CHAPTER II

ELEMENTS OF THE BODY

18. **Proximate principles.** — The cells of all animals contain the same substances, differing in amount and arrangement, yet alike in composition. The simple substances of which the cells are composed are called *proximate principles*. The most important proximate principles are water, albumin, fat, sugar, salt, lime, soda, and potash.

19. **Water and solution.** — Water forms nearly three fourths of the weight of the body and is present in every part. It reaches each minute part of the body through the firm walls of the organs. Water has the power of dissolving solid substances, so that they retain all their properties unchanged. Sugar in water is sugar still; in fact, we can appreciate what sugar is only when it is dissolved. When a substance is dissolved in a liquid, so that each remains unchanged in its essential properties, the result is a *solution*. Most solutions will go anywhere water itself will go. In the stomach the food becomes dissolved, and is taken into the blood tubes. The blood contains a solution of food which penetrates into the spaces around each cell, carrying nourishment to the cell and washing away its waste matters. Water makes the tissues limber and slippery, so that they bend and move easily. By means of the perspiration which carries off surplus heat, water regulates the heat of the body. About three quarts of water are taken into the body each day.

Water is composed of two gases, hydrogen and oxygen, very firmly united.

20. **Albumin.** — The protoplasm of the living cells of the body is almost entirely composed of a substance like the white of an egg. Because it turns white when heated, it is called *albumin* (from the Latin *albus*, white). Pure albumin is hard and brittle as the white of an egg is when it is dry. In the body it is dissolved in from five to twenty times its own weight of water. This solution in water is what is meant by the albumin of the body. In the blood it is liquid, in the flesh it is somewhat jellylike, and in the skin it is strong and tough. It is a very complex body which only plants can form. Animals must get it from vegetables and change it into their own bodies. When once formed it may become part of the bodies of several successive animals, as one makes food of another.

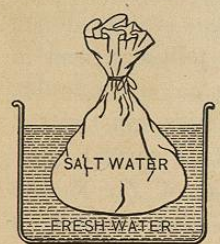
Albumin forms the principal part of the protoplasm of all living cells. Some is used in performing the work of the body and does not reach the cells. About four and one half ounces of pure albumin must be eaten each day to supply the needs of the body.

21. **Forms of albumin.** — There are many forms of albumin, all having essentially the same properties. The white of eggs is almost pure albumin. Lean meat is composed mostly of another form; cheese, gelatine, and glue are composed mainly of still other forms.

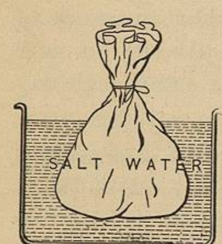
22. **Coagulation.** — Most forms of albumin may be hardened either by heat or acids, and once hardened they cannot be dissolved again to their original state. A boiled egg illustrates this hardening. Changing a liquid to a jellylike or solid form so that it cannot be changed back to its original form is *coagulation*. Coagulation of its albumin destroys the life of a cell.

23. Putrefaction. — When albumin is kept moist and exposed to the warm air it *decays* or *putrefies*, becoming soft and finally completely dissolving, and at the same time giving off offensive odors. If the albumin is kept dry it shrivels up and finally crumbles to an odorless powder. Pure sugar or fat will not putrefy, although both may become sour, but both often contain a slight amount of albumin, and this may putrefy, giving them a slight taste and odor.

24. Diffusion. — When salt and water are placed in a bag of thin skin and suspended in a dish of water, some of the salt and water will pass through the walls of the bag and will mingle with the water in the dish, and, on the other hand, some water will pass into the bag. This will go on until the water in the dish is of the same saltness as the water in the bag. The act of passing through a membrane apparently impervious is a form of *diffusion.* Without pressure albumin will not diffuse except in the form, called *peptone,* which is produced from the others by digestion. Peptone readily diffuses through the thin sides of the blood tubes in the walls of the intestine, and so reaches the blood.



Diffusion at the beginning of the process.

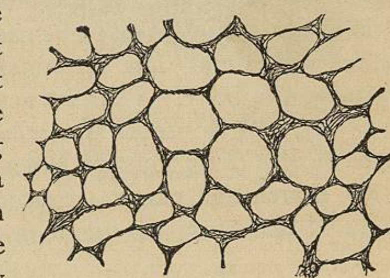


Diffusion at the end of the process.

25. Iron-bearing albumin. — The nucleus of vegetable cells is composed of a form of albumin called *nucleo-albumin,* which contains iron. There are from thirty to sixty grains of iron in the human body, all of which is united with the albumin, so that the metallic properties of the iron are completely absent. A small amount of this iron-bearing albumin is found in the nucleus of every cell, both vegetable and animal, and seems to be essential to the growth and division of the cell. In an animal this substance gives origin to the substance called *hemoglobin,* which forms the coloring

matter of the red blood cells. The iron gives it the power to carry oxygen from the lungs to all parts of the body. Only one or two grains of iron are required each day to supply the loss of the iron in the body, and several times that amount is eaten daily in our food.

26. Fats and oils. — Fats are a series of smooth, slippery substances found in all animals, and in most vegetables. About five per cent of the human body is fat. It is scattered between the cells of all parts of the body, but in places, as in the walls of the abdomen, it forms thick layers. All fats become liquid when heated, but those that are liquid at ordinary temperatures are called *oils.* In the living body fat is always in a *liquid* state, stored in thin-walled pockets made of connective tissue. By boiling, the pockets are softened and the fat runs out upon the water. Each pocket is from $\frac{1}{500}$ to $\frac{1}{400}$ of an inch in diameter. The fat is produced from the albumin of the cells by a breaking-down process. Fat is a simple substance compared with the complex albumin. Probably all the fat which is stored in the body is made out of albumin.



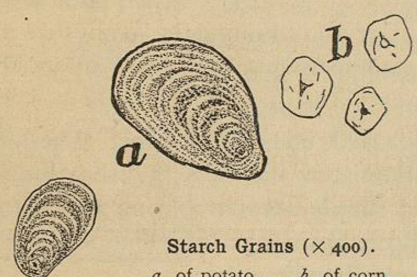
Fat tissue (× 100).
Connective tissue cells form pockets in which the liquid fat is stored.

27. Emulsion of fat. — However much fat may be shaken with water it will remain in tiny particles which soon rise to the surface. If a little white of egg is added, the fat will divide into finer particles and will remain in the water much longer. A mixture of fat and water is an *emulsion.* No emulsion is permanent, but the fat will rise to the surface in time. Milk is the most perfect emulsion, but even in milk the cream, or fat, rises in a few hours.

28. Saponification of fats. — When fat is boiled with soda or potash it is broken up into a small amount of *glycerine* and a large amount of a substance called a *fatty acid*. The fatty acid unites with the soda or potash to form *soap*. When by any means fat is broken up with soda or potash, forming soap, the process is called *saponification*. Both soaps and emulsions are continually being formed during the digestion of fat.

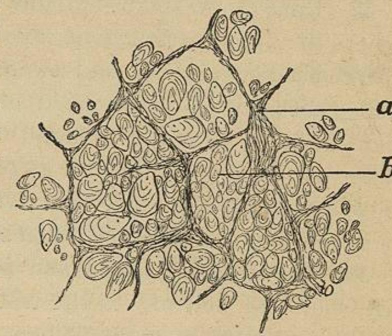
29. Use of fat. — The fat of the body is a living garment, retaining heat and protecting the body from the cold, and rounding out the rugged outlines of the bones and muscles. It is a *cushion*, protecting the internal organs from injury. It is also a *store of food* to be used in sickness when food cannot be eaten. The fat which is eaten is used up in warming the body. Thus fat acts as a *food*, as *armor* for the body, and as useful and ornamental *clothing*. About three ounces of fat must be eaten each day.

30. Starch and sugar. — Starch is produced almost entirely by plants and is stored in the form of little grains which will not dissolve in cold water. Grains of potato starch appear like oyster shells and show distinct markings as though they were built up in layers. It is supposed that starch grains grow by deposits of successive layers of starch between which are layers of a waterproof substance called *cellulose* or plant connective tissue. When the grains are boiled, they swell and burst and then dissolve, forming a paste. As a plant grows, it uses the starch in building up sugar, wood, cotton, cellulose, and other plant substances. Starch, sugar, wood, cotton, and cellulose are similar in chemical composition, but differ widely in character.



Starch Grains (× 400).
a, of potato. *b*, of corn.

Wood is of no use to the body, but starch and sugar are common foods. Starch is changed to sugar before it becomes a part of the body of man. Only a little sugar is found in the body at one time, for almost as fast as it enters it is used up to produce warmth. About five ounces of starch or sugar must be eaten each day.



A thin slice of potato (× 200).
a Albuminous and fibrous pockets.
b Starch grains in the pockets.

Minerals. — The minerals salt, lime, soda, and potash, are always found in the body.

31. Salt. — Common salt is found in the bodies of all animals, and a less amount in vegetables also. There are about six or seven ounces of salt in the human body. In animal food there is enough salt to supply the needs of the body, but some must be added to vegetable food. So flesh-eating animals, like dogs and cats, will not eat salt, while vegetable-feeding animals, as horses, like it.

Salt gives an agreeable *taste* to food, and this causes the "mouth to water," and all the other digestive fluids to flow freely, so that the salted food is quickly and easily digested.

Some kinds of albumin in the body will dissolve in water only when salt is present, and if it is diminished in amount, or is absent, these albumins cannot do their work.

Salt *diffuses* very readily, and also aids in the diffusion of all kinds of food. So salt has very important uses in the body, and when it is not used there is great suffering. The proper amount of salt is present in the food when food tastes just agreeably salt. About one half an ounce needs to be eaten each day.

32. Lime. — A small amount of lime is found everywhere in the body, but bone is over one half lime. In all, there are between ten and twelve pounds of lime in the body, but only six grains need be eaten each day. Much more than this amount is found in all common food. The main use of lime is to give *stiffness* to the bones. It is mixed with the cells and fibers of the bone, just as starch is mixed with the fibers of linen to make it stiff.

33. The alkalies — soda and potash. — Some substances are sour and burning to the taste, and can corrode or eat away flesh and metals. When soda or potash is mixed with such a substance, both ingredients in the mixture are changed and a new substance unlike either is formed. For instance, strong vinegar is such a sour, corrosive substance. When soda is added to it the mixture bubbles for a time, and then the liquid is no longer sour or irritating, but has a flat, bitter taste, and both the soda and vinegar have become changed. A substance which is sour to the taste and corrodes metals and flesh, and unites with soda or potash with a bubbling, is called an *acid.* Soda and potash are called *alkalies.* They also can corrode certain substances, but they always unite with acids at the first opportunity, and by their union each is changed to a less harmful form. So alkalies destroy or *neutralize acids*, and acids *neutralize alkalies.*

34. Chemical action. — When two substances are mixed together so that each becomes changed and substances unlike either are produced, the process is called *chemical action.* Sugar will dissolve in vinegar, but it still remains sugar, and so the mixture is called a *solution* (see p. 22). In contrast with it, when soda is dissolved in vinegar it is

completely changed, and so forms an example of *chemical action.* Some substances are very prone to mix to form solutions. Thus, impure salt has such an attraction for water that it takes it from the air and becomes damp. So salt is said to have an *affinity* for water. In the same way some substances are very prone to mix so as to become changed by chemical action. Thus, there is always chemical action between soda and vinegar when they are brought together, so soda is said to have a *chemical affinity* for vinegar. In the same way, *air* has a great "chemical affinity" for *wood* in a fire. The chief value of gold comes from the fact that it has *no* chemical affinity at all except for one or two uncommon substances. So it will remain unaltered in the midst of substances which would destroy other metals.

35. Use of alkalies. — If a fluid contains an acid, it is said to be *acid* in reaction; if an alkali it is *alkaline;* and if it contains neither it is *neutral* in reaction. Now, the blood is always alkaline from the presence of a small amount of soda and potash. Acid products are being formed in the body continually, and the duty of the alkalies is to unite with them at once and change them to harmless substances, which may be handled by the blood in safety. The alkalies are found in nearly all foods.

36. Chemical actions in the body. — Everything which makes up the cells and fluids of the body is composed of some or all the substances — water, albumin, fat, sugar, or starch, with the minerals — salt, lime, and soda and potash. These must be eaten to sustain life, and so they are *foods.* Other kinds of substances are harmful or poisonous. All food substances are eaten three times a day, and yet only water and the minerals leave the body in anything like the form in which they entered. The rest are entirely changed by chemical actions and leave the body as gases or liquids or as solids dissolved in water. The digestion of food from the time it is taken into the mouth is a chemical action, as is also its becoming a part of the living cells. Breathing and the production of the waste matters of the body are also chemical processes.

These chemical processes can be followed and even imitated in a laboratory. The living principle in the body directs the work, but uses few processes which are not also used outside of the body. It has been a great triumph for science to liberate men from the superstition that the chemical and physical laws of our bodies were governed by the arbitrary feelings of indwelling spirits, and so were different from the laws governing lifeless creatures.

SUMMARY

1. The cells of the body are composed of five substances, viz., water, albumin, fat, sugar, and minerals.
2. Water is three fourths of the body. It carries food to the cells and washes away their waste matters.
3. Albumin is like the white of eggs. It forms the protoplasm of all cells. It warms the body, and gives it strength and weight.
4. Fat is in pockets between the cells. It protects and heats the body.
5. Starch and sugar are similar substances. They warm the body.
6. The minerals in the body are salt, lime, soda, and potash. They are found in all food. In addition some salt must be eaten.
7. Salt aids in the preparation and distribution of food to the cells of the body.
8. Lime stiffens the bones.
9. Soda and potash destroy irritating acids within the body.
10. Water, albumin, sugar or starch, fat and minerals, are foods and must be eaten to sustain life.
11. Most of the vital actions of the body can be imitated in a chemical laboratory.

DEMONSTRATIONS

3. Illustrate the properties of albumin by the white of an egg. Notice its sticky character. Dry some upon a piece of paper over a fire and notice its brittle, gluelike character, and that it will again dissolve in water. Boil some and notice that it becomes hard and will not redissolve. Set some aside and notice that it decays.

4. Inclose a lump of wet flour in a muslin bag and wash it until the water is clear. This removes the starch grains and leaves the grain albumin or *gluten* pure. Notice its tough and sticky character.

5. Show samples of olive oil, lard, and tallow. Show that lard melts at about the temperature of the body, and so is fluid in the body.

6. Shake together some oil and water. Notice that the oil at once floats upon the surface. Now shake the oil with some lime water, and notice that it no longer floats, but that the mixture looks milky, while a few very small oil drops can be seen floating in the liquid. Explain that this is an *emulsion*.

7. Stir together some castor oil and caustic soda, gently heating the mixture, and notice that it forms soap.

8. Scrape a potato into a basin of water. Wash it about and notice that the shreds of potato will float, while a white substance will settle to the bottom of the basin. Explain that this substance is *starch*, and that our great-grandmothers used this method to make starch for laundering.

9. Place a small drop of the wet potato starch upon a glass slide and examine it with a power of at least 50 diameters. Notice that the starch grains appear like oyster shells. Examine also some corn starch and notice that each grain looks like an irregular cube with a star-shaped center. Sketch the starch grains.

10. Boil some starch and notice that it swells and forms a jellylike paste.

Iodine turns starch blue. Apply a drop of the tincture of iodine to the starch and notice the blue color. Apply it to bread, cake, flour, etc. Notice the blue color, showing that they all contain starch. Notice that meat does not respond to the test.

11. Show specimens of sugar. Brown sugar is the impure form, while granulated sugar is the pure crystallized form. Show some sugar scraped from the outside of raisins and explain that this is glucose or grape sugar, and that all sugar and starch must be changed into this form before it can be used by the body.

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.

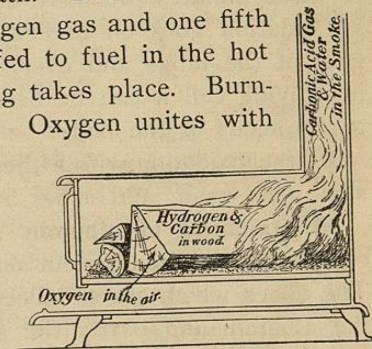


Diagram of burning or oxidation in a stove.

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