APPLIED PHYSIOLOGY

CHAPTER I

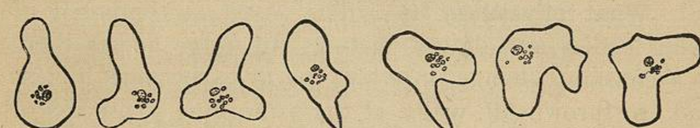
LIVING BODIES AND CELLS

1. What physiology is. — The world is composed of living bodies and lifeless matter. In *living* bodies there is a constant change, in which particles become lifeless and are thrown off, while, at the same time, a process of *creation* is going on by which lifeless matter is given life. This constant destruction and renewal of the particles of the body constitutes *life*.

The science which tells of the *structure* of living bodies is *Anatomy;* that which tells of their *working* is *Physiology;* and that which tells how to keep living bodies in good working order is *Hygiene.* The term *physiology* often includes *anatomy* and *hygiene.*

Some processes in man's physiology were discovered only by studying the lower animals; and others, by observing plants. In fact, it is by studying the workings of lower forms of life that most of our knowledge of the working of man's life has been gained. The physiology of vegetables and animals teaches the physiology of man, because man embodies the characteristics of lower forms of life. During the course of ages life developed through vegetables and lower animals up to its highest point in the most perfect animal, — man.

2. The ameba. — One of the simplest animals lives in stagnant water and is called the *ameba*. It is only a lump of jelly about $\frac{1}{1000}$ of an inch in diameter, yet it is a complete *animal*, for it moves, and eats, and grows, and produces other *amebas*. It has no arms, or legs, or head, but all parts of its body seem very nearly alike. It puts out little fingers from its body and then rolls its whole body into the fingers. In this way it is continually rolling about. When it finds a particle of food it wraps itself around it just as a baker rolls a mass of bread dough around a

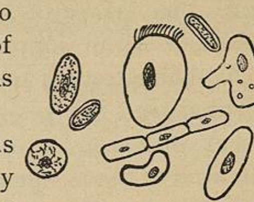


An ameba, sketched at intervals of ten seconds (× 400).

raisin. That part of the body which is in contact with the food digests as much as is needed, and then unwraps itself away from the waste. It has no choice as to what part of its body it shall use for any given purpose. But man uses each part of his body for only definite purposes. He has arms which get food, a mouth which eats it, and a stomach which digests it. The arms cannot eat food, neither can the mouth digest it, but each part does only its own kind of work.

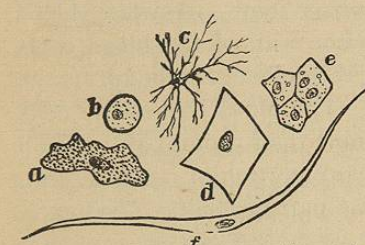
3. Man like an ameba. — Each part of a man's body is made of multitudes of living beings, each of which eats and grows like an ameba. Each tiny being is called a *cell*. One collection of cells forms the *skin*, another the *muscles* of the arm, and another the *stomach*, and so on

through the body. Each collection does its own work, without interfering with the others. The cells work together like a well-trained army, so that we do not feel the workings of each separate cell. If a collection is out of order, the person is sick.



Plants and animals found in stagnant water, each consisting of a single cell (× 200).

4. Cells. — Cells are of various shapes, according to the work they have to do. They are from $\frac{1}{5000}$ to $\frac{1}{100}$ of an inch in length. Each cell is like thick jelly and is almost colorless. Near its center a small mass of slightly different composition may usually be distinguished. This central mass is called the *nucleus*. The substance composing the cell is like the white of an egg and is called *protoplasm*. Although protoplasm is transparent and jellylike, yet under a microscope there appears an interlacing series of beads and lines which suggest a structure as complex as that of the body itself.



Cells from the human body (× 200).

a A colored cell from the eye.
b A white blood cell.
c A connective tissue cell.
d A cell from the lining of the mouth.
e Liver cells.
f A muscle cell from the intestine.

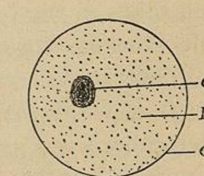


Diagram of the parts of a cell.

a Nucleus.
b Cell-body or protoplasm.
c Covering, generally absent in animal cells.

5. Connective tissue. — The cells are kept in place by a fine network of strong fibers called *connective tissue*. In some parts of the body, as on the outside of the muscles, it is thick and skinlike, but around each separate cell there are only enough fibers to keep the cell in place. Even these connective tissue fibers are the threadlike arms of very small cells set apart for the menial work of supporting other cells.

6. Three tests of life. — We know that each cell is alive; for it moves, it takes in food, and it multiplies.

(1) *Motion.* — Although each cell is held in place by the connective tissue, the tiny particles of its body are in constant motion, just as a boy's eyes and mouth and hands and feet may move, even if he sits still in a chair. Besides this continual motion of the particles within the cell, some cells show a greater motion, in which the cell as a whole takes part. Thus, a muscle cell becomes thicker and shorter when the muscle bends a joint. A white blood cell can force its way through the wall of the blood tube, and can wander about among the cells of the body.

(2) *Nutrition and Growth.* — The blood bathes the cells with food which does not resemble their protoplasm. Each cell takes in the food through any portion of its body, and, endowing it with life, makes it a part of itself. Thus each cell increases in size.

(3) *Reproduction.* — During the period of growth of the body, there is a constant production of the cells; for the man is composed of more cells than the child. Even in a full-grown man certain cells, as those of the skin, are constantly being shed and new ones formed. When a cell reaches mature life, the nucleus first divides into two parts, which separate from each other; then the body of the cell divides between the two nuclei. Thus each cell becomes two cells, and each of the two exactly resembles the original cell, except that it is smaller at first; but it soon grows to be as large as the original cell. All the peculiarities of the life of the first cell go on in each of the two cells into

which it divides; and so we say that the new cell inherits the peculiarities of the parent. This process may be carried on very rapidly; and a new cell may be produced, and itself become divided, in a few hours.

Anything that moves, and eats, and reproduces itself by means of its own power, is alive; and so the cells of the body are alive in the fullest sense of the term.

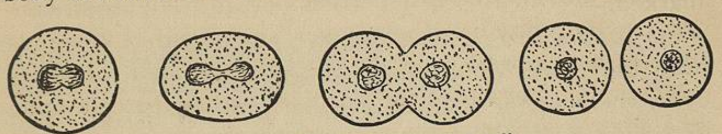


Diagram of the division of a cell.

7. Other distinctions between the living and the dead. — Many living bodies will show some *spontaneous movement* in response to a prick or a blow, or other irritation. Certain causes, as a low temperature, may suspend the ability to respond to an irritation, but it will return when warmth is applied. A lifeless thing never puts forth effort, no matter how much it is irritated.

Decay never occurs in cells while they live; but after death disintegration soon begins, even if no outside power acts upon the cells. On the other hand, a body which has never been alive usually changes very slowly or not at all, unless acted upon by an outside power.

8. Relation of cells. — In the body formed by the cells there exists a controlling spirit of life, whose nature is unknown. When all the cells are obedient to its influence the body as a whole is alive; but if the cells are not obedient, the body as a whole is dead, although each separate cell may remain alive. For example, a blow upon the head may disturb this controlling influence so that it cannot tell the cells how to act. Then they instantly stop work, and the body drops dead. Yet each cell may remain alive for minutes or hours, just as each soldier may remain alive after an army has been disbanded.

9. Tissues. — While each cell eats, grows, and produces other cells more or less independently of the rest, yet, like the members of a large family, each works for the benefit of all the others, and, in turn, is dependent upon them for things which it cannot do so well as they. Cells doing special kinds of work are collected in orderly groups called *tissues*. Six kinds of tissues are well marked, —

(1) *Muscular Tissue.* — Groups of ribbonlike cells which have the power of moving the adjacent parts are found everywhere in the body, and form *muscular* tissue. This tissue is usually as abundant as all the rest of the tissues taken together.

(2) *Epithelial Tissue.* — Covering all the surface of the body, and lining every cavity and tube which connects with the surface of the body, is a layer of firm cells which form *epithelial tissue*. It protects the underlying parts and manufactures all the various fluids of the body. From it, also, the hair and nails are produced. Epithelial tissue is abundant and important.

(3) *Nervous Tissue.* — There are cells which control all the others. By means of their long, threadlike prolongations they convey orders to every cell in the body. They and their prolongations form *nervous* tissue.

(4) *Connective Tissue.* — Surrounding each cell, and holding it in place, are the extremely fine arms of small cells called *connective tissue* (see p. 11). Its amount varies greatly in different parts of the body and in different persons, but its total amount is always very large. In some parts of the body, as in the skin and lungs, there is a special kind of connective tissue which is very *elastic*, and gives to the parts their stretching properties. This tissue is called "*yellow elastic tissue*," from its color.

(5) *Osseous Tissue.* — A special form of connective tissue, in which enough *lime* is mixed to make it stiff, is called *bony* or *osseous tissue*. This tissue is rigid and strong so as to form a *framework* for the rest of the cells of the body. A somewhat similar tissue, containing little or no lime, is called *cartilaginous* tissue. It surrounds the jointed ends of bones and often becomes bone late in life.

(6) *Adipose Tissue.* — Some connective tissue cells are arranged in microscopic pockets filled with oil or fat. This forms *fatty* or *adipose tissue*. Most of the fat in the body is stored in this way (see p. 25).

10. The blood as a tissue. — Blood contains two kinds of cells, each of which has a special work to do. The fluid in which the cells float can become solid, and therefore blood is really a tissue. The *lymph*, which is mainly diluted blood, may also be considered a tissue.

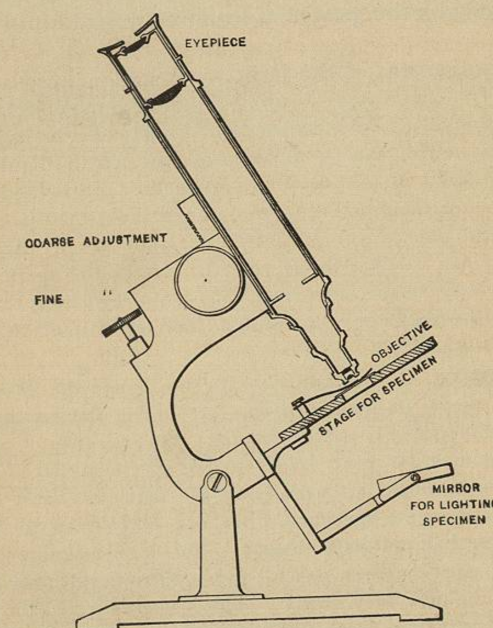
11. Other fluids in the body. — There are other fluids in the body which, while they contain a few cells, do not depend upon them for their properties or actions and so are not tissues. Into the digestive tube there are poured five fluids concerned in digestion, viz.: the *saliva*, the *gastric juice*, the *pancreatic juice*, the *bile*, and the *intestinal juice*. In order to carry off the waste products of the body two fluids, the *perspiration* and the *urine*, are continually being formed, while water is given off in gaseous form by the breath. Three fluids are found in connection with the eye. Two, called the aqueous and the vitreous humors, distend the eyeball, and another, called *tears*, runs over its surface to wash away dirt. Inside the cavity of each joint is a thick fluid, called *synovia*, which lubricates the surface of the bones within the movable joints. Lastly, *milk* is sometimes produced for the nourishment of the young.

12. Organs. — In order to work to the best advantage, several kinds of tissues are usually associated together. Thus, the stomach, which digests food, is composed of *muscular* tissue which moves the food about, and *epithelial* tissue which pours out digestive fluids, and *nervous* tissue which presides over the process, while *connective* tissue binds the whole together. A collection of different tissues always arranged in a definite, compact shape for a special purpose, is called an *organ.* The *stomach, intestine, pancreas,* and the *liver* are the four principal *organs of digestion.* The *lungs* are *organs of respiration,* the *heart* is an organ for the propulsion of blood. The *kidneys* and *skin* are organs which get rid of waste matter, and the *brain* is the *organ of thought.* The term organ is also applied to many other parts of the body, but these are the principal ones.

13. Systems. — Sometimes a definite series of tissues and organs are not arranged in compact form, but are scattered through the whole body. This forms a *system.* Thus the system of tubes formed of muscular and connective tissue in which the blood moves is called the *circulatory system,* while the heart is an organ in the circulatory system. In the same way the brain is an organ in the nervous system. The five main systems are the *digestive, circulatory, respiratory, nervous,* and *excretory* systems. In Physiology the action of the cells of each tissue, organ, and system is studied separately. The structure and arrangement of the cells of each tissue are studied by means of a *microscope.*

14. The microscope. — In order to show even the largest cell, a compound *microscope* magnifying at least twenty times is needed; while for ordinary use, one magnifying at least two hundred times is necessary.

A compound microscope consists of two lenses set in a movable tube. The lower lens is called the *objective,* and does the main part of the magnifying. It can easily be removed from the tube or swung aside, and another objective of different magnifying power substituted for it.



Compound microscope.

The upper lens is called the *eyepiece.* It can be removed from the tube, and another substituted. Usually two or three objectives and two eyepieces of different magnifying powers are furnished with each microscope. A microscope is said to magnify as many *diameters* as the number of times it enlarges the breadth or diameter of an object. Thus a microscope making a cell appear 100 times as broad as it really is, is said to magnify 100 diameters. But the length and thickness are also magnified. So the surface of the cell is made 100 × 100 or 10,000 times as large, while its bulk is 100 × 100 × 100 or 1,000,000 times as large. A table accompanying each instrument tells the power of each combination of lenses.

15. Arrangement of the light. — A small mirror placed at the lower part of the microscope throws light through the object, for otherwise there would not be sufficient light to spread over its magnified surface. The mirror can be tilted so as to catch the light from any direction. Objects usually show best when they are lighted only sufficiently to show their outlines. A stronger light may pass through extremely small objects so that they do not show at all. Each microscope usually has a device for varying the size of the aperture in the plate upon which the specimen rests, thus again regulating the amount of light. It is usually not best to use an amount of light which makes the field of view brilliant.

16. Focusing. — The tube carrying the lenses can be moved up and down by means of a small wheel. Arranging the distance of the lens from the specimen is called *focusing*. An objective of high magnifying power must be much nearer to the specimen than one of low power. Thus an objective magnifying 500 diameters must be about $\frac{1}{10}$ of an inch from the specimen, while one magnifying 50 diameters would be over half an inch distant. For high magnifying powers the focusing must be very exact. So a second wheel is provided which moves the tube very slowly. This wheel is called the *fine adjustment* in distinction from the other wheel or *coarse adjustment*. The finger of the observer should always be upon the fine adjustment, turning it back and forth so as to observe now the top and now the deeper portions of the specimen, for it is magnified in depth as well as in breadth.

It is often very difficult to find a very small specimen with a high power lens, for the space in which it lies is magnified to several feet in diameter. A good plan is to use a low power lens for finding the specimen, and then after bringing it to the center of the field, to substitute the high power lens.

Every movement of the specimen is magnified as much as the specimen itself. So great gentleness is needed in moving it under the objective or else it will be moved out of view altogether. The microscope appears to reverse the sides of the specimen, so in order to move the image in any direction the specimen must be moved in the opposite direction. Care should be taken not to press the lens upon the specimen. If the lens becomes dirty or moist it should be gently wiped with a soft, clean handkerchief. A little alcohol rubbed on will aid in removing the dirt.

17. Preparation of specimens. — Specimens are examined upon glass plates, called *slides*. The regulation size is three inches long and one inch broad. Specimens must be very thin, so as to show only a single layer of cells or fibers. A liquid specimen should be a small drop; a powder should be only a tiny speck. A solid specimen is prepared in either of two ways. Its cells and fibers may be picked apart by means of two needles; but this destroys the natural arrangement of the parts. So the method of slicing off extremely thin layers with a sharp razor is more often used. This requires special training. Nearly all specimens should be examined in a liquid. Water will do for nearly all. Glycerine may be used if the specimen is to be kept, for it does not evaporate. A drop is placed over the specimen on the slide. Over the drop of liquid it is well to place a thin piece of glass, called a *cover glass*, for the purpose of protecting the objective from the liquid, and the specimen from currents of air. Air bubbles under the cover glass interfere with the view. They can be forced out by gently pressing upon the cover glass; but with care the cover glass can be applied so as to avoid them. A supply of slides and cover glasses is a necessary part of every microscopic outfit.

A few fibers scraped off from a handkerchief or a few scales from the back of the hand are good specimens for practice. A tiny bit should be placed upon a slide and a drop of water placed upon it, and the whole covered with a cover glass. Begin to examine it with the lowest powers of the microscope, and so gradually learn to use the higher powers.

SUMMARY

1. Physiology tells how living beings eat and grow and act.
2. The ameba is a tiny lump of living jelly, which eats, and moves, and produces young amebas.
3. The body of a man is made of tiny cells like an army of amebas.
4. Each cell is a lump of thick jelly, in which a small mass called the *nucleus* may usually be distinguished. The cells are held in place by strings called *connective tissue.*
5. Each cell moves, eats, and grows, and produces other cells like the first.
6. The mind lives in the body formed by the cells.
7. The cells obey the mind. When the mind loses control of them the body is dead.
8. Each cell does some special kind of work for the benefit of the rest.
9. A collection of cells doing a special kind of work is called a *tissue.*
10. A collection of different tissues always arranged in a definite and compact shape is called an *organ.*
11. A definite series of tissues and organs scattered through the body for a definite purpose forms a *system.*

DEMONSTRATIONS

1. Scrape the inside of the cheek with a sharp knife and examine a drop under the microscope, with a power of at least 100 diameters.

Notice the flat scales of irregular shape. Each scale is a separate living cell. It is nearly transparent, but its nucleus appears as a slightly darker spot. Make a drawing of the cells.

Examine cells scraped from the skin upon the back of the hand; and cells scraped from the pulp of a leaf. Examine a bit of the green scum, called *pond algæ*, which forms upon stones in fresh-water ponds. Notice the long cells joined end to end and containing green matter.

2. Take a drop of stagnant slimy water from a rain barrel or from a kitchen drain or from a stagnant pool. Examine it with a power of at least 100 diameters. A specimen of the ameba is likely to be found rolling about. Notice its nucleus, and also dark spots in its body which are probably food which it has swallowed. Make a sketch of an ameba.

REVIEW TOPICS

1. Define *Anatomy.*
2. Define *Physiology.*
3. Define *Hygiene.*
4. Describe an *ameba.*
5. Describe a *cell.*
6. Describe *connective tissue.*
7. Give the three tests by which a cell or other body is known to be *alive.*
8. Give other distinctions between *living* and *lifeless* bodies.
9. Give the relation of the *mind* to the *cells* of the body.
10. Define a *tissue* and name the different tissues of the body.
11. Show that the *blood* is a tissue.
12. Give the different *fluids* in the body.
13. Define an *organ.*
14. Define a *system.*
15. Describe the *instrument* by means of which the different cells and tissues of the body are studied.