12. Burn some bread or meat and save the ashes. The ashes represent the mineral part of food, and consist mainly of lime, salt, soda, potash, and iron.

13. Show diffusion by tying a piece of parchment over the end of a large glass tube. Fill the tube with salt and water and immerse it in a jar of fresh water. In a little while the liquid will rise in the tube, while the water in the jar will begin to taste salt. The process will continue until the water in the tube and in the jar are of equal saltness. If the water in the jar were renewed, all the salt could be extracted from the tube.

14. Show the affinity between acids and alkalies by dropping soda in vinegar. Notice that the mixture boils and foams, and both substances become changed. Drop some soda in water and it simply dissolves and forms a *solution*.

15. Drop a pinch of baking soda in a small cup of water. Then stir in some dilute hydrochloric acid, drop by drop, until the mixture ceases to bubble. Taste the mixture and notice that it is salt. Explain that the hydrochloric acid and the soda have formed a chemical combination and each has neutralized the other. The new substance formed is *chloride of sodium* or common *salt*.

REVIEW TOPICS

1. Define and name the *proximate principles*.
2. Describe *water* and define a *solution*.
3. Describe *albumin*.
4. Describe *diffusion*.
5. Describe *putrefaction*.
6. Describe *nucleo-albumin*, and its relation to *iron*.
7. Describe *fats* and *oils*.
8. Describe an *emulsion*.
9. Describe *saponification*.
10. Describe *starch*, *sugar*, and *wood*.
11. Describe *salt*.
12. Describe *lime*.
13. Describe the *alkalies*.
14. Define *chemical action* and *chemical affinity*.
15. Name some chemical actions in the body.

CHAPTER III

OXIDATION

37. The nature of burning or oxidation. — In addition to the substances taken in as food, the body is continually taking in *oxygen* by the breath. The air which is breathed is four fifths nitrogen gas and one fifth oxygen gas. When air is fed to fuel in the hot fire box of a boiler, burning takes place. Burning is a chemical process. Oxygen unites with the carbon and the hydrogen of the wood, so that both the wood and the oxygen disappear. The carbon and part of the oxygen form *carbonic acid* gas. The hydrogen and the rest of the oxygen form *water*. Both substances pass off in the smoke. What is left as ashes is the *mineral* part of the wood.

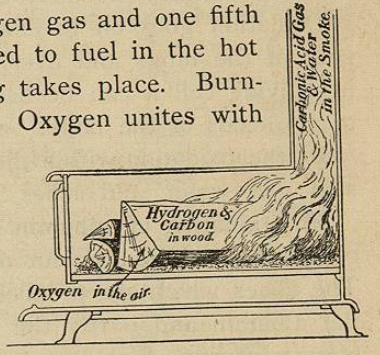


Diagram of burning or oxidation in a stove.

By the burning, heat and a flame are produced. The heat can be used to make steam which will drive an engine and do work. Burning is called *oxidation*.

38. Oxidation within the body. — The body also is an *engine*, — self-regulating and self-sustaining. The oxygen which is breathed into the body slowly burns *food* and the *cells*, just as it oxidizes the wood under the boiler of an

engine. The process goes on so slowly that no flame is produced, but the same amount of heat is produced as though the same substances were burned in a furnace. Some of this heat is used to warm the body, and some is changed to power which enables the body to do work, either of motion, or of manufacturing the various products of the body or of thought. Oxidation is an essential process of life; when it ceases for an instant life ends. When the air is cut off from the body for only a minute, a great feeling of suffocation comes on, and within two or three minutes the body dies.

Oxidation goes on in each cell, but especially in the cells of the lungs and liver. It is a process of life, and in a living cell it can be hastened or retarded according to the needs of the body.

By the oxidation within the cells of the body, carbonic acid gas, water, and ashes are formed, as in a furnace.

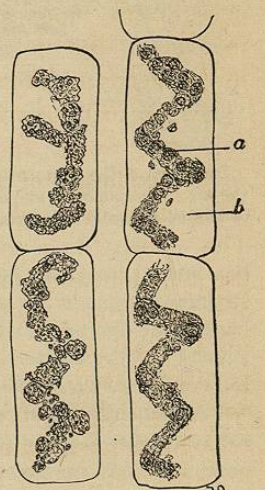
39. Oxidation of albumin. — An ounce of albumin is completely oxidized by an ounce and a half of oxygen. The ashes which are produced are partly the *sulphur* of the albumin and partly the *nitrogen*, which holds some of the carbon, hydrogen and oxygen, combined in a solid called *urea*. Urea must be given off by the kidneys and skin as fast as it is formed. When there is not enough oxygen to burn the albumin entirely, other substances resembling urea are formed, just as a stove smokes instead of burning brightly when the draft is closed. Some of these substances are very poisonous. The albumin of the living cells must be oxidized and replaced continually. Much of the albumin of the food is oxidized before it reaches the cells.

40. Oxidation of fat. — An ounce of fat is completely oxidized by three ounces of oxygen. So it will produce

twice as much heat as the same amount of albumin, and is thus a good food for cold weather. It leaves no ashes behind, for it contains no mineral matter.

41. Oxidation of sugar. — An ounce of sugar is completely oxidized by one and one fifth ounces of oxygen. So it produces only about half as much heat as fat. It is much more easily oxidized than fat or albumin. When the three substances are mixed together as they are in the body, the oxygen will go to the sugar in preference to the fat or albumin, and the latter two substances being unburned will accumulate in the body. Thus sugar is said to be *fattening*. The water and the minerals of the body cannot be oxidized, but enter and leave the body unchanged.

42. Reconstruction of living material by plants. — In every animal the living cells are continually uniting with the oxygen of the air and giving out carbonic acid gas, water, and mineral matters. From these waste matters plants reconstruct the substances which were oxidized in the body. The first substance produced seems to be *starch*, and from it as a basis all other parts of the plant and of animals are built up.



Chlorophyll in pond algæ.
a Chlorophyll arranged in a spiral.
b The clear body of the cell.

The plant cells which contain green coloring matter called *chlorophyll*, are set apart for the special work of reconstructing starch from oxidized material. To them the sap brings water from the soil, and carbonic acid gas from the air. In the chlorophyll these substances are recon-

structed into starch. Using starch as a basis, plants construct fat and albumin and all other substances found in the plant.

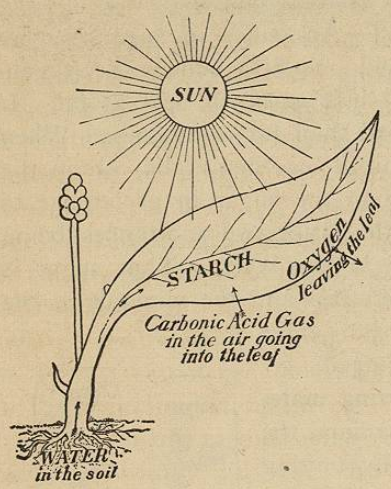


Diagram of the restoration of oxygen to the air after oxidation, and of the rebuilding of burned material into living forms.

43. The sun's work in reconstructing living material. — When oxygen unites with the carbon and hydrogen of the burning substances, heat and energy are given out. Just as much heat and force must be used in tearing away the oxygen as was given out during the oxidation. The sun furnishes this heat and force. The chlorophyll acting as the machine and using the sun's rays for power, frees most of the oxygen from the carbonic acid gas and water, and gives it back to the air. At the same time it unites the remaining oxygen with the carbon and hydrogen to form living starch. Thus the real work of construction is done by the sun. When the starch is oxidized, oxygen goes back to the hydrogen and carbon, and the same amount of heat is given off as was taken from the sun when starch was formed.

The heat of oxidation can be traced back to the sun's heat stored up by living beings or beings once alive. All the carbon of a tree is the carbonic acid gas of the air with its oxygen taken away by the sun's force acting through chlorophyll. Coal is the carbon of trees changed in form during ages of burial.

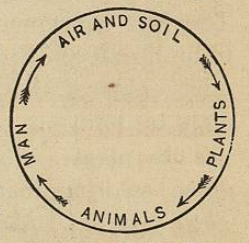


Diagram of the stream of material flowing through man.

44. Conservation of energy. — The *energy of the sun's heat* expended upon the plants in

bygone ages was *conserved* in the coal, and now can be made to appear again as *force* in a steam engine. This force may run an electric dynamo, and the electricity can be transported silently over miles of wire, to appear as light rivaling its original source, the sun. Through all its changes the original energy is preserved.

Observation of the three facts, (1) the heat of the sun acting through plants to tear the oxygen from the carbon and hydrogen, (2) the reunion of the substances in oxidation with the development of the original heat of the sun, and (3) the various forms of power into which the energy can be changed, has given rise to the principle that *any form of energy can be changed into another form without loss.* This principle is called the *conservation of energy.*

This principle is exemplified in the human body. The energy for the work done by the body is the *heat* derived from the oxidation of its food.

45. Relation of plants to animals. — The oxygen of the air would all be used up in a few years if it were not continually torn away by plants from its combinations in carbonic acid gas and water. The carbon and hydrogen would also disappear; but the sun and chlorophyll continually renew the supply both of food and of oxygen. Thus there is a stream of material flowing from lifeless soil and air. It becomes alive in the plant and again in the animal, and then is suddenly oxidized to a lifeless form, and given back to the soil and air, only to repeat the round of life. Plants build up living material which animals use as food and then oxidize back to the form in which it existed before the plant touched it. Plants give off oxygen which supports animal life. Each lives upon what the other discards.

46. Organic substances. — Substances which are built up by living beings are called *organic.* Thus the plant takes carbon from the carbonic acid gas in the air, and builds it up into an organic substance, which forms part of the plant.

47. Difference between plants and animals. — (1) The ability to live upon the ordinary waste products of animal life, or, in other words, to *reconstruct organic matter out of crude minerals and gases*, is a distinguishing mark of a plant. On the other hand an animal always requires *organic food*, and cannot live upon the soil and air. Yet the lowest animals very closely resemble plants, and owing to the difficulty of ascertaining the true source of their food the position of some living bodies is still a matter of dispute.

(2) In animals the cells are bound together by strings of *connective tissue*, which is an albuminous substance of *soft* consistency. In plants the substance between the cells has the composition of *starch* (see p. 27). It is a *hard and firm* substance, and gives the rigid strength to the plant or tree. The outsides of the plant cells often have a thick coating of the same substance. When it is deposited in so great an amount as almost to replace the cells the substance forms *wood*. Yet in some plants it is entirely absent, so that the distinction applies only to higher forms of life, where other distinctions between plants and animals are more obvious.

(3) Most animals have the power of *voluntary motion*, while most plants are *fixed* to one spot. Yet some animals, as the coral, have no more motion than a flower which opens and closes during the day. On the other hand some water plants are continually moving about by means of vibrating hairs projecting from their bodies.

Some *plants* also *move* if irritated. The plant called Venus's flytrap has stiff, toothed leaves, hinged together in twos so as to open and shut like a rat trap. When a fly alights upon the open leaf it suddenly closes upon the insect, crushing it to death. This plant exhibits more movement responsive to a slight irritation and directed to a distinct purpose than many true animals.

(4) Most animals have a *digestive tube*, while plants have no organs of digestion, unless the leaves can be called such. Yet in some animals, as the ameba, the body looks nearly the same throughout.

(5) Most plants are *green* in color, from the presence of chlorophyll. Yet many plants, as toadstools, are destitute of chlorophyll.

48. Source of life. — In the oxidation and reconstruction of animals and plants no *new life* is created. Lifeless material is endowed with life by material already living, and in its turn the new material imparts life. The same

life continues through all the changes of the body, although not a single particle of the original body may remain. The body is but the house in which life resides. The original source of life itself has never been found. The Bible gives the only known origin of life:

"And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so.

"And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good." — Gen. 1 : 11–12.

SUMMARY

1. Oxygen unites with carbon and hydrogen, and produces heat. The process is called *burning* or *oxidation*. A steam engine transforms heat into work.
2. Oxygen from the air is continually entering the body.
3. Within the body it is continually uniting with the albumin, fat, and sugar, and producing heat, some of which is transformed into work. This is the essential process of life.
4. By oxidation, the albumin, fat, and sugar become carbonic acid gas, water, and urea, and are given off from the body.
5. The green coloring matter of plants forms the machine, by means of which the sun's heat tears the oxygen away from the carbonic acid gas and water and forms organic substances again.
6. Plants prepare food for animals, and animals prepare food for plants.

7. All through the oxidation and reconstruction of the body life remains the same, and no new life is created.
8. The Bible gives the only known explanation of the origin of life.

DEMONSTRATIONS

16. Lower a lighted candle into a wide-mouthed bottle. When it goes out pour in a little lime water, then stop the mouth of the bottle and shake it. The water becomes milky, showing that carbonic acid gas has been produced. By means of a straw or glass tube blow a little air through a cup of lime water and notice that again the water becomes milky. This shows the carbonic acid of the breath.

17. Hold a lighted match under a cold tumbler. In a few seconds drops of moisture will condense upon the inside of the glass. Explain that the water is formed by the union of the hydrogen of the match stick with the oxygen of the air.

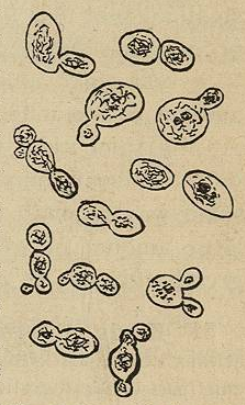
REVIEW TOPICS

1. Describe *oxidation* and its products.
2. Show how oxidation takes place in the body.
3. Describe the oxidation of each proximate principle.
4. Describe the series of changes by which the oxidized materials of the body are again built up into living bodies.
5. Define and illustrate *conservation of energy*, and apply it to man's body.
6. Define *organic* bodies.
7. Give points of difference between *plants* and *animals*.
8. Give the only known *source of life*.

CHAPTER IV

FERMENTATION AND ALCOHOL

49. Production of alcohol and vinegar. — Unless great care is taken to preserve it, a weak solution of sugar soon turns to *vinegar;* a stronger solution turns to *alcohol*, while a thick, sirupy solution remains unchanged. Everywhere there are scattered minute living germs which, falling into a moderately strong solution of sugar in water, grow and produce oval plants each about $\frac{1}{4000}$ inch in length. A collection of these plants is called *yeast.* By their growth and multiplication they change sugar to alcohol and carbonic acid gas. The gas bubbles up through the liquid and makes a froth upon the top, while the alcohol remains in the water.



Yeast plant cells (× 500).

If only a small quantity of sugar is present another kind of germ from the air enters and grows, becoming tiny rodlike plants, each about $\frac{1}{10000}$ inch in length. By their growth and multiplication they change the alcohol to vinegar. They collect in a mass called the *mother* of vinegar.

Boiling destroys both the yeast and vinegar germs. If the sugar and water are boiled and at once sealed tightly, so that new germs cannot enter, the solution will keep