains less than one two-thousandth of its volume of carbonic acid; but the air we breathe out or expire contains one-fiftieth to one-twentieth of its volume of carbonic acid. This can be shown by breathing into a vessel, and afterwards placing lime-water in it; or, what is more easily accom-

plished, by breathing through a portion of the lime-water contained in a tumbler or glass (Fig. 39), when the white carbonate of lime or chalk will make its appearance throughout the liquid.

Fig. 39.

187. The air from our fire-places obtains its carbonic acid by the burning of the charcoal of the coals, and the air breathed out by the animal obtains its carbonic acid by the burning of charcoal in the body. The breath thus contains a gas or air which, however clear, yet contains charcoal; and the quantity of charcoal or coal burned within the system and thus given out by each man is about twelve ounces a day, which in a year amounts to upwards of two hundredweight. A good sized family, therefore annually burns and breathes out a ton of coal matter.

188. Whether charcoal is burned in our grates or in our animal frames, the total amount of heat given out is the same. It is true that no part of the animal becomes red-hot as the coals in our fire-places do; but this difference arises from the burning going on more slowly; and thus, by diffusing the heat over a lengthened period, it makes up for its comparative small intensity.

189. If a cistern be filled with water, and a wide opening made at the lower part for the water to escape, it may be emptied in an hour; whereas, if it be again filled, and a small opening only made, the water may take days to flow out. The same quantity of liquid ultimately escapes during each trial, and, notwithstanding the greater rush of water at

the one period than the other, yet, in lapse of time, the cistern is emptied by the small opening as certainly as by the large.

190. And so in the combustion of coal or charcoal. In our ordinary fires, the fuel burns with great rapidity, and the heat for a short time is intense; but when the combustion is carried on in the animal frame, and the charcoal is there burned to keep up the animal heat, the process goes on more slowly, and, as a consequence, the heat is never so intense. In both cases, however, the same amount of heat is ultimately given off during the combustion of a given amount of fuel.

191. A fire is burning within each animal, and the food supplies the coals; and though the eye may not observe it, yet the food we eat contains, when dry, about one-half of its weight of black charcoal or carbon. This has been more fully stated under the Starch Group (par. 112). Starch is found largely in all food derived from vegetables or plants; and sugar, gum, and oil are present in smaller quantities. The food is conveyed from the mouth to the stomach, and after undergoing important changes, during which the valuable parts are rendered liquid, the atoms of food pass into the blood.

192. These remarks apply more immediately to herbivorous animals, and those whose diet consists in part of the produce of plants. The carnivorous tribes obtain oil or fat ready formed in the animals which they devour and live upon. No doubt it is slightly altered before it enters the blood, but the change is not material.

CIRCULATION THROUGH THE ANIMAL SYSTEM.

193. The heat-producing matters supplied by the food to the blood are carried by it through all parts of the body. The blood is propelled from the heart into a large canal or blood-vessel, which divides and subdivides till very minute tubes or capillaries are arrived at. Thereafter these begin

to run into each other, till they all unite in the large vein which discharges the blood once again into the heart.

194. The heart sending forth its blood may be likened to what is observed in the pipes issuing from a gas-work. At first there is a large main or conduit, which divides and sends branches along a multitude of streets, from each street into many houses, and from every house into many rooms, in each of which it ends in a gas jet. The return flow of blood to the heart is like a multitude of little streamlets joining to streams, and these to make rivers, which converge and flow by one mighty channel into the ocean.

195. The general plan of the circulation of the blood throughout the animal frame may be briefly and popularly stated thus: The heart (Fig. 40, A, A, A) has four distinct compartments, from one of which (B) the blood is forced into a large blood-vessel or artery (C), which divides and divides again and again, till the minute vessels or capillaries (D) are formed; then the capillaries run into each other, and gradually form larger blood-vessels, till, by a large vessel or vein (E), the blood is brought back to the heart (F).

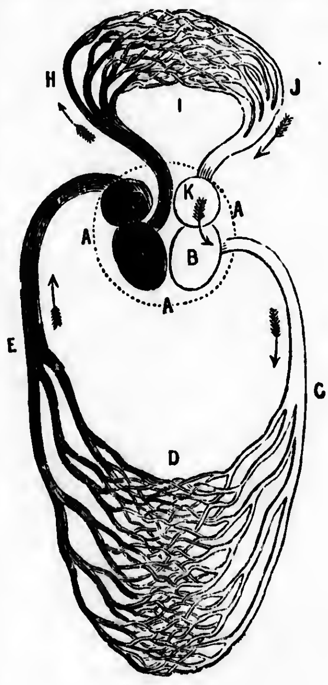


FIG. 40.

196. Thereafter the blood is again forced from a compartment of the heart (G) by larger blood-vessels (H) through minute tubes or capillaries (I) which traverse the lungs; and these capillaries also re-

uniting, become larger canals (J), and the blood flows back to the heart (K), from which it passes to the compartment (B) where it started from, once again to be propelled through the animal system.

197. The blood, therefore, in making a complete circuit of the animal frame, has to leave and return to the heart on two occasions, before it regains the starting-point. The blood of living animals is being every moment carried through the animal system and through the lungs. To make a complete circuit, and get back to the place it started from, the blood must pass through the lungs, and there it is aerated, or supplied with air.

AERATION OF THE BLOOD—RESPIRATION.

198. Although in outline the lungs appear somewhat solid (Fig. 41, F), yet, on referring to the principle of internal structure, they resemble (A, B, C, D) a tree turned upside down, where there is a trunk spreading into branches, and these into twigs, ultimately ending in leaves. The windpipe (A, B) is the trunk which divides or branches (C, D) till finally the little pipes or tubes end in minute sacs (E). In the lungs of man the branchings occur so often, that there are six hundred millions of tubes or sacs. When a breath is drawn, all these tubes get filled with air; and when we breathe out, a considerable portion of the air in the lungs escapes, leaving space for the next breath to fill.

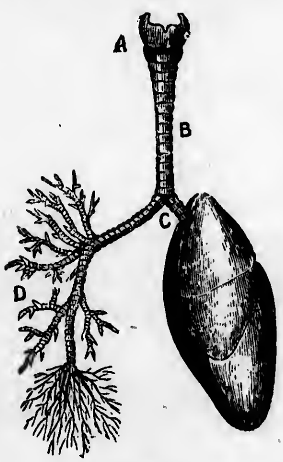


FIG. 41.

199. The average volume of air drawn in at each respiration is forty cubic inches, which will amount to about four thousand gallons each day. The walls and ends of the air-tubes and vessels in the lungs are so extensive, that the air impinges on twenty thousand square inches of surface. These air tubes have no openings into the blood-vessels; they merely lie side by side, and are separated therefrom by a thin membrane or wall, through which air can pass, but not blood; so that when we draw in a breath the air fills the air-tubes, passes through the thin division, and enters the blood. In doing so, the air dissolves in the blood, just as sugar dissolves in water; and, therefore, for the time becomes liquid, and as such it is carried on in the current of the blood.

200. From the solid food and its transformations a supply of coal is sent into the blood; and from the air drawn into the lungs a quantity of oxygen is poured into the same canal. Little or no change takes place in the larger blood-vessels, but when the materials reach the very small blood-vessels called capillaries, there the oxygen in the blood burns part of the coaly matter which has travelled so far with it.

201. It will be remembered that oil consists essentially of carbon and hydrogen; and when it is burned in a lamp, the carbon combines with the oxygen of the air, forming carbonic acid; and the hydrogen also combines with oxygen, producing water. When the sugar and the oil in the blood are burned in the capillaries or small blood-vessels, the same changes take place, carbonic acid and water being produced, which remain in the blood, and are carried in its circuit back to the heart, and thence to the lungs, where the gases are given off by the breath.

202. In this manner the heat of the animal frame is kept up, and the source of the large quantity of carbonic acid present

in respired air is easily accounted for. Formerly it was supposed that all the burning took place in or near the lungs of the animal; but now-a-days it is believed that this inward fire glows at all parts, even at the tips of the fingers and ends of the toes, and indeed in every region of the body, as well as at the lungs.

203. Water vapour is also being constantly evolved by the mouth, as may be easily observed by breathing against a cold surface, such as a looking-glass. The skin also serves as an outlet for liquid and gaseous matter. The examination of the different layers of the skin, when seen under the microscope (Fig. 42, A, B, C), reveals numberless minute openings or pores (D) which pass through the skin into the tissue underneath, and by these pores a certain amount of gases and vapours leave the animal frame. Hairs also stud the skin at all parts (E, F). The respiration by the skin is of importance to all animals, but especially to frogs, who respire much by the skin; and, indeed, if the surface of the frog be rubbed over with oil, and the exhalation by the skin thus stopped, death will shortly take place.

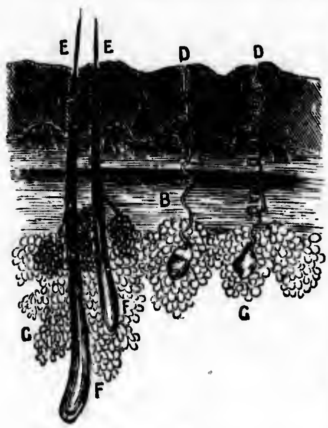


Fig. 42.

204. So far as fuel is concerned, therefore, the warmth of an animal is kept up by a process similar to that by which the steam is raised in the boiler of a locomotive engine. Were a furnace to be filled with coal, and the doors built up to exclude the air, the fire would soon die out. The animal furnace likewise needs aerial food; and when such is not supplied, the animal is choked or suffocated.

EFFECTS OF EXERCISE, TEMPERATURE, AND CLOTHING.

205. When the door of a furnace is open, there is little draught of air through the coals; and as a result only a small quantity of fuel is burned. But when the furnace door is shut, a great draught is produced, more air is drawn through the coals; and as a consequence the combustion is more rapid, and the heat is more quickly evolved. The heat given out at any time depends on the quantity of air passing through the furnace bars, and the more air the greater the heat.

206. An animal, such as a man who passes his days in idleness, and who breathes leisurely, takes fewer breaths, and therefore burns less food, than he who is in active employment, or who is running a race. The more puffs of wind thrown by the bellows into a coal fire, the more rapid the burning, and the greater the heat evolved; and the more actively the animal exerts itself, then, the more numerous the breathings. This necessitates an increase in the heat developed in the living furnace. An arm outstretched, or a step taken, is a poke to the inward animal fire. The result is, that the active man takes in more air than the sluggard, burns more fuel, becomes much warmer, and at last perspires.

207. More food is required in a cold than in a warm country. Wherever man roams over the surface of the earth, whether it be at the hot regions of India, or the cold frozen country at the poles, his body, whilst in a state of health, is nearly always at the same temperature, or degree of warmth (99° F.). In fever it is higher, and in other ailments it becomes lower.

208. An inhabitant of a warm country is surrounded by hot air, which draws away little heat from him; but a dweller in a cold region is enveloped by cold air, which is constantly robbing him of heat. Hence the latter individual,

as he is constantly losing more heat than the former, requires to burn more coals or food in the animal system, to make up for the extra loss of heat.

209. In summer we take less food than we do in winter; and if we did not burn coals in our fire-places, and thus contrive to live partly in rooms hotter than the natural climate really is, the difference would be much greater. Exposure to the open air, either on foot, in a carriage, or on the deck of a ship, by assisting the loss of heat, tends, with other causes, to give us an appetite for food which at the season of the year would be otherwise not so craving.

210. In warm countries less food is consumed than even in our own summer time; and in cold countries much more is required, as instanced in the case of the Samoyedes, of whom it is confidently asserted by travellers that each adult is able to consume daily half a calf, and a dozen of tallow candles into the bargain.

211. Clothes are an equivalent for food; and badly or scantily clothed people require more food than well and warmly clothed ones. Wrappers of all kinds tend to keep in the animal heat, which would be otherwise lost; but they afford no heat of themselves.

212. Flannel feels warm, because it is a bad conductor of heat; and whilst it is a good material for keeping the heat in, it is one of the best for keeping the heat out, as instanced in the preservation of ice which has been rolled up in it. Our clothes, therefore, form a coating betwixt which and ourselves there is a layer of the atmosphere of greater warmth than the surrounding air, so that each one of us envelops himself in a more temperate climate than Britain really is, and thus carries about with him a kind of *portable Madeira.*

213. A well-dressed boy is like a room in which all the windows and doors are in good condition, and which requires

very little fire to keep it warm; but let that boy be dressed in rags and tatters, and he becomes like a room the windows and doors of which have been blown out, and which now requires more fuel to keep it warm. Though necessary for the preservation of health, yet the principle is seldom or never acted on, that a beggar requires more food than a prince.

214. The clothing afforded by the plant, viz., cotton, linen, and caoutchouc, is thus an equivalent for the food it gives us; and the wool of the sheep and the skins of animals play the same part. In both instances the materials last longer as clothing than they would do as food. The benefits are more lasting, and we are saved the trouble of digestion. The clothing of the lower animals, including the waterproof coat of the duck, is of great importance to them.

215. Living in well-warmed houses diminishes the necessity for food; because in burning coals in our grates we keep ourselves warmer than we would be in the external air, and if we did not take advantage of this extra source of heat, we would require to burn more heat-producing matter within the animal frame. A good fire, therefore, really saves food, and enables us to spare ourselves the labour of digesting a much larger quantity of food; and thus the fires in our rooms are virtually extra mouths and stomachs assisting the animal in keeping the body warm.

EXCESS OF FOOD AND FORMATION OF FAT.

216. When more heat-producing food is taken than is necessary, the excess generally forms fat. A grown-up man each day consumes a variable quantity of food, and neither increases nor diminishes in weight from day to day. This is the same which happens with all other animals in their native condition.

217. But when animals are overfed, or are suffering under disease, the ordinary supply of air is often insufficient to burn up all the coaly or oily matter. Hence there is an accumulation of fat, which is stored up. The same thing occurs if additional supplies of coal are thrown into a furnace before the previous quantities are burned up, and when, necessarily, the fire-place or stove gets full and choked up.

218. Wild animals have very little fat; but domesticated ones, especially stall-fed, very rapidly increase their stock of fat. Exercise of all kinds diminishes the power of the system to grow corpulent; and hence an ox which has been stall-fed, and thereby grown fat, will tend to diminish in weight if allowed to graze in an open park, where it can stroll about.

219. Fat is a non-conductor of heat, and is thus serviceable in animals of the whale kind, who are warm-blooded, and by the coating of blubber with which they are surrounded lose very little heat, although constantly living in an ocean of cold water.

220. Animals can change many parts of their food into fat. In ordinary food, very little oil is found; and yet animals grow fat. The starch and sugar present in their diet become in good part fat. In one instance, a goose ate in one month 24 ℔ maize or Indian corn, and was found to have increased in weight 5 ℔, of which 3½ ℔ were fat. Now the maize partaken of did not contain above one or two ounces of oil, and therefore the other constituents of food must have been transformed into fat.

221. Again, a hive of bees fed on honey, at first convert this sugar into the wax with which they build their cells. What the goose and the bees can and do perform, all animals are in the custom of doing every day of their lives.

222. The influence of heated rooms, excess of food, and

limited exercise, on the production of fat, is well noticed in the cruel process of preparing *pâtés de foies gras*, where geese are confined in heated coops and constantly stuffed with food. Their livers become enormously enlarged, and often contain two pounds of fat. Butter, the oil of milk, is likewise an instance of the production of fatty matters within the animal.

SCARCITY OF FOOD AND STARVATION.

223. Fat serves as a reservoir of combustible matter, and the length of time which an animal can live without food depends to a great extent on the stock of fat which it has laid up. Some animals pass into a state of torpor during the winter months, and are then said to hibernate. Bears afford the best example of this peculiar condition. When a bear goes to sleep, it is fat and plump; and when it awakes, in some six weeks thereafter, all the fat has disappeared, and the animal is reduced to a mere skeleton.

224. The bear in this respect is like many industrious families who, in the latter end of summer, lay in a stock of coals to burn over the winter. The marmot hibernates for six months. During that period the pulsations of the heart fall from 150 to 15 an hour; and the respiratory movements, or number of times of breathing, decrease from 500 to 14 in the same time.

225. Animals who do not hibernate have the power of enduring hunger for longer or shorter periods. A mole must be fed every day, and a bird dies on the third day after it has been deprived of food. A dog has been known to live without a meal for 36 days; a cat for 20 days; an eagle for 5 weeks; and a fat pig, which was enveloped in a slip of earth, lived for 160 days, and during that time lost 120 lb in weight. The duration of life is best seen in serpents, where the

breathing is very slow, and where, therefore, little matter is burned up. A boa constrictor takes a month to digest a meal, and can live three months or longer without food.

226. An animal deprived of food sooner or later dies from starvation. There is a certain limit to an animal retaining its life independently of immediate sustenance from food. There is a dark side to the picture, and that the unfortunate one, where no food is taken in, and the breathing still goes on. Each breath burns up some oily matter, and the fat disappears by instalments.

227. A lamp burns so long as any oil remains; and when that is exhausted, the flame lays hold of the wick itself, for a moment flickers, and then dies out. And a starving man continues to live so long as the parts which are being burned can be spared from the living organism; and when this is accomplished, the burning begins to extend to the parts inseparable from life, the flame of life flickers for a moment, and death ensues.

CHAPTER VII.

THE ANIMAL, AND WHAT IT FEEDS ON.

THE FLESH-FORMING CONSTITUENTS OF FOOD.

228. So far as the production of heat is concerned, it is only necessary that the animal should eat starch, sugar, gum, or oil; but if fed on these alone, it would soon drag its life to a close. Experiments have been made on dogs, which were abundantly supplied with those substances; and they have day after day fallen off in condition, and ultimately died, with all the symptoms of death by starvation.

229. Food has another office to fulfil than the mere production of heat. It supplies flesh as well as heat. A calf does, in process of time, become an ox; and whilst it eats grass, it not only keeps up the heat of its body, but also increases its stock of flesh. This is one instance out of the many so situated; and we at once think it probable that there exists in grass either fleshy particles ready formed, or, if not, then that which can produce flesh when it is eaten.

230. This appears more certain when it becomes known that not a step can be taken, nor an arm thrust out, a finger moved, a word uttered, an eye turned, nor even a thought pass through our mind, but at the same moment, and in consequence of such exertion, however feeble, a multitude of the little particles of matter constituting part of our frame are destroyed. There is a saying, that the constant dropping of water will wear away a stone; and sure it is, that work

the slightest and thought the most trifling will as certainly wear away the body of the animal. This constant destruction of matter must be replaced.

231. The principal waste in the animal system is in what is commonly included under the general term of flesh or muscle. When a piece of flesh is thoroughly washed at a pipe of water, it leaves a stringy or fibrous substance, which, when dried and thrown on a fire, is consumed with the odour of burning feathers. This odour is a good popular index of the presence of the element named *nitrogen;* and as it is found in all flesh, it must be considered essential to its existence, and therefore to its formation.

232. Now starch and its associates contain no nitrogen; hence they can be of no use in supplying material for the production of muscle. They may be very good things for raising the animal heat, but it is an impossibility that they can produce flesh; and thus we must look for some other substance in plants which contains nitrogen, and which can be made useful in forming muscle or flesh.

ALBUMEN, FIBRIN, AND CASEIN.

233. The substances present in food derived from plants, and which contain nitrogen, and are useful in supplying materials for the production of flesh, are albumen, glutin or fibrin, and legumin or casein. These are found in all plants, but especially in the seeds of the cereals such as corn, wheat, barley, &c., which are employed in the feeding of the higher animals.

234. In the food derived from the animal kingdom, the three important flesh-forming substances are likewise found. The egg affords the best example of albumen, as the white part may be said to consist entirely of a water solution of that substance. 100 parts of the glair or white of egg con-

sist of water 85, albumen (dry) 12, and saline matters 3; whilst 100 parts of the yelk or yolk of egg contain water 54, albumen (dry) $17\frac{1}{2}$, and oil and salts $28\frac{1}{2}$. Albumen is also found in blood, juice of flesh, &c. As got from the egg, it is a clear and transparent liquid, soluble in cold water, but coagulated or becoming solid when heated. As procured from an animal, it is called animal albumen, to distinguish it from the same substance as got from potatoes, and which is called vegetable albumen.

235. When flesh is well washed with water, there is left nearly pure fibrin, which, as procured from that source, is from the first stringy and solid. Fibrin, however, is not always so, for in the blood it is present in the liquid condition, and it is only when the blood is drawn from the animal that the fibrin assumes the fibrous aspect, and a clot of blood is produced. As procured from either of these sources, it is called animal fibrin, and is similar to that obtained from wheat flour, which is termed vegetable fibrin.

236. Cheese is the best example of animal casein in a condition insoluble in water. In milk the casein is a liquid, but when rennet or vinegar is added, the casein separates as a curd, and liquid whey is left. This is similar to the substance which can be procured from pease, when it is spoken of as vegetable casein.

237. Animal albumen, fibrin, and casein are nearly alike, and can be changed the one into the other. These three substances, as obtained from the animal, are not only made of the same substances, but the quantity of the ingredients is so nearly identical, that they may be considered as chemically the same. Hence white of egg, flesh, and cheese, whilst they differ widely in taste and appearance, are yet built up of the same materials; and further, they are convertible into each other.

238. The egg contains little else than albumen dissolved in water. An egg weighing 1000 grains consists of shell and membrane 107, glair or white of egg 604, and yolk or yelk 289—the two latter being essentially strong solutions of albumen in water. During the process of hatching, changes take place, and when the chick breaks the shell and steps forth, the greater portion of the albumen has been converted into flesh, in other words, into fibrin, whilst only a little is left as albumen in the blood and juice of the flesh. Again, a young animal living upon milk obtains from that milk a portion of casein, which it changes into albumen and fibrin in the blood, and thereafter builds it up in its body as flesh or fibrin.

239. When the above substances are partaken of as food, and are thus introduced into the system of the animal, each and all become converted into animal albumen, whether it be casein from milk, cheese, or pease, or fibrin from flesh or wheaten bread, or albumen from a hard-boiled egg or a potato.

240. It is a rule that no solid substance can as a solid enter a plant or an animal. We may eat solids, but if they are food at all, they are rendered liquid in the stomach and the other parts of the alimentary canal, no matter how hard they are. As the food passes from the mouth to the stomach, and from the stomach to the blood, the changes take place; and at a part of the road, albumen is alone to be found, and not a particle of fibrin or casein.

241. Just previous to the nourishing fluid flowing into the blood, a little of the albumen changes into fibrin; and whilst the blood is circling round every nook and corner of the animal frame, the conversion of albumen into fibrin (liquid flesh) is going on; so that the blood contains, amongst its other numerous occupants, a quantity of albumen and of fibrin. The appearance of a drop of blood when seen under

the microscope (Fig. 43) is most interesting—the minute

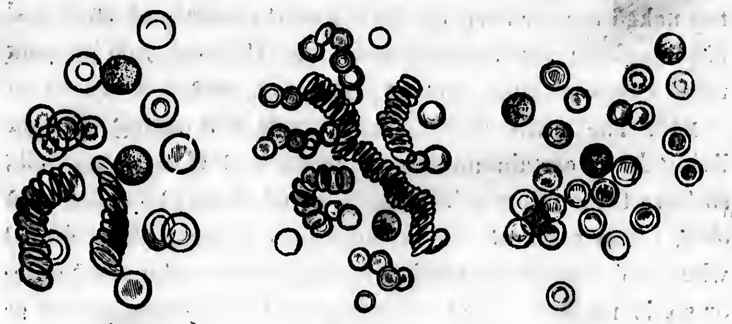


Fig. 43.

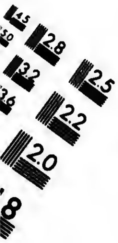
globules, like rows of penny pieces, be[illegible] the blood corpuscles which float in the serum or liquid.

WEAR AND TEAR OF THE ANIMAL SYSTEM.

242. Albuminous compounds are useful in supplying the waste of the animal system occasioned by work of any kind, and which may be better understood by calling it the *wear* and *tear* of the animal frame. The tree is at certain seasons deprived of its leaves, which partially decay and fall off, only to be renewed when the appointed time comes round again in the succeeding spring. This affords a visible instance of death in parts of plants, and the subsequent renewal of the parts thus rendered useless.

243. Similar changes are observed in animals. The whole epidermis (outer skin) of frogs, serpents, and other reptiles, peels off periodically, and is replaced by a new one. Birds cast off and renew their feathers. Many of the higher animals regularly shed their hair. The deer tribe have their massive antlers renewed every year.

244. What takes place before our eyes, and on what may be called the large scale, also occurs, though invisibly, on the little atoms of flesh of which every part of the animal frame




is made up. These atoms are far too minute to be seen by the naked eye, or even by the use of the most powerful magnifying-glass; but there is no doubt that at every moment these atoms are dying and are being renewed.

245. The entire animal has a limited duration in time, living for a certain number of years, and then dying; and so have these minute flesh atoms, or what may be called *flesh dust.* The term of life is, however, different. The animal whose sojourn on the earth is extended to one hundred years or so, is made up of atoms, some of which scarcely live as many seconds.

246. The duration of animal tissue is closely related to the activity of the animal of which it forms part. Birds of flight are the most active creatures in the world, whilst serpents are amongst the laziest. Hence the former are sooner wasted or worn out than the latter.

247. The more work, and the harder that work is, then the destruction of animal tissue is the greater; so that the work done may be taken as a measure of the waste of the animal frame. A man doing a hard day's work occasions three times more waste of his system than a man who is not working at all, either with body or mind, but in a condition analogous to that of sleep. Every one is familiar with the loss of strength when they labour long; and if weighed previous to and after work, it will be found that a difference in weight is also very apparent.

248. As an example of hard work, it may be stated that men working near the furnaces of iron-works and gas-works, where they are exposed to severe labour, and at the same time to great heat, occasionally lose five pounds in weight during a single hour. A considerable portion of this loss is doubtless water given off by the breath and by the skin in perspiration; but still a good part is owing to the destruction of the

flesh, &c., consequent on the severe manual work. Excessive exercise of any kind produces the same effects.

249. The destruction of flesh matter takes place in every little corner and crevice all over and through the body, excepting the hair and nails. The blood travels everywhere through its little canals, which are so numerous, that no part of the body can be pricked, however slightly, by a needle, but that some of the smaller blood-vessels are broken, and as a consequence, the blood oozes forth. When any power is exerted—as, for instance, an arm thrust out—a multitude of the little particles of the arm are destroyed; they become liquid or gas, and pass into the nearest blood-vessels, which carry them away.

250. As the destruction of flesh matter proceeds, little spaces are left in the animal system, which are very soon filled up with new particles brought by the blood. The renewal of flesh atoms will be more intelligible if the animal frame be likened to a house built of red bricks, which the owner disliking wishes to convert into a house of white bricks. If he were to go round the house picking out one red brick at a time and thrusting in a white one, by-and-by the red brick house would become a white brick one.

251. And so in every animal. The little bricks or particles of flesh which build up the animal structure are constantly falling to pieces, and are carried away by the blood, leaving spaces for new ones to be put in. The blood is alike the carrier of the old and time-worn materials, which it sweeps along till they pass from the system, and the new materials, which it floats along till they are built up in the vacant spaces. This is an event of every moment's occurrence, and reminds us of the cry of the magician in Aladdin, who offered to exchange "a new lamp for an old one."

252. The destruction or wear and tear of the animal frame

is greatest during the day, and the renewal of the destroyed parts takes place mostly at night. During day, when the animal force is principally expended, it is natural to expect that then the principal portion of the waste goes on, and little is renewed. At night, however, and during sleep, the waste of matter is at a minimum, and the building goes on with activity.

253. When it is necessary to work for several days and nights at a time, then the waste exceeds the supply, and feebleness is the result. The same happens when people foolishly exert themselves more than their strength will admit of, and thus over-work themselves. The animal frame is like a house constantly under repair, and into which new stones must be cemented. The greater or less waste in the animal economy is on the same footing as that observed on the streets of our cities, where the greater the traffic, the greater the waste and need of repair.

254. The wear and tear of the animal system may be said to be quite independent of the animal heat, as in the breaking up or destruction of flesh within the body very little heat is evolved. The blood of the animal carries materials of an oily character for the production of heat, and of an albuminous (white of egg) nature for the restoration of those parts which in their destruction evolve force capable of being made available by the animal.

255. In many respects an animal may be compared to a steam-engine, where the coals, on being burned, afford a supply of heat; ar[illegible]e water heated thereby passes into steam, which can propel the crank, the wheel, or the paddle. And so in the animal kingdom; the oily matters keep up the heat of the body, and the albuminous or flesh-forming elements furnish the material for the production of animal force. Since these matters are being constantly removed from the

blood it is necessary that the supply be kept up, and this is done, as already stated, by means of our food.

CLASSIFICATION OF FOOD—PROPORTION OF THE CONSTITUENTS.

256. It is of great importance that our food be of such a nature as to be able to supply the heat-producing and flesh-forming constituents in the right proportion, for neither of these separately can maintain the life of the animal. Experiments made on dogs have shown that, when forced to partake of one kind of food to the total exclusion of the other, they have died under the treatment.

257. The proportions in which the heat-producing and flesh-producing elements of food exist in some of the articles of diet are given in the following table, constructed by Liebig, and which exhibits the proportion of heat-producing for every ten parts of flesh-forming :—

	Albuminous, or flesh-forming.	Starch, Gum, Oil, &c., or heat-producing.
Milk	10	40
Beans	10	22
Fat Mutton	10	27
Fat Pork	10	30
Beef	10	17
Hare	10	2
Veal	10	1
Wheat Flour	10	46
Oat Meal	10	50
Barley	10	57
Potatoes	10	115
Rice	10	123

258. The best type of what food should be is milk. All the higher animals furnish instances of the capability of a milk diet to sustain the living powers in an efficient manner.

It contains for every 10 parts of flesh-forming ingredients, 40 parts of heat-producing. Wheat flour and oatmeal have respectively for every 10 parts of flesh-forming, 46 and 50 of heat-producing.

259. These three substances, milk, wheaten flour, and oatmeal, may be regarded as pattern diets, as they contain the heat-producing and flesh-forming elements in the proportion most fitting for the sustenance of the animal, and the other kinds of food may be considered as useful in so far as they approach in composition to this standard.

260. Beef, hare, and veal are very good so far as the production of flesh is concerned, but are of comparatively little value as sources of heat. Potatoes and rice, on the other hand, can supply abundance of heat-producing matter, whilst they are very little worth as flesh-formers.

261. A person fed on potatoes alone requires to consume a comparatively large quantity before he can get from them the requisite supply of flesh-forming matter. If a man were content with 1 lb of wheaten bread, he would require to eat $2\frac{1}{2}$ lb of potatoes to obtain the same amount of nourishment; therefore potatoes are bad for work. The same remark applies to rice; and the Hindoos, who subsist almost entirely on that article, are accustomed to take very large meals of it.

262. Lean meat is useful as a flesh-forming agent, but of little importance as a heat-producing one. It is almost pure fibrin; and though a small quantity would suffice for the production of a good supply of flesh, yet, when it is eaten alone, a very much larger quantity is required to supply heat-producing elements.

263. As a source of heat, fat is the best substance which can be partaken of, and lean meat the worst, whilst starch and sugar stand intermediate. The following table repre-

sents the relative amount of the several substances requisite to obtain an equal quantity of heat:—

100 parts of Fat.		
240	do.	Starch.
249	do.	Sugar.
770	do.	Lean Meat.

264. The correct inference to be drawn from the above figures is, that a man who can keep himself warm during one day by eating 100 parts of fat, would require to consume, if he altered his diet from fat to starch, 240 parts of the latter, otherwise he would not have enough to supply the requisite warmth; and if lean meat were the substance partaken of instead of fat, it would be necessary to consume no less than 770 parts, so as to sustain the same standard of heat.

265. Similar differences in the heating powers of various substances are also noticed in the burning of fuel out of the body—a given weight, say 100 ℔ of charcoal, will boil more water than the same weight of coal, and the latter is better in this respect than wood.

266. The right proportions in which the heat-producing and flesh-forming constituents should be present in food are those observed in milk, which contains 10 of flesh-forming for every 40 of heat-producing. So far as man is concerned, any deviation from the standard, in one way or the other, may be considered hurtful to the bodily and mental powers. But articles of food not very well fitted for the support of life, when taken separately, may be advantageously partaken of when mixed with food of an opposite character. Thus, potatoes, with little flesh-forming and much heat-producing powers, can be profitably eaten with beef, which has much flesh-forming and little heat-producing; the mixture giving a diet approximating to milk in chemical composition.

267. The quality and quantity of food depend to a great

extent on the amount of exercise or work which the animal has to undergo. Exercise of one sort or other is necessary for the keeping up of the healthy condition of every animal, and it cannot be discontinued without a certain unfavourable reäction on the system. But exercise or work destroys flesh; and hence, in the feeding of animals, it makes a very great difference to the stock-farmer whether the oxen have been allowed to roam at pleasure through a field, or are shut up in a warm place, where freedom of motion is hardly allowed. Persons inclined to be corpulent can, by moderate exercise, reduce themselves in size and weight.

268. The man who performs little or no work does not require to partake of such nutritive food as his neighbour who is in active employment. The force which a man of ordinary strength exerts in working is sufficient to raise 13$\frac{1}{4}$ lb to a height of 3$\frac{1}{4}$ feet every second for eight hours a day. In that time he will have exerted a force capable of lifting 170 tons to the height of 3$\frac{1}{4}$ feet. This can only be done at the expense of his system, and the loss so sustained must be replenished by food. If it is not so returned, no more work can be performed.

269. An animal fed entirely on potatoes, and allowed to take as much as it can, will keep in good condition provided it does no work; but if the animal is compelled to work, then the waste becomes more than it can extract from the potatoes alone; and the result is, the animal loses weight and falls off.

270. Pigs, which are so proverbial for their fattening tendency, when restricted to potatoes do not become fat on that diet; but when with the potatoes they obtain butter-milk, whey, and all sorts of kitchen refuse, then a rapid increase in their stock of fat immediately ensues.

271. Flesh-devouring animals receive little true heat-pro-

ducing material in their food, and they are compelled to consume a large quantity of flesh. Carnivorous animals, such as the lion, who live on their weaker brethren, receive in their food too little fat, by the burning of which the necessary temperature is kept up; and this compels them to burn flesh instead, which gives out very little heat during its combustion.

272. What 1 lb of flesh and a little starch would do, requires about 4 lb of flesh. Hence the enormous dinners the lion is forced to consume. This is also exemplified in the human family, in the tribe of the Gauchos of South America, who live for many months in each year entirely on animal food, and who undergo a great amount of exercise, on horse and foot, in order that the flesh so largely partaken of may be burned. It is stated that this race of people consider a piece of a fat buffalo one of the greatest of delicacies; and when a fat animal of the chase appears in sight, the Gauchos make a desperate run to secure it.

GRASS AND FLESH.

273. The animals on the earth may be conveniently arranged into the three classes—herbivorous, carnivorous, and omnivorous: herbivorous, or those which eat grass and other vegetables, and do not partake of flesh; carnivorous, or those which live entirely on animal food, such as flesh; and omnivorous, or those which consume any kind of food, whether that be vegetable or animal. As man belongs to the third class, it follows that his food is of the most varied description.

274. Grass, and especially the seeds of grasses, contain more or less nutriment. Ordinary grass yields very little nourishing matter for its bulk, and for this reason grass-living animals are almost constantly eating, and have, besides, enormous stomachs. The seeds of grasses, such as wheat and

oats, are very nutritious. Hence wheat flour baked into loaves and scones, and oatmeal in the form of bannocks, porridge, and stir-about, are good articles of diet, and people may and do live upon them.

275. In some of the South American mines, where the metallic ore has to be carried a considerable height up ladders, it is found that the best food for keeping up the strength of the men at this laborious work is a good supply of beans, which constitute the greater part of their daily diet.

276. When grass becomes flesh, as it does in the ox, a great deal of useless matter is got rid of, and the true food in the grass is stored up by the ox in one part or other of its carcass. That part which forms the edible portion of the animal, and which is generally called beef, has been sifted, so to speak, by the ox from the dross accompanying it in grass, and the true golden material—the portion really useful to man—is presented to us in the form in which we can, with least work to ourselves, make a proper use of it. What is stated here of the ox applies also to the sheep, the goat, the deer, and indeed to all the animals upon which we feed, and which in their turn live upon grass.

277. The ox, sheep, &c., aid us in preparing our flesh, by taking the crude material grass, and so treating it that they disentangle the good from the bad, and hand over to us only that which can be useful to us. We may live upon grass or parts of grasses, such as the seeds, but it requires a greater degree of force for us to form our flesh from such food than from an animal diet, as in the latter case a part of the work has been already done for us in the stomachs of the ox and the sheep.

278. Living on a diet consisting in part of animal food is a saving to our digestive powers, and a saving of work implies a storing up of force. Each man in a healthy con-

dition has a stock of force, which he can expend in manual labour at the anvil or elsewhere, or in thinking, writing, and speaking. In either case the force so expended may be the direct means of procuring bread for himself and his household.

279. To *think* and to *work* are, in popular language, so separated from each other that at first sight they appear quite different in all their relations; but the thinking or mental powers and the bodily or physical,—in other words, the thought and the arm,—draw on the same bank or stock-in-trade. They are two partners in the same concern, and the more there is squandered by the one, the less there is left for the other. And thus the smaller the force which is expended in the digestion of food—and of all work stomach work is the hardest—then the more force or power there remains for the exercise of thought.

MILK.

280. Milk is the first food with which the majority of the higher animals are acquainted, and consists in greater part of water with variable quantities of oil, casein, sugar, and earthy matter. The oil or butter is floating about in countless little globular particles, which, being lighter than the liquid in which they are suspended, begin to rise to the surface when the milk has been at rest for some time. This accumulation of oily matter at the surface is familiarly called cream, and is generally accompanied by some casein.

281. When milk is agitated for some time, the little oil globules run into each other and form butter. There is always a small quantity of casein present in butter, which tends to make it become soon rancid. When it is desired that butter should be preserved for a length of time, a little common salt, and occasionally saltpetre and sugar, are added.

A deeper and richer colour is imparted by the addition of the colouring matter called arnotto.

282. The casein or cheese matter of milk is easily separated from the other substances present, by the addition of an acid such as vinegar, when a coagulum is formed, consisting in greater part of the casein with a varying quantity of butter. When milk gets old and begins to sour an acid called lactic acid is formed out of the sugar, which has the power of rendering the casein solid. The same is accomplished by the addition of a piece of the stomach of the calf, or of water which has been in contact with a calf's stomach, and which is known as rennet. In the preparation of casein for cheese, the latter substance is the one generally employed.

283. The richness of cheese depends on the proportion of butter in it. The best cheese contains most butter, and becomes soft and viscid when toasted; whilst the poorer kind, which contains little butter, shrivels up and assumes a horny appearance when heated before the fire. Stilton cheese is made from milk to which cream is added; Cheshire and the better kind of Gloucester cheeses are prepared from ordinary milk; and Suffolk and Parmesan cheeses from skimmed milk. Arnotto is also used for colouring cheese.

284. The *sugar of milk* is left in the whey when the casein is separated, and by boiling the whey down to dryness, an impure specimen of sugar of milk may be obtained. Large quantities of milk sugar are prepared in the Swiss dairies, and though possessing a brown colour at the first, yet it can be purified, and is generally to be seen in pieces like loaf sugar. It is much less sweet to the taste than cane sugar, and is very hard, even fragments of it feeling like sand when placed between the teeth.

285. From the many useful substances present in milk

it must be ranked as an important article of diet, whether partaken of, either as it is first procured, as skimmed milk, or as butter milk. Butter milk, or *sour* milk, as it is sometimes called, when not largely diluted with water is very little behind the other varieties in its nutritive powers, and affords a cheap source of milk largely taken advantage of by the working classes in Scotland and in Ireland.

286. Blood is sometimes used as an article of diet. It is present to a small extent in all flesh, notwithstanding the prevailing custom of allowing the greater portion to flow away when the animal is killed. The pig is the only animal whose blood is eaten among civilized nations: mixed with fat and aromatics it forms the sausages sold by the name of black puddings. In cases of great destitution, blood has been had recourse to with success for alleviating hunger and strengthening the frame. The spider affords the best proof of the power of blood to sustain life, as the poor flies know too well.

INFLUENCE OF BAKING AND COOKING.

287. Before any portion of food can become available for the support of the animal, it must undergo certain changes to fit it for its office. So far as every animal but man is concerned, these changes happen after the food has been eaten and before it reaches the blood, the stomach being the chief seat of this re-modelling of parts. Now man aids his stomach in this laborious work by previously subjecting his food to the process of cooking, whereby the different matters are more or less broken up and thus rendered more easily acted upon by the various juices which are mingled with it in and near the stomach.

288. The simplest mode of preparing food is that employed in the making of cakes and bannocks. The meal is

simply stirred up with water, kneaded, rolled out into thin sheets, and heated on a hot iron plate. Common sea biscuits are formed of wheaten flour and some bran and water, and they are heated in an oven. Butter biscuits receive their name from the small quantity of butter which they contain.

289. In the process of baking ordinary wheaten bread, the flour is mixed with salt, water, and a little yeast. The latter substance causes a quantity of carbonic acid gas to be developed all through the dough, which, when the loaf is placed in the oven, becomes expanded by the heat and forms the spongy appearance characteristic of loaf bread. As procured by this process it is called fermented or leavened bread, and as the gas which fills up the little blisters or cavities is generated from a part of the flour used, it follows that in baking by this plan, there is a loss of a portion of the material.

290. Recently a good deal of bread has been prepared without the use of yeast, and by the addition of baking powders—consisting of bi-carbonate of soda and hydrochloric acid—to the dough. The action which takes place is similar to that which happens when the contents of the two papers of a soda powder are mixed together, the result being that carbonic acid is evolved, and when this occurs in the dough, little air bells are left in every part, which swell up when the batch is placed in the oven. A more recent suggestion is to force water containing an excess of carbonic acid into the dough.

291. Bread thus prepared is called *unfermented* bread, is not so liable to get sour as by the yeast process, and is generally considered a better kind of bread, more especially for those who are subject to stomach complaints. In an economic point of view also it is to be preferred, for a certain

quantity of flour which is lost by the yeast process is saved by the unfermented process.

292. During the baking of the bread a portion of the starch in the wheat flour is converted into a kind of gum called dextrine (British gum), and this is specially observable in the crust. This takes place to a much greater extent when a slice of the loaf is toasted before a fire. By baking, wheat flour and other kinds of grain are rendered more palatable, and, from the spongy texture, are in a better condition to be acted on by the juices in the stomach. Moreover, the change of a part of the insoluble starch into the gum dextrine, which is readily soluble in water, renders the bread more easily digested.

293. In the preparation of flesh as food, many different methods of cooking are had recourse to. When a piece of beef is thrown into cold water, there is a great deal of matter dissolved out of it, and what is left is stringy and tough. The liquid thus obtained contains amongst other matters animal albumen, which renders it highly nutritious. Now this albumen is the same as white of egg, and just as the white part of the egg becomes solid (coagulates) when the egg is thrown into hot water, so a piece of meat containing albumen, when thrown into boiling water, has the albumen immediately solidified all round it, forming a kind of case or shell through which the water cannot readily pass in or the rich juice of the meat pass out.

294. If the object be to boil the meat and use it without the water in which it was boiled, then the meat should be thrown into hot water and the nutritive material is thereby retained within the meat; but if soup be wanted, cold water must be used at the commencement of the operation.

295. The latter method yields the extract of meat known as beef tea, which is highly nutritious and is easily digested,

both of which properties render it of immense service in the recovery of wounded or sick people. In Australia and South America, where cattle are boiled up principally for their fat, there is a great waste of what with a little care and management might be placed in proper vessels and sent all over the world. To a small extent this waste is now stopped in the preparation of Liebig's Extract of Meat, which is at present beginning to arrive in quantities from South America. The common practice of taking both the soup and the meat which was boiled in it, is certainly the most profitable, when the stomach is in good condition.

296. The use of bones in the making of soup is serviceable in imparting a small amount of flesh-forming constituents to the soup, but likewise in communicating a considerable amount of gelatinous matter, which gives a consistence or apparent strength. This is due to the large quantity of gelatin present in bones, which amounts to about one-third of their weight when dry. A similar thickening of the soup is often obtained by the addition of gelatin as derived from the hides of animals.

297. The benefits obtained from the employment of bones or ordinary gelatin in the preparation of soup are more apparent than real, and though some time ago the gelatin of bones and hides was considered highly nutritious, yet it is now believed that the gelatinous matter cannot assist in supplying the ordinary wear and tear of the system, or build up the muscular part of the animal frame. The benefits derivable from the gelatinous substance are mainly restricted to yielding material to form the external covering of skin, and in supplying the waste of the gelatin in the bones.

298. In the cooking of food a good deal depends on the water employed in the operations. A *very hard* water, or one which contains much lime dissolved in it, and which may be known by its forming an incrustation or *fur* in

kettles, acts injuriously in the preparation of food, as it hinders the extraction of the nutritious elements, owing to the readiness with which it deposits a coating of lime over the partially cooked food. In this way, much waste not only of vegetables and other eatables occurs, but also in the preparation of beverages such as tea and coffee.

299. On the other hand, a *very soft* water, such as rain water, does not contain those saline ingredients which are essential to the healthiness of the animal. The water, therefore, should be of a medium quality; and one which contains from three to twelve grains of saline matter dissolved in each imperial gallon, may be regarded as the most useful, economical, and healthy.

300. Care should likewise be taken that the water used as a beverage, or for culinary purposes, is free from contamination with the products of the putrefaction of organic matter. Water taken from ditches or reservoirs where decaying plants are rotting away, or where other organic matter can find access, should not be used for household purposes. Such water sometimes appears coloured when placed in a glass, and may possess a mawkish taste, which should be sufficient popular evidence of the unsuitability of the water for dietetic purposes. At times, however, the water may appear clear and transparent, and have an unexceptionable taste, and yet be contaminated with organic matter to an extent to render it more or less unwholesome

DIGESTION OF FOOD.

301. The process of cooking is useful as a means of assisting to loosen the little particles of flesh from each other. Roasting, frying, baking, stewing, and broiling, are the other processes resorted to in cooking animal food, and though the mechanical means employed in their prosecution are

different, yet they agree in more or less separating the little particles of flesh from each other, and thereby rendering the meat more readily digestible. To accomplish this, meat should be well done, but not overdone. In the latter case total destruction of the parts takes place, as in a piece of burned meat; or the matters are rendered much less digestible, as in a hard-boiled egg.

302. Vegetables, such as potatoes, cabbage, cauliflower, &c., are likewise changed for the better when well boiled with water. It may be taken as a general rule that food is best fitted for our support when well cooked. The only exceptions to this rule are oysters, apples, pears, and some other fruits, which are more wholesome in the raw than in the cooked condition.

303. Many other circumstances influence the digestibility of food. Violent exercise immediately previous to the death of an animal, as occurs in hunted animals, renders the flesh more easily digested than it would be if otherwise and more quietly put to death. The length of time which elapses between the death of an animal and the consumption of the flesh, also determines to a certain extent, as in the case of game, the most fitting time to partake of the food.

304. No general rule can be laid down for the diet of a nation. Every person differs from each other, not only in features but in the particular aptitude which each has of living upon certain kinds of food to the exclusion of others. The same individual also may relish one kind of food to-day and another to-morrow, much depending on the state of his body and mind, the time which has elapsed since the preceding meal was taken, the state of the weather, &c.

305. The length of time which any article of food remains in the stomach is a measure of the facility or difficulty which attends its conversion into useful matter. The following

table gives the length of time required for the digestion of many common articles of daily diet:—

Articles of Diet.	Mean time of Digestion in Stomach.	
	How prepared.	Time in Hours.
Milk,	boiled	2
Milk,	raw	2¼
Turkey, domestic,	roasted	2½
Lamb, fresh,	broiled	2½
Potatoes,	roasted or baked	2½
Beef (with salt only),	boiled	2¾
Oysters, fresh,	raw	3
Eggs, fresh,	soft boiled	3
Beefsteak,	broiled	3
Mutton, fresh,	boiled or broiled	3
Chicken soup,	boiled	3
Oysters, fresh,	roasted	3¼
Bread, corn,	baked	3¼
Oysters, fresh,	stewed	3½
Beef, fresh, lean, dry,	roasted	3½
Beef (with mustard, &c.),	boiled	3½
Butter,	melted	3½
Cheese, old, strong,	raw	3½
Soup, mutton,	boiled	3½
Bread, wheat, fresh,	baked	3½
Potatoes,	boiled	3½
Eggs, fresh,	hard boiled or fried	3½
Salmon, salted,	boiled	4
Veal, fresh,	broiled	4
Fowls, domestic,	roasted or boiled	4
Soup, beef, vegetables, and bread,	boiled	4
Soup, marrow bones	boiled	4¼
Cabbage,	boiled	4½
Suet, mutton,	boiled	4½
Pork, fat and lean,	roasted	5¼
Suet, beef, fresh,	boiled	5½

306. The above results were obtained from experiments made upon a Canadian, by name Alexis St. Martin, who received a gun-shot wound which made an opening directly into his stomach, and which, when the wound healed, became a permanent passage, through which food might be taken out of the stomach at any time. After he partook of a meal, and during the time it was being digested, repeated quantities

of the food were withdrawn and the progress made was recorded.

307. At first sight it does look strange that any good should result from cooking our food. If we are very thin and weak, and desire to be stout and strong, it appears as if that would be most easily accomplished by partaking of raw flesh, which is so much more like what we require than roasted or boiled meat is. And this would undoubtedly be the case if the meat passed as a whole to the place it was needed;—if, for instance when a finger was cut and matter was required to bridge over the gap, a little piece of flesh were eaten, and in some way or other it were to run along the arm as if it were a tube, and ultimately arriving at the finger, fill up the sore as one might plug up a rent in a water barrel.

308. But this is not the way in which nourishment is carried to a suffering finger or a weakened limb. Such a plan of healing and strengthening would be like building a large house by taking the walls of cottages and piling them one above the other, when, as every one knows, the whole would be unstable and the first storm would bring it down. If we wish a house to be secure, every stone must be taken separately and placed on the new wall, and be cemented by new lime to its neighbour stone. It matters not if the stones have been used before, in cottage or house, provided they are still good and not in a state of decay.

309. What experience dictates in reference to a house of stone and lime, science has shown to be the everyday means adopted by Nature in building up and repairing the body of the animal, which is a house of flesh, and blood, and bones. Each mouthful of food is like a small cottage. The albumen, fat, gelatin, &c., are the stones, lime, and wood, and these are present in countless little atoms in every piece of food. The fire, the teeth, and the stomach are the instruments which

break up these food walls, and separate every albumen stone from each other.

310. The blood carries these stones in countless numbers to all parts of the system, and when, through old age, a little flesh stone decays, or through accident a portion of the living wall which encircles the body, or of the numberless corridors and chambers in its interior are destroyed, then the material is at hand for rebuilding the decayed or injured part. This is done slowly but securely and firmly by laying down each stone by itself, one after the other, stone above stone, till the fabric is reared or restored.

311. So far as diet is concerned, an animal is like a steam engine;—the food of the one consisting of bread, potatoes, beef, &c; and that of the other of coals and water. This similarity can be carried to a much greater length than at first sight it would appear.

312. The food of the engine lies in basin-shaped depressions in the interior of the earth, like an immense oyster shell, buried in sand and lime, and broken through in a number of places. From this region the workmen or colliers with their picks detach blocks of coal, which are carried up the shaft or pit leading from the bed of coal to the surface of the ground. At the pit head there is the great deposit of coal, which is there assorted and sent off in every direction to feed the engines of the country. And the same happens with the food of the animal.

313. The contents of our plates are cut and divided by knife and fork, are transferred to the mouth and descend the shaft leading to the stomach, are there arranged, and the better parts are carried to the blood by its tributaries. When arrived there, the food becomes fuel, as strictly so as the coals in the engine fire, and it is in the blood where the food can become useful in the sense of the food of the engine. The coals are

dug out of the earth the one day and may be used during the next; and our food taken late the one day is assorted during the night, and may become of service on the succeeding day.

314. Knives and forks are useful auxiliaries to the teeth and stomach. The same spirit and principle which has reduced manual labour in our power-loom factories, has invented the knife and fork to serve as allies to the natural grinders of food. The laborious physical exertion lately required in the production of woven fabrics is now handed over to the steam engine and the driving belt; and the hard chewing, masticating, and digesting of food, which must have originally been the lot of humanity, is now in great part accomplished by the knife and fork, aided by their powerful ally the fire.

315. In the elaboration of food into useful material for nourishing the body, many animal organs are at work night and day, and a glance at the interior of the body of an animal, such as a rabbit (Fig. 44), at once shows that the stom-

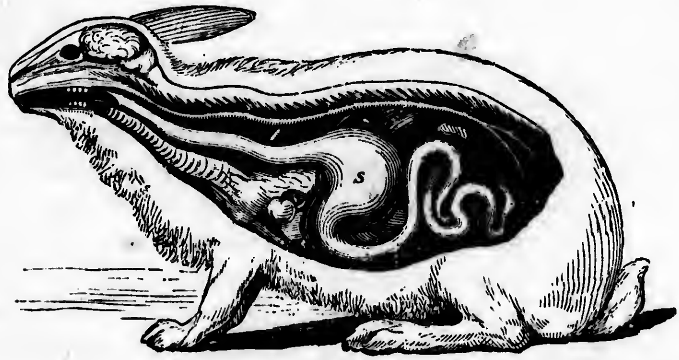


Fig. 44.

ach (s) of the animal forms but one of many parts which apparently minister to the health and sustenance of the animal.

316. A similar remark applies to the complex but perfect arrangements in the human system for the thorough digestion of food. Thus our daily food passes by the œsophagus or gullet (Fig. 45 A) to the stomach (B), where it is acted on by certain fluids, and being partially worked up, is forwarded to the intestines (C C), where the process of digestion is completed, and the fluid is prepared for being absorbed into the blood.

FIG. 45.

317. But in the elaboration of suitable food, and in the healthy supply of the wants of the animal frame, the spleen (D), the pancreas (E), the liver (F), and the gall-bladder (G), all have most important offices to fulfil. Even during the chewing or mastication of food, the intermingling of the saliva with the elements is of essential importance. The saliva contains a ferment called ptyalin, which has the property of converting starch into sugar; and when ordinary bread, potatoes, or other vegetable food, is partaken of, the thorough chewing and mingling of the food with the saliva is requisite for thorough digestion.

318. Not only in the preparation of the food for reception into the blood, but in direct co-operation with the blood itself, many organs of the animal frame take an active part. Thus in the circulation of the blood from the heart

(Fig. 46 A), through various parts of the body (CG), not only is the fluid purified by passing through the lungs (B), but the spleen (D) and intestines (E) give their aid to supply nutritive matter to replenish waste, and the kidneys (F) and liver (H) work actively to purify the blood and preserve it in a state of health.

FIG. 46.

319. How wonderful the mechanism which each human being is possessor of, and how delicately formed are the animal structures which we tenant during our earthly sojourn! The disarrangement of a single organ necessitates loss of nutriment to the blood, or want of means to remove impurities from the blood, and thus the living stream which flows in every direction may be starved or polluted, and the animal die.

320. Animals are much affected by the quality and quantity of the viands they consume. On the death or disappearance of the queen bee, the hive select one of themselves, and by careful nursing and feeding on royal food, the ordinary-sized bee becomes the monster queen bee. Our prize-cattle, too, are good instances of the enlargement of the animal frame by the plentiful eating of rich food. Again, the half-starved cur which picks up its living on our streets, as truly represents the results of insufficient food, as the plump poodle in the drawing-room attests the over-abundance or surfeit of proper food. And to pass from the lower animals to man, the highest; what a contrast between the tall, portly London draymen, on the one hand, and the Bushmen of Southern Africa, or the aborigines of New Holland, on the other!

321. Light exercises an important influence over the well-being of animated nature. Silkworm eggs hatch sooner and in greater numbers in a light room than they do in a dark apartment.

322. Tadpoles exposed to light very soon put forth front legs, then hind legs, by-and-by assuming much of the appearance of the frog, and ultimately becoming a true frog. But if the tadpole be kept in a dark place, these changes will not occur. The animal will increase in size, but will always retain the fishlike form.

323. The human body is less subject to epidemic attacks when it is exposed to much light. In extensive barracks in St. Petersburgh, one side of which was directed towards the south, and was thus presented to the sun, and the other looked to the north, and was comparatively obscured, it was found that the number of men exposed to attacks of disease on the dark side was three times that on the light side, and that the recoveries of the sick were more numerous on the light side than on the dark one.

324. A low temperature is inconsistent with unimpaired vital activity. The death of many a fellow-being in snow-wreaths, and on icy cold nights, can best testify to this fact. Frost-bitten limbs are in many cases lost to the owners, though sometimes, by judicious appliances, they recover.

325. Many insects may be frozen and thawed a number of times, and yet still retain life. Other insects may be thoroughly dried, and yet, when again made wet, recover their activity, and appear none the worse for it. In our hospitals for aged people, the influence of the cold months of the year is much felt, and is shown in the greater number of deaths.

326. Domestication and cultivation greatly modify the appearance and form of animals and plants. The many

different breeds of dogs, which have all sprung from a common origin, afford abundant evidence of the influence of domestication aided by climate, in multiplying diverse forms of the same kind. Horses, oxen, &c., afford other examples. The plants growing in our garden-plots and conservatories likewise testify to the modifying influences of human care and ingenuity.

327. In the preservation of the health of the animal, it is necessary that it be supplied with certain saline matters, which are, in part, already present in the food it partakes of, but in other part are purposely added thereto.

328. Thus common salt is almost invariably mingled in considerable quantity with the food whilst undergoing the process of cooking, and also during the time of being partaken of.

329. These saline matters are so requisite for the sustenance of the animal frame in a state of health, that any lengthened deprivation of them leads to disease in the animal. Special allusion will be made to those earthy or saline substances in the subsequent division.

PART II.

THE EARTH, OR SOIL, IN ITS RELATION TO PLANTS AND ANIMALS.

CHAPTER VIII.

IMPORTANCE OF SALINE FOOD.

330. Plants and animals derive the greater part of their food, directly or indirectly, from the atmosphere, but they likewise obtain some from the soil. Not more than half a century ago it was considered that, as a plant left a very small amount of ash when it was burned, the ash was of little importance, and was merely present by chance or accident, and that the true and only office which the soil fulfilled, was to allow the plant to fix its roots in it, and thus to anchor itself to the Earth. Now-a-days the soil has ceased to be looked upon simply in the light of a vice, holding the plant fast to its home, and the previously despised ash, or saline matter, has been raised to the first rank.

331. What the lime is to the stones of a house, the ash of a plant is to its other ingredients. It is quite possible to place stone on stone, and thus form a rude kind of hut—a tottering dwelling through which the wind may whistle; but to make the house a home, we must cement stone to stone by the aid of lime. And so in the plant structure. No doubt, the greater part of a plant is combustible or aerial

matter, and, therefore, not earthy; but the ash or earthy portion may be regarded of as much importance to the healthy growth of the plant as the cement to the stones of the house, enabling the aerial particles to be bound together, and to be built firmly, adding inch to inch as the plant raises its head above the ground.

332. Saline, or earthy matters, are of great use to plants and animals, as without such they could not live and thrive. Two fields in the same or adjoining districts may be sown with the same kind of wheat. At harvest time, the one field will bear a tall, waving, full-headed crop, and the other a stunted, thin, and meagre one. It is obvious that the difference in the produce cannot be owing to the grain, for the same seed may have been sown over both fields; nor to the weather, for the shower and the sunshine may have fallen alike on both; nor to the air, for the same gentle breeze may have nourished both; nor to the mechanical condition, as the coarseness or fineness of the soil on both portions of ground may have been identical.

333. The great crop and the little crop differ, however, because the ground on which the first grew contained abundance of the salts necessary for the healthy growth of the plant, whilst the soil on which the scanty crop eked out its existence was nearly destitute of the right materials.

334. Again, two dogs of the same size and breed may be taken and fed with an equal quantity of meat each day, the one dog receiving the meat as it comes from the butcher's shop, and the other obtaining his share after the juice containing the saline matters has been washed out of it. After some days it will be found that the dog who has been fed on the entire meat will have remained stout and healthy, whilst the second animal, who partook of washed meat, will have become thin and emaciated, begins to dislike his food,

and will die within two months. These instances show us that the saline or earthy matters are of great importance to the life of plants and animals.

DISINTEGRATION OF THE SOIL BY THE AIR AND WATER.

335. The plant is dependent on the soil for its earthy food, and the soil in its turn derives its nutriment in greater part from the rocks lying beneath. Wherever the loose clay or sand is cleared away from a spot of ground, there is always found, at a greater or less depth, a stony or rocky mass. This is well seen in a quarry, an exposed sea-cliff, the banks of a river, or a railway cutting.

336. In many instances the rocks are lying in layers or bands (Fig. 47), like a number of roofing slates placed beside

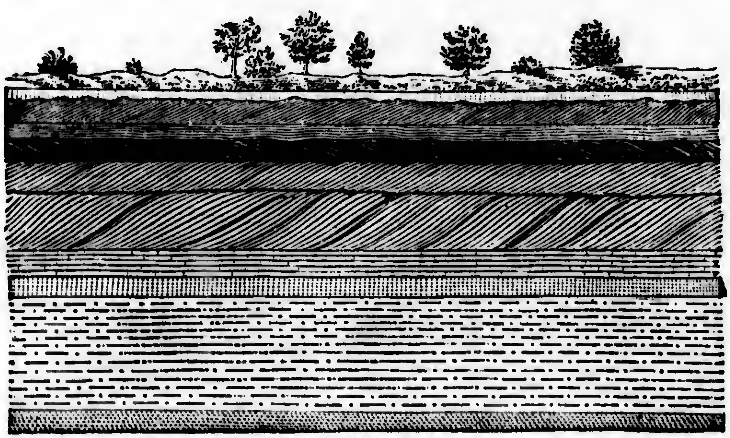


FIG. 47.

or piled above each other. These layers or bands of rock need not be disposed in the same order; but whilst some of the layers, called strata, are in a straight or horizontal position, other layers or strata are inclined at various angles. In other cases the rocks occur in irregularly shaped masses, with more or less of a crystalline texture, and not resting in layers. Occasionally the crystalline rocks are found in regular masses, forming a columnar appearance, which is very striking (Figs. 48 and 49).

FIG. 48

337. As examples of the former, or stratified class of rocks we have the layers of sandstone, limestone, ironstone, coal, and shale; and of the latter, or unstratified rocks, there are granite and greenstone (whinstone), which form a considerable part of many mountainous regions, and are much used for Macadamising public roads. The various classes of rocks are forming every day, and it is only by devoting some time to the

consideration of the forces at present at work that we can understand how the older rocks have been fashioned.

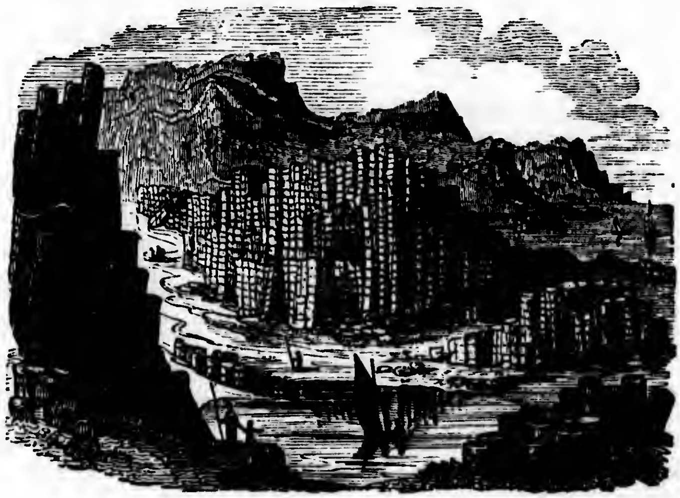


FIG. 49.

338. The oxygen of the air, aided by carbonic acid and water, is constantly wearing down to powder the hardest rocks. When a stone has been for a year or two exposed to the action of the atmosphere, it exhibits traces of a change which it has at least partially undergone. In some rocks, such as whinstone, this change extends merely to a slight discoloration of the exposed surface, and if a piece be struck off, it will be found that the decay is merely on the outer film, and that immediately within the earthy coating, the mass has preserved its original structure and colour.

339. At other times the action of the atmosphere is quick, and extends to a considerable distance within the outer coating, and what was once a hard mineral mass, becomes in a short time eaten through, and falls down as a coarse powder.

340. This change is, to a great extent, due to the power

which the oxygen of the air exerts on the iron part of the stone, forming rust with it; and just as an iron hoop or nail, left exposed to the air, cannot withstand this invisible enemy, oxygen, and, metal though it be, is broken down into iron dust; so the rock, much less hard to begin with, falls still more easily before the unseen foe.

341. No doubt the carbonic acid of the air and also water assist the oxygen in its work of destruction; for *dry* iron keys and ironstones lying in dry places remain untarnished.

342. Water transports rocks, and rock powder, from place to place. Although water acts on the ground and on rocks in many ways, there is none of more importance than its power of carrying along mud, sand, and stones.

343. Every long continued rain gives convincing proof of this. A drop of rain on the summit of a hill is comparatively nothing, but as a number of drops run into each other and form a streamlet, and streamlets join to make a stream, and streams in their turn become a river, then we find the accumulated rain-drops dashing along with great velocity, carrying along with them mud, sand, pebbles, and even stones.

344. Whilst the land waters are doing their work, the sea is also at its post, breaking up and carrying away rocks. All

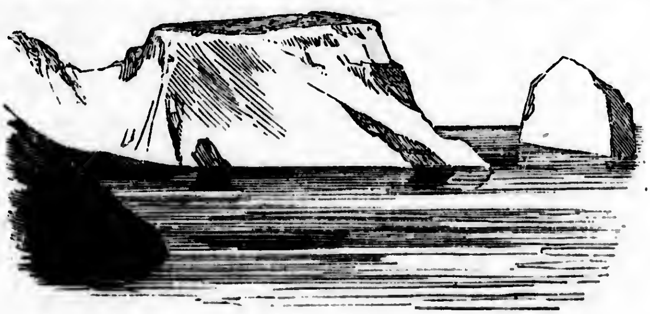


FIG. 50.

along our coasts, at every prominent headland (Fig. 50), the waves dash against the rocks (Fig. 51), grind away a portion, and thus undermine the rock situated above, which

FIG. 51.

by-and-by tumbles down in fragments, only to be ground to powder by the incessant marching and countermarching of the waves—ocean's artillery. Though it is not so obvious, yet, in reality, the sea removes fully twice as much earthy matter as all the rivers in the world do.

FORMATION OF ROCK AND SOIL.

345. Water in a state of motion has a great power of moving sand, gravel, and stones, but it loses this power when it is brought to rest. If some fine sand be thrown into a tumbler of water, and the whole be well stirred so as to make the water whirl round and round, the sand will be floated along with it; but when the water is allowed to come to rest, the sand sinks to the lower part of the vessel, and leaves a clear liquid above. So rivers, with their load of mud and sand, the moment their speed is checked, begin to deposit the matter which they have carried along.

346. The ocean, too, while it does its work in breaking down the exposed parts of coasts, carries the fragments of rocks out to seaward, and in some quiet nook or deep sea bottom, loses its hold of them, and strews them over the ocean-covered land.

347. The action of water, in carrying along and depositing mud and sand to form rocky masses, is well seen in the case of the Rhone as it enters the Lake of Geneva, which is about thirty-seven miles in length, and two to eight miles in breadth. The Rhone, as it flows in at the one end of the lake, is a very muddy river, and, as it passes out at the other extremity, it is clear and transparent. Plainly, therefore, the mud which the river carries into the lake must be deposited there, as it does not flow out again with the water.

348. Now it is found that the lake has a uniform depth of a hundred and twenty to a hundred and sixty fathoms, excepting near the upper end, where about two miles from the mouth of the Rhone it gradually gets shallower, and exhibits the appearance of a lengthened slope. From this observation it is with great reason inferred, that all the mud, sand, pebbles, and stones brought down by the Rhone, are deposited on this two-mile incline.

349. Every year a large quantity of earthy matter is finding a resting-place there, and as the filling up of the lake is constantly going on, there is no doubt but the layers or deposits of new-formed rocks will by-and-by stretch the whole length of the lake, and leave only sufficient room for the river to meander through it.

350. The earthy matters carried by rivers into the sea, and the materials ground by the waves from the face of every prominent headland, are thrown down in a similar manner, although these are much influenced by tides and currents.

351. Running water likewise transports parts of plants and animals, which it deposits with the mud and stones. When a river is in a state of flood, it generally carries along more than earthy matter; if a bush or tree stands in its way, the current gradually undermines it, and carries it on.

352. If the river overflows its banks and comes near a farm-house, the produce of the land built up in stacks is speedily engulfed. Chickens from the hen-roost, dogs from the kennel, and rats from their underground dwellings, are snatched away and carried on. These shrubs, and trees, and animals are thrown down by the mud and covered by it; and thus the plants and the animals of the present day are entombed in the rocks forming at the present time.

353. This explains why we should find in the rocks, now high and dry, remains of different plants and animals, such as leaves, branches, bones, and shells (Fig. 52). These have

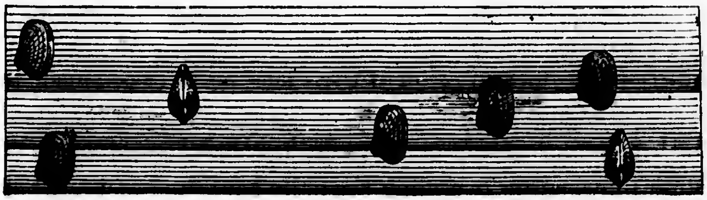


FIG. 52.

been placed or buried in the stony mass in which they are now embedded whilst that was soft, or, at least, easily moved, and have remained there when the whole has been hardened by time, or otherwise.

354. Water has formed the stratified rocks which cover the greater part of the earth's surface, and appear in many different positions. The thickness of each layer or band of rock depends on the quantity of stony matter carried down during any one time or season by water to the place where the rock is being formed.

INFLUENCE OF EARTHQUAKES AND VOLCANOES.

355. If water had been the only agent at work in forming the upper crust of the earth, then we should have had all the rocks lying in the position they were laid down. But this

is not the case, as the greater number of layers of rock are more or less tilted upon end (Fig. 53), and afford distinct evidence that some other agent has been at work, besides the levelling one of water.

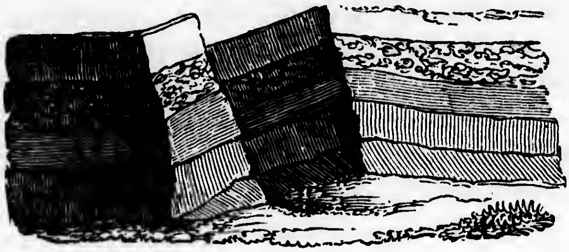


FIG. 53.

356. These upturned layers of rock were originally laid down in a horizontal position, but some uprending force has since their formation altered their position.

357. The upturning of rocks has been occasioned by earthquakes and volcanoes. Even in our day, large tracts of land are being slowly or suddenly upheaved; and could we obtain information regarding the daily condition of the whole surface of the globe, there is no doubt that we should find the earth is constantly undergoing shocks at one part or other of its surface, and is continually being thereby influenced by the reäction of the interior on the exterior.

358. Earthquakes may be limited to a small area or district, or they may extend over a large portion of the earth's surface. In 1755 an extent of country four times greater than that of Europe was simultaneously shaken; and in six minutes the city of Lisbon was completely destroyed, and sixty thousand persons perished. On other occasions, the shock of the earthquake is only felt within a small area.

359. Not only are houses rent by earthquakes, but the solid earth, at times, is observed to be cracked through. The appearance which these fissures present when a bird's-eye view is obtained— as from a balloon—is often similar to that

which is observed when a marble passes through a pane of glass. In the centre where the cra[illegible] has been, the opening is greatest, and from that point there stretch in every direction a multitude of cracks.

360. When a side view or section can be observed, then the rock either appears as if a part had slipped down, or it had been split and separated, or even the three conjoined, where the stony mass has been cracked, separated, and thereafter one or other of the sides has been raised or lowered. The disturbed appearance of the crust of the earth is often well seen in the section of a coal field (Fig. 54). Sometimes

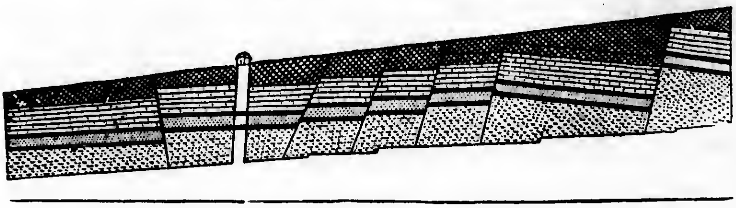


Fig. 54.

the cracks or fissures are left open; at other times they open and shut violently, and engulf houses, trees, &c.

361. When the terrestrial crust is fissured deeply by earthquakes, and a communication is established between the surface and the interior of the earth, divers matters are emitted by these openings. Some fissures throw out gases, others hot water, whilst the majority pour forth white hot liquid lava, or project clouds of volcanic ashes into the air.

362. Many of the openings are filled up with a hard substance, resembling whinstone, and often so much matter is thrust forth, that a volcanic mountain is formed.

363. Whilst many of the rock fissures are filled up with white hot matter which has been thrust into them, others are left open, and are, in course of time, filled up with a very different kind of substance.

364. When these openings are partially filled up with metallic substances, or with matter not referable to volcanic agency, they are called *veins*. It is in such veins (Fig. 55),

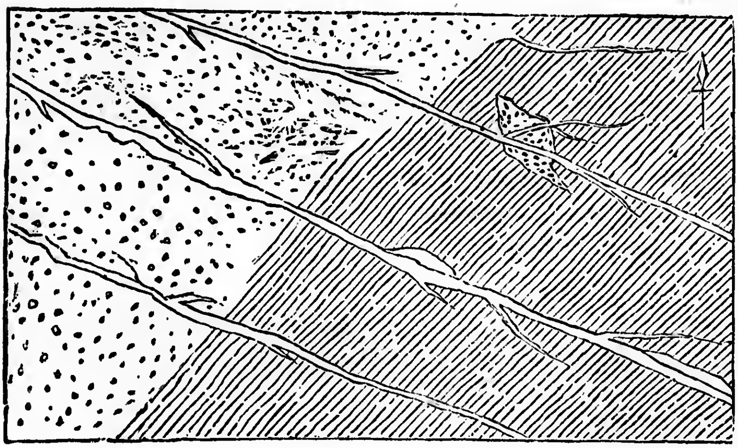


FIG. 55.

fissures, or cracks, that by far the greater portion of the metallic ores are found, such as the native compounds of zinc, silver, mercury, lead, copper, tin, antimony, and bismuth.

CONCLUDING REMARKS ON THE FORMATION OF ROCK.

365. Water, and the earthquake and volcano, have each worked turn by turn, till all the various rocks have been produced, and the crust of the earth has been moulded into the form we now find it. By means of water we have rocks laid down in long layers; and by the earthquake and the volcano these rocks are slowly or suddenly thrown up, and often cracked, whilst into these cracks or fissures there often runs white hot liquid lava.

366. Water is the great leveller, which tends to grind down every stone, and carry the fragments to the lowest depths it can; and the earthquake and the volcano are the

mighty upraisers, that now and then throw the rocks of the world into commotion, and fashion our hills.

367. Frost, the growth of plants and animals, as well as the chemical action of the air and water, influence much the breaking up and formation of rocks. Water, when frozen in crevices or cavities in rocks, expands much, and rends the mass in two. This takes place not only on the large scale in ponderous masses of rock, but in every fragment of stone lying on our way-sides or mountain-flanks.

368. The growth of plants supplies us with coal beds and peat bogs; and animals, such as the coral, yield us limestone and other rocks, which are formed from the trituration of shell beds, coral reefs, and myriads of infusoria.

369. Chemical action is unceasingly though quietly performing its work too, dissolving salts out of stony masses, and forming *earthy icicles* or stalactites and stalagmites in caverns (Fig. 56), and depositing ochre and other matters at

FIG. 56.

the mouths of our springs. But these latter forces are insignificant in their results compared with the ordinary action of water, the earthquake, and the volcano.

370. The geological changes which are every day taking place and altering the surface of the earth, are of vast importance to the agriculturist. By these changes the producer of food has different kinds of rocks disposed in every district, which, by being weathered, crumble into dust, and supply him with soils of varying texture and composition, which, for the most part, are admirably suited for the sustenance and growth of the many plants directly and indirectly cultivated as food for man and other animals.

371. Every soil can, by the application of more or less expensive manures, and the ordinary farm-steading appliances, be brought into a higher state of productiveness than that in which nature hands it over to man; but, in the main, it stands as an undoubted fact that the fertility of a country is more dependent on its geological strata, and the chemical constituents of the rocks composing its surface, than on any, even the most thorough, system of manuring, and the best and most sacrificing efforts of modern agriculture.

372. The solid earth is likewise of interest to the manufacturer, the miner, and the engineer. Certain saline matters constitute part of our daily food, but the greater portion of these are useful in the preparation of commodities serviceable to us in other ways.

373. Salt, for instance, is employed to a small extent mixed with our viands as a condiment, but a much larger quantity is used in the arts and manufactures, where it is treated with other matters, and fashioned into soda, soap, &c.

374. The rocky masses which compose this earth are therefore of great importance in connection with the arts and manufactures, as well as in regard to the production of our food.

CHAPTER IX.

THE SALINE FOOD OF PLANTS AND ANIMALS.

375. The relative quantity of ash left by different plants and parts of plants is various. When the plant is burned the amount of ash, or saline matter, is as follows :—

100	parts of	Wheat	leave	2	parts of ash.
100	,,	Oats	,,	4	,,
100	,,	Beans	,,	3	,,
100	,,	Clover	,,	9	,,
100	,,	Potatoes	,,	12	,,

376. Different parts of the same plant yield more or less of ash than other parts. The stalk or stem of the plant generally contains more than the seed, and the leaves more than the roots.

377. However various the quantities left by the different parts of a plant, yet the same plant yields very nearly the same amount of ash wherever it is grown. No doubt the soil, the variety of the seed, and the climate, influence the proportion of earthy matters, but the variation is slight, and such as not to alter materially the proportions.

378. Some plants require more of one earthy matter than of another. Turnips and potatoes desire much alkali (potash or soda); and beans, pease, and clover require a great deal of lime. The stems of wheat and the other cereals contain much silica, and hence the soil must contain that substance if it is properly fit for growing wheat.

379. In like manner, a soil with much potash and soda does well for potatoes and turnips; and one containing lime in abundance will be equally serviceable for beans, pease, and clover.

380. Now, the proportion of silica, potash, and lime in a soil, to a great extent depends on the rocks which are beneath. The soil is constantly forming, and in its roughest state it exists as a hard rock.

381. In a section of country (Fig. 57) we may notice

FIG. 57.

one rock extending only a short distance, and succeeded by a second and a third, till every variety of rock may be gone through; which, by disintegration, form many different kinds of soil above.

382. As a general rule, all soils contain the various ingredients required by plants, which are every day being set free, and thus becoming available. The air and water are constantly engaged breaking up the little pieces and grains of soil in a field, and liberating the various materials which are there present.

383. This loosening of the useful matters in a soil may be best likened to what goes on in the mint. Every year immense numbers of gold, silver, and copper pieces are coined. This process is a work of time; and if the demand is not greater than the supply, every one obtains the coin he asks for. One man asks for gold, and gets it; another asks for silver, and another for copper; and by the time the demand for gold comes round again, more gold pieces are ready to be given out. But if every one asked for gold, and

the cry were gold, gold, gold, then the demand for gold might exceed the quantity coined.

384. The soil is the agriculturist's mint; so much saline matter is coined every year by the air and water. Silica is coined for wheat and other cereals, which call for it in abundance for their stems; potash for potatoes and turnips; and lime for beans and clover. If the crop were constantly wheat, wheat, wheat, then the soil would be exhausted of silica, as the mint would run dry of gold; and if the growing of wheat were persevered in, bad crops would be the result.

385. But if wheat is grown one year, then potatoes, then clover, it follows that by the time wheat comes round again, there is plenty of silica for it. This is the principle of rotation of crops. Some soils break up more readily than others; they often require more than three years to replenish themselves. At times, it is necessary that the soil lie for a year or two in fallow, which gives it time to prepare a supply of what is useful.

386. The best soils, if too much is demanded from them, become barren, as instanced in Maryland, Virginia, and North Carolina. A single seed placed in the ground contains a small amount of saline matter, but when the seed germinates in the soil and ultimately becomes mature, it bears 100 seeds or more, each of which will carry off the land as much saline matter as the parent seed originally contained.

387. The forced system of agriculture pursued at the present day, necessitates the addition of manure to land. The principle of manuring is well noticed in the instance of the wood-cutters of Heidelberg, who fell the trees, cut off the branches, roots, and leaves, and burn them, thereafter strewing the ashes over the land on which the trees grew. In this way they return in great part what the tree derived from the soil, and thus preserve its fertility.

388. So in our fields, every crop of wheat takes away sc much of the valuable ingredients of the soil; and to make that soil as fertile as it was before, we ought to return what was taken away. One way of doing so, although a very expensive one, would be to burn the wheat crop, and strew the ashes over the field again. In a chemical point of view, it is a matter of little moment whether that be done, or the matters abstracted be returned in some other way.

389. Barren soils have been made fertile by the proper addition of manures. If one of the necessary ingredients be absent from a soil, a plant will not grow there; but if that substance be added, then a healthy growth immediately begins. One field may be rendered fertile by one kind of manure, which would be comparatively useless if applied to other fields.

390. At first it does seem very likely, that if bone dust is good for a neighbour's field, it ought to be good for ours; but the principle is not to be relied upon. We might as well attempt to cure all the ailments of mankind by the administration of one kind of medicine, as to make all barren soils fertile by one form of manure.

391. Farm-yard manure is the type of all manures. The refuse of the farm steading contains much organic (combustible) matter, and likewise many salts. When it begins to rot or putrefy, gases are evolved which are of value to the growth of the plant, as much as the ash is.

392. It is bad policy to allow the rotting process to proceed far before the manure is added to the land, as much valuable matter is thereby lost. Above all, lime should never be mixed with the farm-yard manure in heaps, as is often done; for by that means the most valuable constituent—ammonia—is driven off and lost.

393. Every substance which is present in the ashes of a

plant or an animal is useful as food, and cannot be withheld from the plant without diminishing its growth, or from an animal without seriously risking its health.

394. The grains of iodine or fluorine which require the most diligent search and skilful manipulation to find in the animal tissue, are of as much importance to the animal as the pounds of bone earth.

395. The following table includes the names of the substances present in greater or less quantity in the ashes of plants and animals :—

Potash,	Sulphuric acid,
Soda,	Phosphoric acid,
Lime,	Silicic acid (sand),
Magnesia,	Chlorine,
Oxide of iron,	Iodine,
Oxide of manganese,	Bromine.
	Fluorine.

COMMON SALT.

396. No one saline substance is more important than another, for though present in small quantity, it is yet useful; but if quantity is allowed the pre-eminence, common salt must rank among the first, so far as the animal is concerned. From the constant use of salt in the preparation of our food, its cheapness, and the consequent carelessness with which we handle and often waste it, it seldom occurs to us that this very common substance may be also a very important one.

397. When the blood of an animal is burned, a reddish-white saline residue is left, which consists in great part of common salt; indeed, one half of the whole ash of blood is made up of salt. Its presence in such quantity in the most important fluid of the animal system, and its daily escape

from that fluid, tell us of its value in the maintenance of life, and of the necessity for its presence in our food.

398. All nations and animals partake of salt, and its use cannot be discontinued without serious injury being the result of its withdrawal. In North and South America, there are immense tracts of land several feet below the level of the neighbouring districts, where an accumulation of salt takes place.

399. During the rainy season, streams of water flow into these low-lying valleys, and a shallow lake of salt water is produced. In the dry season the water evaporates, and leaves the ground covered with crystals of salt. In North America, these salt-covered districts are called "buffalo licks," and in South America, "salinas." The cattle come great distances, and lick up the salt in large quantity.

400. In the inland parts of Africa common salt is very scarce, and consequently dear. A handful of salt will purchase one or two slaves, and sisters, wives, and children have been sold to obtain it. Mungo Park says, that a rich man is known there, not by the horses, carriages, or money he may possess, but by the fact, that he regularly flavours his food with salt. Some tribes use it only as an article of luxury, or on festival days.

401. In this country, children suck barley-sugar and other sweets, whilst in the interior of Africa the little ones delight in small bits of rock salt. The rudest nations employ salt, more or less as they can obtain it, and there is no instance of a people who entirely abstain from its use. The ancient laws of Holland ordained that offenders should be fed on bread unmixed with salt, as the severest punishment which was known.

402. The ocean is the principal natural repository of this valuable material, common salt. Every 1000 lb of sea water

contain 27 lb of common salt; and it has been calculated that if the waters of the ocean were dried up, the space at present occupied by them would be left covered by a layer of salt more than 700 feet thick.

403. In the preparation of salt from sea water, the latter is, in some districts, run into shallow ponds, where it is fully exposed to the action of dry air and of the sun's rays; and being thereby rapidly evaporated, a very salt liquid is obtained, which is afterwards pumped into pans, and boiled down till the salt is thrown down in crystals.

404. The Dead Sea is a familiar instance of a large inland salt lake; and the craters of many of the volcanic mountains in the Pacific Ocean are filled with salt water, forming little brine lakes.

405. Common salt is found largely in the interior of the earth as a hard stony mass, called rock salt or salt gem. It occurs in beds or strata in the crust of the globe, in the same way as our coal and ironstone beds occur. It is present in considerable quantity in the rocks of Cheshire in our own country, and in many places abroad. The largest bed of rock salt in the world is that worked in Galicia, which is 460 miles long, 20 miles broad, and 1200 feet thick. This mine has been so long worked and is so extensive, that if the various passages were placed end to end, an express railway train, running at the rate of forty miles an hour, would take ten hours to traverse the whole.

406. Rock salt occurs, to a small extent, quite colourless and transparent; but generally it possesses a reddish tinge of colour, from its admixture with clay and sand. To free it from these impurities, the rock salt is dissolved in water, and the earthy matters being allowed to settle, the strong brine is drawn off, and evaporated down like the sea water.

407. Many spring waters are employed as a source of

common salt. Some spring waters contain 25 per cent. of salt, but the greater number are not so rich. They are found abundantly in our own country, both above and below the beds of rock salt; and the supply of water which these springs constantly give forth would lead to the belief that they communicate with immense lakes of salt water situated in the interior of the earth. When the brine is strong, the water is at once placed in pans, and evaporated till the salt separates.

408. In many districts of Germany, spring water with little salt is made strong by allowing the liquid to trickle down a thorn wall, in other words, a pile of brushwood; where, from the large surface exposed, the water rapidly passes away, and what is received at the lower part of the wall is a strong brine. A water containing $1\frac{1}{2}$ per cent. of salt can thus have its strength increased to 22 per cent.

409. In commerce, salt presents itself in larger or smaller crystals, which are soluble in water. Common salt crystallizes in the form of a cube; and it very often happens that a number of such cubes join together at their edges, and by degrees build up a structure resembling in form an Egyptian pyramid turned upside down.

410. The difference in size of the various kinds of salt is owing to the greater or less rapidity with which the salt liquid is boiled down. In the preparation of fine, or *lump salt*, the brine is evaporated very quickly, and small crystals are alone formed; whilst *kitchen salt* is obtained when the fires burn more slowly. A coarse variety, called *Sunday salt*, is so named from its being produced on that day, when the fires are being burned out; and a still larger grained salt, called *fishery salt*, is procured by very slow evaporation during five or six days.

411. Common salt is composed of two substances, sodium

and chlorine. Sodium is a soft metal, and is very combustible. It has a white colour, with a shade of red, and a metallic lustre. It is preserved under naphtha, has the consistence of bees-wax, and can readily be moulded into any shape when pressed between the fingers.

412. Exposed to the air, sodium passes into a white mass, known to chemists as soda; and when thrown into cold water, it rolls itself up into a little ball, runs about from side to side of the vessel, and hisses like hot iron quenched in water. Placed in hot water, or on ice, or when a little cold water is dropped on it, the sodium bursts into full flame, and burns with a very strong yellow colour.

413. Chlorine is a greenish-yellow gas, very heavy, and possessing suffocating properties. It is much used as a bleacher and disinfectant. Chlorine is most readily prepared by placing in a flask with bent tube (Fig. 58) one or two ounces of strong hydrochloric acid, and a small quantity of black oxide of manganese, and thereafter heating the mixture. Chlorine gas is evolved, and may be collected at the pneumatic trough.

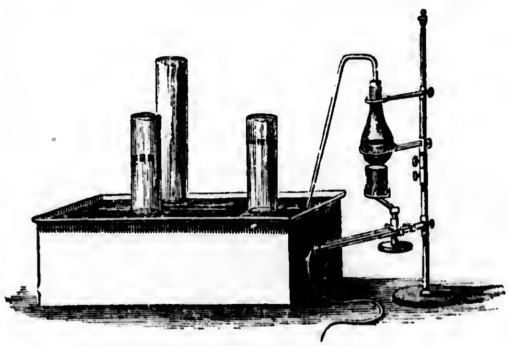


FIG. 58.

414. Chlorine is $2\frac{1}{2}$ times heavier than ordinary air, has a peculiar odour, and, when breathed in small quantity, produces coughing and irritation in the windpipe. A large dose may lead to fatal results. It is a powerful bleaching agent, and is employed by bleachers and papermakers to whiten

cloth and rags. Chlorine is likewise of vast importance as a destroyer of bad odours and infectious matters.

415. How strange it is that common salt, so harmless in itself, should be made up of sodium, a metal taking fire when water is thrown on it, and chlorine, a greenish gas, possessing suffocating and other extraordinary properties!

SODA AND POTASH.

416. Washing soda was formerly prepared from the ashes of seaweed, but is now in greater part prepared from common salt. After passing through a long and complicated process, the common salt is changed into common washing soda. Large manufactories in this and other countries are daily compelling, by fire and acids, the salt to lose its saltness, and become soda.

417. Not many years ago the only source of soda was the ashes of seaweeds and other plants growing in the sea, and called *kelp*, or of plants growing on the sea shore, and the ashes of which were called *barilla.*

418. When war broke out between this country and France in the days of Napoleon I., the price of soda rose enormously in France, as that country was mainly dependent on us or our allies for their supply of it. It was then discovered that soda could be easily obtained from common salt; and as its preparation from salt was much cheaper than from kelp or barilla, the latter ceased to be of so much interest or profit in countries where common salt could be readily obtained.

419. Common soda, besides being employed for cleansing purposes, is much used in the preparation of glass, hard soap, &c. Window-glass consists of sand, soda, and lime; and is prepared by heating these in a furnace, when they melt and run together into a transparent mass. Green bottle-glass contains sand, soda, lime, alumina, and oxide of iron.

420. Hard soap is prepared by boiling soda and an oil together, when the two combine, and after separation of the greater portion of the water, and cooling in an iron upright tank, a mass of soap is obtained which is easily cut into bars. Transparent soap may be formed by dissolving ordinary soap in hot alcohol (strong whisky) and thereafter cooling.

421. Whilst the ashes of sea plants contain soda, the ashes of inland plants yield much potash. In North America, where timber is abundant, immense quantities of wood, such as the branches of trees, are burned solely for the potash in their ashes. In Russia straw and weeds, in France the refuse of the wine manufactories, and in Java the stem and leaves of the indigo plant, are each dried and burned for the potash they contain.

422. The ashes of these various plants are placed in a large tub with a false bottom, and water being poured over them, dissolves the potash and then escapes by an aperture placed at the lower part of the tub. The impure solution of potash thus obtained is evaporated to dryness, and constitutes the *crude potashes* of commerce. By repeated solution in water, and crystallization, the impurities are got rid of, and potash or *pearl ashes* are obtained.

423. Potashes are composed of a metal, potassium, which burns when thrown on water; and two gases, oxygen and carbonic acid. The metal potassium is obtained when a mixture of potashes and charcoal is subjected to a high heat in a retort, when the metal distils over.

424. Crude tartar, or argol, a salt formed in the wine vats during the fermentation of wine, yields, when heated, a black mass which contains both potashes and charcoal, and is the best material which can be employed for preparing potassium. The metal is very soft, much resembling sodium;

takes fire readily when thrown on water or ice; and when exposed to the air, rapidly passes into a white powder (pure potash).

425. Potash enters into the composition of many kinds of glass, and also of soft soap. Flint glass, crystal, and Bohemian glass, contain potash in greater or less quantity.

426. Flint glass and crystal, so much used for making tumblers, &c., are prepared by heating to complete fusion (melting) a mixture of sand, potash, and oxide of lead; whilst the materials required for Bohemian glass, prepared and used largely on the Continent, are sand, potash, and lime.

427. Soft soap is a compound of potash with an oil, which may be either whale, seal, olive, or linseed oil; a little tallow is likewise added, which, when the whole is boiled together, combines with a portion of the potash, and in course of time goes to form the little white specks characteristic of soft soap, and known as *figging*.

BONE AND BONE EARTH.

428. The saline or earthy substance most characteristic of the high animal, is bony matter. Eighteen centuries ago the cities of Pompeii and Herculaneum were overwhelmed with ashes and lava thrown out by the neighbouring volcanic mountain, Vesuvius. In our own day, the earth has been removed from these buried cities, and the explorers, as they pass from house to house, now and then encounter a human skeleton. The flesh and blood which once clothed it have passed away, and a heap of bones is alone left to testify that there a man or woman lay down to die.

429. In every age, and for many purposes, men have left their homes to sojourn in desert places, or to travel in foreign countries; and, years rolling past without their returning, succeeding travellers have found and gazed upon some bony

relics, which are all that are left to tell us, that, by famine or otherwise, these brave fellows had lost their lives.

430. The bone is that part of the animal frame which of all others holds longest together, and which, when all other portions disappear, remains behind as a tombstone or token, to mark the place where a fellow-creature parted this life.

431. The average amount of bones in man is about 10 lb; but this proportion is constantly being added to, and taken from. The bony matter contains from 1 lb to 2 lb of phosphorus. The child, of course, has less weight of bones; and the very tall, large boned, and muscular man possesses more. During the whole course of life, there is a constant passage of blood through each bone, by means of which, material may be added to or taken from the bone.

432. Each bone is made up of a multitude of bony tubes lying side by side and bound together. When a bone is examined carelessly, without paying particular attention to its structure, it appears as if it were made up of particles, no way different from that of a piece of marble or sandstone. But on minute and careful inspection—especially of an old bone—it becomes apparent that the structure is different.

433. This becomes more evident if thin slices be cut off, and examined under the microscope. If the specimen be taken *lengthways*, we notice that a series of little canals run irregularly through the bone, forming a net-work somewhat like a sponge. And when a slice is taken *across* the bone, we come upon the ends of these tubes or canals.

434. Around each of these canals several rings of bone are perceived, forming thickened walls. It is not difficult to notice the likeness, in shape and structure, between a branch of a tree and a bone. In the branch there is the pith with the woody matter encircling it; and in the bone

there is the central cavity containing marrow, and surrounded by bony matter.

435. This likeness can be carried much further. Wood is made up of a multitude of fibres, or woody threads, the ends of which can be seen when it is cross cut; and every bone is similarly composed of minute bony threads.

436. The blood is every day carrying bony matter to the bones. As the youth becomes the man, and the weight of his bones increases, it is evident that additional bony matter is being built up. In cases of accident, likewise, such as a broken limb, new bone is required to cement the crack or fissure, and to unite the parts broken.

437. In fact, during the whole course of life, there is a constant passage of blood through the bone canals. This is proved by feeding animals, in part, on a red colouring substance called madder, and afterwards killing them, when the bones are found quite red.

438. A healthy bone is every day undergoing some change, and deriving new material from the blood, which passes in every direction through it. Whilst in the blood. the main constituents of bone (lime and phosphoric acid) are not united; but as the blood passes through a bone, it has the power to take these up, and compel them to unite and form hard bone.

439. Every portion of flesh and every egg contains within itself some bony matter, without which it cannot be formed. An egg, when healthy, consists of liquid matter, principally albumen; but when hatched, and the chick makes its appearance, this liquid appears in the form of flesh, blood, bones, feathers, &c. Plainly, therefore, an ordinary egg, though soft and liquid, contains materials to form bone. The same remark applies to flesh.

440. Every day we live, some part of the animal system is

broken up and carried away, and some portion of bone requires renewing, and this waste must be supplied. Every piece of bone and flesh is momentarily demanding more bony matter from the blood; and as the abstraction would ultimately lead to the impoverishment of the blood, it is evident that there must be some way in which the blood is replenished with the constituents of bone.

441. The railways passing to a large town convey cattle there, which are slaughtered and devoured, and never sent back. To keep up the supply in the market, the cattle must be constantly pouring in.

442. In like manner, the blood is the highway through which nutriment is conveyed to all parts of the living frame, and is there consumed. To keep up the supply, new matter must be added to the blood.

443. When a bone is placed on a fire, it first blackens and then burns like a coal. On the steppes of Tartary, and in the pampas of America, it is considered that the heat given out during the combustion of the bones of an animal, is sufficient to cook the entire flesh. After the bone has ceased to burn, it leaves a white ash, of the same size and shape as the original, but different in weight.

444. A dry bone, which weighs 3 ℔ before being placed on the fire, will weigh 2 ℔ when taken off;—in other words, a bone contains one-third of matter capable of being burned away, and two-thirds of ash or incombustible substance.

445. This ash, known as bone-earth, mainly consists of phosphate of lime. Teeth, when burned, likewise leave an ash, which is mostly phosphate of lime. In both cases, the combustible matter is principally gelatin, so that—

Bones and teeth are composed of

Gelatin (Combustible).	and	Phosphate of lime (Not combustible)

446. The proportions of gelatin and phosphate of lime in bones vary according to the age, &c., of the animals. The ordinary per centage of gelatin in the dried bones of a man in the prime of life is 33·30, or one-third of the entire weight of the bones. In childhood, when the bones are somewhat flexible, there is more gelatin; and in old age, when the bones become more brittle, the gelatin decreases, and the earthy matter increases in quantity.

447. In some diseases, to which man and other animals are subject, the earthy part of the bones to a great extent disappears, and they become so flexible that they cannot support the frame. On the other hand, the bones of animals long buried, are found to have lost most, if not all, of their gelatin, and the earthy matter being alone left, the bones readily crumble into dust.

448. Phosphate of lime is made up of phosphorus, oxygen, and lime. When bone-earth is intimately mixed with two-thirds of its weight of oil of vitriol, thereafter diluted with water, and allowed to stand at rest till it settles, a white substance, sulphate of lime, falls to the bottom of the vessel, and a clear liquid, mainly consisting of phosphorus in combination with oxygen (phosphoric acid) remains above.

449. If this liquid be evaporated to dryness, charcoal added, and the mixture placed in an earthenware retort, the bulb of which is heated by fire, and the neck ending in a vessel of cold water, it is found that the charcoal acts on the phosphoric acid, takes away its oxygen and sets free phosphorus, which, passing as gas through the neck of the retort, drops down in pieces the size of peas in the receiver containing cold water. These pellets quickly melt when placed in hot water, and are then poured into moulds of the thickness of a quill or finger, as may be required.

450. Ordinary phosphorus is soft and flexible, with a waxy

consistence, and readily inflames when heated. The elasticity of freshly-prepared phosphorus disappears in time, and by-and-by it becomes very brittle. From its liability to catch fire spontaneously, phosphorus is always kept under water, in which it is not soluble.

451. When taken out of the water, and exposed to the air, it begins to smoke, in other words, burns slowly, and in a short time the heat so generated is sufficient to enable the phosphorus to pass into lively combustion. Very slight friction, likewise, causes it to inflame immediately, so that any one working with phosphorus requires to be very careful to keep it under water as much as possible.

452. The practice of drawing figures with sticks of phosphorus in dark corners is for this reason a very dangerous one. A burn with phosphorus is very severe, as independently of the real burn received, an acid substance is left in the sore, which continues to exert a corrosive action.

453. Phosphorus in burning combines with oxygen, and forms phosphoric acid. Phosphorus burns for the same reason as coal gas does. It is true the one produces a white smoke, and the other an invisible gas, but nevertheless the chemical change produced in both is the same. Coal gas in burning combines with the oxygen of the air, and so does phosphorus.

454. This is best seen when a small piece of phosphorus is placed on a pedestal support (Fig. 59), resting on a plate or tray, set fire to and covered with a bell-jar.

Fig. 59.

455. The white cloud (phosphoric acid) which rises in the jar, in a short time falls down like snow on the plate, and may then be

scraped off and examined. When placed in water, it hisses like the quenching of red-hot iron, and dissolves, giving a sour liquid which, when tasted, sets the teeth on edge.

456. Ordinary phosphorus is a poison, and therefore cannot be used as food. There is a variety of this substance called amorphous or red phosphorus, which is identical with yellow phosphorus, so far as its chemical constitution is concerned, but differs from it in nearly every property.

457. Red phosphorus may be prepared by the careful heating of common phosphorus in a retort, the bulb of which is immersed in an oil bath, and the tube end drawn out. By degrees the change goes on, and ultimately a red powder is alone left.

458. The difference in properties presented by these two varieties of the same substance, are the following:—

Ordinary phosphorus is	*Red phosphorus* is
Yellow and resinous,	Red and not resinous,
Smokes in the air,	Does not smoke,
Dissolves in bisulphide of carbon, &c., &c.,	Does not dissolve in bisulphide of carbon, &c., &c.
Very poisonous,	Not poisonous,
Burns at a low temperature.	Burns only at a high temperature.

459. It is difficult to imagine how two substances, so unlike each other, can still be composed of the same ingredient; but as the one readily passes into the other without change of weight, they must be considered alike. From its non-poisonous property, the red phosphorus is now employed to some extent in the preparation of lucifer matches. At the present time, ordinary phosphorus is also used, and many people suffer from inhaling the phosphorus fumes, which would be entirely obviated, if the red variety only were used.

LIME AND CHALK.

460. Lime is found in plants and animals in many different conditions. In combination with other substances, it constitutes part of the vegetable and animal frames. As carbonate of lime (chalk), it forms almost the entire shell of the myriads of shell-fish which inhabit our waters, as likewise the shell of every egg, and the hard case in which each member of the crab tribe resides, besides being present in the ashes of every plant.

461. As phosphate of lime, it makes up the greater part of the weight of every bone and tooth, and may also be detected in the ashes of plants; whilst as sulphate of lime (stucco), it is found in small quantities, here and there, throughout each living organism.

462. On the commercial scale, pure or caustic lime is obtained from limestone, which is a compound of lime and carbonic acid, by placing it along with coal in a lime-kiln. The coal, in burning, passes into gas, which, aided by heat, has the power of robbing the carbonate of lime of its carbonic acid, which it carries away as gas, and leaves the free lime (lime-shell) in the kiln.

463. Lime consists in part of a metal named calcium, which possesses a faint yellow colour, and resembles in shade an alloy of gold and silver. The metal calcium can be readily drawn out into thin wire, and be beaten out into thin sheets. When heated to a red heat, it bursts into flame, and burns with an intense light.

464. Burned lime (lime-shell) becomes slaked lime when water is thrown on it, and in this state is much employed in making mortar, cement, wall-plaster, &c. The great heat evolved when water is brought in contact with lime-shell, is familiarly known to every one who has watched the prepara-

tion of lime in connection with the building of a house. The heat is oftentimes so great, that not only is steam evolved, but wood embedded in or surrounded by the lime is set fire to. Instances have occurred where even carts conveying lime-shell, during a heavy rain, have been set fire to from the heat evolved by the action of the rain-water on the lime.

465. This evolution of heat is due to the chemical affinity which exists between the lime and the water, which combine together and form slaked lime. Common mortar is composed of coarse sand and slaked lime; whilst hydraulic cement, which readily becomes hard under water, contains sand, lime, and clay.

466. Many limestones, called argillaceous limestones, are found in nature, which contain enough of clay, and when burned and slaked, are ready for use. The first coat of plaster on any wall is composed of ordinary mortar (sand and lime), mixed with ox or horse hair, and the subsequent coats are of lime, more or less pure.

467. Chalk, limestone, and marble, are varieties of the same substance, carbonate of lime, and contain lime and carbonic acid. The soft and easily pulverizable matter, chalk, differs from the hard limestone and marble only in its particles being less firmly attached to each other. Marble has undergone changes, some time or other during its formation, whereby the particles have adhered more firmly together.

468. When chalk, limestone, or marble is placed in a vessel, and drenched with hydrochloric acid, much carbonic acid gas is given off, and a lighted candle placed in the jar is immediately extinguished.

469. The pretty stony icicles which present themselves in many caves are likewise composed of lime and carbonic acid. These chalk pillars owe their formation to the power which the carbonic acid in the air has of dissolving the

carbonate of lime in rocks. Rain, as it falls through the air, dissolves some carbonic acid, and carries it down into the rocks, there to act on and dissolve any limestone which may be present. This solution on dropping from the roof of a cave allows a part of the carbonic acid to escape, and at the same time deposits the carbonate of lime, which forms a

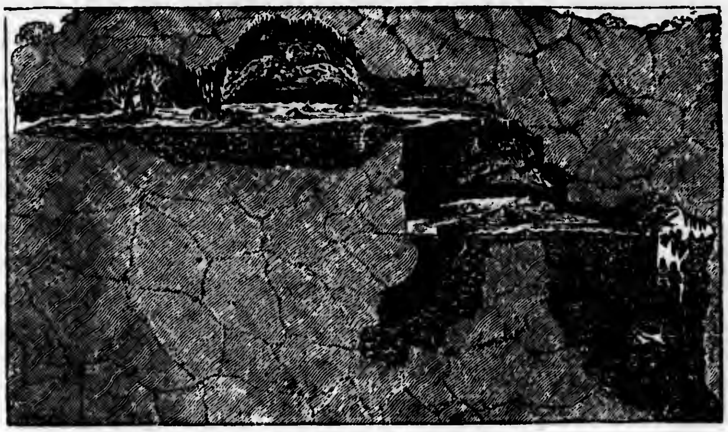


Fig. 60.

stalactite. (Fig. 60.) Occasionally these caves contain the bones of animals, covered by the lime incrustations.

IRON.

470. Iron forms part of the system of each plant and animal. In the blood a large portion is present, and it is presumed that that substance is partly the cause of the red colour. When blood is burned, the ash which is left is quite red from the iron rust which it contains.

471. One hundred parts of blood contain 80 parts of water and 20 parts of solid matter, which, when burned, leave $1\frac{1}{2}$ parts of ash. One hundred parts of the blood ash contain 50 parts of common salt and 10 parts of iron rust.

472. The best proof of the existence of iron in the blood, is the fact that instances have occurred where large quantities of blood have had so much iron extracted from them, as to make rings, pins, &c.

473. Iron rust is composed of metallic iron and oxygen. An iron nail left exposed to the air, becomes rapidly covered over with rust. At first it would appear as if the rust had been blown like sand over the nail; but this is not the case. Each particle of iron in the nail has a tendency to seize some oxygen from the air which passes over it, and when the union of the iron and oxygen takes place, rust is the material which is formed.

474. Iron is the most extensively diffused metal, being found in every spring and river water, and in nearly every rock, besides being present in plants and animals. Some springs contain so much iron dissolved in their waters, that they deposit an ochry or rusty powder on the stones and pebbles which surround their mouths.

475. As rivers are fed largely by springs, it is to be expected that iron will be found in river waters. The greater number of springs and rivers contain water which has so little iron in it, that no rusty matter lines the stones over which it runs.

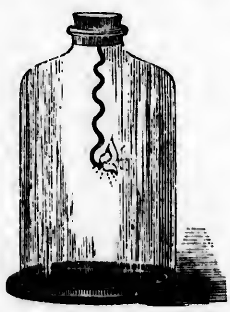


Fig. 61.

476. In ordinary circumstances iron will not take fire, but when placed in oxygen gas, it burns with a bright white light. When a coal fire is lighted in an iron grate, we do not find that while the coal burns, the iron blazes too; but if a coil of very fine iron wire be tipped at the one extremity with sulphur, lighted, and plunged into a bell jar of oxygen (Fig. 61), open at the bottom, and standing in a tin tray or saucer, the iron takes

fire, burns, gives out an intense light, and much heat, whilst every now and then a bright white-hot globule of iron falls as ash into the tin tray.

477. In this experiment, the iron is as truly burned as a piece of wood is when it is thrown on a fire. In the case of iron, the product of combustion is a solid black globule; while in the case of wood, the whole disappears as gas.

CLAY.

478. Clay is composed of sand (silica) and alumina with water, and is known to chemists as the silicate of alumina. Pure clay is nearly as white as snow, and is found largely in Cornwall, whence its name, *Cornish clay.* The common varieties of clay are, more or less, coloured yellow and red, from containing red oxide of iron (rust).

479. *Pipe clay* exhibits a light cream colour when burned, and is employed in the manufacture of tobacco pipes and white pottery. *Potter's clay* becomes red when heated. A mixture of sand and potter's clay is fashioned into bricks and tiles. *Stourbridge clay* is similar to potter's clay, but is generally used for making crucibles to withstand high temperatures.

480. Silica occurs in nature as sand, quartz, agate, and flint, and enters largely into the composition of all kinds of glass, and likewise nearly every rock. The sand on the sea-shore owes its formation to the incessant grinding action of the waves upon sandstone rocks. In the Isle of Wight and other places the sand is found white and pure, but generally it is coloured yellow by a slight admixture with red oxide of iron.

481. The term quartz is applied to silica in the transparent condition. As such, it occurs in granite and other rocks, and often forms groups of crystals in cavities of rocks. Pure quartz, or rock crystal, is colourless, but is often found coloured, and then forms several of our precious stones.

482. When purplish violet, it is called the *amethyst;* when yellow, the *gold topaz;* when blue, the *siderite*, &c. Agate is a variety of silica, not transparent like quartz, but opaque, and forming nodular masses of extreme hardness. The well-known substance flint is another variety of quartz. The many different kinds of glass are composed of silica, with the addition of potash, soda, and oxide of lead. The majority of rocks contain silica in greater or less quantity.

483. Silica, as occurring in the form of sand, &c., is very hard and gritty; but it may be obtained as a jelly, and in powder as fine as wheat flour. When a mixture of equal parts of finely-powdered sand and fluor spar are placed in a flask, drenched with oil of vitriol, and heat cautiously applied, a gas is evolved, which, in being passed along a tube, can be conducted into a vessel containing mercury in the lower part and water above.

484. After the air has been driven out of the arrangement, a variety of silica or sand gas arises, which, as it passes through the water in the vessel, sets free the most of its silica in the form of a jelly, which is called gelatinous silica.

485. If this be dried, the jelly-like mass disappears, and in its place there is left a very fine white powder; so light, that it can be blown about in the air like a feather; and so soft, that it does not feel gritty when placed between the teeth. This soft powder is the same substance as hard flint.

486. Alumina is largely present in clay and shales, as likewise in felspar and other minerals. In its native state, alumina is generally found associated with silica. Ordinary clay consists mainly of silica and alumina, with a little iron, lime, &c. Shales have a similar composition, but also contain more or less coal. Felspar, one of the constituents of granite, contains silica, alumina, potash, and soda.

487. Alumina contains a white silvery metal, aluminum,

and oxygen gas. The metal is prepared on the commercial scale by various processes. It is a white metal, with a shade of blue, is not liable to corrode or become tarnished, and many ornaments, as well as useful vessels, &c., can be manufactured out of it. It can be frosted like silver, and combined with copper, it forms an alloy which resembles gold.

488. Alumina is useful in the preparation of alum, and in the fixation of many colours. Common alum consists of alumina, sulphuric acid and potash, soda or ammonia. On the large scale, alum shale is exposed to the air till it becomes covered with efflorescence. It is then digested in water, a salt of potash, soda, or ammonia added, and the liquid boiled down and left to crystallize in large vats.

489. Alum crystallizes generally in groups of great beauty and large size. When ammonia is added to a solution of alum, a white gelatinous precipitate of alumina is thrown down; and if the precipitation takes place in an alum solution coloured by cochineal or madder, the alumina falls in combination with the red colour, leaving the solution colourless. Colours prepared in this way are called *lakes.*

490. Sulphuric acid, magnesia, iodine, bromine, and fluorine are found to a small extent in plants and animals. Sulphuric acid, or oil of vitriol, is better known in commerce, as an article much used in the arts and manufactures. When pure and free it is very corrosive, but when associated with lime, soda, or potash, it is comparatively harmless. It is in such a condition that it is present in plants and animals. Sulphuric acid contains sulphur and oxygen. Magnesia is associated with the lime in the ashes of plants in greater or less quantity. Iodine, bromine, and fluorine are three substances similar to chlorine, which are found in very minute quantity in land plants and animals, and in larger amount in sea weeds and sea animals.

PART III.

CHAPTER X.

DECAY OF PLANTS AND ANIMALS.

491. THE plant and animal are able, so long as life remains in them, to battle the storm and the breeze, and to withstand the corroding effects which the air endeavours to exert on both.

492. An apple will continue in good condition for a long period if the skin be not broken; but the moment this covering is cut, as when a slice is taken from the apple, then it gets coloured, and begins to rot and decay. This shows that the air is the agent which, when once it gets admittance into the fruit, begins the work of destruction.

493. In the same way, the mightiest tree, when cut down by lightning or the woodman's axe, gradually decays, and, whilst doing so, passes into gas and disappears; so that, in some forty years, one of the largest trees will have vanished, leaving only a little black mould to mark the place where once it grew. Animals, too, when they die, quickly begin to rot and pass away as gas, leaving scarcely more than the bony matter behind.

494. The oxygen of the air is the agent which causes decay and putrefaction to commence; but in many cases its presence thereafter is not required. Those substances which,

with the aid of air and moisture, begin to rot of themselves, are called *putrescible*, and the process itself is termed *putrefaction*.

495. As these putrescible substances are very widely distributed, it would appear at first as if they were many in number; but although they appear in many different garbs and situations, yet the more important may be comprised under albumen, fibrin, casein, and gelatin.

496. In every vegetable juice and animal fluid one or more of these kinds of putrescible matter is present, so that when the juice or fluid is allowed to stand exposed to the air, putrefaction commences. If not arrested in some way or other, the change goes on till little, if any, of the material is left.

497. The gases evolved during decay and putrefaction are carbonic acid, water vapour, and ammonia. The formation and escape of carbonic acid are best noticed by enclosing some damp hay, or other vegetable matter, in a large bottle, when in a short time the air will have become so changed, that on the introduction of a lighted candle, the flame will be extinguished—plainly indicative of carbonic acid having been developed. In fact, this decay is a very slow kind of burning, which takes months to consume what minutes would do if a light were applied to the decaying substance. Yet the principal product of both processes, namely, carbonic acid, is the same.

498. Water is likewise produced, but from the hay being moist to begin with, the additional quantity cannot be readily observed. Ammonia, however, can be distinctly observed as being evolved from decaying substances; and when the quantity is somewhat large, the odour of ammonia (hartshorn) may be easily recognised.

499. Those substances which are capable of becoming putrescent simply by the action of moist air, have the power

of compelling many other materials to change, which would otherwise not alter. Sugar will remain good for a very long time, but the addition of a putrescible substance quickly causes the sugar to undergo changes.

500. The observations of all periods show us, that wherever matter is rotting, the district is unhealthy, and can be predicted to be so. The decay and putrefaction of plants and animals, especially in marshy places, increases the mortality in the neighbouring country.

501. This increase in the amount of sickness may be constant, as where marshes exist all the year through, or periodical, where there is a lake in the winter and a marsh in the summer. In the latter instance the mortality is greater in summer than in winter. It has been also observed, that stagnant water, however small in quantity, is liable to predispose to disease.

502. The overcrowding of people together, as in the confined districts of our cities, is likewise a fruitful source of ill health and disease. The pernicious gases evolved in every breath are sufficient of themselves to render an atmosphere dangerous and destructive of life, but when these are coupled with the presence of filth of any kind, their fatal effects are rendered doubly worse, and much more certain.

503. Each individual can, by personal and household cleanliness, do much to ward off any epidemic or flying disease. It must not be supposed that personal cleanliness merely includes washing our faces every morning. Such a process is identical with that followed by the ostrich when, being pursued by its enemies, it ducks its head beneath the sands, and thinks there is no danger.

504. It would be better for us to do nothing, than to stop short at a mere partial cleansing; because we deceive ourselves, and think we are more cleanly than we really are.

Every one should repeatedly wash and cleanse the whole body. There is nothing so useful in a household as soap and water.

505. Then, as to our houses, every nook and corner ought to be systematically scrubbed and cleansed, and no rubbish, in the strictest sense of the term, be allowed to lie about. Back yards, &c., ought to be drained well, and not a single particle of water allowed to lie stagnant near any door or window.

506. Food, above all things, ought to be wholesome, and nothing should ever be partaken of which we know will do us harm. Tainted meat is dangerous, always injures the man who partakes of it, and sometimes causes death. Many articles of dessert are likewise injurious. No article should ever be tasted which will put the bodily system out of its ordinary healthy condition.

507. For, it must be remembered that health is not a thing to be tampered with. The damage sustained may be healed up, but still it may be merely a *patch*, and not complete recovery. The mended part forms a weak point, where the enemy, disease, may more easily assail us. When cleanly habits and proper food are rigidly and regularly adhered to, the chances are in our favour, in reference even to the most dread disease; but the opposite conduct can only lead to the opposite result, however calamitous that may be.

508. In large towns, the inhabitants are, to a certain extent, at the mercy of their neighbours, whose bad habits at times affect us all. When infectious matter once appears, it does not confine itself to a central point. The great hot-bed of disease is in those places where inattention to cleanly habits is most in the ascendant.

509. A plant, such as wheat, will not grow everywhere, it requires a certain kind of soil from which to suck its food;

and so infectious matter, or *miasma*, will not nestle everywhere, but seeks out generally a shattered and neglected animal frame, and there finds a suitable lodgment.

510. But, just as a stone thrown into the ice produces a central crash which radiates in various directions, so many people, whilst they are being engulfed in the pit of disease dug by themselves, may often drag the passers-by after them. They produce a central mass of disease, and we may chance to fall into one of the many cracks which pass in every direction.

511. Whilst such is the case, we must remember that though we cannot control our neighbour's house, or keep him from polluting our share of the atmosphere, yet the danger is less the further we recede from the central weak point.

512. The cause of all miasma and infectious matter is, at first, within our grasp, and may be overpowered. In towns, especially, the matter in a state of putrefaction is tangible, and within our grasp. The rotting process may be stopped for a time or altogether;—a household method of doing so is to add common salt, as in salting meat, herring, &c.

513. The majority of poisons, including corrosive sublimate, arsenic, &c., are also efficacious. The process of embalming depends on this principle.

514. The best substance for stopping putrefaction is sulphurous acid, prepared by burning sulphur. Sulphurous acid may be used in a room, provided all metal articles have been removed. A convenient form of using the acid is in combination with soda, when it forms sulphite of soda, a solution of which may be poured over any offensive matter.

515. To prepare the acid, some fragments of roll sulphur are thrown on a stone slab, and ignited by placing a red-hot cinder in the midst, when the gas begins to be evolved.

Another method of preparing sulphurous acid is to pour sulphuric acid (oil of vitriol) on some charcoal chips placed in a basin, till the charcoal is thoroughly drenched, and thereafter applying heat, when the suffocating sulphurous acid gas is evolved.

516. Sulphurous acid contains sulphur and oxygen, and belongs to a class of substances called antiseptics. These are useful only in so far as they stop for a time further decay in the putrefying substance. Hence they form a barrier to the supply of infectious matter. But they are of no use in destroying that matter when it once reaches the air.

517. Cold is likewise an antiseptic. Animals may be preserved in ice for any period of time, as well instanced in the mammoth elephants found in the Arctic regions, as perfect now as they were when buried in the ice some thousands of years ago, and their flesh is still relished by wolves and other carnivorous animals.

518. During all plagues, there is miasma, an unseen enemy flying overhead, which our cannon shot cannot reach, but which may yet be battled with. No one knows whether the enemy be a gas, or a plant or animal organism, but we are all aware that at certain seasons infectious matter is floating about in the air.

519. The most powerful magnifying-glass that has as yet been constructed cannot find out the enemy; and chemistry, too, has failed to discover anything capable of being observed by the naked eye. Nevertheless, there are some gases called disinfectants, which, when passed into the air, are able to do us good service.

520. Chlorine is an excellent disinfectant. It acts rapidly on a great number of organic substances. Turpentine placed on paper and plunged into chlorine gas is immediately decomposed, giving forth much black smoke.

521. So energetic a substance is one undoubtedly capable of rendering service in combating miasma. When common salt, oxide of manganese, and oil of vitriol are heated in a vessel, the green-coloured chlorine is evolved with its suffocating fumes. It may also be prepared from oxide of manganese and hydrochloric acid. If a small quantity be required, the safest and easiest method of procuring it is simply to expose some bleaching powder in a shallow vessel to the action of the air.

522. Another powder of great use in purifying the atmosphere is M'Dougall's disinfecting powder, which is a compound carbolate and sulphite of lime and magnesia. It can readily be purchased; and when exposed in an open vessel in a room or elsewhere, or sprinkled over decomposing matter, it renders the air sweet and innocuous.

523. Ozone is the great natural disinfectant or purifier of the atmosphere. Wherever it encounters decaying organic matter, it tends to combine with and quietly burn up the bad-smelling gases which are evolved therefrom. So powerful is its action, that a piece of tainted meat immersed in an atmosphere of ozone, has all the disagreeable effluvia at once removed from it.

524. The country air, which has much ozone in it, when it blows towards a town or assemblage of houses where more or less animal matter is putrefying, quickly loses the ozone; and therefore in the atmosphere of our large towns no ozone is to be found. In its passage through the streets and lanes, the ozone has been active in combining with the organic substances, and then ceases to be present as free ozone in the air.

525. With ordinary cleanliness, ozone is powerful enough by itself in keeping down the proportion of hurtful gases in the atmosphere even of towns; but where unclean habits in-

crease the quantity of organic matter in a state of putrefaction, and consequently cause the atmosphere which animals breathe in large volume to be more than ordinarily tainted with miasma, the ozone fails to overcome or burn up all the deadly matter, and the result is the production of an unhealthy district of country.

PART IV.

CHAPTER XI.

THE CIRCULATION OF MATTER.

526. The endless circle round which matter is constantly revolving is observable in inanimate as well as animate nature. Thus water, the great reservoir of which is the ocean, may rise therefrom and pass into the atmosphere as invisible vapour, which at the proper time becomes a cloud, and falls as rain on the surface of the earth, from whence it more or less quickly finds its way in greater part, by streams and rivers, to the great ocean once again.

527. No doubt some of the water may become encased or entombed in the earth, from which, however, it by-and-by issues as a natural spring. In other parts the water may be retained at one spot for some time, as in those masses of ice known as glaciers and icebergs; but these ultimately cast off their moorings and float to more genial climes, or they slowly evaporate in their frozen homes.

528. The rock and soil, or the more solid part of the earth, has its circulation in geologic time. The hills and mountains become reduced to powder, and the fragments are washed or rolled down into valleys, where they re-form rock in the river bed; or they are carried to some quiet deep sea nook or corner in the ocean, there to be deposited as soft

rock, which in ages becomes hardened, and may once again be raised by the action of the earthquake and the volcano, and become dry land.

529. The atmosphere likewise exhibits an endless circulation. The air is ever on the move, and in the winds and gusts which sweep across land and ocean, the gases are carried from town to country, and from country to town; from continent to ocean, and from ocean to continent; and from one hemisphere to the other.

530. Not only do the gases in the atmosphere circulate as gases amongst their neighbour gases, but the more important enter into new states of combination, and form liquids, and even solids; which, however, in the long run, ultimately return to the position from whence they started, merely to pass once and again through a similar series of transformations.

531. One of the best illustrations of the circulation of matter is observable in the changes which carbonic acid undergoes in its journey through the different kingdoms of nature. The carbonic acid is composed of carbon and oxygen; and many times these elements are combined to form the carbonic acid, and as often the acid is broken up into its elements.

532. Frequent allusion has been made to the presence of carbonic acid in the atmosphere. By the burning of coals, and candles, and coal gas, as well as by the breathing of every animal, and the processes of decay and fermentation, large quantities of carbonic acid gas are constantly passing into the air; and it must be distinctly and clearly spoken of as a poison, from whatever source it may be derived.

533. The Parisian who wishes to become a suicide, lights his charcoal fire, places it in the centre of his room, stops up every crevice in the walls, flooring and ceiling, and lays himself down to die. The carbonic acid gas rises from the

burning charcoal, and slowly but surely lays its death hand on its victim.

534. Similar instances of death by inhaling carbonic acid produced during the burning of fuel, are observed in coal mines after an explosion of coal gas (fire-damp), when carbonic acid (choke-damp) is produced; and even in several of the tents in the Crimea, where British officers were killed by this gas evolved from small fires introduced into the tents during the evening.

535. In the Black Hole of Calcutta, where many of our countrymen perished, the casualty occurred not because the prisoners had too little room to stand, and were crushed to death, but because every human being imprisoned there was breathing out the deadly gas, carbonic acid, and there was no way for this gas to escape. Each breath added more poison to the air, and by-and-by there came the time when the poisonous carbonic acid did its fatal work, and one hundred and twenty-three human beings perished within a few hours. The change in the composition of the air by breathing is much greater than what is generally supposed; for whilst the ordinary air contains only one part of carbonic acid in 2500 of air, the air expired, or breathed out by the animal, contains one part in 25, or 100 times more than what is found in the ordinary atmospheric air.

536. Other illustrations might be adduced of the same deadly effects of carbonic acid as exhaled by animals in crowded cabins of vessels; as given off during fermentation; as left in fermenting tuns; and as evolved by the decay of plant and animal matter, as well as in the poisonous nature of the air in old wells and other places containing decaying organic matter, and where there is defective ventilation. Instances are not uncommon of men incautiously entering such places, and being overcome and poisoned by

the carbonic acid. The clear and transparent appearance of the atmosphere in such localities is no evidence of purity of air, as the deadly carbonic acid is perfectly colourless, and cannot be seen by the eye of man.

537. Carbonic acid is not only a poisonous gas, but its comparative weight is so great, that when poured from a jar, it falls through the air like a stone. This may be observed by placing a lighted candle in a wide glass jar and pouring into it the carbonic acid from a second jar (Fig. 62), when the gas, though invisible, will at once extinguish the flame and prove that the carbonic acid has fallen through the air into the jar where the candle was burning.

FIG. 62.

538. The great weight of carbonic acid may also be shown by taking two jars (Fig. 63) filled with the gas, and opening them both at the same time. The jar with its mouth upwards will not allow the heavy gas to escape; whilst the second jar, which has the open end downwards, will allow the carbonic acid to flow away; and very shortly a candle will continue to burn in this jar, whilst if introduced into the first jar, the candle will be instantly extinguished.

FIG. 63.

539. Still further: a jar filled with carbonic acid may be taken, and a small pail containing common air be introduced (Fig. 64), when the comparatively light air will leave the pail and heavy carbonic acid gas enter, so that the pail on being lifted out, and tilted to the side near a candle, will allow the contents to flow out and extinguish the candle.

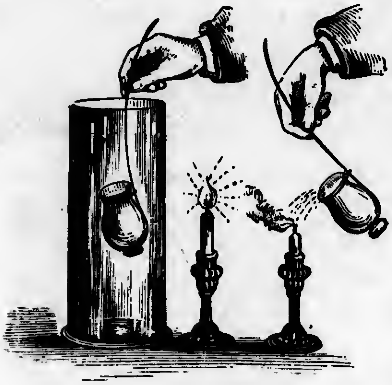


Fig. 64.

540. And, lastly, if several candles be placed at different heights in a glass vessel and lighted (Fig. 65), and a stream of carbonic acid gas be transmitted into the jar, the heavy gas will fill up all the lower part of the jar first, and creeping up will gradually extinguish the candles one by one as it ascends the jar and chases out the air.

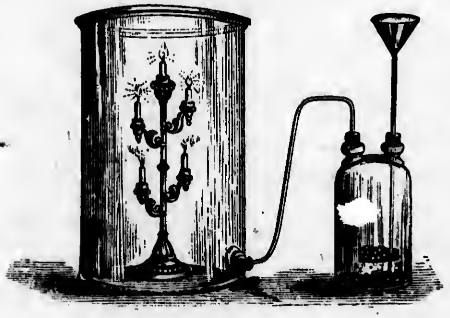


Fig. 65.

541. The question comes to be, Why is it that this gas, so heavy and so poisonous, does not gather about the low-lying districts in town and country, roll into our cellars and rooms, and kill every one of us. This observation leads us to the consideration of one of the most extraordinary, and at the same time one of the most beautiful, laws which

regulate the materials of this globe, and which performs an important part in the circulation of matter.

542. When liquids which do not act on each other are mixed, they arrange themselves according to their relative weights. Two liquids such as mercury and water may be placed together in a bottle, and it will be found that the heavier of the two, namely, the mercury, will occupy the lower part, and the lighter, the water, will float above. They may be well shaken together, but the moment they come to rest, they return to their natural positions.

543. The same thing may be observed with oil and water, where the oil being the lighter of the two will rest upon the water, and no amount of shaking will compel the two permanently to reverse their positions, or to become thoroughly intermingled.

544. The same observation holds true of all liquids which have no chemical affinity for each other; and the law to be deduced from this is, that liquids arrange themselves according to their relative weights, the heaviest being lowermost, and the lightest being uppermost.

545. But with gases or airs a very different result is observed, for a heavy gas rises through a light one, and a light gas descends through a heavy one. A heavy gas, such as carbonic acid, may be placed in one bottle or globe (Fig. 66), and a light gas such as hydrogen in a second, and the two may be joined together by a glass tube, taking care always to keep the light gas uppermost.

Fig. 66.

546. It is found that from the moment the vessels are attached together, the heavy gas, carbonic

acid, begins to creep up the narrow tube, and mixes with the light gas, hydrogen; whilst the latter steals down the tube and falls through and intermingles with the heavy gas. This goes on till the gases become thoroughly diffused or mixed, and there is as much of the one gas in each of the bottles as there is of the other.

547. The relative weight of the gases named is such, that a bottle which when filled with hydrogen, will contain only one grain of it, will hold 22 grains of carbonic acid; so that the gas in the lower vessel (Fig. 66), is 22 times heavier than that in the upper vessel.

548. What takes place here is just as extraordinary as if all the stones in the bed of a stream were to rise and float like wood down the current, or as if the large stones and boulders lying at the bottom of the sea were to set about swimming on the surface of the ocean.

549. As proof that the heavy carbonic acid has ascended through the light hydrogen, it is only necessary to shake some lime water in the hydrogen or upper vessel, and a white substance will be formed, which is carbonate of lime or chalk.

550. Since carbonic acid can be shown to rise through a gas 22 times lighter than itself, it will be easy to understand how it can ascend in ordinary air, which is only one-third lighter than itself. In this manner, the noxious gases evolved from our chimneys and our mouths rise into the vast atmosphere, and there commence to pass up through, and thoroughly mix with, the other gases, to the very summit of the aerial covering. The law which regulates the mixture of gases in this manner is called the law of diffusion of gases.

551. When mixed with air, winds waft the carbonic acid here and there. Near the surface of the earth the wind is variable in its direction, coming from the north, south, east, or west, just as it seems to take a fancy to; but above all

these local winds there are the trade-winds, which constantly blow in one direction. Above this country, there is high up in the air a current of wind always blowing from the north-east; at the equator it is an east wind; and on the other side of the equator, approaching the south pole, it becomes a south-east wind.

552. These trade-winds are well known, and advantage is taken of them in the sailing of vessels from one country to another, and where if the wind be favourable the sailor endeavours to get his ship into the region where it is blowing, and if contrary, he steers out of it as quickly as possible. Various American aeronauts have likewise purposed taking advantage of these winds, and paying a visit to the Eastern hemisphere on some future day.

553. Winds travel very rapidly. A gentle breeze blowing from north to south, might pass from this country to the tropics in six days, and in other six days it might be in America; so that, country places generally, and even in the New World, no doubt get a share of the bad gases evolved from our populous towns.

554. The plant is antagonistic to the animal. The air contains much of carbonic acid which the plant is always working to diminish, whilst the animal is as constantly labouring to augment the quantity. The trees and grasses of our own country, no doubt, work hard in their endeavours to free the air of carbonic acid, by sucking it in, storing up its carbon and setting free its oxygen, but very probably they are assisted in this process by the plants of all countries.

555. Any increase in the amount of carbonic acid in the atmosphere is impossible, as the more there is at any one moment but serves to make plants purify the air the quicker. A miniature world may be fitted up in a small glass house, such as a Ward case, and the phenomena here referred to

observed in working order (Fig. 67). If a number of flies be

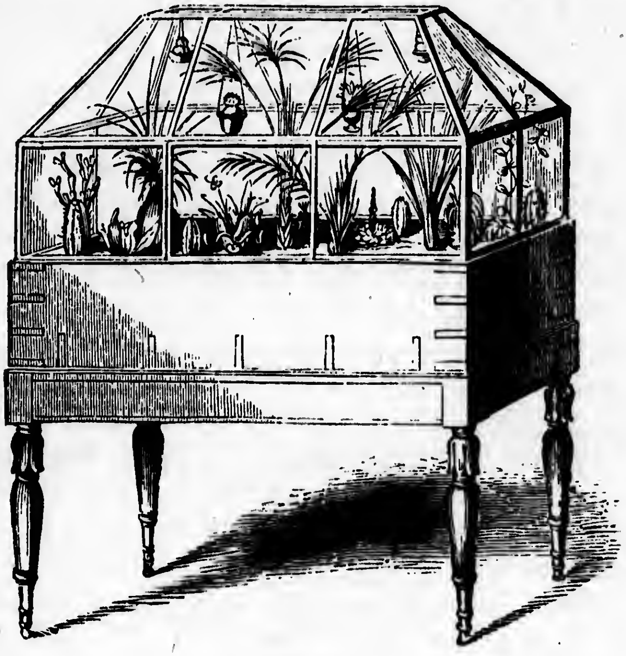


FIG. 67.

placed under a glass shade between which and the external air there is no communication, it will be found that although they may have plenty of sugar to feed upon, yet in a few days they will have generated sufficient carbonic acid to poison the air, and they one by one die off.

556. But when a few flowers are placed along with the flies under the shade, the flies will continue to live for months, all the time in perfect health and devouring their food with undiminished activity. What goes on in this pigmy world, takes place on the large scale on the earth itself, and the ultimate purification of the atmosphere is due to every plant doing its utmost to take up the poisonous gas.

557. This much is certain, that the air has not materially changed in composition since 1800 years ago, when Pompeii was overwhelmed by an eruption of the volcanic mountain Vesuvius, as sealed jars, containing air only, have been found in that buried city, and the air in these is the same as that now floating over and about us.

558. The purification of the atmosphere cannot go on in close rooms. In the diffusion of gases, we have a force quite competent to carry away all noxious gases, provided it is not hindered by our own carelessness. The foregoing remarks on the purification of the atmosphere only apply to the air which is free to move in our streets and lanes.

559. In places where the air is retained in ill-ventilated rooms, it is impossible for the law of diffusion of gases to go on as it ought to do. In a room 8 feet high, 9 long, and 8 wide, a man will feel uneasy in 24 hours. Bad air may not kill at once, but though it may do its work slowly, yet it does it surely.

560. People would be considered insane if they continued to sit in a room they knew contained the vapour of arsenic; and yet, if that poison is in small quantity, it is not more deadly than carbonic acid.

561. The purification of the air by the circulation of carbonic acid is of primary importance to all the animal creation. For were the law of the diffusion of gases for some moments stayed in its useful work, the deadly carbonic acid, as it issues from the mouth of the animal, would hover around and fall like a dark curtain on the unconscious sleeper.

562. Were winds no longer to sweep across this earth, then the noxious vapours, as they are streamed forth from our smoky towns, would hang over us like a black cloud ready to quench us.

563. Were plants to sicken and die, or even were they only to cease filtering our poisonous gases through their green leaves, then this world would but be in the long run a vast Black Hole of Calcutta, and man, unwittingly suicidal, would be generating a poison for himself to die with.

564. As we have it, it is an atmosphère which contains, amongst other things, oxygen for animals to breathe, and carbonic acid for plants to live upon; and these in such proportions, that whilst it imparts life and energy to both the vegetable and animal kingdoms, it injures neither the one nor the other.

565. The circulation of matter is not confined to dead, inanimate substances, but is likewise observed in living bodies, in plants and animals, and that in modes of action which are much more intricate than what occurs in mineral matter.

566. The office which the plant fulfils in the circulation of matter, is to build up the various more simple substances into complex ones; and the office which the animal essentially performs, is to break down the complex bodies which the plant has reared into more simple ones; and this it may do by partaking of the plant matter (flour, potatoes, &c.) as food, or by using it as ordinary fuel (coal and wood).

567. In the apparent destruction of these substances by the animal there is no loss of matter, and they are merely instances of dust returning to dust, and air to air.

568. The part which plants occupy in the circulation of matter may be best noticed by observing what occurs during the germination of the seed and the growth of the plant.

569. When a seed is placed in the ground, three things are necessary for its growth—air, water, and warmth. It requires air, for seeds buried so deep that they are out of the reach of the atmosphere, do not sprout or germinate; it

requires water, for dry seeds will not germinate; and warmth, for an icy temperature puts a stop to germination.

570. The air and water are supplied by the atmosphere, and the sun gives forth the requisite warmth. At this stage the seed itself develops some heat; and though the heat supplied by one seed is so minute that it is not sensible to the touch, yet if a number of seeds be thrown together, as in the process of malting, the mass will feel hot when the hand is thrust in. The source of heat is the combustion of a portion of the coaly matter of the seed, and thus at the birth of every plant, a pigmy bonfire is lit up.

571. During the first stage, the seed remodels itself, and puts forth roots, and a minute stem which ultimately bears leaves. A little water being absorbed, the seed, which may be round and plump like the oat, gradually sends down the little roots, and passes up the short stem. Whilst this is going on, darkness is beneficial; but afterwards light is essential, and that it obtains in abundance in the solar rays. Without light no plant will thrive, as it is necessary to enable the plant to live on the gases in the air, and the salts in the soil.

572. Whenever a seed fixes its roots in the ground, it ceases to depend on the food originally in the seed, and begins to live on air and soil. The germination of a seed is just like the development of the chick from the egg.

573. During the process of hatching, the egg affords material enough to fashion the bones, flesh, feathers, bill, claws, &c.; in short, to set the chick up in life; but when out of the shell, it must look after itself. So the little wheat or oat seed. It contains within itself a stock-in-trade —plenty of material to form roots and a stem with; in other words, to supply it with implements to earn its bread by; but when that is disposed of, it must commence business for itself.

574. This work the new-formed plant does well, for every moment of its existence it is sucking in food from the soil by its roots, and drawing in air by its leaves. Juices are constantly traversing the numberless canals which pass from stem to branch or leaf. The plant manufactures the gases and other matters into straw, wood and seed, into starch, sugar, albumen, fibrin, &c. Plants generally build slowly, and take some time to perfect, but a puff-ball grows so rapidly that four thousand millions of cells are formed every hour, which is equal to sixty-six millions every minute.

575. Water-plants and sea-weeds feed much in the same way as plants growing in air. Ocean and lake, in common with other varieties of water, have the power of dissolving the gases of the air. In every drop of water there is a little atmosphere. Water-plants and sea-weeds, therefore, find in the medium in which they live the very same gases as terrestrial plants obtain direct from the atmosphere, and are thus enabled to fashion similar materials. In all natural waters a certain amount of saline matter is present, which becomes useful in aiding the soil to supply the water-plant with its saline food.

576. The animal in its place, however, is ever ready to consume or otherwise use up the plant, so that in time, the matters which the plant builds up become loosened and detached, and are returned to the atmosphere and the soil from whence the plant obtained them.

577. It may be that the matter may become resident in the structure of the animal for a time, as in the case of the bones, but even during the life of the animal there is a slow wasting away and return of the bone matter to the soil; and certainly, at the death of the animal, all this bone substance returns to mother earth.

578. Plants, while performing their part in the circulation

of matter, not only furnish starch, sugar, and other substances for the immediate use of the animal as food, but they likewise manufacture and yield us cotton and linen for clothing, and many medicines, such as opium, castor-oil, &c. And indirectly, the plant yields woody matter, which in ages becomes changed into coal for heating purposes; and starch, which can become sugar, then alcohol, and afterwards ether and chloroform.

579. Animals also, in ministering to the wants of the high animal, man, not only yield him food to eat, but supply him with wool, silk, and skins for clothing; with horns, bones, tusks, and scales, which can be formed into spoons, knife-handles, and many other useful and ornamental articles; with skins, which can be prepared and used as leather, parchment, vellum, &c.; and with oils and fat, which are largely used in the manufacture of candles and soaps.

CONCLUSION.

580. Man owes much to the atmosphere; for it gives him pure air to breathe; it carries away his bad gases; it feeds the plants he requires as food; and it wafts his ships from shore to shore.

581. Man owes much to the ocean; for it rises into the air and rains down water to refresh his fields, and to cleanse his home and self; it issues forth as springs, and runs through the country as rivers; whilst it forms a highway on which his ships can glide to distant lands.

582. Man owes much to the land; for it hands him sandstones, limestones, coal, ironstones, and precious metals; it gives him salt and other saline matter for food; and affords him anchorage ground in his sojourn through space.

583. Man owes much to plants; for they suck in the noxious gases of the air, and make him food therefrom; they give him wood and coal, cotton and linen, spices, perfumes, and medicines.

584. Man owes much to animals; for they aid him in his daily toil; they afford him nourishment in its most condensed and suitable form; they clothe him with material to resist the inclemency of winter; and they watch over his welfare during the dark hours of midnight.

585. And man owes everything to God, who governs all things, and has so ordained that the atmosphere, the ocean, the land, the plants, and the animals, should minister to his wants; who lights up and guides each star in its course through space; who watches over each drop of water as it sojourns from ocean to sky, from cloud to earth, and from river to ocean again; who directs each atom of gas and salt as they perform their endless circuit, from atmosphere and soil to plant, from plant to animal, and from animal to atmosphere and soil again; who so allots each atom of matter, that, whilst all is in endless motion, and forms part of a mighty circle, yet nothing is lost, and the minute as well as the great fall in and form part of a Mighty Plan.

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*** *The figures refer to paragraphs, and not to pages.*

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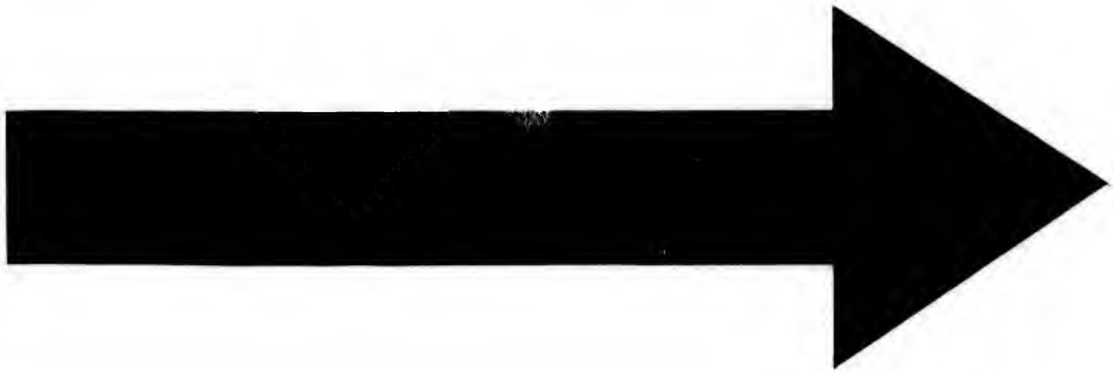

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