PRINCIPLES OF

PHYSIOLOGY AND HYGIENE

BY

GEORGE WELLS FITZ, M.D.

*Sometime Assistant Professor of Physiology
and Hygiene and Medical Visitor,
Harvard University*

SECOND EDITION, REVISED

PREFACE

MANY years of experience in teaching physiology [1] have convinced me that the ideal of a text-book should be the clearness, accuracy and simplicity obtained by viewing the human body as a machine automatically adjusted to its work and its surroundings. From such a viewpoint, its complex structure is resolved into the definite working parts of a well-regulated mechanism; its varied forms of activity are revealed as organized effort toward development, maintenance and adaptation to environment; and the laws of its health are seen to be the reasonable conditions essential to its effective working.

Whenever possible, technical terms and names have been omitted for the sake of relieving overburdened memories and of leaving them receptive for the important practical aspects of the subject. Indeed, the attempt throughout has been to utilize and supplement the knowledge of the student and thus to give to the physiology, and especially to the hygiene, a working value in his daily thought and life. When technical terms have of necessity been used, they have been italicized, not in every case where they first occur, but where they are most fully explained. This method supplemented by an accurate index is believed to be preferable to the very inadequate glossary often used.

[1] State Normal School, Oswego, N. Y.; Cook Co. Normal School, Illinois; Sargent Normal School of Physical Education, Cambridge, Mass.; Harvard University, Cambridge, Mass.

While fully realizing and urging the value of experimental work, I have, nevertheless, so planned the text that it is independent of the experiments in connection with each chapter. Those schools, therefore, which lack either the time or the equipment for such work, will not find the book less well fitted for their use. By them, the book can be completed in half a year. For those who can carry out the laboratory work, the book offers either a half or a full year's course, depending upon whether the experiments are demonstrated by the teacher or done by the students.

The experiments and demonstrations should be so planned that, when necessary, the one-hour period may be extended to two hours. In nearly all cases, the experiments should precede the text, that the student may be led, in so far as is possible, to make his own observations and conclusions. In order to get the most value from the work, a systematic record of the experiments should be kept in a notebook, to be regularly examined by the teacher.

Aside from those herewith acknowledged, many of the illustrations are new, being either original or redrawn from the best sources obtainable. To Dr. O. P. Dellinger of Clark University I am indebted for permission to copy his remarkable photographs of the ameba. I am further indebted to the following authors and publishers for permission to use certain cuts from their works: Tigerstedt's Physiology, Mill's Comparative Physiology, Doty's Prompt Aid to the Injured, (D. Appleton and Co.); Bergen and Davis' Principles of Botany, Conn's Bacteria, Yeasts and Molds in the Home, Hough and Sedgwick's The Human Mechanism, (Ginn and Co.); Gerrish's Anatomy, Hall's Physiology, Egbert's Hygiene, (Lea Bros. and Co.); Martin's Human Body,

Barnes' Plant Life, Sedgwick and Wilson's Biology, (Henry Holt and Co.) ; Ziegler's Pathology, Foster and Shore's Physiology, (The Macmillan Co.) ; Scudder and Cotton's Fractures and Dislocations, Quain's Anatomy, (W. B. Saunders).

The manuscript has been read by Professor C. F. Hodge of Clark University, to whom I am much indebted for criticism and suggestion. I am further indebted to my wife for her invaluable assistance throughout the preparation of the manuscript and the correction of the proofs.
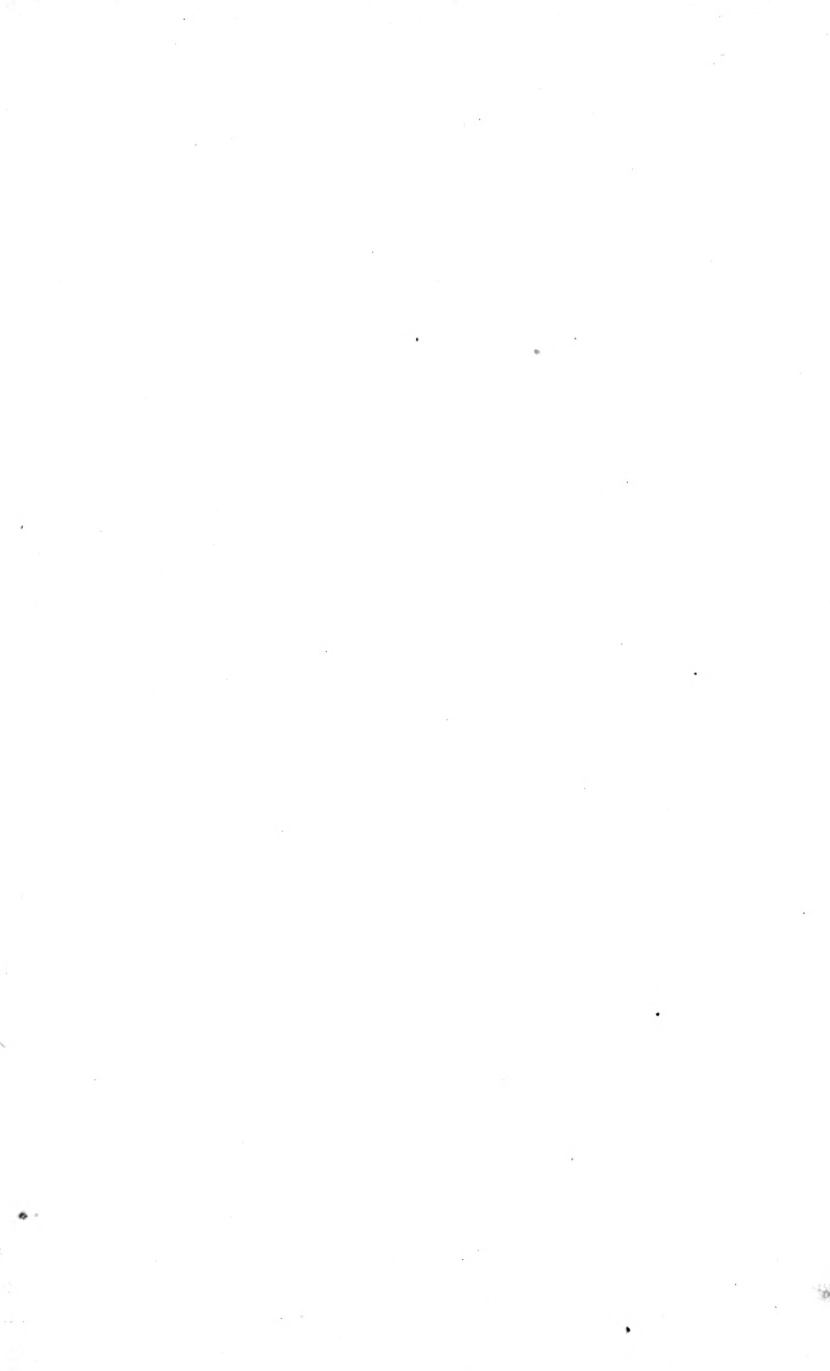
G. W. F.

Boston, March 3, 1908.

PREFACE TO SECOND EDITION

The necessity for a second edition has afforded the opportunity not only of making certain slight verbal changes in the text but of substituting for the modified Sylvester method of resuscitation from drowning Schafer's new prone pressure method, and of adding a table of infectious diseases which gives the incubation periods, early symptoms, modes of entry, causes and school quarantine periods for the several diseases, including common diseases of the skin and eyes.

G. W. F.

Boston, January 15, 1909.

CONTENTS

CHAPTER I

PLANT AND ANIMAL LIFE

CHAPTER II

THE GENERAL STRUCTURE OF THE HUMAN BODY

CHAPTER III

BONES, JOINTS AND LIGAMENTS

CHAPTER IV

MUSCLES AND TENDONS

vii

CHAPTER V

MOTION AND LOCOMOTION

CHAPTER VI

MUSCULAR WORK

CHAPTER VII

SELECTION AND PREPARATION OF FOODS

CHAPTER VIII

FOOD MATERIALS

CHAPTER IX

WATER AND OTHER BEVERAGES

CHAPTER X

DIGESTION

CHAPTER XI

THE HYGIENE OF DIGESTION

CHAPTER XII

THE BLOOD

CHAPTER XIII

THE CIRCULATION OF THE BLOOD

CHAPTER XIX

THE HEAT OF THE BODY

CHAPTER XX

THE NERVOUS SYSTEM

CHAPTER XXI

USE AND CARE OF THE NERVOUS SYSTEM

CHAPTER XXII

THE SPECIAL SENSES

PHYSIOLOGY AND HYGIENE

CHAPTER I

PLANT AND ANIMAL LIFE

Growth.—As we watch plants and animals grow, we see how many changes they are making in the world about them. The plants are taking the materials which they need from the earth, air and water,[1] and are building these materials into themselves. The animals in turn are taking the plant substances and are building their own bodies out of them.

A clover plant starts from a seed within which is hidden a minute plant and food prepared by the mother plant for its use. When placed in the moist warm earth, the plant awakens and by living upon the stored-up food quickly becomes larger and stronger. After it has thrust its head out of the ground and its roots down into the soil, it is able to take a gas known as carbon dioxide from the air and water, with a small amount of soluble material from the earth. From these, with the aid of the sun's light and heat, it gradually builds up a large and strong clover plant. The gas and water are no longer simply gas and water, but are combined

[1] The soil contributes mainly water containing a small amount of salts in solution. The air contributes a colorless gas, carbon dioxide (CO_2), which is produced by the burning and decay of wood and other organic materials; and a small amount of nitrogen. Water (H_2O) consists of 2 parts of hydrogen to 1 of oxygen. For a further discussion, see Appendix, p. 315.

and changed to form the woody stem, the luxuriant leaves, the nectar-laden blossoms. A lamb eating the clover changes it so that it is no longer clover, nor yet the gas and water from which the clover was built, but the flesh and bone of the sheep.
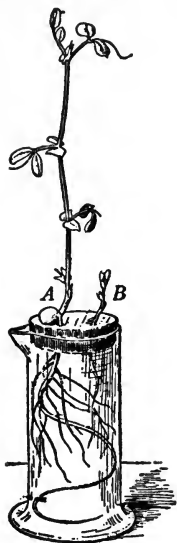
Fig. 1. Germinating peas, growing in water, one (*B*) deprived of its cotyledons, which contain the stored-up food. (Bergen.)

Food of plants and animals.—The building materials, or food, taken by the plant or the animal are so completely changed that they become a living part of it. If it lives, they live as woody fibre, bone, muscle, or other tissue. If it dies, they too are dead, and quickly or slowly decay, returning to the simple chemical compounds which the plant had previously utilized and which thus again become available for other plants and through them for other animals.

Organisms.—Plants and animals are called *organisms*,[1] because they lead a more or less independent life, during which they grow and develop. Most organisms begin life comparatively small and weak.[2] They develop rapidly or gradually into the size, strength and perfection of the adult. They once again become weak in old age, with subsequent death and decay. This sequence of growth and decay is in marked contrast to the non-living world of things, which cannot grow but instead are changed by being worn away and destroyed.

---

[1] Literally, an organism is a living unit which possesses organs. The term has, however, come to include all plants and animals.

[2] The exceptions are the microscopic plants and animals.

The stone, for example, is worn into fine particles of dust by ceaseless grinding against sand and stone; mountains are broken into rocks and loose earth by frost and washed down into the valleys by rain; wood decays to the carbon dioxide and water from which the plant built it.

Multiplication of organisms.—Organisms also differ from non-living things in their power to produce new organisms. In the lower forms of both plants and animals, this process of reproducing or continuing life has its simplest example in the division of the adult into two or more young individuals, which, after they have developed into maturity, again divide. In this way, the species is rapidly multiplied, and death and decay through old age are avoided.

In higher forms of plants and animals, the process of reproduction consists in the development of the young organism as an offshoot or bud from the adult. When capable of independent development, it is set free as a young plant or animal and thereupon begins a new life, in which lies this same power of starting young organisms.

Organic substances.—The substances which plants and animals produce, are called *organic substances,* since they are dependent for their existence upon the life and activity of plant and animal organisms. From plants come such organic substances as wood, cotton, hemp, oil, flour, starch, sugar, coal, coal oil, paraffin and natural gas. From animals come such substances as flesh, leather, hair, wool and silk.

Inorganic substances.—In contrast to these are *inorganic substances,* which are found in nature independent of plant and animal life, such as air, water, minerals (except coal in its various forms) and metals.

Building materials of animals.—Certain of the organic substances produced by plants, such as starch, oil and sugar, together with such inorganic materials as water, lime and other salts, are used by animals as food and from them they build up their bodies.[1] The bodies thus built may be so simple as to consist of but a single speck of living matter or so complicated as to have the
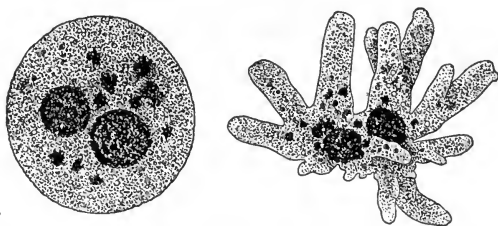
Fig. 2. Ameba at rest and branching (viewed from above). After micro-photographs by Dellinger.

various organs and tissues possessed by the higher animals and man.

A simple type of animal.—One of the simpler animals which has been most studied because it is commonly found in stagnant waters, is the *ameba*. The ameba has neither eyes nor ears, nose nor mouth, head nor legs, but is just a minute mass of a living jelly-like substance called *protoplasm*. Within this is a more solid body known as the *nucleus*. The entire mass is filled with granules and when at rest is more or less spherical in form. When active, it assumes various shapes and is able to move about by throwing out from its body projections which serve as feet. Although it has no mouth, it is able to swallow particles of food when they come in contact with its body and later to expel their undigested portions. This bit of independent, self-directing

[1] Many animals also eat the flesh of other animals.

and self-supporting matter is an animal, although it is so small that it can hardly be seen. Its body of protoplasm with its more solid spherical nucleus, makes up a single *cell*.[1]

The ameba, like all other animals consisting of but one cell, has, in spite of its smallness and simplicity, the be-
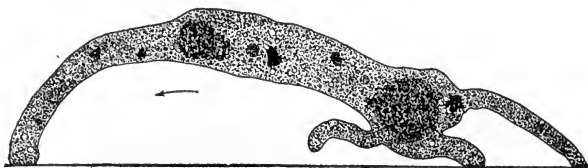
FIG. 3. Ameba progressing (side view). After photo-micrograph by Dellinger.

ginnings of the faculties and powers which are so highly developed in us. The possible exceptions are sight and hearing, although it would seem not entirely to lack even these, since experiments have shown that it is influenced by light and even possibly by sound. Barring accident, their lives may be said to be endless, since each healthy adult undergoes division into young twin cells of half the original size. These immediately take on the characteristics and powers of the older cell, and growing rapidly to maturity redivide in their turn.

Reproduction by division.—This process of division begins and is completed in the nucleus before the surrounding mass of protoplasm, the *cytoplasm,* changes. The cytoplasm then proceeds to divide, and in a short time the two new cells have entered upon an independent life. This process is called *reproduction by divi-*

[1] Curiously enough, an independent cell somewhat like the ameba is found in large numbers in the blood of the higher animals, and is called a white blood corpuscle. The white blood corpuscles are produced and set free within the body for the purpose of seeking out and destroying any disease germs or other foreign substances which have found a lurking place there.

sion and is the final outcome of the growth and development which have taken place in the cell. It marks the passing of the adult, since its life is now turned over to the young cells which represent it.

Development from the germ cell.—Nearly all animals, no matter how complicated their structure, begin their life as a single cell, *the germ cell.* The germ cell in the higher animals undergoes a series of rapid divisions into smaller and smaller cells, until a mulberry-
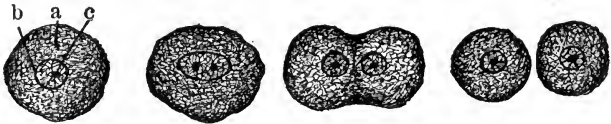
FIG. 4. Diagrams illustrating direct cell-division: *a*, cell-body; *b*, nucleus; *c*, nucleolus.

like mass is produced by this process of *segmentation.* These cells all appear alike at first and are mixed together seemingly without order in a spherical cellular mass. Later, the cells enlarge and are arranged in three definite layers.

The upper layer develops into the skin of the animal. Through a curious infolding of the cells, it also forms the nervous system.

The middle and larger layer forms the greater part of the body, namely, the muscles, bones, fibrous tissues, heart, blood-vessels and urinary system.

The lowest layer forms the lining of the gullet, stomach, intestines and lungs.

Development of organs from cells.—As the few primitive cells of the three layers change and grow into the millions of special cells which make up the different organs and tissues of the body,[1] and develop the power to do

[1] *Differentiation.*

the special work of these organs and tissues,[1] they undergo marked changes in size, shape and behavior. In our study, we are not concerned with their rapid and perplexing changes, but with the cells as finally completed. It will be sufficient for us to realize that these changes in the case of a human being are fairly well established within two or three months of the single cell stage. The re-
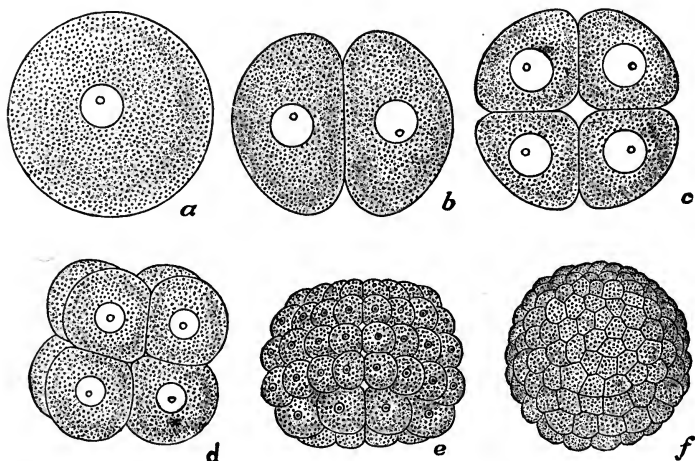
FIG. 5. Cleavage or segmentation of an ovum, showing successive division of the germ cell (a) into two (b), four (c), and eight (d). Later stages are shown at e and f. The first four figures are diagrammatic: e and f are after Hatschek's figures of the development of a very simple vertebrate (Amphioxus).

maining six or seven months before birth and eighteen or nineteen years of growth and development after birth, are devoted to the enlargement and perfection of the organs and tissues [2] already formed in miniature.

[1] *Specialization.*
[2] The term tissue is applied to such parts of the body as are made up of similar cells, as, for example, muscular tissue and nerve tissue. A tissue may do a special work, in which case it is also an organ.

Differentiation of cells.—In animals thus made up of many cells, the cells have fixed positions in the body and are crowded by one another into such permanent shape as best adapts them to their position and work. Unlike the single cell of the ameba, no one cell has the power of doing all the kinds of work required by the body, as moving the limbs, digesting food and breathing, but each group of cells constitutes an organ which does a special part of the body's work. The outer cells, for example, do the work of protecting the inner ones and for this purpose become tough and resistant, forming the skin. The inner ones in turn carry on the special functions of the body, as motion, digestion and respiration.

Individuality of cells.—Although the cells have thus lost the power of doing more than one kind of work for the body as a whole, they nevertheless resemble the single cell of the ameba in that they can do the various kinds of work necessary to maintain their own existence. For example, each one absorbs and uses the nourishment which it needs to do its work and maintain its health and strength. It takes in the oxygen necessary for the production of energy [1] and throws out carbon dioxide and other waste products.

Forms of cells. — The cells have further lost the ameba's power of radically changing their shape and they cannot perpetuate life by mere division of themselves. Each cell is limited to the shape best adapted to its service in the organism. If, for example, it forms part of the deep layers of the skin, it is small and block-shaped. If it forms a part of the connection between the muscle and its bony attachment, it is long and slender like a silk fibre. If it is a part of the muscle,

[1] See Appendix, p. 316.

it is broader and has the power of shortening itself so
as to aid in pulling the bones about. In other words, the
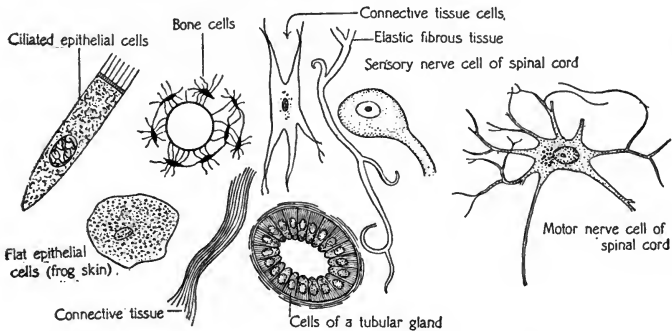
Fig. 6. Various forms of cells found in the body.

forms of the various cells are as numerous as their posi-
tions and functions in the body.

Nutrition of cells.—Instead of having the power of
independent movement which was necessitated by the
ameba's constant search for food suitable to its needs,
the cells in the animal body remain relatively stationary,
with the exception of the red and white cells of the blood.
The stationary cells have food and oxygen prepared for
their use and brought to them by the blood through an
intricate system of canals, the blood-vessels. The waste
products of their activity are borne away without effort
on their part by this same blood supply, which bathes
all the tissues of the body.

DEMONSTRATION

Demonstrate under the microscope the ameba as found in the
slime from stagnant pond water.

CHAPTER II

THE GENERAL STRUCTURE OF THE HUMAN BODY

Definition of Physiology.—Although all animals have to procure and digest food, to absorb oxygen and eliminate waste materials, yet the ways in which they accomplish this are so varied as to give rise to many kinds of structure. In accordance with the degree of their complexity, animals may be arranged in a series. At the bottom, we may place the one-celled animal with its simple structure, any part of which is convertible to any use, being interchangeably stomach, lung, foot or excretory organ; and at the top, man, whose millions of cells are arranged in groups as organs and tissues, each group of which is able to do only its own particular work. The study of the structure of animals is *anatomy*. The study of the work done by these structures and the way in which it is done is *physiology*. That branch of physiology devoted to man is *human physiology*.

Man a mammal.—Man belongs to the higher class of animals which have a backbone or vertebral column and which are therefore called *vertebrates*. Man further belongs to the highest division among vertebrates which suckle their young and because of this are called *mammals*. In structure, man differs from some of the other mammals, especially from the higher apes, only in minor details. He has, for example, shorter arms and a larger

cranium. His feet are made for walking, not for grasping, and his body is held erect.

Gibbon   Chimpanzee   Man
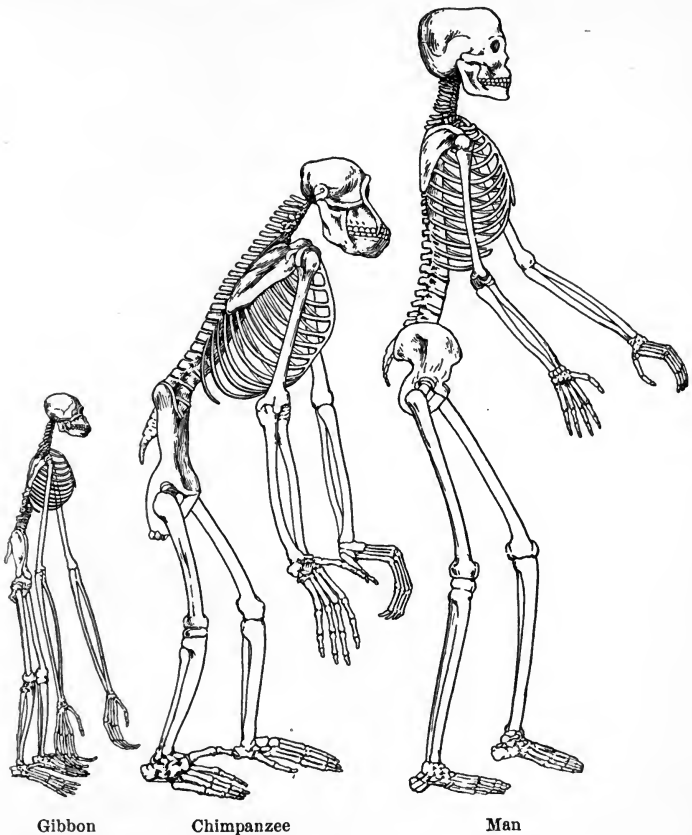
FIG. 7. Skeletons of gibbon, chimpanzee and man drawn in natural relations of size. (After Huxley.)

Skeleton.—The human body consists of two distinct parts, a bony framework called the *skeleton,* and the soft flesh, skin and other tissues and organs which clothe it. In many animals, such as crabs and lobsters,

the skeleton lies entirely outside of the softer tissues. In vertebrates, on the contrary, the skeleton is entirely covered by the flesh.[1] By this arrangement, the skeleton
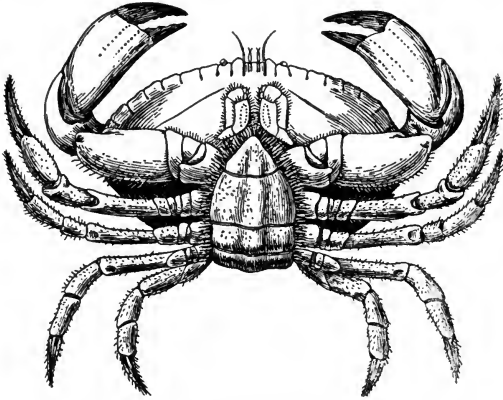
FIG. 8. Animal with external skeleton (crab).

supports and protects the softer tissues and is in turn protected by them.

Arrangement of bones and organs.—The human skeleton consists of a large number of bones (about 208) so arranged and distributed in and about the body's central axis, the spinal column, as to be alike on both sides, that is, bilaterally symmetrical. The two sides are, however, complements of each other in shape and position, that is, rights and lefts. Most of the soft tissues are also symmetrically arranged in pairs, as for example the muscles, blood-vessels, nerves, lungs and kidneys. The exceptions to this are such organs as the heart, stomach, liver and intestines, which are irregular in shape and not in pairs.

[1] The turtle, although a vertebrate, has its backbone and ribs so blended that they form a shell which in certain particulars resembles an outside skeleton.

Spinal Column.—The fundamental part of the skeleton and the only part possessed by some of the lower forms of vertebrates is the backbone called the *spinal* or *vertebral column.* The spinal column varies in form from the simple rod of gristle found in some of the lowest vertebrates, to the many jointed flexible bony structure which distinguishes the higher species.

Vertebræ of the neck.—In man, the vertebral column consists of 31 short bones, the *vertebræ.* These vertebræ vary in form according to their position in the spine and the work which they have to do. For example, to permit the head to turn and bend in various directions, the vertebræ in the neck must move freely. They are therefore comparatively small and loosely connected by strong bands of gristle, the *ligaments,* and firmly held by strong contractile bands, the *muscles.* Movement beyond a certain amount is checked by the ligaments which at the danger point become tense. As a result, dislocation of the bones of the neck is rare. To allow the head

Fig. 9. The spinal column, right lateral view and dorsal view. (Testut.)

to nod, the upper or first of the neck vertebræ is so shaped as to permit the lower portion of the skull which rests upon it to slip readily. To permit the

head to turn from side to side, that is to rotate, a pivot projects upward from the second vertebra into a ring on the first vertebra.

Of the back.—In the upper part of the trunk, or *dorsal* region, on the contrary, stability rather than
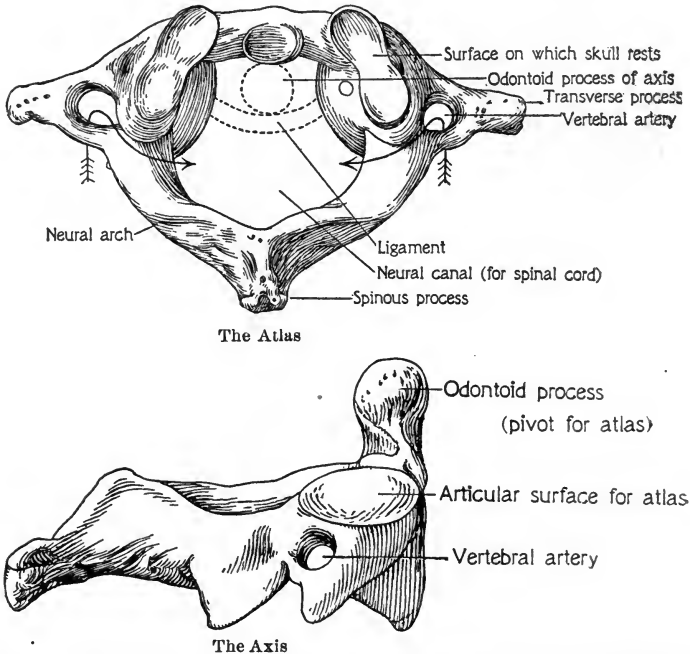
Fig. 10. The relation between the 1st and 2nd vertebræ, permitting rotation of the head.

freedom of movement is required, in order that the ribs which are attached to the vertebræ may receive adequate support. The vertebræ of the back are therefore firmly united by additional ligaments and bony extensions or *processes*, in order that any considerable movement of the vertebræ may be checked. In childhood, the

movement permitted is more extensive than in later life, owing to the greater looseness of the ligaments and the larger spaces between the processes, but even then the movement between adjacent vertebræ is slight.

Of the lower back.—In the lower part of the back, the *lumbar* region, bending is essential. The parts of the vertebræ which come together, the *articular surfaces,*
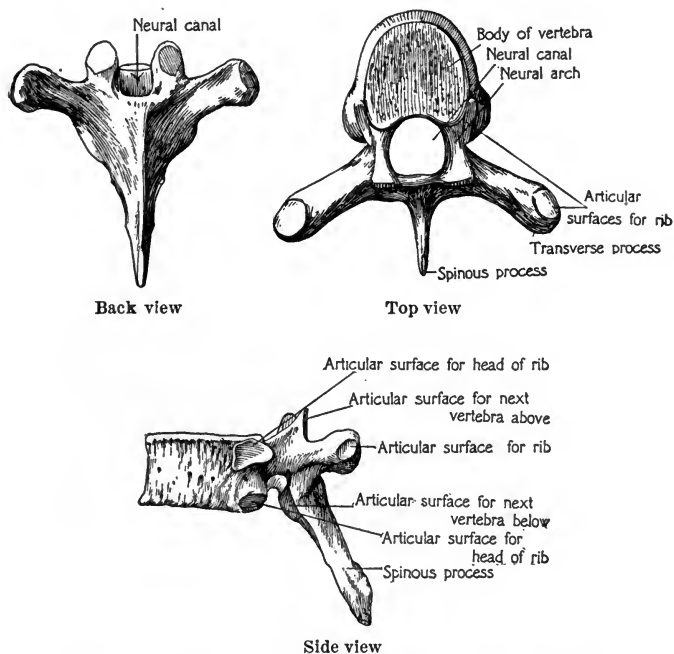
FIG. 11. Views of dorsal vertebræ showing parts and relations.

are therefore arranged so that they slip readily upon each other and thus permit free bending backward and forward but only a moderate amount of bending sidewise.

Sacrum.—Below the lumbar region, the greatest strength and stability are required because the weight of the trunk is here transmitted through the hip bones to the legs. Five of the vertebral bones are therefore united to form a single broad strong bone, the *sacrum*.

Coccyx.—Below the sacrum are several small bones which constitute the *coccyx*. They are the sole remnant of a possible prehistoric tail and owing to their exposed position are somewhat frequently injured.

Flexibility of spine.—As we have seen, the vertebræ form a series of short branching bones knit together by ligaments into the spinal column. The movement per-

Front ligament

Back ligaments

Body of vertebra
Spine of vertebra

Intervertebral discs
of elastic cartilage

Canal for spinal cord
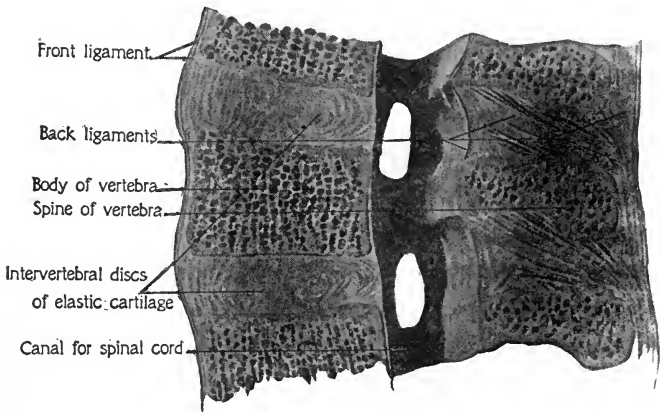
FIG. 12. A section through three vertabræ, showing structure of bone and arrangement of ligaments.

mitted between each pair of vertebræ is slight and the ligaments which bind them together are strong. As a result, the spinal column is firm. Its flexibility is not sacrificed, however, because there are so many joints that a slight movement on the part of each results in a considerable curve of the whole
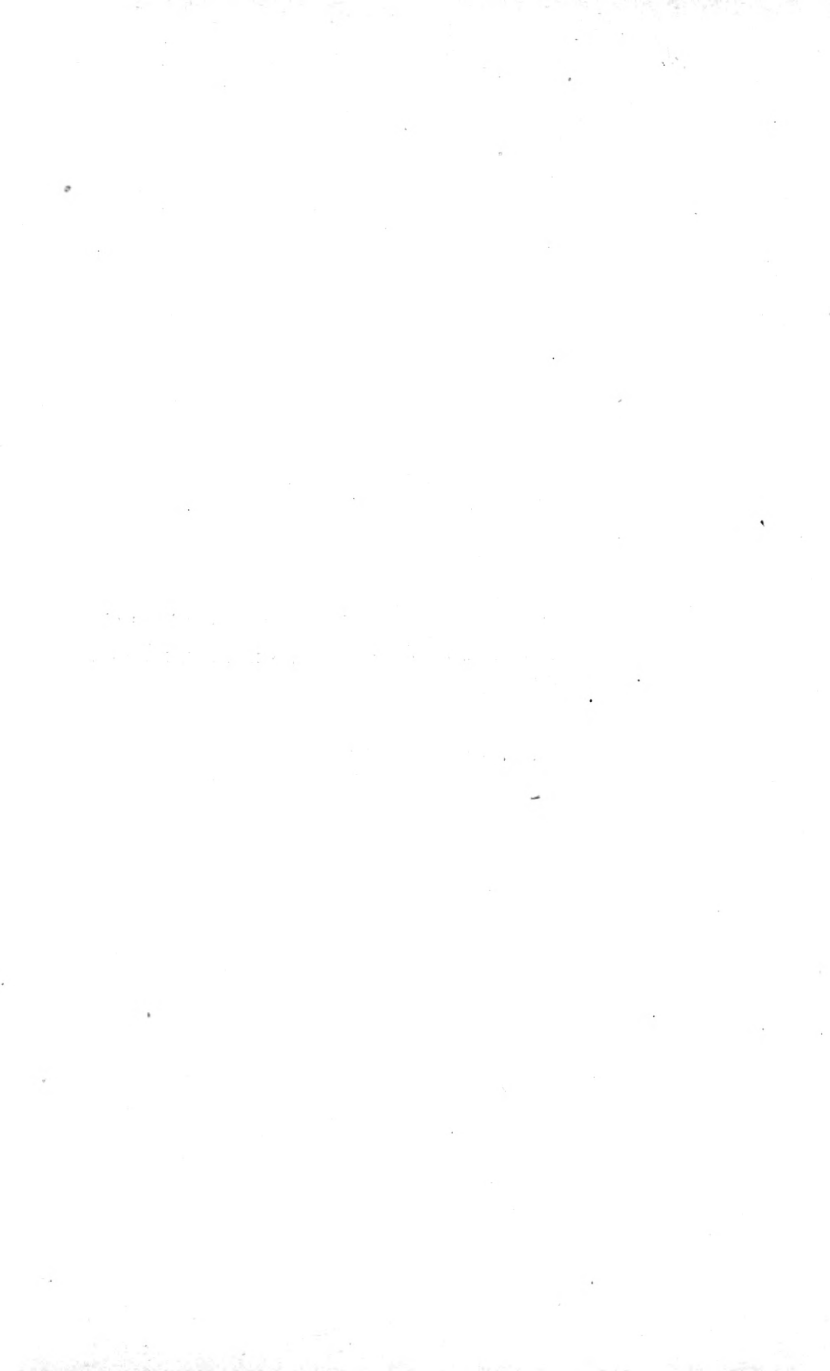
EXPLANATION OF PLATE I.

A front view of an adult human skeleton to illustrate the mode in which the bones are connected at the different joints.

a Ligaments of the Elbow Joint.
b The Ligament which is connected with the ventral surfaces of the bodies of the Vertebrae.
e Ligament connecting the Pelvis to the Spine.
f Ligament connecting the Pelvis to the Sacrum.
g The Ligaments of the Wrist Joint.
h The Membrane which fills up the interval between the two bones of the Forearm.
l A similar Membrane between the two bones of the Leg, and, lower down, *l*, ligaments of the Ankle Joint.
n Ligaments of the Knee Joint.
oo Ligaments of the Toes and Fingers.
p Capsular Ligament of the Hip Joint.
q Capsular Ligament of the Shoulder Joint.
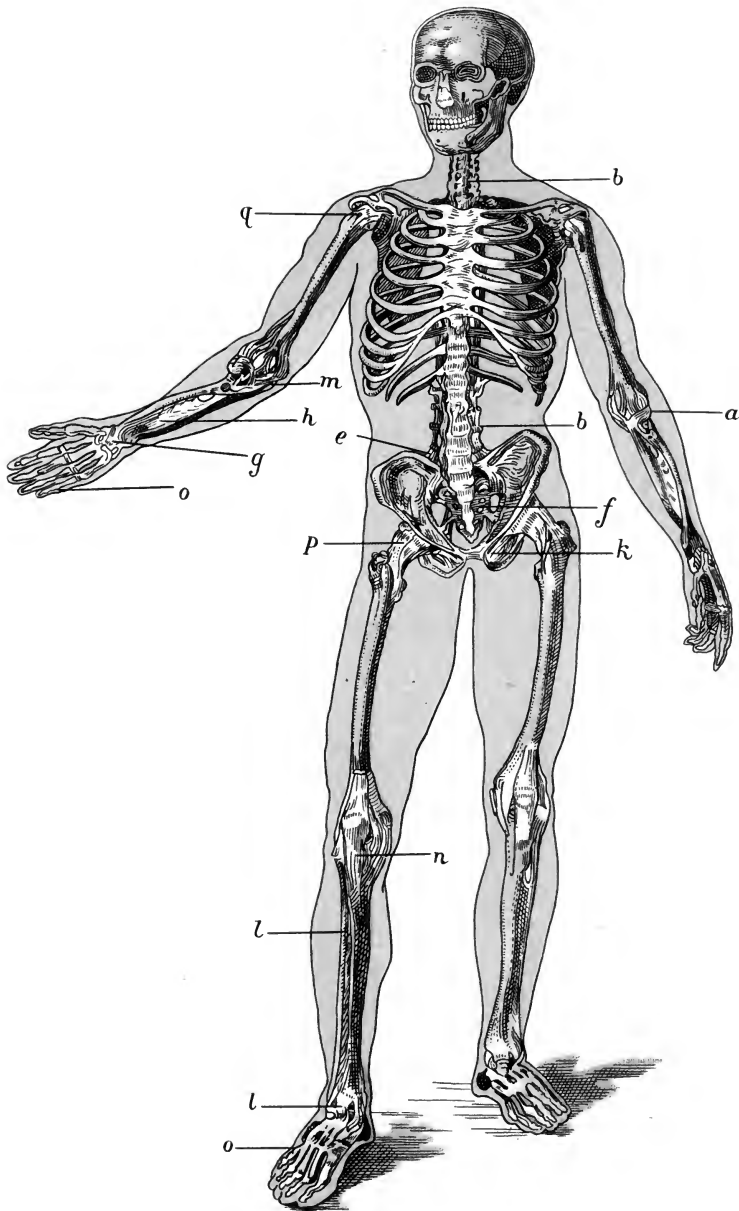
PLATE 1.—THE BONES, JOINTS, AND LIGAMENTS.

Injuries and deformities.—Because of the great strain to which the spine is often subjected, minor injuries and deformities are not uncommon. They are caused mainly by wrenching or tearing some of the ligaments, by bruising the articular surfaces, and by one-sided growth and development due to irregularities in the shapes and numbers of the bones, to faulty postures, or to the habitual carrying of heavy weights upon one
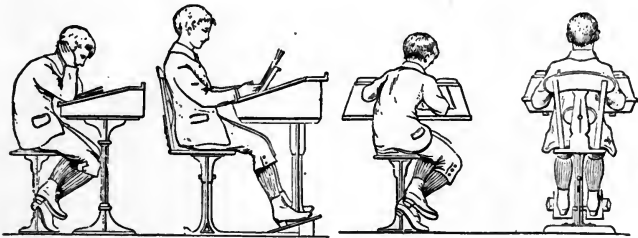
FIG. 13. Side and back views of correct and faulty positions at school desks. (Tubby.)

side of the body. Children who carry heavy babies are frequently deformed in this way.

Head.—The spinal column, which serves as the axis of the skeleton, is surmounted by the bones of the head. Here, man's difference from other animals is most pronounced, in that the face bones are smaller and the brain cavity, the cranium, is larger. The accompanying illustration shows more accurately than any description the shape and position of the cranial and face bones.

Appendages of the spine.—In addition to the vertebral column surmounted by the skull, the bony framework of the body also includes the *shoulder girdle,* the *ribs* and the *pelvic girdle.* The shoulder girdle carries the arms and consists of two shoulder blades or *scapulæ,* two collar bones or *clavicles,* and the breast bone or

sternum. The ribs arise from the dorsal vertebræ, en-
circle the chest and are united together in front by the
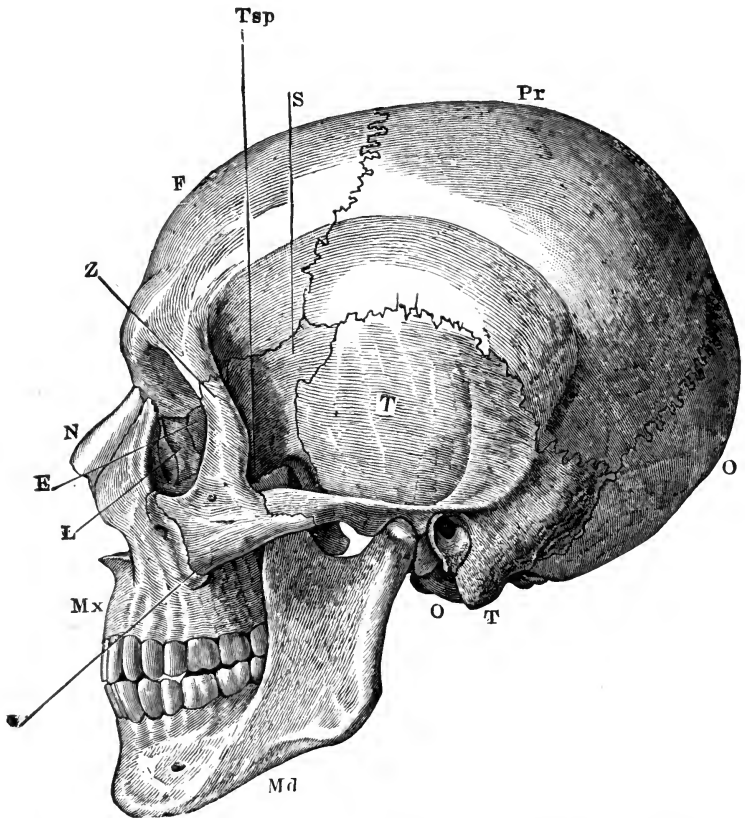
FIG. 14. A side view of the skull. O, occipital bone; T, temporal; Pr, parietal;
F, frontal; S, sphenoid; Z, malar; Mx, maxilla; N, nasal; E, ethmoid; L,
lachrymal; Md, inferior maxilla.

sternum. The pelvic girdle starts from the sacrum and
consists of the broad flaring bones of the hips, to which
the legs are attached.

Ribs.—Of these appendages of the axial skeleton,[1] the ribs are of great importance since they enclose and protect the heart and lungs. They also make breathing
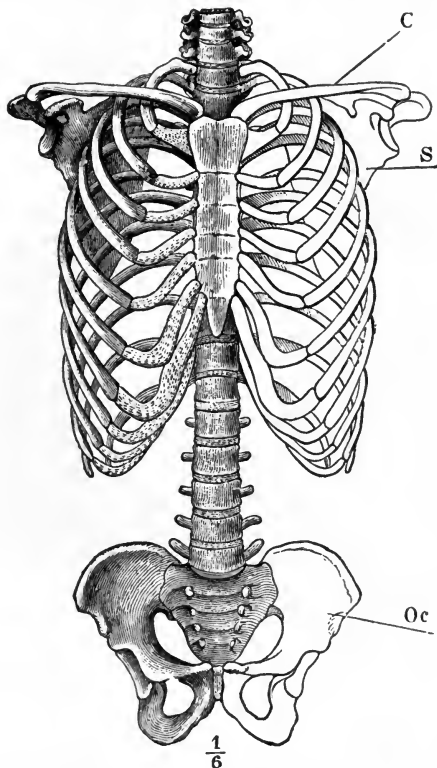
FIG. 15. The skeleton of the trunk seen from the front. C, clavicle; S, scapula; Oc, pelvic bone attached to the side of the sacrum dorsally.

possible by furnishing stiff yet movable walls for the chest cavity in which the lungs lie. Through the sternum

[1] The axial skeleton is that part of the skeleton which forms the central line or axis of the body.
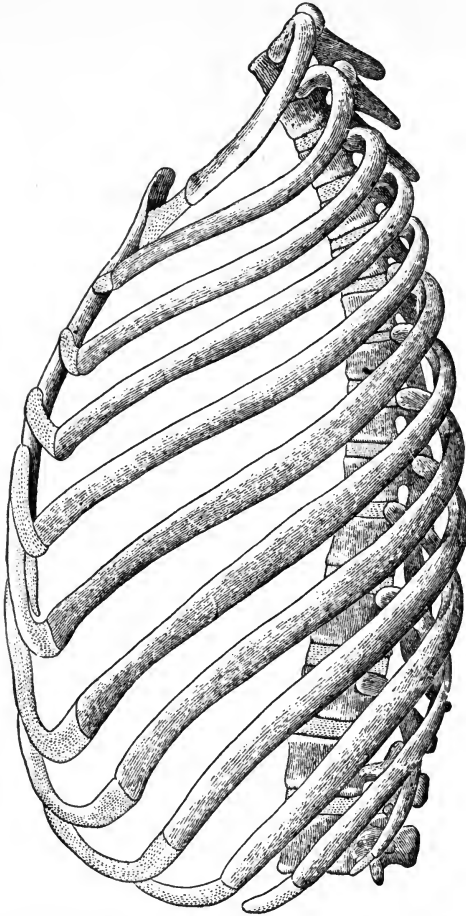
Fig. 16.   The ribs of the left side, with the dorsal and two lumbar vertebræ, the rib cartilages, and the sternum.

which unites the ribs in front, they further furnish the necessary bony support for the shoulder girdle and for the muscles which move the arms.

Shoulder girdle.—The shoulder girdle is made up of two parts, one for each side of the body. Each part consists of two bones, the scapula and the clavicle. The scapula is broad and flat and lies at the back of the shoulder. The clavicle is long and slender, and connects

Rib cartilage
Sternum

FIG. 17. Articulation of a pair of ribs to a vertebra and to the sternum.

the tip of the shoulder with the upper portion of the sternum at the root of the neck. Through the clavicle, the shoulder is attached on each side by means of ligaments to the top of the sternum. It is also held in place by powerful muscles which control the movements of the shoulders and arms.

Arm.—At the upper outer end of the scapula lies a shallow cup, into which the rounded head of the bone of the upper arm fits. The arm itself consists of two parts, the *upper arm* and the *forearm*. The upper arm

has but one bone, the *humerus*. The forearm contains two bones, the *ulna* and the *radius*. The expanded end of the ulna forms the elbow joint, into which the radius enters only with its small tip. At the wrist, on the contrary, the expanded end of the radius makes up most of the joint, the ulna in turn entering with its small end. This arrangement permits the extensive rotation of the hand which is most important for its free use.

Wrist.—The wrist is made up of a number of irregularly shaped block-like bones. They are small and are knit together by strong ligaments, so that they give considerable freedom of movement without loss of strength.

Hand.—The palm of the hand is formed of five slender bones, which lead from the wrist bones to the roots of the fingers. The first of these is tipped with two fairly stout bones, which form the thumb. Each of the remaining four bones carries three slender bones, which form the fingers.

The hand of man resembles that of the higher apes much more closely than does his foot, but it is superior to theirs in the position and flexibility of the thumb. To this, man owes a part of the power of delicately handling objects, which characterizes the use of his hands.

Pelvic girdle.—The pelvic girdle consists of two broad flaring bones which in front are joined together by ligaments and behind are also firmly connected by ligaments to the sacrum. In young children, as in many of the lower vertebrates, each of these two bones consists of three distinct bones. Their union gives a much firmer support for the legs and trunk.

Leg.—The legs are attached to the pelvic girdle by means of the hip joints. Each leg consists of two main

parts, the upper or *thigh*, and the lower or *leg*. The thigh consists of the longest and strongest bone in the
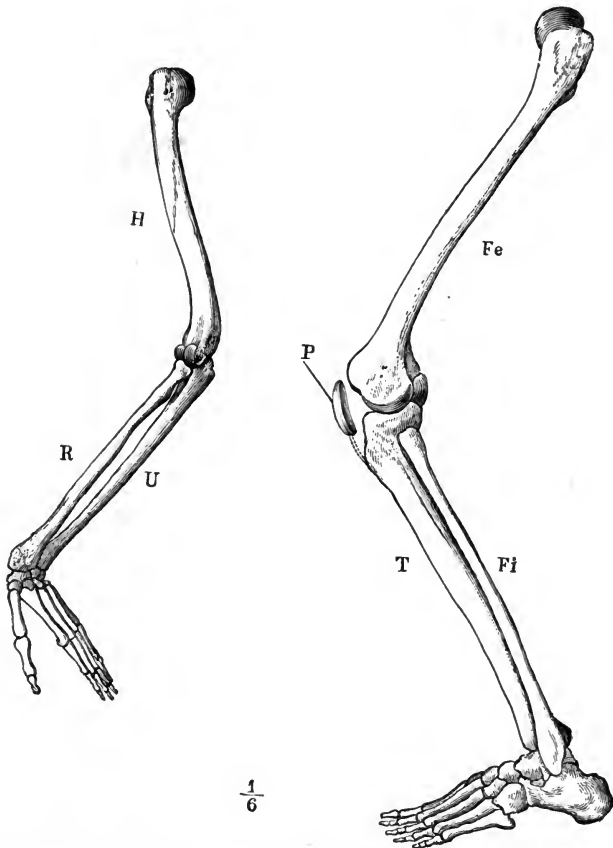
FIG. 18. Bones of arm and leg;—Fe, femur; Fi, fibula; H, humerus; P, patella; R, radius; T, tibia; U, ulna.

human body, the *femur*. The leg, like the forearm, has two parallel bones, the *tibia*, which is its main bone;

and the *fibula,* or slender splint bone.   The enlarged
ends of the femur and the tibia meet together to form
the knee joint.

Foot.—Connected with the lower ends of the tibia and
the fibula by means of the ankle joint are the bones of
the ankle.   They are a series of strong irregular block-
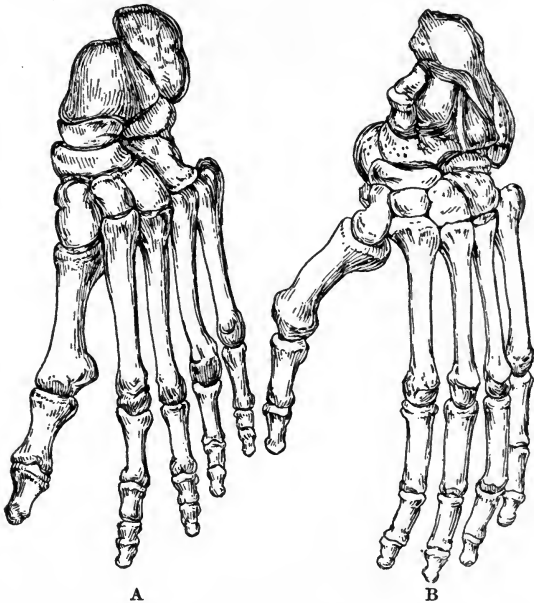
FIG. 19.   Skeleton of foot of a man (A) and a gorilla (B), showing the more
flexible ankle and prehensile big toe of the gorilla.

like bones, which are fastened firmly together by liga-
ments.   They form the ankle, heel and a portion of the
arch of the foot.   Jointed to the front of this series there
are five slender bones, which complete the arch and reach
to the ball of the foot.   As in the hand, the ends of the
second, third, fourth and fifth of these have three short

slender bones attached to them, which form the smaller toes. The first has two heavier and longer bones, which form the big toe.

The human foot differs markedly from that of man's nearest relatives in the animal world, the apes. It is so firmly knit together that, unlike theirs, it is nearly useless for grasping and for climbing. This disadvantage is more than counterbalanced, however, by the fact that its strength enables man to walk firmly upon his feet and thereby to maintain an upright posture.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Human skeleton; skeletons of monkey, cat (dog or rabbit), bird and fish; dissection of cat (dog or rabbit) with all flesh removed; lobster; crab; fly (spider); and clam (mussel).

1) Demonstrate the human skeleton as a whole and in detail.

2) Compare the human skeleton with those of a monkey, cat or dog, bird and fish.

3) Demonstrate the freshly dissected skeleton of a cat, dog, or rabbit, to show bones, ligaments and joints.

4) Compare the skeleton of a vertebrate with those of a lobster, crab, fly (spider) and clam (mussel).

5) Imitate the natural shoulder movements upward, forward and backward, with the skeleton. Carefully compare those made with the body with those made with the skeleton, noticing in detail the movements of clavicle and scapula.

6) Imitate in like manner the various movements of the arms and hands. Write them out and illustrate.

CHAPTER III

BONES, JOINTS AND LIGAMENTS

Purpose of the skeleton.—The purpose of a skeleton is to maintain the shape of the body in spite of its weight and the pull of its muscles. To serve this purpose, the bones must be rigid, strong and light. Their strength and rigidity they owe to the material of which they are made. Their lightness in proportion to their strength is due to the fact that they are hollow.[1]

Composition of bone.—Bones contain about sixteen per cent of an animal substance called *collagen*, which

Cancellated bone   Periosteum of shaft   Ivory bone.
Epiphyseal line   Medullary canal
Epiphysis
Articular cartilage
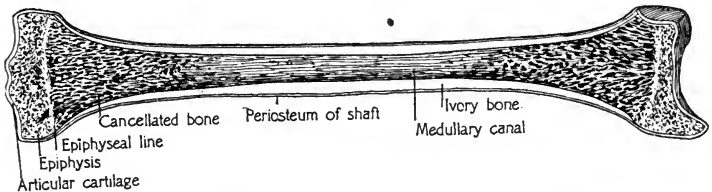
FIG. 20. Longitudinal section of long bone (tibia), showing structure.

when boiled becomes gelatine; thirty-four per cent of earthy matter, chiefly salts of lime; and the remaining fifty per cent, water. To the collagen, the bone owes its toughness; to the salts of lime, its rigidity and hardness. Although bone without moisture might possess the advantage of increased lightness in proportion to its

[1] Hollow stems, like hollow bones, are found throughout nature, as in grass, grains, reeds and bamboo. In manufactures, man has imitated this, as in the bicycle frame, which combines great strength and lightness.

strength, yet without moisture the bones could not remain alive, grow and repair themselves when injured. The collagen represents the part of the bone which has life. The earthy part is simply a deposit of salts of lime made by the living part.

Changes from infancy to old age.—The composition of bone undergoes certain changes with age. In

FIG. 21. Greenstick fracture of bones of left forearm. (Scudder and Cotton.)

FIG. 22. Fracture of bones of left forearm. (Scudder and Cotton.)

childhood, there is more of the animal matter and less of the lime salts than in the adult. The bones of a child are therefore more flexible and less easily broken. Even when a bone is broken, the break usually does not extend across it but makes what is called a greenstick fracture. In adult life, on the contrary, the deposit of earthy

matter is sufficient to give a maximum of strength and
rigidity to the bone. It therefore requires greater force
to break the bones of an adult and the break is com-
plete. In old age, the earthy material increases still
more in proportion to the animal matter and, as a result,
the bones become more brittle and are not apt to heal
as readily when broken.

Shapes of bones.—The forms of bones differ accord-
ing to their position and use in the skeleton. Those of
the arm, leg, palm, finger, arch of the foot, and toes
are called *long bones,* because they have relatively long
shafts. All the long bones have enlarged ends which
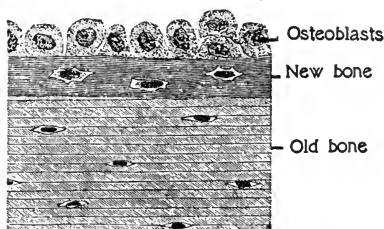
Fig. 23. The formation of new bone on the surface of old bone by means of a
layer of osteoblasts.

form joints. The block-shaped bones of the wrist and
ankle, on the contrary, have the enlarged joint ends
but no shafts and are therefore called *short bones.* The
vertebræ are essentially short bones but they possess so
many extensions or processes that they have earned
the name of *irregular bones.* The sternum and bones
of the skull, which are each formed of two dense bony
plates united by a layer of spongy (*cancellated*) bone,
are called *flat* or *tabular bones.* The ribs are also ordi-
narily classed as flat bones in spite of their length, be-
cause they are built in the same way.

Building of bone.—The structure of bone can best be understood, if its growth and development are studied. The long bones take shape in a gristly substance called *cartilage,* which like collagen yields gelatine when boiled. The cartilage is then stiffened by a
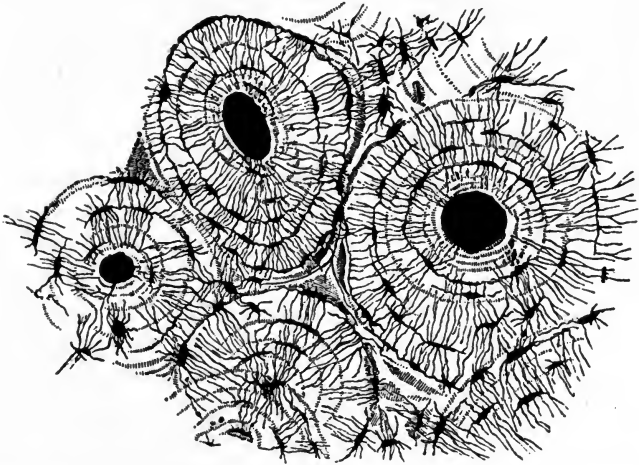
Fig. 24. A small piece of bone, ground very thin and highly magnified, showing central canals for blood-vessels and bone cells with connecting filaments.

deposit of lime salts, and at the time of birth this stiffened cartilage constitutes the bone. Soon after birth, this is eaten into by large independent cells,[1] which make a sort of honeycomb of it. Another army of cells [2] builds this honeycomb full of layers of bone, in which many of them become buried. The original cartilage which formed the wall of the honeycomb is also eventually changed into true bone.

Growth of long bone in length.—The way in which the bones when once formed grow, depends somewhat

[1] The *osteoclasts.*   [2] The *osteoblasts.*

upon whether they are long, short, or flat. The increase
of the long bone in length is provided for by a continu-
ous growth of cartilage just within the ends, or *epiph-
yses*, of the bone, which as fast as it grows is honey-
combed and built into true bone. At the age of from
seventeen to twenty, the cartilage ceases to form and
bone growth stops.

Growth in thickness.—The growth in diameter of
the bone from the slenderness of childhood to the thick-
ness of the adult, takes place under the tough mem-
brane, the *periosteum,* which encloses the entire bone.
The periosteum deposits layers of bone beneath itself,
thus building up the outside as it grows in length. As
the bone becomes thicker through the deposits by the
periosteum, its central portion is hollowed out. The
central or *medullary canal* running through the shaft of
each long bone is thus formed and kept proportionate to
its size. In this way, the size and strength of the bone
are greatly increased, whereas its weight is kept down.[1]

Growth of short bone.—The growth of short bones
is in general similar to that of long. Their structure,
however, is spongy rather than dense and they have no
definite central canal.

Growth of flat bone.—The flat bones develop chiefly
from the periosteum, instead of from the cartilage which
forms the starting point of both long and short bones.

Ends of bones.—The enlarged ends of bones which
form joints have a spongy structure with no central
canal. When these ends are sawed open, it is seen that
the sponginess is due to an arrangement of interlacing

---

[1] In most animals, the central canal is filled, if the animals are
young, with blood-forming tissue, the *red marrow;* if the animals
are mature, with fat, the *yellow marrow.* In birds, the bones are
partially filled with air, thus giving greater lightness.

arches and supporting trusses of bony tissue, which branch out from the dense bone of the shaft. This expansion distributes over a broad surface the pressure between the ends of the bones, and also gives a wide foundation for the attachment of the ligaments and muscles.

Structure of a joint.—The joint ends of the bone are further adapted to slip easily upon one another and are protected from injury by a thin cushion of smooth elastic cartilage, the *articular cartilage*. The articular cartilage is kept moist and slippery by a thin fluid, the *synovial fluid,* which is secreted by a sleeve of membrane called the *synovial membrane*. This membrane, which makes a closed cavity of the joint, is so loose that it is not stretched or torn by any movements of the joint. Normally, the amount of fluid secreted is small, but in diseased conditions or after injury the secretion may be so increased as greatly to distend the synovial membrane and the surrounding ligaments. When this happens in the knee joint, it is popularly called water on the knee.

Range of movement.—Some joints permit but a slight slip, such as that which occurs between the sacrum and the hip bone. Others have a wider but still comparatively restricted movement, as in the knuckles of the fingers. Still others have a relatively free movement, as the shoulders. The main exceptions to the presence of joints at the points of contact between bones, are found in the skull, where the bones are so firmly held by the interlocking of their jagged edges that all movement is made impossible soon after birth; in the pelvic bones, which in youth become perfectly blended to form the hip bones; and in the sacrum, which, as we have seen, results from the very early fusion of five vertebræ.

Characteristics of a true joint.—The three charac-
teristics of a true joint are the smooth cartilage-covered
ends of the bones; the synovial membrane; and the liga-
ments, which completely enclose the joint and, while
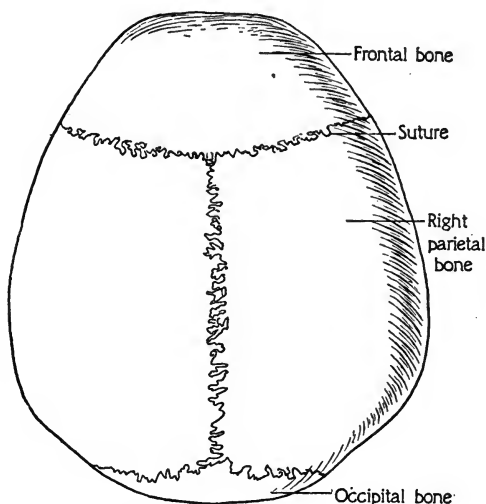
Fig. 25. The skull viewed from above, showing arrangement of bones and method
of locking together.

permitting natural movement, are tough and tight
enough to prevent any movement harmful either in
direction or extent.

Kinds of joints.—Joints are classified according to
their range and character of movement, which depend
upon their shape and the arrangement and tightness
of the ligaments. The joints permitting the greatest
range are the *ball-and-socket* joints, in which the
rounded head of one bone moves in the hollow socket of
another. Their capsular ligaments are sufficiently loose
to allow the ball to move freely in its socket up to the

point at which it might be pried out, or *dislocated*. At that point, the ligaments on the farther side of the joint become tight and thereby prevent dislocation. Examples
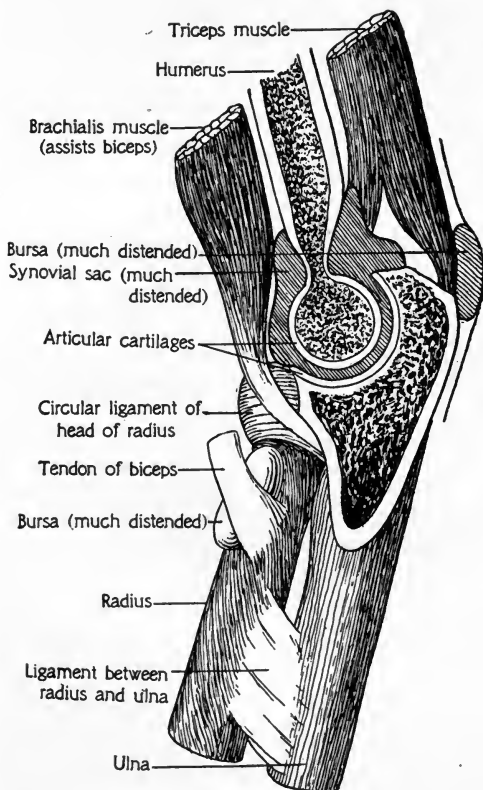
FIG. 26. Section of elbow, showing both a hinge joint (humerus and ulna), and a pivot joint (radius and ulna). (The surfaces of the elbow joint are shown unnaturally separated, and the synovial sac and bursæ injected with fluid.)

of ball-and-socket joints are the shoulder and hip and in a measure the knuckles.

Hinge joints.—Joints which have free motion in but one direction, as in the elbow, the knee and the first and second joints of the fingers, are called *hinge joints*. Usually in this class of joints, the ends of the bones have more or less perfect ridges which tend to strengthen the joint against any sidewise slip. They also have strong tight ligaments at the sides.

Knee joint.—The knee joint, although classed among the hinge joints, is somewhat complicated by the
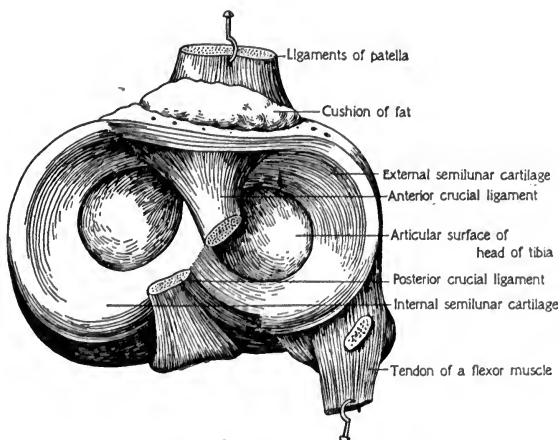
Fig. 27. Right knee joint, showing the cartilages and ligaments attached to head of tibia.

various additional structures necessary to protect and strengthen it, because of its exposed position and the heavy weight which it is called upon to bear. Upon either side are loose pads of cartilage,[1] which serve to cushion the ends of the bones and protect them against side strain. For further protection, the kneecap or

[1] The *semilunar cartilages*.

patella [1] is inserted into the tendon which runs from the thigh muscle over the front of the knee to the tibia. The patella is a flattened rounded bone, which protects
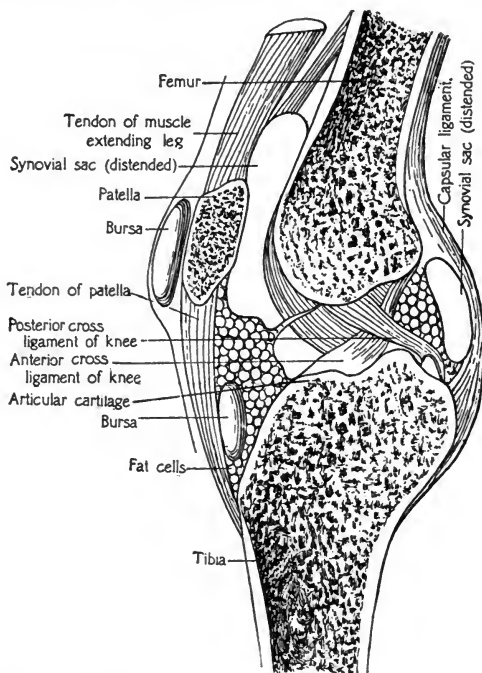
FIG. 28. Cross section of knee, showing the various structures which make up the knee joint (somewhat diagrammatic).

the tendon and to some extent the knee joint also. It is, however, itself subject to rather frequent injury on account of its exposed position.

[1] The patella is really a specialized part of the tendon itself, developed for the purpose of making the tendon better able to withstand contact with objects. Similar examples of the development of bone in tendons is found in other places where tendons are liable to injury, as under the second joint of the big toe.

Pivotal joints.—Another form of motion in one direction is that permitted by the *pivotal joints,* in which the

movement is rotary, as on a pivot. An example of a pivotal joint is that between the first and second cervical vertebræ, which permits the head to turn from side to side. Another example is the joint at the elbow end of the radius, which turns as a pivot within a circular ligament at the side of the ulna and thereby allows the palm of the hand to turn either up or down.
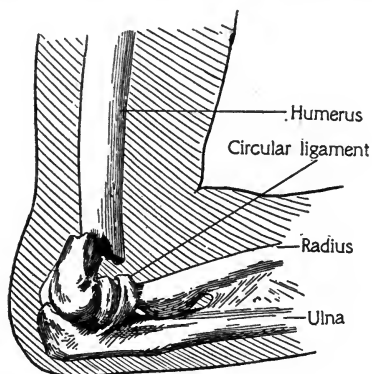
Fig. 29. Fracture of humerus. (Scudder and Cotton.)

Sliding joints.—Other forms of joints, such as those between the articular processes of the vertebræ, permit a sliding movement and are therefore called *sliding joints.* Still others, like the joints between the bodies of the vertebræ, allow merely a slight tipping in all directions. In the case of the vertebræ, this would seem to be largely a rocking motion upon the pads of elastic cartilage between the bones, rather than a true slip of the joint surfaces.

Ligaments.—The supporting ligaments, which are so important in every joint structure, take the form of a sleeve or capsule, which encloses the ends of the bones and is called the *capsular ligament.* Besides the capsular ligament, most joints have additional ligaments which strengthen them where necessary. All ligaments con-

sist of fine fibres of tough, flexible and inelastic tissue, which run from bone to bone across the joint.[1]

Kinds of movement.—The various kinds of movement which joints permit us to make with our limbs are chiefly bending, or *flexion;* straightening, or *extension;* turning as on an axis, or *rotation;* moving away from the middle of the body, or *abduction;* towards the middle line, or *adduction;* and swinging in a circle, or *circumduction.*

Joint injuries.—Joints are points of weakness in the skeleton, as shown by the fact that injuries to them are much more numerous than to bones. Their weakness is due to the difficulty of combining freedom of movement with strength. When a severe wrench is given a joint from which pain and swelling result, it is said to be *sprained.* In sprains, the fibres of the ligaments are more or less torn and their blood-vessels are ruptured. If the injury is severe, there is swelling and subsequent black and blue discoloration, due to the blood

Fig. 30. Dislocation of elbow. (Scudder and Cotton.)

which has escaped from the ruptured blood-vessels. Sprains heal slowly and may require even more careful and prolonged treatment than fractures, in order to prevent permanent stiffness and weakness.[2]

[1] Where the capsular ligaments are loose, as at the elbow, there is great danger of their being pinched when the joint is flexed or extended. To avoid this, muscle fibres are inserted to pull the loose portion of the capsular ligament out of the joint.

[2] In sprains, the ends of the bones are sometimes fractured. If

Dislocation.—When the bones forming a joint are put under such severe strain that they are pried or pulled out of place, the joint is said to be *dislocated*. In the case of most joints, dislocation is accompanied by more or less tearing of the capsular ligaments, and at times even by injury to the ends of the bones.

Bone-building materials.—The earthy material for the building of bones is present in all food in small but sufficient quantities for normal growth and constitutes a portion of the ash which remains when food is burned. Although all foods contain a certain amount of bone-building material, some contain more than others.[1]   It is therefore of the greatest importance, especially during such a period of rapid growth as early childhood, to have food which will give the bones proper nourishment.   Although pure milk, for example, is a sufficient food for infants, yet when the child at the age of from eight to ten months becomes active and supports his weight by his bones in sitting, standing and walking, milk should be supplemented by cereals and fruit juices.   If this is not done, the bones are frequently so poorly built that they bend under the weight of the child and he becomes bow-legged, knock-kneed, or flat-footed, and may even have deformed arms and a crooked back.[2]   Plenty of wholesome food, fresh air and sunshine

this complication is overlooked, as frequently happens, the seriousness of the sprain is greatly aggravated.

[1] See table of food materials, p. 86.

[2] A similar condition of weakness of bones arises even more frequently when the food of babies is limited to certain infant foods which are largely modified starch and so fail to give the other constituents of a complete diet.   Many parents are deceived by the resulting fatness of the baby and do not realize that a child may be fat and yet be weak, because it is being deprived of necessary food constituents.   The excess of fat is even a great disadvantage, because it overburdens weak bones, which normally are none too strong in a child who is just beginning to walk.

will lead to a strong and complete growth of the bones and a fine development of the body as a whole. Poor food and bad air have a distinctly stunting effect upon bone as upon other growth.[1]

EXPERIMENTS AND DEMONSTRATIONS

Materials: Bones of the hind leg of a lamb sawed lengthwise through the joints; pieces of fresh ivory bone, such as the thin bones found in the legs of fowls; pieces of dry ivory bone; hydrochloric acid; ammonia; piece of sheet iron; weighing balance; human skeleton such as may be purchased for $25 or $30; microscope.

1) *Structure of a long bone:* Demonstrate position and arrangement of dense (ivory) and cancellated bone; the medullary canal; joint ends with epiphyses; articular cartilage; the periosteum; red and yellow marrow; and the microscopic structure of bone.

2) *Composition of bone:*

a) Boil a piece of fresh bone in water to extract gelatine.

b) Burn a piece of fresh bone to destroy animal matter.

c) Put a piece of burned bone and a piece of fresh bone into dilute hydrochloric acid (1 part acid to 3 parts water) and let stand 2 days, in order to remove the earthy matter.

3) *Proportions of water and solid in fresh bone:* Break a piece of bone into small fragments, weigh; then dry in a current of warm air to a constant weight and determine loss.

4) *Proportions of animal and mineral matter in dry bone:*

a) Weigh a piece of dry bone, burn on a piece of sheet iron over live coals or over Bunsen burner, and reweigh.

b) Second method: Weigh, dissolve in 10 per cent hydrochloric acid, dry in a warm place for 3 or 4 days to obtain a constant weight, and determine loss.

c) Demonstrate the presence of mineral matter in the solution of b) by precipitating it with ammonia.

5) *Structure of joint:* Demonstrate by dissection the capsular and reinforcing ligaments; the synovial fluid; the articular cartilage; the function of ligaments.

[1] If the vitality of the bones is weakened, they seem predisposed to disease. The most common disease of bones in childhood is tuberculosis, which forms destructive abscesses in the bones and joints, and thereby causes marked deformities.

CHAPTER IV

MUSCLES AND TENDONS

Muscles.—The bones of the skeleton are moved by the muscles, which form the chief bulk of the limbs and of a considerable portion of the trunk and give to the body its rounded graceful form. Many of them are immediately under the skin, so that we can feel them as they work. If, for example, we grasp with our left hand the large muscle which lies between the shoulder and the elbow on the front of the arm, the biceps, and then pull and push against some object, we can trace the muscle from its origin in the shoulder to its insertion upon the radius. We can also feel the difference between the soft elastic belly of the muscle when relaxed and its hardness when contracted.

Structure. — The structure of muscle can be studied in the flesh of animals, especially in cross section as in a steak. The mass of muscle is seen
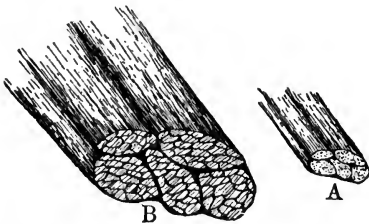
Fig. 31. A small bit of muscle composed of five primary fasciculi. A, natural size ; B, the same magnified, showing the secondary fasciculi of which the primary are composed.

to be made up of fairly large sections, an inch or two in diameter, which can be pulled apart easily, since they are held together only by delicate fibres of connective tissue with a certain amount of fat interspersed.

Muscle fibres.—The large muscle sections are made up of smaller divisions, the *fasciculi*. Under the micro-

scope, the fasciculi are seen to be bundles of fibres packed tightly together. These fibres, when traced throughout their length, are found to be slender hair-like cells about one and a half inches long and one-thousandth of an inch in diameter, crossed by many dark and light bands and covered with a thin membrane. Each fibre in turn consists of many much finer contractile threads, the *fibrils*.

Tendon fibres.—To one or both ends of each of the muscle fibres is usually attached a fine silky thread of
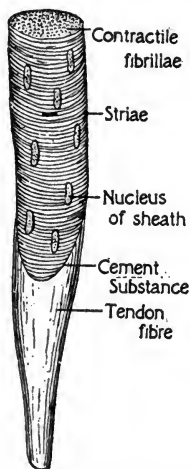
Fig. 32. End of striated (voluntary) muscle fibre, showing its attachment to tendon fibre.
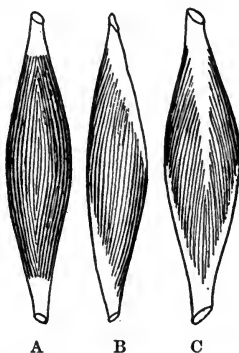
Fig. 33. Diagram showing arrangement of muscle fibres in relation to their tendons: A, in muscles contracting through a considerable distance; B, in muscles of shorter and more powerful contraction; C, in muscles of very short and powerful contraction.

tough inelastic material, the *tendon fibre*. Since the muscle fibres are usually much shorter than the muscle itself, these threads have to run well up into the muscle in order to reach the ends of the fibres. By blending together, they form the strong hard continuation of the muscle, the *tendon*, which joins the muscle to the bone.

Union of muscle and tendon.—The large majority of muscles have but one tendon, which is at the outer end, or insertion, of the muscle. The inner end, the origin, of the muscle is attached directly to the bone. At the origin, the muscle fibres are attached to the bone by means of a cement so strong that, in spite of the tremendous pulls to which it is subjected, it seldom or never gives way. The other ends of the muscle fibres are cemented to the tendon fibres, which in turn are cemented to the bone.

Advantages of tendons.—An important purpose of the tendon is to economize space, since a slender tendon is strong enough to carry the pull of a powerful muscle over a joint or series of joints, as in the case of the muscles of the forearm which move the fingers. If it were not for the tendons, bulky muscles would be required wherever movement was necessary, even in the fingers and toes. Tendons are furthermore so flexible and slippery that they readily pass around corners, as in the ankle, without any appreciable loss of power through friction.

An examination of the arms shows that the muscles which move it lie upon the trunk and are not carried by the arm in its movement. The muscles which move the forearm lie upon the upper arm and as close to the shoulder as possible. In like manner, the muscles which move the wrist, palm and fingers are placed not in the hand but upon the forearm close to the elbow. The long tendons make it possible thus to bring the weight of the muscles upon the more slowly moving parts of the limbs. Upon this distribution of weight, ease and quickness of movement depend.

Control of joint movements.—Wherever in the human skeleton a joint is found, the movement of the
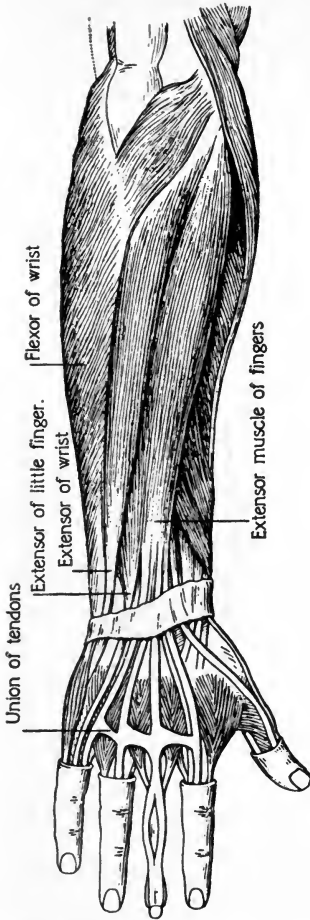
FIG. 34. Back of forearm and hand.
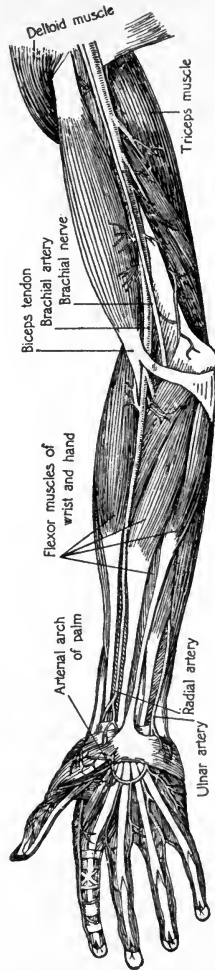
FIG. 35. Front of right arm, showing muscles, tendons, arteries and nerve.

bones which enter into it is perfectly controlled by the pull of the muscles. The number of muscles about each

joint depends largely upon the amount of motion permitted in it. In a simple joint, for example, such as
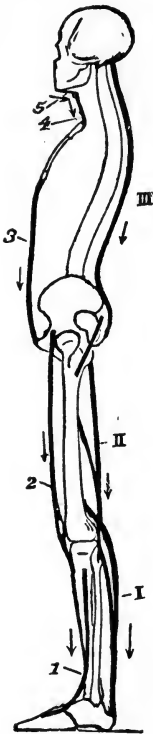
FIG. 36. Diagram illustrating the muscles (drawn in thick black lines) which pass before and behind the joints, and by their balanced contraction keep the joints rigid and the body erect.
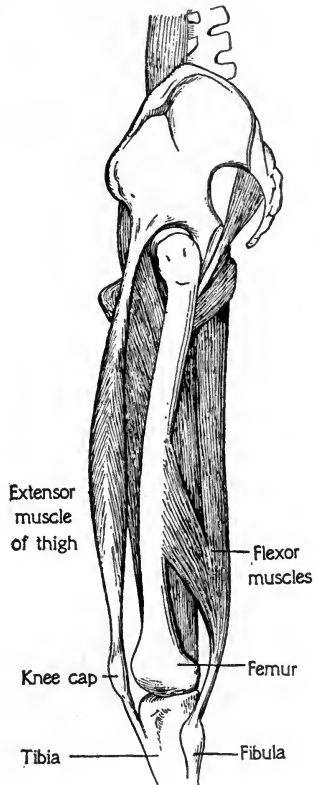
FIG. 37. Flexor and extensor muscles of the left thigh (somewhat diagrammatic).

the hinge joint in the finger which permits only flexion and extension, but two controlling muscles are essential, a flexor and an extensor. In a ball-and-socket joint,

such as the shoulder, a larger number of muscles is necessary to insure exact and powerful control. In general, muscles are arranged in pairs, so that each muscle as it lies on one side of the joint has on the other side an opposing muscle ready to pull the bone in the opposite direction. In many cases where powerful action is required, the principal pair of opposed muscles is reinforced by assisting muscles. Sometimes, there are as many as four or five muscles on one or both sides of a joint, as in the knee.[1]

Production of energy.—During muscular activity, animals give off in their breath an increased amount of carbon dioxide,[2] which is produced by the union of the oxygen that they breathe with the carbon in the food that they eat. This union is a form of combustion, or *oxidation*, and like all combustion sets free energy, which in the case of the muscles is partly muscular energy and partly heat. In addition to the carbon, other food materials are brought to the muscles by the blood and are oxidized by them for the production of energy.[3] The muscle is able to convert one-third of the total energy developed by the combustion into a definite pull upon the bones, whereas the best steam engines are able to convert only one-sixth of the total force produced by the combustion of their fuel into effective work.

Nerve control.—In order that a muscle may develop energy, its cells must be stimulated by their nerves. When the main nerve leading to a muscle is injured or cut, the muscle is unable to work, it becomes soft and

---

[1] On the front of the thigh, one very large muscle extends the leg; at the back, five much smaller muscles flex it.

[2] Carbon dioxide (CO_2) equals 1 part of carbon to 2 of oxygen. (See Appendix A, p. 316.)

[3] Each cell of the muscle acts as a separate little engine for the generation of this power.

soon begins to waste away, or atrophy. In other words, the muscle is paralyzed and cannot act.

Tonicity.—In a healthy muscle with its nerve uninjured, we find a constant slight elastic resistance, or tension, which persists even when the muscle is not contracted. This tension is called the *tonicity* of the muscle, since it gives it the elastic tone characteristic of health. It is due to a continuous but very slight contraction of the muscle. The contraction is in turn due to a constant slight stimulation of the muscle by its nerve and a consequent continuous setting free of energy by combustion. Each muscle, even when idle, is thus given sufficient exercise to keep it in a healthy condition. Moreover, by being kept tense, it is instantly ready for action. The constant combustion is further useful in helping to keep the body warm during inactivity and sleep.[1]

Clavicle
Scapula
Short head of biceps
Long head

Biceps

FIG. 38. Lengthening of biceps when arm is extended.

Voluntary muscles.—Most of our muscles are under our control and can be made to do what we will. Because of this, they are called *voluntary* muscles. They

[1] When the body is chilled, the shivering which results consists of the rapid contraction of many muscles. Its purpose is to develop heat enough to warm the body.

EXPLANATION OF PLATE II.

A view of the muscles situated on the front surface of the body seen in their natural position. It must be understood that beneath these muscles many others are situated, which cannot be represented in the figure.

Muscles of the Face, Head and Neck:

1. Muscle of the Forehead. This, together with a muscle at the back of the head, has the power of moving the scalp.
2. Muscle that closes the Eyelids. The muscle that raises the upper eyelid so as to open the eye is situated within the orbit, and consequently cannot be seen in this figure.
3, 4, 5. Muscles that raise the Upper Lip and angle of the Mouth.
6, 7. Muscles that depress the Lower Lip and angle of the Mouth. By the action of the muscles which raise the upper lip, and those that depress the lower lip, the lips are separated.
8. Muscle that draws the Lips together.
9. Muscle of the Temple (Temporal Muscle).
10. Masseter Muscle. 9 and 10 are the two chief muscles of mastication, for when they contract the movable lower jaw is elevated, so as to crush the food between the teeth in the upper and lower jaws.
11. Muscle that compresses the Nostril. Close to its outer side is a small muscle that dilates the nostril.
12. Muscle that wrinkles the Skin of the Neck, and assists in depressing the lower jaw.
13. Muscle that assists in steadying the Head, and also in moving it from side to side.
14. Muscles that depress the Windpipe and Organ of Voice. The muscles that elevate the same parts are placed beneath the lower jaw, and cannot be seen in the figure.

Muscles that connect the upper extremity of the trunk. Portions of four of these muscles are represented in the figure, viz.:

15. Muscle that elevates the Shoulder (Trapezius Muscle).
17. Great Muscle of the Chest, which draws the Arm in front of the Chest (Great Pectoral Muscle).
18. Broad Muscle of the Back, which draws the Arm downwards across the back of the Body (Latissimus Dorsi).
19. Serrated Muscle, which extends between the Ribs and Shoulder blade, and draws the Shoulder forwards and rotates it, a movement which takes place in the elevation of the arm above the head (Serratus magnus).

At a lower part of the trunk, on each side, may be seen the large muscle which, from the oblique direction of its fibres, is called

20. Outer Oblique Muscle of the Abdomen.

Several muscles lie beneath it. The outline of one of these,

21. Straight Muscle of the Abdomen, may be seen beneath the expanded tendon of insertion of the oblique muscle. These abdominal muscles, by their contraction, possess the power of compressing the contents of the abdomen.

Muscles of the upper extremity :

16. Muscle that elevates the Arm (Deltoid Muscle).
22. Biceps or Two-headed Muscle (see also page 46).
23. Anterior Muscle of the Arm. This and the Biceps are for the purpose of bending the Forearm.
24. Triceps, or Three-headed Muscle. This counteracts the last two muscles, for it extends the Forearm.
25. Muscles that bend the Wrist and Fingers, and pronate the Forearm and Hand—that is, turn the Hand with the palm downwards. They are called the Flexor and Pronator Muscles.
26. Muscles that extend the Wrist and Fingers, and supinate the Forearm and Hand—that is, turn the hand with its palm upwards. They are called the Extensor and Supinator Muscles.
27. Muscles that constitute the ball of the thumb. They move it in different directions.
28. Muscles that move the Little Finger.

Muscles which connect the lower extremity to the pelvic bone (several are represented in the figure) :

29. Muscle usually stated to have the power of crossing one Leg over the other, hence called the Tailor's Muscle, or Sartorius; its real action is to assist in bending the knee.
30. Muscles that draw the Thighs together (Adductor Muscles).
31. Muscles that extend or straighten the Leg (Extensor Muscles). The muscles that bend the Leg are placed on the back of the thigh, so that they cannot be seen in the figure.

Muscles of the leg and foot :

32. Muscles that bend the Foot upon the Leg, and extend the Toes.
33. Muscles that raise the Heel—these form the prominence of the calf of the Leg.
34. Muscles that turn the Foot outwards.
35. A band of Membrane which retains in position the tendons which pass from the leg to the foot.
36. A short muscle which extends the Toes.

The muscles which turn the foot inwards, so as to counteract the last-named muscles, lie beneath the great muscles of the calf, which consequently conceal them. The foot possesses numerous muscles, which act upon the toes, so as to move them about in various directions. These are principally placed on the sole of the foot and they cannot therefore be seen in the figure. Only one muscle, 36, which assists in extending the toes, is placed on the back of the foot.
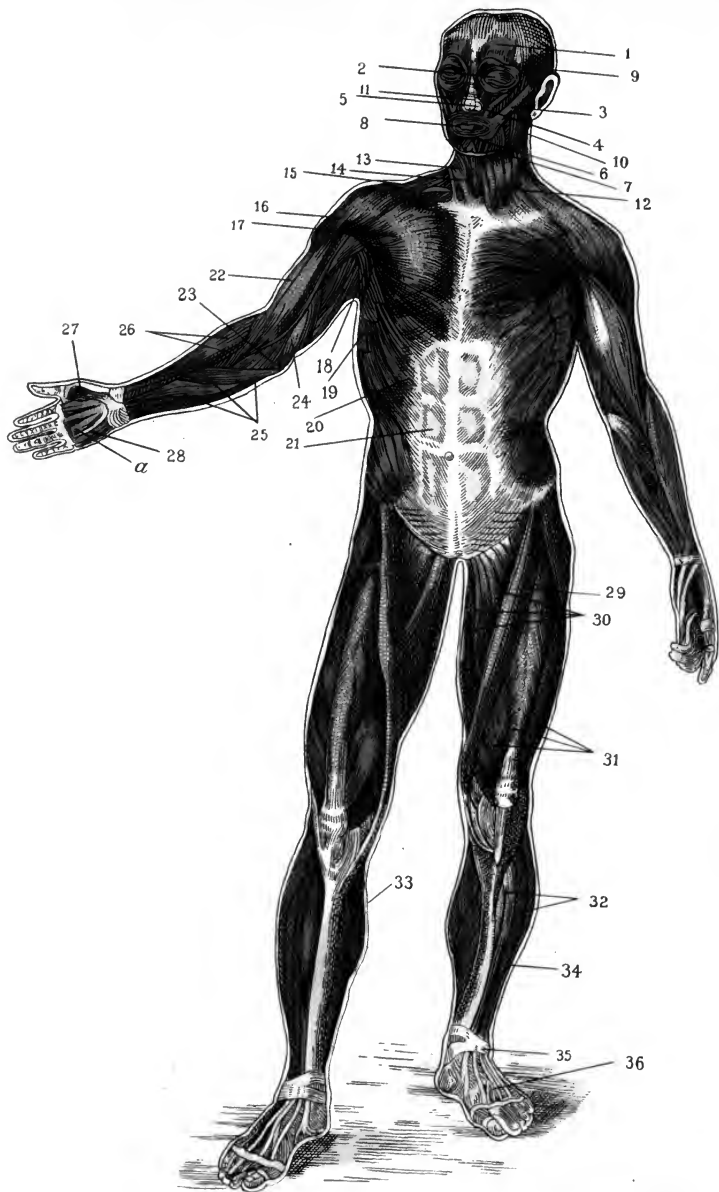
PLATE II.—THE SUPERFICIAL MUSCLES OF THE FRONT OF THE BODY.
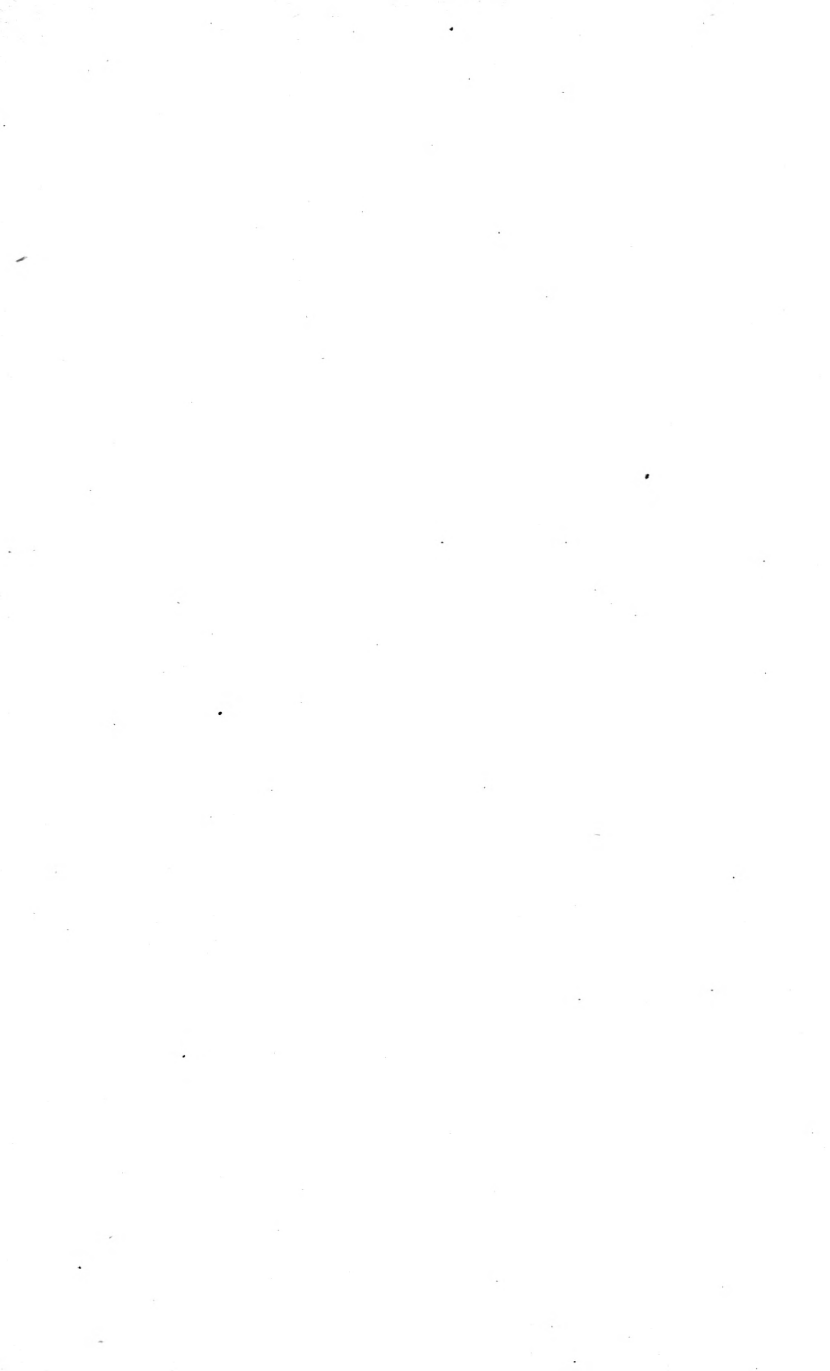
are made up, as we have seen, of slender fibres having a characteristic cross-striped, or striated, appearance. When they contract, their fibres become shorter and thicker, thus shortening and thickening the muscle as a whole. The time required for contraction may be very slow or as quick as one-tenth to one-twentieth of a second. All muscles connected directly or indirectly with the bones are classed as voluntary.

Involuntary muscles. —The muscles in the walls of the stomach, intestines and blood-vessels are independent of the control of the will and are therefore called *involuntary.* They differ from the voluntary

Fig. 39. Contraction of biceps to flex arm.

in that they are comparatively short, are non-striated or "smooth," and require as long as from ten to sixty seconds for a complete contraction.

Comparison of voluntary and involuntary muscles. —The distinction between the voluntary and the involuntary muscles cannot be drawn too closely, since, although they differ markedly from each other in size and structure, yet the voluntary muscles may act involuntarily. A good illustration of this is seen in the movements due to sudden danger, as in winking or starting at a noise. Although the muscles controlling these movements are usually under voluntary control, yet in times of danger they may act so quickly for the protection of the body that interference by the will is impossible. This is also true of many other muscles,

as, for example, those which cause the movements of the chest in respiration. These muscles seem thoroughly under the control of the will, since we can prolong, shorten, or even stop breathing for a time. There is, however, a point where the voluntary control is mastered by the involuntary and we are forced to breathe and not suffocate.
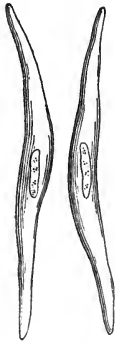
FIG. 40. Isolated smooth muscle fibres.
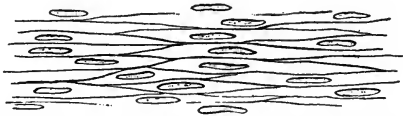
FIG. 41. Smooth or involuntary muscle fibres, showing their arrangement.

Heart muscle.—In addition to these two types of muscle structure, there is a third found only in the heart, which somewhat resembles both. Its cells are striped like those of the voluntary muscles and yet its action is like that of the involuntary muscles, since it is not under the control of the will. It contracts more quickly than the involuntary and yet not so quickly as the voluntary.

Effect of work.—The muscles do an amount of work far beyond our comprehension, as we shall see in our study of motion and locomotion. They thrive upon hard work and grow larger and stronger as the demands upon them increase, provided only that they are not exhausted by overwork. Conversely, when the demands upon them are slight, they become smaller and weaker. Contrary to popular belief, however, they are never completely lost through disuse, because, even when they are idle, there is yet sufficient tonic contraction to main-

tain them. Thus, in spite of thousands of years of disuse, we still retain the muscles which presumably at some time moved the ears of our ancestors.

Influence upon other organs.—As we have seen, the muscular energy of animals and man is derived from the combustion of the food materials furnished by plants and animals. A sufficient diet is therefore essential, if our muscles are to do their work easily and well. Since the muscles constitute a large part of the active tissues of the body, a correspondingly large proportion of the food which we eat finds its way to them. The digestive system prepares this food for their use. The blood conveys it to them and takes away the waste products of their activity. The lungs and kidneys remove these waste products from the blood. And, finally, their activity as a whole is controlled by the nervous system. We can thus see that the muscles are responsible for a large part of the body's activity. As a result, the amount of work which the muscles are called upon to do determines very largely not only the growth and development of the muscles themselves, but the activity and development of the other organs of the body as well.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Frog killed by ether or chloroform; a slice of meat cut across the grain, such as a low cut of the leg including the bone; normal salt solution (1½ drs. table salt to 1 qt. water).

1) Dissect away the skin of frog's leg and note the outlines of muscles; the tendon attachments; and the relation of muscles to joints. Sketch observations.

2) Examine in a slice of meat the cross sections of muscle bundles. Also note and sketch the connective tissue in its relation to the muscle bundles; the surface tendons; and the intermuscular tendons.

3) Prepare muscle fibre by plunging the leg of a freshly killed frog into water at 131° F. and allowing it to cool. Teaze out the muscle fibres with needles in a normal salt solution. Examine under microscope and sketch.

4) *Location of various muscles:* Identify 10 of the muscles in Plate II by attempting movement against resistance and then locating the muscles which are contracted. Trace from origin to insertion.

5) *Arrangement of tendons:* Using the same method as in 4), determine whether the muscles have tendons at one or at both ends.

CHAPTER V

MOTION AND LOCOMOTION

Simple forms of movement.—The ability to move is a more or less general property of living matter, since it is found in many plants and all animals. One of the most primitive devices for motion we have already seen in the ameba, which moves about by changes of form in its soft elastic body. Many other one-celled plants and animals are able to move by the lashing of hair-like projections from their bodies. Animals which float in water have the advantage of requiring but little effort to produce motion, since their weight is supported by the water. Some aquatic animals much higher in the scale of development than the ameba, as, for example, certain jelly fishes, are able to get about quite swiftly by hair-like processes similar to those of one-celled plants and animals.

More complex forms.—Land animals, on the contrary, must either drag their bodies along on the ground or lift their weight and, therefore, as their bodies increase in weight the means of producing motion becomes more and more complex. In many worms, motion is accomplished by a laborious process of shortening and lengthening the body. Others attain much greater speed by their many little legs, which lift the body from the ground and enable them to take definite steps unhindered by its drag. As we get higher in the animal scale, the legs are longer and are stiffened in

various ways, in order to lift the body and increase the length of the step. In insects, the legs are tubes of horny substance, within which lie the muscles for mov-

FIG. 42. Angle worm progressing by contracting and extending body.

ing them. In all the higher animals, the legs are stiffened by bones, which make possible long steps and correspondingly rapid progress. The bones are moved by muscles surrounding and protecting them and act as
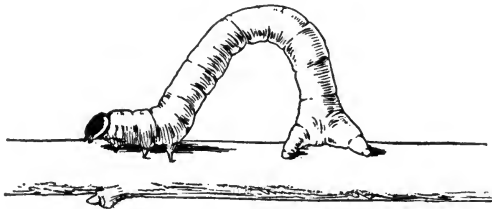
FIG. 43. Measuring worm ready to "step" forward.

levers greatly to increase the range of movement brought about by the contraction of the muscles.

Definition of lever.—A lever is a device for the application of force (*power*) to overcome resistance (*weight*) by utilizing a third force or support (*fulcrum*). Thus in every case there must be three forces acting at different points on a lever.

Law of leverage.—The simplest form of lever is that used by children in a see-saw. The weights of the two children are the two forces acting downward upon the ends of the board, and the support upon which the middle of the board rests is the third force acting upward. It

will be found by careful measurement that, if the two children are of exactly equal weight, they must sit at equal distances from the fulcrum. In other words, the two *arms* of the lever must be of equal length. If, however, one child is twice the weight of the other, the lighter must sit twice as far from the fulcrum to balance the heavier.

It is thus seen that the long arm of a lever and a light weight are equal to a short arm and a heavy weight. The fundamental law of leverage is that the forces are inversely proportional to the lengths of the arms on which they act, that is, to their distance from the fulcrum.

Classes of levers.—Levers are ordinarily divided into three classes, as determined by the relative posi-
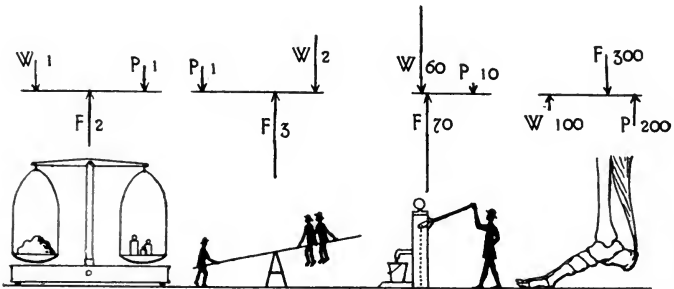
Fig. 44. Examples of levers of the first class, with analysis of the forces involved. The direction of the forces is indicated by the direction of the arrows; their relative amounts by both the length of the arrows and the figures. F = fulcrum; P = power; W = weight.

tions of the fulcrum, the power and the weight. To the *first* class belongs the lever which has the fulcrum in the middle; to the *second*, that which has the weight in the middle; to the *third*, that which has the power in the middle. It will be readily seen that, given the same lengths of arms and the same forces, the balance remains

the same, regardless of whether one end, or the middle, or the other end of the lever is the fulcrum, power, or weight.

Leverage in animal bodies.—In animals, a joint is always the fulcrum and the muscles always furnish the
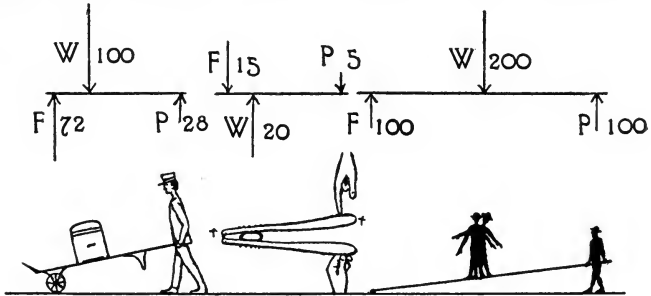
FIG. 45. Examples of levers of the second class.

power. The levers of the animal body are of the first or third class, and, in order to give speed and range of movement, the power arm is short and the weight arm
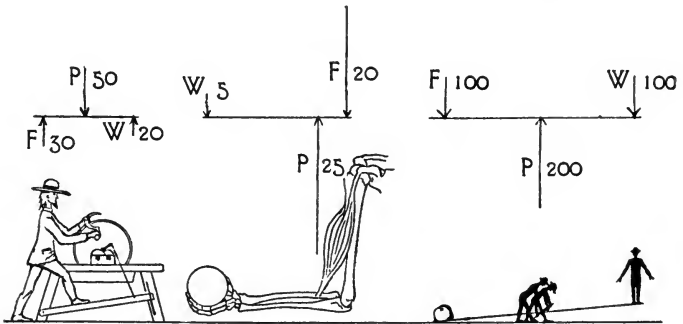
FIG. 46. Examples of levers of the third class.

long. This arrangement necessitates great strength of muscle applied to the short arm, in order to counterbalance the weight applied to the long arm.

Examples of levers of the first class.—Examples of the first form of lever are found in the nodding of the head, in the extension of the elbow by the triceps muscle on the back of the arm, and in the raising of the body upon the toes by means of the calf muscles. In the latter case, the pressure upon the floor by the weight of the body is equivalent to the support, or pressure against the foot, given by the floor. Since the floor support is the external force counterbalanced by the pull of the muscles, it is the weight.[1]

Examples of the third class.—Of the third class of levers, we find examples in the action of the biceps in raising weights by the flexion of the elbow; in the action of the pectorals in drawing the arm inward; and in the action of the muscles which draw the arm downward, as in hauling or climbing a rope.

Body as a weight.—A study of the problems in body leverage shows that the force exerted by the muscles is surprisingly large. It is further greatly increased if the body gets heavier without a corresponding increase in muscle power. For example, if a man weighing two hundred pounds climbs a stair, the quadriceps muscle must exert, when his leg is bent, a pull amounting to about a ton. A man weighing but one hundred and fifty pounds would require of his muscle five hundred pounds less force.[2]

---

[1] Many text-books of physiology analyze this so that the floor becomes the fulcrum and the body the weight applied at the ankle. The error of this is seen when further analysis discloses the fact that, were this true, two-thirds of the weight of the body would be supported by the muscle and but one-third upon the floor. In other words a man weighing one hundred and fifty pounds, were he to rise on his toes on weighing scales, would press down upon them with a force of but fifty pounds!

[2] In this study of leverage, we have considered the mechanical relations only in those cases in which the forces act at right angles to the length of the lever, in order to make the treatment as simple

Power exerted by the muscles. — In walking, the power required of the muscles is that which is necessary to carry the weight of the body, which is borne entirely by the muscles of the legs. When a hod-carrier takes up a load of bricks, or the soldier his equipment, the extra power demanded of the leg muscles amounts to not more than a quarter or a half of the regular work of carrying the body's weight. The arm and trunk mus-
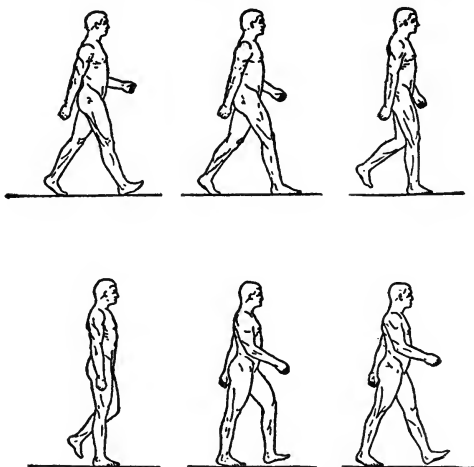
Fig. 47. Analysis of a single step in ordinary walking. (Bradford.)

cles are able to do a larger amount of work in proportion to their weight than the legs, since they do not have to support the weight of the body as a whole. The freedom of the arms for this work is made possible by

as possible. It is, however, not difficult to convert oblique forces into rectangular forces by the application of the principle that the true lever length for use in a problem involving an oblique force, is not the full length but is equivalent only to the shortest distance between the fulcrum and the line of action of the weight and of the power.

man's erect posture. In most animals, the four limbs
are adapted chiefly to locomotion, so that their heads and
mouths have to do much of the work which we do with
our hands.

Locomotion.—Locomotion for man presents more dif-
ficulties than for four-footed animals, since the support
afforded by the ground is limited to his two feet in-
stead of to their widely separated four. As a result,
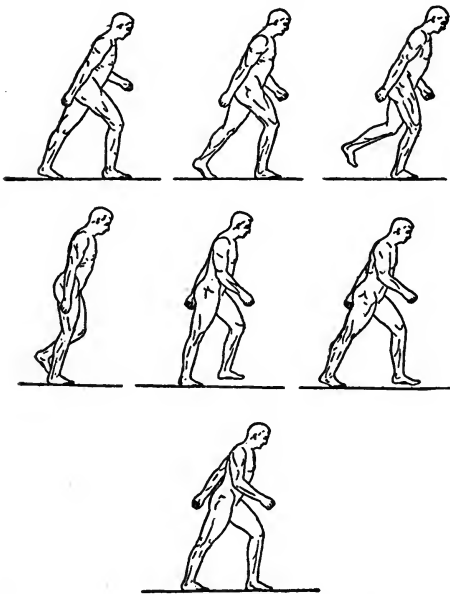
FIG. 48. Analysis of a single step in bent-knee walking. (Bradford.)

the difficulty of maintaining his balance is what makes
a baby so slow in learning to stand and walk. In walk-
ing, the weight is alternately supported by first one
leg and then the other. The leg which supports the
weight is ordinarily straightened to its full length. At

the end of the step, the leg flexes at the knee and hip and is carried forward in this bent and shortened form.

Energy expended.—In slow walking, the muscular force required is but little in excess of that required to support the body's weight. It is estimated to be one-twentieth of the weight of the body multiplied by the number of feet walked per hour.[1] In walking up or down hill, the amount of power demanded is greatly increased because of the fact that the body weight has to be raised or lowered at every step. In bent-knee walking, which has been experimented with for military purposes, the body is allowed to fall forward, to be caught by the swinging forward of the other leg. The total effort required in rapid walking is thus somewhat reduced. In running, the body is tossed quickly from one foot to the other, in addition to being thrust

---

[1] Thus a man weighing 150 pounds and walking at the rate of 4 miles per hour, would exert $\frac{150}{20} \times 4 \times 5280$ ft. $= 158,400$ *foot pounds* per hour, or 2640 foot pounds per minute. A foot pound equals the energy necessary to raise a weight of 1 pound to a height of 1 foot. Corresponding to this are the units, *foot ton,* which means the raising of 1 ton to a height of 1 foot; and the French unit, *kilogrammeter,* which means the raising of 1 kilogram to a height of 1 meter. The energy required to raise 1 pound 10 feet is equivalent to that required to raise 10 pounds 1 foot, or 20 pounds ½ foot, and so on.

Kind of Work	Foot pounds per minute	Foot pounds per day
Bicycle riding, 10 seconds	19,000	
Bicycle riding, 60 seconds	8,750	
Soldier marching with load	5,000	3,000,000
Climbing stairs for 8 hours	4,032	1,935,360
Walking for 10 hours	3,987	2,394,000
Using heavy hammer 5 hours	3,808	1,142,400
Man pushing on lever in circular path	3,667	2,200,000
Horse pulling on lever	17,166	8,500,000
Working on treadmill 7 hours ...	3,360	1,480,000
Average work of man	3,330	2,000.000

forward much more rapidly against the resistance of
the air. The amount of power required is therefore
much greater than for walking.

EXPERIMENTS AND DEMONSTRATIONS

Apparatus: Lever apparatus made with 2 spring scales
weighing up to 24 lbs. and 2 pieces of lath arranged as shown in
diagram.

1) Set up apparatus for foot leverage, assuming 1 in. as
distance from ankle joint (*fulcrum*) to insertion of tendon of
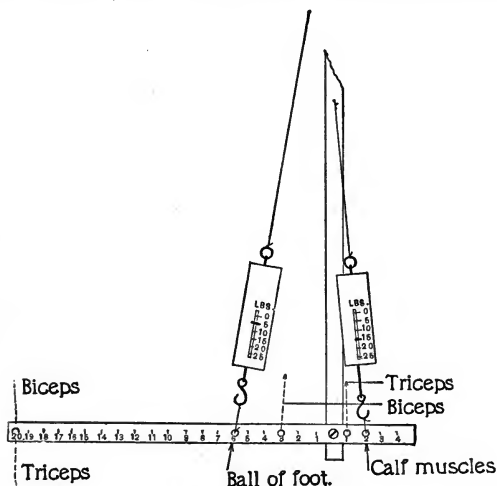
Fɪɢ. 49. Lever apparatus made of lath and spring balances arranged for foot as
acted on by calf muscles in rising on toe. The arrangements for arm when flexed
by biceps muscle and extended by triceps are indicated by the dotted arrows.
(Figures indicate half inches.)

calf muscles (*power arm*), and 3 in. from ankle joint to ball of
foot (*weight arm*). Use various body weights (taking 1-100
of body weight as weight) and determine the muscle pull
necessary to balance them.

2) Set up apparatus to illustrate action of biceps when a
weight is lifted in hand, allowing 1½ in. for length of power

arm and 10 in. for length of weight arm. Note the muscle pull for various weights.

3) Set up apparatus to illustrate action of triceps, when "heel" of hand is used for pushing, as in pushing up a weight. Allow ½ in. for length of power arm and 10 in. for length of weight arm.

Problems: (Each pupil should use his own weight and make the necessary measurements on himself or on a skeleton.)

1, a) How much force do the calf muscles exert in raising heel from floor, when person is standing on one foot, if the ratio between power and weight arms is assumed to be 1 to 3?

b) How much is the pressure in ankle joint?

2, a) How much does the biceps pull when, by flexing forearm, 15 lbs. are raised in palm of hand, if ratio between arm lengths is assumed to be 1 to 7?

b) How much is the pressure in elbow joint?

CHAPTER VI

MUSCULAR WORK

Influence of muscular activity upon development.— The muscular system determines very largely the activity of the other organs by its demands for food, oxygen and the removal of its waste products. During the years of growth from early infancy to the age of about twenty, the various organs and tissues of the body are being developed and perfected by these demands. If the muscular activity is slight, not only the muscular system, but the heart, lungs, nervous system and every other part of the body remain weak and poorly developed. If, on the contrary, the muscles are given work in proportion to their strength and endurance, every tissue of the body gets a generous and healthy development.

Play.— All young animals possess an instinct for that muscular development which is essential for their proper growth. The joyous rolling and tumbling of kittens and babies, the apparently aimless racing about and frolicking of puppies and children, the happy play of all growing animals, is nature's provision to insure activity for the muscles, in order that their bodies may attain full strength and complete development in every part. The most valuable forms of play are active games, which develop the strength and endurance demanded for their success. They differ from both exercise and work in that they are full of joyous excitement. During child-

hood and youth, pleasurable activity leads to a much
more wholesome development of the nervous system than
the same amount of exercise taken in a sober humdrum
fashion. The old adage, "All work and no play makes
Jack a dull boy," is truer to-day than ever, when exer-
cise is too often made another form of work.

Exercise.—Exercise differs from play, because it has
a definite conscious object, the development of the body.
It is planned to supplement the ordinary muscular work
of the body, in order to bring about an all-round and
complete development, which ordinary play and work
may not accomplish.

Work.—Work, in contrast to both play and exercise,
ignores the individual's pleasure and development and
concerns itself solely with the thing to be accomplished.
Throughout the history of the human race, a fair share
of hard physical work has been the lot of practically
all persons. In very early times, when hardships were
many and the conveniences of life few, the keeping of
body and soul together was a physical task of no mean
proportions and those who survived were hardy and
strong. As civilization progressed, physical activity was
still essential to success and physical perfection was
eagerly sought. In recent years, however, labor-saving
invention has progressed so rapidly that the conven-
iences of life have been enormously increased. Machines
have tended to take the place of the muscular work of
men and brain work has become the most productive
form of activity. As a result, the necessity and the
opportunity for physical activity have become for many
persons so slight that their bodies do not get the vigor-
ous muscular work which they need. The danger of
mental work without physical activity during the period
of growth is proved to be very real by the tendency

to weakness, imperfect development and nervous break-down which is so commonly observed to-day.

Disadvantages of work.—The disadvantage of work is that it may be so monotonous and prolonged as to cause exhaustion of muscles and nerves. Overwork during the growing period is especially harmful because it interferes seriously with both the strength of the muscles and their control by the nerves. It is especially important that this should be considered in the training for such games as football and baseball, where exhaustion and heart strain are not uncommon.

Fatigue.—Since muscular activity is based upon the combustion of food materials in the muscles, the exhaustion of these materials or the accumulation of waste products results in fatigue and weakness. In order that the muscles may be able to work for a long time, therefore, the rate of work must be such as to permit the food supply to be renewed and the waste to be cleared away. Even under these conditions, however, a limit is set to the working time of the muscles by the fatigue of the nervous system, which is often shown by the person's inability to keep his attention upon his work.

Rest.—Periods of rest are therefore essential to wholesome work. This is especially true during the growing period when exhaustion of the muscles and nerves leads to their imperfect or unbalanced development. It has been found that a single small muscle may be so completely exhausted by hard work that it will no longer contract, and yet after two hours of complete rest it will be as strong as ever. If large groups of muscles are exhausted in this way, however, their recovery from fatigue is much slower. This is apparently due to the much greater quantity of food materials oxidized and of waste products produced. When the waste products

are in excessive amounts, they weaken and fatigue the whole body, including even those portions which have not shared in the activity. From this more general form of fatigue, prolonged rest in the form of sleep is necessary.

Recuperation.—During rest, especially during sleep, the waste products are removed from the body, and the food supplies of the tissues are renewed and built up into the special forms required for quick combustion, so that the body as a whole is ready to enter upon a new period of activity. If the rest and sleep periods are too short, recovery from fatigue is not complete and growth in the young or full development of strength and efficiency in the adult is impeded.

CHAPTER VII

SELECTION AND PREPARATION OF FOODS

Foods.—The development of energy in the body depends upon its fuel or food supply. When the food supply gets low, the need of the tissues for more food causes an increasing discomfort until we satisfy our hunger. Those substances which satisfy hunger by furnishing the energy necessary for the various activities of the body, and which are also wholesome in all their effects when taken in moderate amounts, are *foods*. The foods which animals need for their growth and activity are manufactured by plants from the simple substances furnished by the air, water and soil. After the plants have built them into their own complex tissues, they are found to be of three principal kinds, namely, carbohydrates, hydrocarbons and proteids.

Carbohydrates.—To the first group belong cellulose, starch and sugar, which are found in varying amounts in most vegetable tissues and furnish the main food of the majority of animals. They consist of carbon, hydrogen and oxygen in a number of different proportions.[1] Since they all have twice as much hydrogen as oxygen, they are in the right ratio to form water (H_2O), and for this reason they are called carbohydrates (literally, carbon watered).

Hydrocarbons.—The second class is represented by the oils obtained from nuts and from the palm, olive,

---

[1] Starches (gums and cellulose), $C_6H_{10}O_5$.
Sugars (grape sugar, glucose, etc.), $C_6H_{12}O_6$.

linseed and cottonseed. In this group, there is more than enough hydrogen to form water with the oxygen present,[1] and because of this excess of hydrogen they are called hydrocarbons. They are much more valuable as heat producers than the carbohydrates.[2]

Proteids.—The presence of nitrogen and sulphur characterizes the third class, examples of which are found in the gluten [3] of wheat and other cereals, and in peas, beans and nuts. These nitrogen-containing substances are called proteids. They have a most complex chemical structure, which differs according to the source from which the proteid is obtained.[4]

Animal manufactures.—The substances which are found in the bodies of animals closely resemble in chemical composition those portions of plants which are used by them for foods and may be similarly classified into carbohydrates, hydrocarbons and proteids. The carbohydrates are chiefly represented by milk sugar and by a starch found in the liver called glycogen; the hydrocarbons, by various fats and oils; and the proteids, by flesh, egg albumin and cheese. They differ from the substances found in plants, however, in the much larger proportion of proteids and hydrocarbons and the much smaller proportion of carbohydrates which they contain.[5]

---

[1] Palm oil, $C_{51}H_{101}O_6$.

[2] The hydrogen not already in combination unites with the oxygen of the air, as does also the carbon. The result is the production of much additional heat and energy.

[3] Gluten is the tenacious gum which remains when raw wheat is chewed.

[4] On the average, 100 lbs. of ordinary dry proteid contain nearly 52 lbs. of carbon, 7 lbs. of hydrogen, 16 lbs. of nitrogen, 2 lbs. of sulphur, 25 lbs. of oxygen and a certain amount of mineral material.

[5] Glycogen, $C_6H_{10}O_5$; milk sugar, $C_{12}H_{22}O_{11}$; fat (stearin), $C_{57}H_{110}O_6$; egg albumin, $C_{204}H_{322}N_{52}O_{66}S_2$.

Diets of animals.—The feeding habits of animals differ greatly. Some animals, as sheep, cows and horses, live entirely upon plants and on this account are called *herbivorous*. Others, like wolves, lions and tigers, live only upon the flesh of other animals and are therefore called *carnivorous*. Still others, as birds, apes and men, live upon a mixed diet of plants and animal flesh and are called *omnivorous*.

Selection of diets.—The foods chosen by animals have depended upon the kinds obtainable and their liking for them. The food habits of animals as observed to-day are to a large degree the result of a process of natural selection. Those animals which liked the food which made them strong and were fortunate enough to be able to get it, produced strong offspring. These in turn tended to continue the same food habits with the same beneficial results. In the end, their families survived, whereas those which for any reason did not eat wisely perished in the struggle for existence against enemies and disease. To-day, therefore, the natural diets of the various species of animals are not the result of accident or of mere individual choice, but are rather the final outcome of a long series of experiments to determine the foods best adapted to their needs.

Adjustment of teeth to diet.—During the long period of selection, the animal gradually became adapted to the diet chosen. For example, the teeth of herbivorous animals became so changed in order to adapt them to the grinding demanded by their diet, that now they could not eat flesh easily, even if they wanted to. Carnivorous animals, on the other hand, have teeth which are perfect for tearing flesh and crushing bone, but which are quite useless for chewing grass and grinding small grains. Those animals, like the ape and man, whose normal diet

combines the two, have some teeth adapted for one kind
of food and some for the other.

Of stomach and intestines.—The stomach and intes-
tines of animals are also adapted to their diet.   The
uncooked flesh of animals is the most easily digested of
foods and therefore carnivorous animals have a simple
stomach and short intestines.   Plant tissues, on the con-
trary, are very difficult of digestion and in consequence
the majority of herbivorous animals have a large and
complicated stomach and very long intestines.   Animals
living upon both a flesh and a vegetable diet have a
stomach and intestines the size and structure of which
lie between these two extremes.   The same is true of
animals like squirrels which, although herbivorous, live
upon the more easily digested forms of plant substances,
as fruits.[1]

Diet of man.—As man is the most widely distributed
animal upon the earth's surface, the different races of
men have been for many thousands of years exposed to
very different conditions of climate and food supply.
The diet of man is therefore as varied as are the con-
ditions under which he lives.   In the frozen north, his
diet is principally fatty animal food; in the equatorial
regions, it is largely vegetable; whereas in the tem-
perate regions, it ordinarily combines both.

Relation of food to muscular energy.—In spite of
these variations in the kinds of food eaten, it has never-
theless been found that in general the amount and funda-
mental character of the food required by men depend
upon the amount of work which they do.   The doing
of work depends upon the development of energy.   This
in turn means that the food eaten must be combined

---

[1] Technically, fruits include all seeds of plants with their closely
related structures, as nuts, grains, pumpkins and apples.

in the active tissues with the oxygen breathed, in order
that combustion (oxidation) may take place and energy
be thereby developed. Those, therefore, who work hard-
est require the foods which develop the most energy.
If, moreover, they live in a very cold climate where
additional energy must be developed in order to keep
the body itself warm, then still more food must be eaten.
In any case, it is the development of given amounts of
energy which determines the amount and composition
of the food eaten. For example, a Chinaman, an Italian
and an American who do equal amounts of hard work,
have been shown to eat approximately the same quantity
of food made up in general of the same proportions of
carbohydrates, hydrocarbons and proteids, although the
Chinaman may get his from rice and fish, the Italian
from macaroni and oil, and the American from potato,
meat, bread and butter.[1]

Primitive cooking.—Food substances as furnished by
plants and animals were eaten in their raw state by very
primitive peoples. The general practice of both primi-
tive and civilized nations, however, is to prepare many
of them by means of heat. In early times, before the
development of cooking utensils, there were two methods
of using heat. The first was roasting or broiling, which
was done on coals or on a spit before an open fire. The
second was baking, a primitive form of which was the
heating of smooth stones by building a fire on them.

[1] That the amount and character of the food required by an
individual are determined by the work which he is called upon to do,
has been further proved by the experience of the Japanese army
and navy in their wars with China and Russia. The moment that
the Japanese, who are light eaters, were called upon to do the
heavy work of drilling, marching and fighting, the insufficiency of
their diet was apparent. To maintain their health and strength,
it had to be raised to the European standards both in variety and
amount.

When the stones were sufficiently hot, the fire was brushed off, and the food, whether dough, fish, or fowl, was spread upon them. Ultimately, quite elaborate bak-
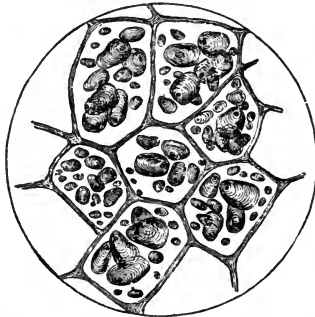
Fig. 50. Cells of a raw potato, with starch grains in natural condition.

ing structures were developed, of which the brick oven used by our grandmothers is an example.

Boiling.—With the invention of pottery and later of metal vessels which would hold liquids without
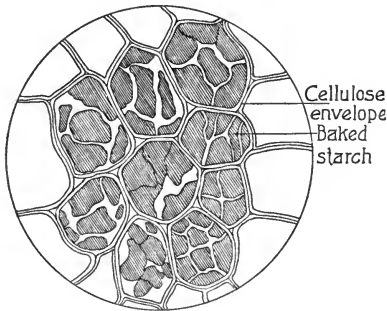
Fig. 51. Baked potato, showing masses of cooked starch within envelopes of cellulose. (Bulletin of Agricultural Department.)

cracking, cooking by boiling was naturally added to roasting and baking. Frying, which is such a com-

mon method in modern times, was probably also of later development since it required the use of grease in an earthen or metal receptacle.

Effects of cooking.—Cooking has won favor because the added flavor and delicacy which it imparts to food stimulate the appetite and promote digestion.   By
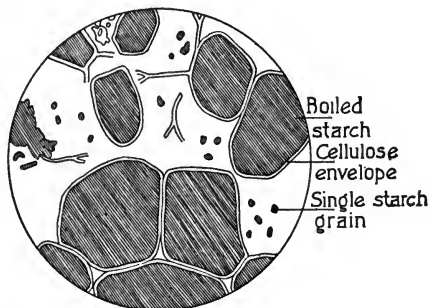
Fig. 52. Mashed boiled potato. (Bulletin of Agricultural Department.)

means of it, meat becomes tender, hard grains are softened, and fruits which were unwholesome because of their bitterness or acidity are made wholesome and pleasant. Moreover, through the destruction of disease-producing microbes,[1] the food is made safe and much disease thereby avoided.

From the standpoint of cooking, foods fall into two distinct classes, animal and vegetable. In animal tissues, the strengthening framework of connective tissue, to which their toughness is largely due, is changed by the cooking to tender soluble gelatine.[2] In vegetable foods, the binding structure is largely tough hard cellulose, which resists chewing and digestion. This becomes

[1] See p. 282.
[2] Gelatine itself has little food value.

softened through heat and broken by the swelling starch grains, so that mastication and digestion are made easy.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Potatoes, raw, baked and boiled; wheat flour; corn meal; cheap cut of steak, ½ broiled, ½ stewed.

1) Examine scrapings of a raw potato under microscope. Note starch cells, each of which is enclosed in a tough envelope of cellulose.

2) Examine similarly scrapings from baked and boiled potatoes.

3) Examine similarly wheat flour, corn meal, etc., both cooked and raw.

4) Compare textures of 2 pieces of the same tough cut of meat, one of which has been broiled or fried quickly over a hot fire, the other slowly cooked for several hours in a small amount of water.

CHAPTER VIII

FOOD MATERIALS

THE ordinary diet of mankind includes both animal and vegetable food and consists principally of cereals, vegetables, fruit, milk, meat and eggs. In addition to these, many miscellaneous substances such as tea, coffee, chocolate, alcohol and the various condiments whose nutritive value is slight, are used for their stimulating or sedative effects.

Plant foods.—Cereals deservedly occupy a most important place in all diets, since they furnish more nutri-
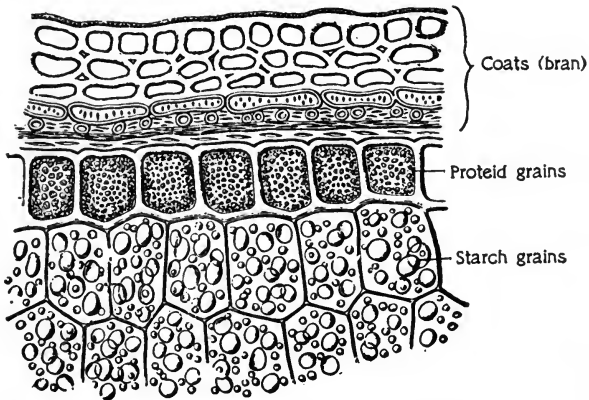
FIG. 53. Section through outer part of a grain of wheat.

ment in proportion to their weight and cost than other food substances. The cereal most generally used the world over is wheat. The grains of wheat are enclosed

in an outer covering, or capsule, of hard cellulose. Just within the capsules lie large cells which contain the proteid part of the wheat, the gluten. The rest of the kernel consists mainly of starch cells, which lie in a fine meshwork of cellulose. In addition, each kernel contains an embryo plant for which the starch and gluten have been prepared as food and which is itself nutritious. Certain of the cereals, especially wheat, oats and corn, are of special value as foods, because they contain about the right proportions of proteid and starch for a full diet. With the addition of a hydrocarbon in the form of butter or oil, an almost complete food [1] may be obtained.

Bread.—Bread [2] is a favorite method of using cereals, especially wheat, because of its ease of digestion and its agreeable flavor. Its digestibility depends upon its sponginess, which is due to the myriads of small bubbles caught in the dough because of the tenacity imparted to it by the gluten. The bubbles themselves are ordinarily produced by yeast, which consists of a large number of microscopic one-celled plants. These develop rapidly in the warm dough and during their growth give off bubbles of carbon dioxide. [3]

The fact that wheat flour makes a light bread has caused the other cereals which do not make so light a bread, to be undervalued as food, when, as a matter of

[1] A complete food is one that furnishes in their proper proportions all the carbohydrate, hydrocarbon and proteid necessary to sustain life and activity. According to recently accepted standards, bread and butter lack only a small amount of proteid.

[2] There are many kinds of bread, both leavened (raised) and unleavened. A primitive form is a mere flour paste baked by being spread thinly upon a hot stone. Certain hard crackers resemble this.

[3] Carbon dioxide may also be produced by the union of the two chemicals cream of tartar and bicarbonate of soda, as in the best baking powders.

fact, they are little, if any inferior and have the advantage in some cases of greater cheapness. Corn is especially valuable because it contains more hydrocarbon than wheat and fully as much proteid, although the proteid is not in the form of tenacious gluten.[1]

Patent breakfast foods.—In recent years, various preparations of cereals have been exploited in the form of patent breakfast foods. These are mainly preparations of wheat, oats, or corn, which have been steamed, baked, or roasted in such a way as to develop appetizing flavors. Their chief value lies in the fact that in the majority of cases they are easily digested. As far as actual nutriment goes, they are very deceptive, since they are so bulky that one has to pay a good deal for very little nutriment.

Vegetables.—Certain of the vegetables,[2] as white potatoes, sweet potatoes and tapioca, resemble the cereals in that they are rich in starch. Others, as peas, beans and peanuts, are rich in proteid material. Still others, as beets, are rich in sugar. Some vegetables, however, as cabbages and turnips, consist mainly of cellulose, which is so indigestible as to give little nutriment except when young and tender. All vegetables contain organic salts which are essential to health, as has been abundantly proved by sailors, who when deprived of them for long periods become weak and diseased.[3] Vegetables are also

---

[1] In spite of this, corn is but little used by Europeans as food. When, during a famine in Russia, a large amount of corn was contributed by America, it was necessary both to show the Russians how to use it and to overcome their prejudice against it.

[2] Peas, beans and peanuts, although popularly known as vegetables, are really fruits.

[3] Scurvy, which used to be the bane of whalers who went on three-year cruises, has been practically obliterated by the use of canned vegetables and fruits, now made compulsory by the various governments.

important articles of diet because they contain large amounts of cellulose. Although this cannot be digested, yet it is valuable in that it furnishes a considerable residue in the intestine, thus insuring a regular onward movement of the bowel contents.

Dangers of raw vegetables.—Raw vegetables, such as radishes, lettuce and celery, are often dangerous to health, more especially in European countries, because animal excretions are used to fertilize them. Many cases of dysentery, typhoid and other diseases have been traced to this source. They should therefore never be eaten unless they have been previously thoroughly washed, or scraped and rinsed under running water.

Potatoes.—Common or white potatoes have long been recognized as the most valuable of all cheap vegetables, because they contain considerable nutriment and furnish the salts necessary to maintain health. In addition, they are always appetizing and can be kept from one season to the next.

Fruits.—Besides cereals and vegetables, plants furnish us with another most important and attractive kind of food, namely, fruits and nuts. Juicy fruits contain large amounts of fruit or *grape* sugar, together with a considerable amount of cellulose and some starch. Melons and grapes are particularly rich in sugar, bananas in starch. Nuts contain large amounts of hydrocarbon and proteid and thus resemble meat in composition. Like vegetables, fruits also contain the acids and salts which are so important for health. They should be used freely in all diets, either raw or cooked.

Preserved fruits.—Fruits are prepared for use out of their season, by being dried, preserved, or canned. Dried fruits are almost as valuable as fresh and are

much cheaper when fresh fruits are out of season. Preserved fruits are kept from fermentation by the large amount of sugar which is cooked with them. They are less healthful because they are oversweet and they are expensive for the same reason.[1] Canned fruits depend for their preservation upon the fact that all microbes which would cause fermentation are killed by cooking, and all others are kept out by the tightness of the cans. They have about the same value as fresh fruits. Unless glass cans with glass tops are used, however, there is always some chance of lead poisoning, through the use of a mixture of tin and lead, instead of pure tin, as a coating for the sheet iron of the cans. On this account, the fruit should never be allowed to remain in a metal can after it has been once opened, since acids develop which attack the coating of the can.

Animal foods: milk.—Of the foods contributed by animals, milk is more nearly a complete food than any other. It has in solution proteids in the form of albumin and casein. It also contains sugar (*milk sugar*) together with fat in the form of minute drops.

The casein of milk is readily separated out as a flaky solid by adding to the milk a little dilute acid, or rennet from a pig's or calf's stomach. When properly pressed and dried, it forms cheese.

The fat of milk rises to the top because of its light-

---

[1] Many of the commercial preparations contain glucose instead of cane sugar. Glucose is prepared by boiling starch with sulphuric acid and neutralizing the acid with caustic lime. It is wholesome if the acid is pure and is wholly neutralized by the lime. Unfortunately, the acid sometimes contains poisonous substances, such as arsenic. Glucose is much cheaper than the natural fruit and cane sugars, for which it was formerly sold. As it is considered to be an adulteration of food, the law prescribes that its presence must be stated on the label of the package in which it is sold. To comply with the law and yet avoid the term glucose, corn syrup and other pleasing names are used.

ness. It becomes butter when the thin membranes which cover the fat drops are broken open by churning.

After the cream and cheese have been removed from milk, the sugar remains in solution and can be obtained by evaporating the water. Milk sugar is a valuable article of food and is used largely in the feeding
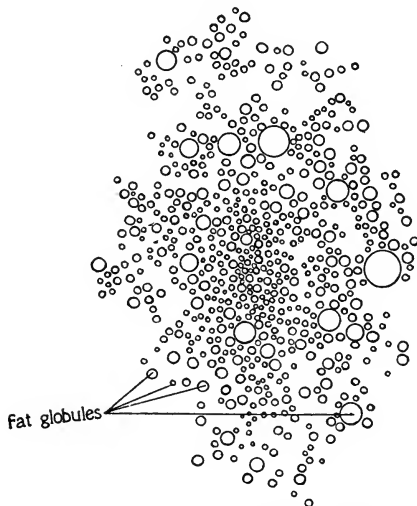
fat globules

Fig. 54. A portion of a drop of cow's milk highly magnified, showing the fat globules.

of infants. It helps to make cow's milk more like human milk and so makes it better adapted to their digestion.

Contamination of milk.—Since milk is so valuable a food, it is most unfortunate that it is difficult both to get and to keep it clean and fresh. In the cow itself, on the hands of the milkmen, in the pails, cans and bottles, may lurk millions of microbes, some of which are not infrequently productive of disease. Only the milk

which comes from a clean healthy cow, is milked by a clean person free from disease into carefully boiled (sterilized) vessels, and is not afterward contaminated by handling nor subjected to a temperature higher than 40° or 50° F., is so free from microbes as to be absolutely safe. If the cow has some such disease as tuberculosis, the milk, even when fresh, will often contain the germs of the disease and thus be a most dangerous food. During the milking process, the microbe-laden dust and dirt on the skins of the cows and on the hands of the milkmen sometimes get into the milk in such quantities that a cubic centimetre of fresh milk contains millions of microbes.[1] Fortunately, many or most of these are not ordinarily harmful, but one cannot be sure that this is the case. After milking, the milk may be put into cans which are full of microbes that will hasten its spoiling; the milk cans may even have been washed in water contaminated with typhoid or other disease-producing microbes, or handled by those who are themselves ill, as has only too often been found to be the case in epidemics of typhoid and scarlet fever. The milk may further be left uncovered so that the microbes carried by insects or by the air find ready access to it. In short, milk, because of its large use in the uncooked or raw state, is subject to contamination on every hand.

Effect of temperature.—In order to keep milk sweet, it must not only be kept clean but in addition it must be chilled as soon as it is milked and thereafter be kept

[1] The laws of Massachusetts permit 500,000 microbes to the cu. cm. and consider such milk moderately clean. Of course, these are not supposed to be disease-producing microbes. Their number is considered to be a measure of the cleanliness of the premises, the age of the milk, the care with which it has been handled, and the temperature at which it has been kept.

as nearly at the temperature of ice as possible. In this way, the development of microbes, which is exceedingly rapid in warm milk,[1] may be checked.[2]

Eggs.—Eggs are another important food contributed by animals. Every egg is a package of food especially prepared for the nourishment of the young animal contained within it, during its development. It is, therefore, a complete food for an actively growing animal. It consists of a transparent portion, the egg albumin, and a yolk which contains a relatively large amount of fat together with proteid and other substances. As a complete food for man, it lacks carbohydrate material.

Eggs are valuable as food whether eaten raw, slightly cooked or thoroughly boiled. When heated, the white coagulates into a firm hard mass, which when well chewed is not indigestible. Fried eggs are least digestible because the white is made tough by the hot grease.

Neither milk nor eggs are very economical foods except in the country. The same amount of nutriment, although not always in so pleasing or digestible a form,

---

[1] The development of microbes in milk at different temperatures is about as follows:

Temperature	At end of 24 hrs.	At end of 48 hrs.
60°	180,000	28,000,000
68°	450,000	25,000,000,000
86°	1,400,000,000	
94°	25,000,000,000	

Below 50°, the development of microbes in milk is comparatively slow.

[2] It was formerly a common practice to get rid of the microbes in milk for infants by heating it to a boiling point (*sterilization*). In recent years, however, it has been found that to heat milk in this way so changes its character that it lessens its value as food. The best practice therefore seems to be to prevent the entrance of microbes into the milk and their subsequent development, in order that the milk may be as safe as possible in its raw state. Still greater safety may be insured for infant feeding by heating the milk to 150°-160° F. for 15 minutes (*Pasteurization*), and then putting it upon ice. Even pasteurization, however, does not protect against the germs of tuberculosis.

can be obtained from such foods as cheap cuts of meat, vegetables and especially cereals.

Meats and fish.—Meats and fish form a class of animal food which is very rich in proteid material. They average in composition about three-quarters of water and one-quarter of dry proteid and fat. The edible portions of both meat and fish consist mainly of the muscular part of the animal. Meat is easily digested and ordinarily ninety-five per cent is utilized by the body as compared with sixty to eighty per cent of plant proteid. It is therefore a more economical source of proteid than its price per pound would indicate, although even with this allowance plant proteid is much cheaper. The cheaper and tougher cuts of meat are just as nutritious as the more expensive ones and if
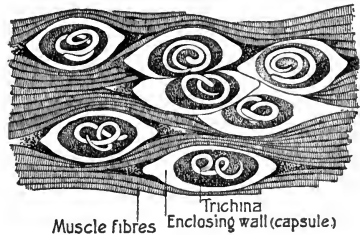
Fig. 55. Trichinæ in "measly" pork. (Magnified 60 times.)

skilfully cooked are often quite as satisfactory. Since flesh contains no carbohydrate material, it is not a complete food for man.

Parasites in meat.—On account of the fact that the flesh of animals is sometimes infested by parasites, meats should always be cooked and never eaten raw, as is done with certain kinds of sausage. The most common parasites found in meats are the *tapeworm* from beef and the *trichina* from pork.

Putrefaction.—Meat which has been kept too long putrefies because of its infection by microbes from the air and from insects. Decaying meat is especially dangerous in that it produces severe and often fatal forms

of poisoning. It should be remembered that after meat has become offensive, no amount of cooking or deodorizing will make it wholesome, since the poisonous products of the microbes, the *ptomaines*,[1] are not destroyed by cooking, although the microbes themselves are.

Meat stews.—Although meat alone is not a complete food because of its lack of carbohydrate, it may be so combined with vegetables and cereals in stews and pies as to make good this deficiency. Stews and pies are especially valuable in an economical diet because they are cooked so long that cheap tough meats become tender and appetizing.

Soups.—In marked contrast to stews are thin soups, which consist mostly of water and flavoring materials from meat. Although valuable at the beginning of a meal to increase the appetite, they furnish little nutriment. Bouillon and beef tea are thus stimulants rather than foods and should never be relied upon for nourishment, even in the diet of an invalid.

Fish.—As a food, fish is neither more nor less nutritious than meat. It has not the special value as brain food which has been frequently claimed for it.

Condiments.—Besides bouillons and soups, there are certain condiments or seasonings, such as salt, pepper, mustard, ginger and other spices, which stimulate the appetite by increasing the flavor of the food. This is their sole purpose, as they do not furnish any nutriment. When used in moderate quantities, they serve to increase the secretion of the digestive fluids and thereby aid the whole process of digestion. In the use of condiments, however, great care must be taken not to use them unnecessarily or in too large amounts. In normal health,

---

[1] Ptomaines are produced by the activity of microbes and are among the most poisonous substances known.

stimulation, aside from that obtained from the natural flavors of the food increased by the addition of a little salt, is ordinarily not needed.

Salt.—Salt evidently serves a more important purpose in the body than any mere condiment, since many animals, especially the herbivorous whose food is poorest in salt, have such a strong craving for it that they will ignore danger for the sake of reaching salt licks. This is due to the fact that it is essential in the tissues in order that the right proportion of water in them may be maintained. Salt is being constantly lost from the body through perspiration and other excretions, and this loss must be made good through the salt taken as food. In carnivorous animals, the flesh food supplies enough salt in itself, so that they have no craving for an additional supply.

Sugar.—Sugar is habitually used as a condiment because of its pleasant taste, but it differs from other condiments in being a valuable food. Sugar, especially in the form of candy, should, however, be used with caution and eaten only at meal times or after other food. If taken at other times, it destroys the appetite for more wholesome food and may even induce painful digestion. The chocolate which is combined with sugar in candy, is also a valuable food, if taken at the proper times and in moderate quantities.

EXPERIMENTS AND DEMONSTRATIONS .

Materials and apparatus: Yeast cake; wheat flour; corn, rye and oat meal; breakfast foods; vegetables, as potato, turnip, beet and cabbage; fruits, as apple, banana and orange; milk; egg; meat; glucose (grape juice or raisins stewed in a small amount of water); solution of iodine made by diluting 1 dr. tincture of iodine with 1 oz. of water in which 20 grs. of potassic iodide have been dissolved; solution of copper sulphate,

10 grs. to 1 oz. of water; solution of sodic hydrate, 20 grs. to 1 oz. of water; nitric acid, concentrated; ammonia, strong; gasolene, to be used only in small amounts by teacher; scales; test tubes; bottles; microscope.

	Milk	Egg	Meat	Potato	Beet	Apple	Banana	Nuts	Flour	Bread	Raisins
Starch											
Sugar											
Proteid							·				
Fat											

Note: The class may be conveniently divided into groups, to each of which is assigned a given number of substances for test and report.

1) Prepare a raised dough of each flour to be tested, as wheat, corn, rye and oat. Bake and compare textures of the various breads.

2) Separate out one cent's worth each of various patent breakfast foods and oatmeal, cracked wheat, rolled oats, etc. Assuming that equal weights have equal nutritive values, how do they compare in cost?

3) *Test for starch:* Put one or two drops of iodine solution upon a bit of flour and note result. Boil starch and test similarly.

Test in like manner various meals, breakfast foods, vegetables and fruits, and record as in the accompanying schedule.

4) *Test for fat:* Place a few drops of gasolene upon a piece of fat. Apply a drop of the mixture to a piece of paper and to a piece of glass; allow to dry. *Caution:* Be sure that there is no fire of any sort in the room.

Test similarly corn and oat meal, wheat flour, crushed nuts, yolk of egg and milk.

5) *Test for sugar* [1] *:* Make a dilute solution of glucose or soak a mashed raisin in water. Put a few drops into a test tube,

[1] Ordinary (cane) sugar does not respond to this test. A solution of such sugar must be boiled with a few drops of acid, as sulphuric.

add 1 in. of water and ¼ in. of sodic hydrate solution. Then add carefully 1 to 2 drops of copper sulphate solution. Heat the upper half of mixture in flame of Bunsen burner or alcohol lamp, by holding tube at an angle of 45°. Bring to a boil and note the characteristic change due to the presence of sugar (*Trommer's Test*). Test similarly [1] various vegetables, fruits and milk.

6) *Test for proteid* (*Xantho-proteic reaction*): Put in a test tube ½ in. of solution of white of egg.[2] Add ½ in. of concentrated nitric acid. Heat gently to boiling and continue until a yellow color develops. Let cool and add strong ammonia until the solution is alkaline (turns red litmus paper blue). Note the change to orange color, which is characteristic of proteid reaction.

Test similarly [3] wheat flour, various meals, vegetables, fruits, milk and meats.

7) Determine the proportion of water in meat, fat, milk, vegetables and fruits, by weighing fresh, chopping fine, drying quickly where they will be warm but not heated and re-weighing.[4]

8, a) *Structure of milk:* Examine a drop under microscope and sketch the oil globules.

b) *Test for fat:* Dry with moderate heat a tablespoonful of milk in a shallow tin vessel. When perfectly dry, pour upon it a small amount of gasolene or ether, being sure to have no flame of any kind in the room. Put some of the solution upon a glass or piece of paper and allow to evaporate. Note residue.

c) *Precipitation of casein:* Place warmed milk in a small glass. Add drop by drop a dilute solution of acetic acid (vinegar) and stir constantly until a precipitation of casein together with fat is formed. Let settle or filter. Dry precipitate

---

[1] In case of solid vegetables and fruits, crush, shake in a little water and use the clear solution.

[2] Cut white of raw egg repeatedly with scissors. Shake in a bottle with 20 parts of water; let settle and filter. Use clear solution.

[3] In case of solids, put ½ in. of water into a test tube and add the solids to be tested. Proceed as with white of egg solution.

[4] Ordinarily drying takes from 24 to 48 hours even under the most favorable circumstances.

by squeezing out the fluid and spreading out the remainder. When dry, collect in a small vessel and remove fat with gasolene or ether.

d) *Test for milk sugar:* Test the clear liquid obtained in c) by Trommer's Test.

e) *Test for proteid:* Test by Xantho-proteic reaction residue in c) left after fat has been extracted.

COMPOSITION OF FOOD MATERIALS

	Water	Proteid	Starch	Sugar	Fat	Salts
Bread.....................	37	8	47	3	1	2
Wheat flour..............	15	11	66	3	1	2
Oatmeal......	15	12.6	58	5.4	5.6	3
Rice	13	6	79	0.4	0.7	0.5
Peas	15	23	55	2	2	2
Potatoes.................	75	2	18	3	0.2	0.7
Milk	86	4	—	5	4	0.8
Cheese	37	33	—	—	24	5
Lean beef...............	72	19	—	—	3	1
Fat beef.................	51	14	—	—	29	1
Mutton..................	72	18	—	—	5	1
Veal....	63	16	—	—	16	1
White fish	78	18	—	—	3	1
Salmon..................	77	16	—	—	5.5	1.5
Egg.....................	74	14	—	—	10 5	1 5
Butter...................	15	—	—	—	83	3

CHAPTER IX

WATER AND OTHER BEVERAGES

WATER is indispensable for animal life, since no food can be absorbed and utilized by the body unless it is in solution. Because of its power to dissolve substances, natural water is never found pure, although fortunately its impurities are not usually harmful. Ordinarily, water contains in solution oxygen, carbon dioxide and traces of such salts as nitrates, chlorides and carbonates.

Mineral contents.—When water contains much lime or other carbonate, it will not readily dissolve soap and it is therefore said to be *hard*. Most spring and well waters become charged with carbon dioxide from decaying vegetation in the upper layers of the soil. The presence of the carbon dioxide gives them the power of dissolving carbonates from the soil as they filter through it and they are consequently apt to be hard. Surface waters, on the contrary, especially rain water, are relatively *soft*, as are also distilled waters. For drinking purposes, neither the very hard nor yet the soft pure distilled waters are good, since the hard waters contain an objectionable amount of carbonate, while distilled water is so pure that it is irritating to the stomach. The best water for drinking, therefore, is one that is neither very hard nor very soft but contains a moderate amount of air in solution together with a moderate amount of carbonates and other earthy salts, including

common salt. Such water is not irritating when in contact with the delicate tissues of the body.

Organic contents.—Besides these ordinary contents, surface waters frequently contain minute living plants and animals. Many of these organisms are entirely harmless, since they cannot grow in the bodies of animals. Some of them, however, when introduced into the body thrive and multiply as parasites. The most harmful of these, because of their power to cause disease, are certain kinds of microbes which have been introduced into the water from animals or man. When taken into the body, they multiply at so rapid a rate and develop such powerful poisons that they may even overwhelm and kill the animal which acts as their host. Some of the most dangerous of these are the microbes of typhoid, cholera, dysentery and scarlet fever. They may be introduced into the system not only by drinking the water contaminated by them but also by eating raw shellfish which have lived in the contaminated water, by drinking milk from receptacles washed in it, or by eating raw vegetables watered or washed with it.

Water supply.—To secure pure drinking water has become one of the great problems of civilized life, especially in the larger towns and cities. The main sources of supply are surface water, spring, well and lake water.

Surface water.—Surface water, as found in rivers and brooks, is always liable to contamination and should be avoided for drinking purposes, even in sparsely settled regions. For example, in a country district in the hilly part of Pennsylvania there was an epidemic of typhoid fever in the spring. It was finally traced to the contamination of the water supply by the excretions of a case of typhoid. These had been thrown out upon the snow on a hillside, and when the snow melted in

the spring they had washed down into the stream from which the people in the town some distance away got their drinking water.

Spring water.—Spring water, if from the side of a sandy hill through which the water has filtered, is usually safe, provided, of course, that it is protected from all the surface water which has not been so filtered.

Well water.—Well water is usually good if the well is entirely protected from the entrance of any water
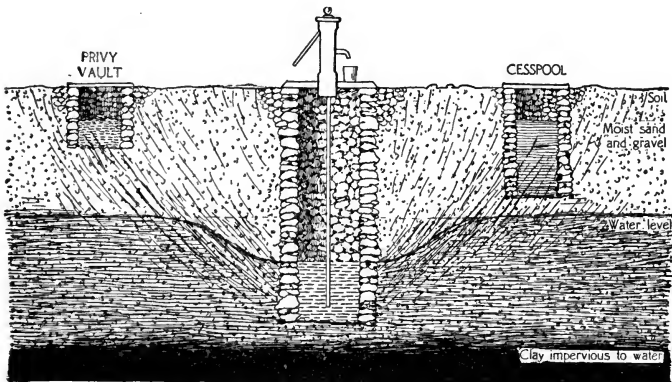
FIG. 56. A well contaminated by its surroundings because of the constant flow of water toward it from all sides, owing to the removal of water from the well itself.

which has not been slowly filtered through at least ten or fifteen feet of porous air-filled earth. Wells should preferably be at least fifteen feet deep. Those which are driven or bored are ordinarily much safer than open wells because they are more adequately protected from surface drainage. Many small towns obtain an adequate and safe water supply from such sources.

Lake water.—Lake water is frequently used as a source of supply for large cities. Like other surface

waters, it is extremely unsafe, since exposure to the sun and air will not purify it from any contaminating drainage which may run into it. To be made safe, it must be purified by some such efficient means as sand filtration.

Protection of water supply.—Various methods of protecting and purifying water have been adopted by cities and towns. If a natural watershed can be protected so that the water which falls upon it and drains off is uncontaminated by human life, it is usually safe for consumption. In mountain regions, such water supplies are readily secured without undue expense. Not infrequently, water is thus obtained for cities at great distances from the watershed.

Sand filtration.—The problem of obtaining pure water for flat, thickly settled regions has been solved
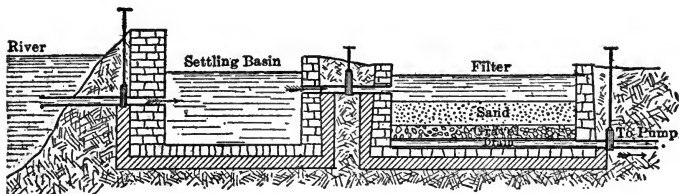
FIG. 57. Diagram showing arrangement of a filter plant. (Egbert.)

by the discovery that if the water from lakes and rivers is filtered slowly and intermittently through beds of sand several feet thick, the living organisms are removed from it and the water rendered pure.[1] Many cities,[2] therefore, have constructed large filtering beds to insure

[1] This process of purification is due to the action of harmless microbes in the soil, which form a thin film upon the sand grains. They have the power of destroying both the organic substances and the microbes in the water as they pass through it in the process of filtering. Since the soil microbes require air, the passage of the water through the sand has to be intermittent, in order to permit air to enter the sand.

[2] As Philadelphia, Lawrence and Berlin.

the purity of their water supply and thus to protect themselves from the epidemics of typhoid which prevail where the drinking water is impure.[1]

Small filters.—The attempt to render water pure by rapid filtration through small filters attached to faucets, is useless. Slow filtration through unglazed porcelain, as in the Pasteur filter, is effective, but is ordinarily too slow for general use. The most satisfactory method of protecting ourselves against suspicious water is by boiling the water and then shaking it up with air. In this way, the boiled water is made palatable through the restoration of the gases driven out by the heat.

Water as a beverage.—Water satisfies fully the needs of the body for fluids. When drunk cold, however, it has for certain persons a depressing effect. Hot water, especially when sipped, does not depress but rather stimulates the processes of digestion. Since hot water has not an agreeable flavor, certain substances, as salt, sugar, cocoa, chocolate, tea and coffee, are ordinarily introduced. Unfortunately, some of these substances used for flavoring are harmful.

Cambric tea.—Perhaps the best warm drink is that simple mixture of milk, sugar and water, called cambric tea. This warms and stimulates and has no harmful

---

[1] The following table shows the death rates from typhoid fever in the city of Lawrence per 10,000 of population, for the 4 years immediately preceding and the 4 years immediately following the introduction in 1893 of sand filtration for the water of the Merrimac River:

Preceding change	Following change
1889........12.7	4.7..........1894
1890........13.4	3.1..........1895
1891........11.9	1.9..........1896
1892........10.5	1.6..........1897

During 1893, 1894 and 1895, a considerable number of persons were still using unfiltered water and were responsible for about half the deaths in those years.

effects, except that it may lead to the regular use of a hot drink and thus eventually to the use of tea and coffee.

Cocoa and chocolate.—Cocoa and chocolate are really dilute foods, of which chocolate is the richer owing to the fat in the form of cocoa butter contained in it. Otherwise, they are identical in effect. Both contain small amounts of *theobromine,* which resembles the caffeine of tea and coffee and which in very large doses may be harmful. As found in cocoa and chocolate, however, it has practically no effect. Cocoa and chocolate, if simply prepared and taken in moderate quantities, are ordinarily agreeable and wholesome beverages. For some persons, however, the chocolate especially is too rich.

Tea and coffee.—The most popular beverages are tea and coffee. Although these have such different flavors, they are almost identical in composition and effect. Both contain a powerful drug, *caffeine,* which in tea is known as *theine,* together with a powerful astringent, *tannic acid,* which is very harmful to the lining membrane of the stomach. The effects of tea and coffee depend to a large extent upon the method of preparation as well as upon the quantity drunk. *Caffeine* and *theine* are both quite soluble and are very quickly abstracted by hot water from the finely ground coffee and thin tea leaves. The tannic acid, on the contrary, takes some time to dissolve out and appears in large quantities only when tea and coffee are boiled. They should, therefore, be steeped for only a few minutes. For this, tea balls or small bags are desirable, since in this way the tea leaves or coffee grounds can be removed at the proper time and the solution of tannic acid avoided. If drunk occasionally at meals, the amounts of caffeine and theine taken

are not thought to be sufficient to do serious harm. As stimulants, they have a considerable value if not taken habitually.

Dangers of tea and coffee.—When, however, tea and coffee are used without food for their stimulating effect or when they are regularly depended upon to supply a feeling of well-being and strength, they are undoubtedly doing harm. They then act as goads to prick a flagging vitality into exhausting itself still further. The slave of tea and coffee is quite as weak and as foolish as the victim of alcohol, since he is constantly losing his nervous strength and physical vitality in proportion to the degree of his indulgence. His nervous strength is weakened, his digestion impaired, and his normal restful sleep seriously lessened, until in the end he becomes a nervous, irritable dyspeptic.

Alcohol.—Another substance which is extensively used as a beverage in various forms is alcohol. Alcohol is derived from the fermentation of sugar by the action of various forms of microscopic plants called yeasts.[1] The alcohol of wine and cider is derived from the sugar in the fruit juices of the grape and apple, acted upon by the yeasts present in the dust upon the fruits. If the process is continued farther, acetic acid (vinegar) is in turn produced from the alcohol. Beers are made in a more roundabout way from the starch of grains, which is first converted into sugar by allowing the grains to sprout. The stronger liquors, as brandy and whiskey, are distilled from the products of previous fermentation, as brandy from wine. Alcohol as found in wines and liquors is in dilute form and is more or less flavored by the substances from which it is made. It

---

[1] Sugar+yeast = alcohol +carbon dioxide
$C_6H_{12}O_6+$ yeast$=2\ C_2H_6O+2\ CO_2$.

varies in amount from two to seventy per cent of the total bulk of the solution.

Oxidation of alcohol.—In its concentrated form, alcohol is a valuable fuel for cooking and heating purposes, because of the large amount of carbon and hydrogen contained in it. In dilute form, a certain amount of it is oxidized in the animal body and gives rise to carbon dioxide and water. Scientists have long disputed as to whether this combustion is similar to that which food undergoes in the body and whether, as is the case with food, it produces available energy. The essential test has been whether it would replace an equivalent amount of starch and sugar in a diet. At first, it was thought that this was not possible, but recent experiments seem to indicate that, when taken in moderate quantities, it does act as a food. This would seem to be especially true in certain illnesses where other foods cannot be properly digested and assimilated. In such cases, dilute alcohol appears to have the advantage of not requiring previous digestion before it is absorbed and utilized.

Fig. 58. Yeast: a, full-grown plant, with a branch (bud) partially developed; b, c, colonies formed by budding, the individuals still attached. (Magnified 750 diam.).

Dangers of alcohol. — Although alcohol may occasionally have a certain value as food, this is the only thing which can be said in its favor. Its other effects upon animal organisms make it a very undesirable food, except in cases of extreme illness. It acts upon the nervous system in such a harmful way, even when taken in comparatively small doses, that it must be considered

as a drug and not as a food. It paralyzes the higher
nerve centres which are responsible for our ideas of right
and wrong, as well as those which control the larger
movements of the body. As a result, the person who
comes under its influence ceases to be normal in his
thoughts or actions.[1]

EXPERIMENTS AND DEMONSTRATIONS

Materials: Samples of water; yeast cake; iodine solution
(p. 83); microscope with powers up to 450 diameters; tall
glass bottles.

1) Fill a tall glass with water and allow to settle. Pour off
carefully so as to leave sediment undisturbed. Study a drop of
the sediment under microscope.

2) Boil water for 10 minutes. Cool and taste.

3) Shake up some of the boiled water in 2) in a large clean
bottle, ¾ of which is filled with air. Repeat several times at
intervals of a few minutes, and compare with the taste of 2).

4) If your water supply is from well or cistern, draw a
diagram of premises to show possible sources of contamination.

If it is from a general town supply, describe its source and
the precautions taken to insure its purity.

5) Dissolve a small piece of yeast cake in a few drops of
water. a) Examine a drop of the fluid under microscope and
make drawings of the cells present.

b) Add a small drop of iodine solution and again examine.

[1] For a more complete discussion of the effects of alcohol, see
Chapter XXVI.

CHAPTER X

DIGESTION

THE development of energy by animals is based, as we have seen, upon the combustion of food materials. In order to bring food to the state in which it can be utilized by their tissues for the production of energy, it must be made soluble by means of digestion.

Simplest form of digestion.—The process of digestion may be very simple or extremely complex. In the ameba, a particle of food is taken into its body apparently at any point. The nutritious part is then dissolved through the action of certain peculiar substances called enzymes, which are found in the protoplasm. Thus dissolved, it is distributed throughout the body by the flowing and mixing of the protoplasm itself. The part of the food which cannot be dissolved is finally pushed out through the side of the body.

More complex forms.—In animals which consist of many cells, a special opening, or mouth, is found through which alone food can enter. Connected with this is a special canal running through the body, within which all undissolved food material is kept. This canal has a definite wall lined with cells, which secrete substances capable of dissolving the food materials. It ends in an opening through which all the undigested parts of the food are expelled. This canal for food, the *alimentary canal*, is really an infolding of the outside surface of the body, for the double purpose of furnishing a reservoir

for the food and a special organ for its digestion.   In
man, as in the higher animals, the alimentary canal
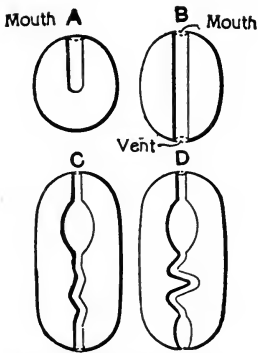
FIG. 59. Diagram to illustrate
the gradual development of
the alimentary tube as found
in the lower and higher forms
of animal structure. (Testut.)
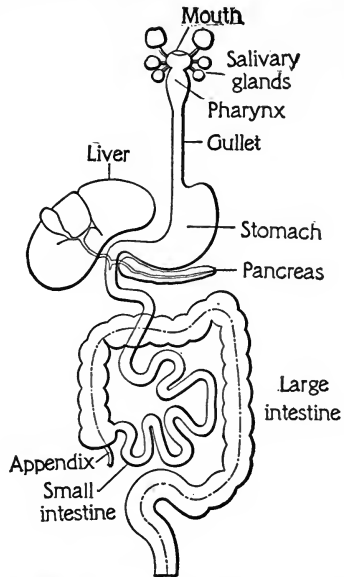
FIG. 60. Diagram of the alimentary tube
and its appendages. (Testut.)

has become a complicated system of organs, each of
which has its own peculiar work to do.

Mouth.—The first section of the alimentary canal,
the *mouth*, receives the food.   It is provided with grind-
ing stones, the teeth; with a device for stirring it up,
the tongue; with muscular walls for keeping it between
the teeth and for moving the jaws, the cheeks; and with
glands for moistening it with a digestive fluid, the
saliva.

Teeth.—The *teeth* are peculiarly adapted to reduc-
ing masses of food into the fine particles required for

digestion. As soon as the human infant begins to be active and to require other food than milk, his teeth
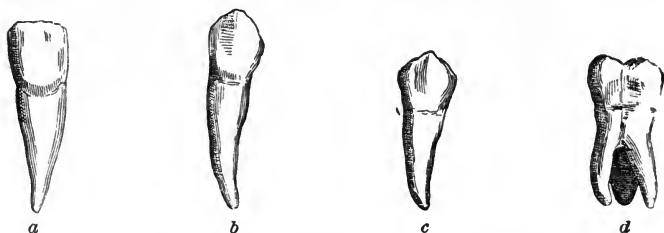
FIG. 61. *a*, An incisor tooth. *b*, A canine or eye tooth. *c*, A bicuspid tooth seen from its outer side; the inner cusp is accordingly not visible. *d*, A molar tooth.

push their way out through the soft gums from the bones of the jaws in which they have been developing. The first tooth usually comes when the baby is about seven
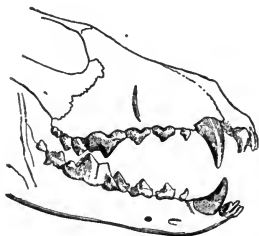
FIG. 62. Teeth of dog.

FIG. 63. Teeth of horse.

months old. At two years of age, he should have his first set of twenty teeth. Of these, each jaw contains

ten, divided into two sets of five on each side. In each of these sets of five, there are found in front two sharp teeth with edges like a chisel for cutting, called *incisors*. Next to these at the sides is one pointed tooth for tearing, called from its resemblance to the corresponding tooth in the dog, the *canine*. Last of all come two back teeth with broad irregular flat tops for grinding, which are appropriately named *molars*.[1]

Permanent set.—When the child is almost six years of age, another molar appears at the back end of each
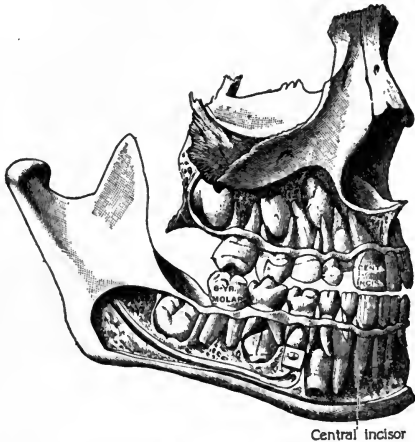
Fig. 64. The jaws of a child of seven and a half years, with the external table of bone cut away to show how the teeth of the second set push their way out. (Testut.)

series of five. These four molars are the first of the permanent teeth. The next of the permanent set to come are the incisors, which push their way out from under the temporary teeth. The roots of the temporary teeth are destroyed by the pressure of the budding teeth

[1] Latin, *molere*, to grind.

beneath, and the teeth themselves fall out when there is nothing left to hold them in. In this way, all of the temporary teeth are displaced one after another by the permanent ones, which consist of four sets of eight teeth each. Each set has two incisors, a canine, two bicuspids and
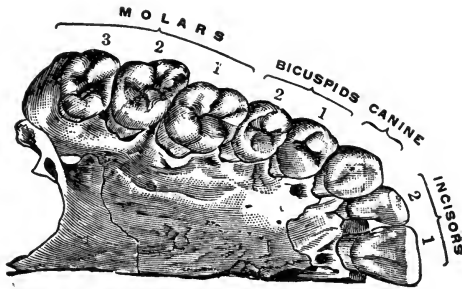
FIG. 65. The teetn of the right half of the upper jaw in their sockets, viewed from below.

three molars. The bicuspids are so named because they each have two prominences or cusps on their crowns. They are used for crushing and also, like the molars, for grinding. The third molar of each of the four sets, known as the *wisdom tooth,* develops late and is often deficient in strength and endurance.

Development of teeth.—The teeth closely resemble bone and are formed as buds within the jawbones, where their roots permanently remain. They are, however, not true bone, as shown by their structure and method of development. They are to be classed rather with the other specialized outgrowths from the skin, such as the nails and hair.

Roots.—By means of *roots,* the teeth are rigidly held in the bones of the jaws. The incisors and canines have single roots. Some of the bicuspids have single roots,

whereas others have roots which are forked near the tip. Most of the molars have three roots.

Structure.—Each tooth consists of the exposed portion, or *crown;* the narrowed part enclosed by the edges of the gums, called the *neck;* and the portion imbedded in the bones, the *roots.* When sawed through lengthwise, a tooth is found to consist of a bony portion and an inner cavity. The crown of the tooth is capped with the hardest substance found in the human body, a white *enamel,* which is all of the tooth that we ordinarily see. Enamel is made up of the same earthy material as bone but contains none of the

Fig. 66. Section through jaw bone and tooth of cat. (Waldeyer.)

animal material and but a slight amount of water.

Within the enamel lies a less hard bony material, the ivory or *dentine,* which forms the bulk of both crown and root. Dentine also contains less animal matter and less water than bone. The dentine of the root is protected by a substance which closely resembles true bone. It is called *cement,* because it serves to hold the teeth firmly in their sockets by wedging their roots against the bony walls.

The cavity within the tooth is filled with blood-vessels and nerves, which form the so-called *pulp* of the tooth and enter it through small holes at the tips of the roots. They supply the dentine with nourishment and keep it

alive. When for any reason they are destroyed, the tooth is dead; but this does not interfere with its usefulness, since a dead tooth, if properly cared for, may remain in the jaw for many years.

Tongue.—The *tongue,* which helps to hold and move the food in chewing, consists of a mass of interlacing muscular bands, so distributed that they can move the tongue

Sterno-mastoid muscle
Parotid gland and duct
Jugular vein
Carotid artery
Submaxillary gland and duct
Sublingual gland and duct
Jaw bone

Tooth
Lip
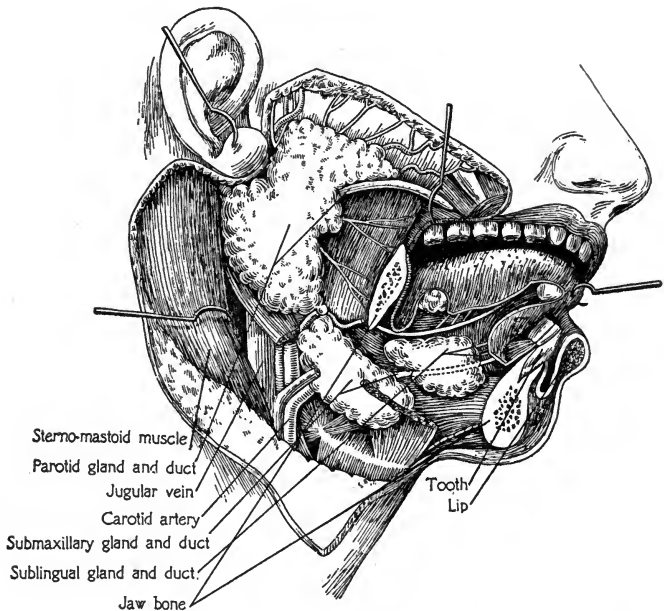
Fig. 67. The salivary glands, a portion of lower jaw having been removed.

to any part of the mouth or curl it up so that its tip can reach to all the teeth. The tongue is richly supplied with blood-vessels and nerves, and is covered with a thick membrane, which contains upon its upper surface the organs of taste.

Cheeks.—The *cheeks*, which are so necessary for keeping the food between the teeth, consist chiefly of powerful muscles. These draw the lower jaw upward, so as to bring the teeth firmly together for biting and chewing.

Salivary glands.—The *glands* of the mouth secrete a large amount of watery fluid, the saliva, which moistens the food as it is chewed. There are three pairs of salivary glands, one pair of which, the *sublingual,* lies under the sides of the tongue. Another pair, the *submaxillary*, lies just beneath the angles of the lower jaw, at each side. The third pair, the *parotid*, lies in the cheeks just in front of the ears. In mumps, the parotids become swollen.

Saliva.—The *saliva* is a thin alkaline solution of various substances, the most important of which is a ferment [1] called *ptyalin*. Ptyalin has the power of changing insoluble starch into a soluble kind of sugar, called *maltose*, without undergoing any change itself. Since ptyalin, like all other ferments, requires time to do its work, starchy food should not be swallowed without a good deal of chewing. Of all foods, starch alone is thus acted upon by the saliva. The others are merely moistened, that chewing and swallowing may be made easy.

Pharynx.—When a mouthful of food has been properly chewed, it is reduced to a thin watery mixture. The tongue and the cheeks then squeeze it into the cavity at the back of the mouth, the *pharynx,* from which it

---

[1] A ferment or enzyme is a substance produced by living cells, which causes chemical changes in other substances without itself undergoing change. There are many ferments, each one of which can act only upon a single kind of substance, as ptyalin upon starch, pepsin upon proteids, amylopsin of the pancreatic juice upon starch, and lipase of the pancreatic juice upon fat. Many ferments are also found in the various tissues of the body and assist the cells in the oxidation of food and the development of energy therefrom.

has been previously kept by a muscular curtain, the *soft
palate.* The pharynx opens into both the mouth and
the nose and is the part of the throat which we see when
we look into an open mouth. At the bottom of the
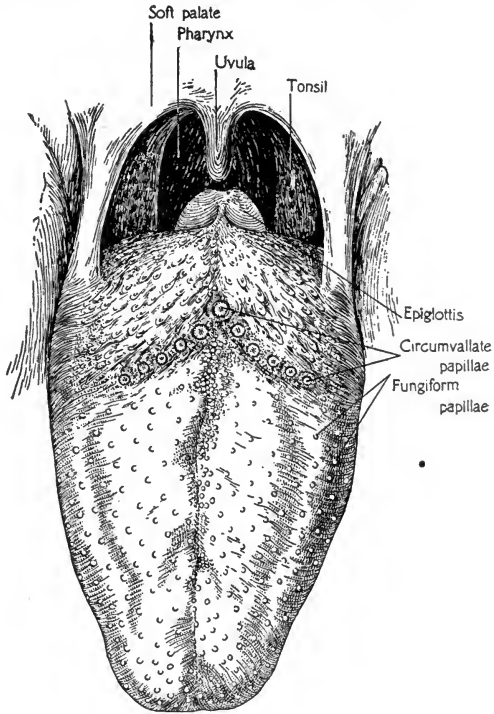
FIG. 68. The upper surface of tongue and the throat.

pharynx there are two openings. One of these, the wind-
pipe or *trachea,* has a swinging lid which closes during
swallowing so as to keep the food out. The other, the
gullet or esophagus, is the regular passage for the food
and is open only during swallowing.

Esophagus.—When the food reaches the pharynx, its muscular walls push it over the top of the trachea into the *esophagus,* which relaxes to receive it. The muscular fibres which make up the walls of the esophagus close
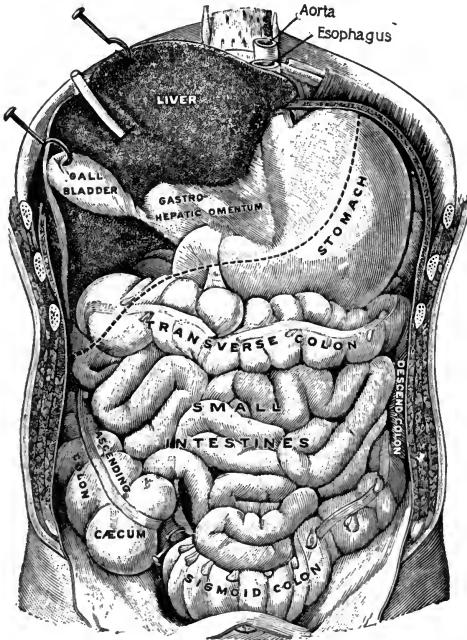
FIG. 69. The stomach and intestines, front view, with the liver turned up and to the left. The dotted line shows the normal position of the anterior border of the liver. (Testut.)

above the food and, by relaxing in front and contracting behind it, force it quickly into the large food reservoir, the stomach.

Stomach.—The *stomach* is a loose muscular elastic bag, which in an adult contains about three pints when normally distended. Its walls consist of several thin

layers, one of which is made up of muscle fibres inter-
laced to form a thin elastic coat. This coat can increase
or diminish the stomach's capacity by relaxing or con-
tracting. The inner layer or lining of the stomach is a
thick coat of cells, in which lie the glands for secreting
a digestive fluid, the gastric juice. The stomach is
shaped like a pear, sharply curved to one side. The
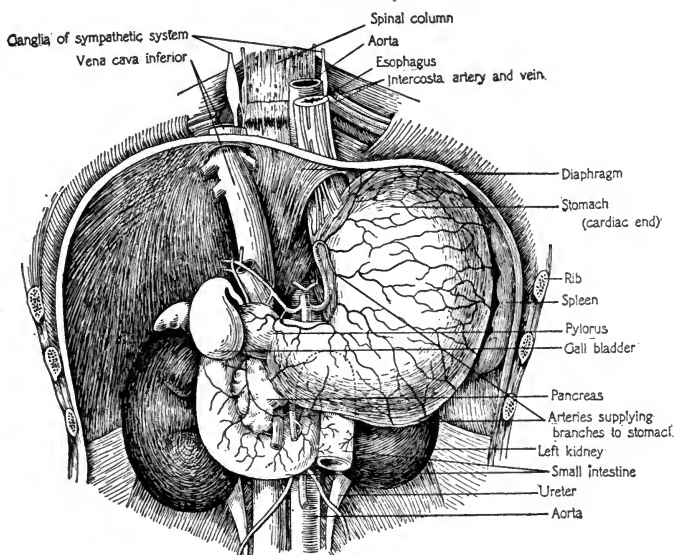
Fig. 70. The stomach and a portion of the small intestine, the remainder of in-
testine and liver having been removed.

esophagus leads into its larger end, and its smaller end
is continued into the intestine.

Gastric juice.—The innumerable small glands which
secrete the *gastric juice,* are embedded in the walls of
the stomach, with their mouths opening into its cavity.
The gastric juice is composed of hydrochloric acid and

a ferment [1] called *pepsin*. During the digestion of a meal, a large amount of gastric juice is secreted and is thoroughly mixed with the food by the contractions of the stomach, forming a grayish acid liquid called *chyme*.

The gastric juice changes the proteids in the food into soluble forms which can be readily absorbed, called *peptones*, but it has no effect upon the carbohydrates or hydrocarbons.

Exit of chyme from the stomach.—During the first hour or so of digestion, the opening from the stomach, the *pylorus*, is comparatively small. Only the liquefied contents, such as the starches and sugars and those proteids which have been changed into peptones, are allowed to pass through it in small amounts. During the later period of digestion, when the stomach becomes fatigued or considerably emptied, the pylorus relaxes more completely and permits particles of considerable size to pass through. The relaxation

Fig. 71. Section through a stomach gland, showing its central canal and the arrangement of its cells. (Gerrish.)

under the normal conditions of health is sufficient to empty the stomach at the end of from two and a half to three hours. The stomach then enters upon a period of rest, during which the glands are preparing for a subsequent period of work.

[1] Another ferment called *rennin* is found in the stomach, especially in babies and other sucking animals. Rennin has the power of coagulating milk as a preliminary to its digestion.

Rejection of food.—In case the food taken is irritating to the stomach because of its poisonous nature, or is so excessive in amount as unduly to stretch its walls, the stomach empties itself by sending the food back the way it came. This swallowing up, as it may be called, is accomplished on the part of both stomach and esophagus by a reverse process of muscular contraction. The esophagus relaxes to permit the food's exit, instead of the pylorus.

Fig. 72. Diagram illustrating the muscular contractions of a cat's stomach after eating a meal just before 11 A.M. By these contractions, the contents are squeezed toward the pylorus. (Cannon.)

Small intestine.—After its exit from the stomach through the pylorus, the chyme passes into the upper end of the *small intestine*. This is a tube about twenty feet in length, with muscular walls lined with a mucous membrane of closely packed cells. Lying in and beneath this membrane are many small glands, which discharge into the intestine a secretion, the *intestinal juice*. The intestinal juice contains a number of ferments that have the power of digesting starch and proteid, and of changing cane sugar into grape sugar, in which form only it can be utilized by the body.

Liver.—Opening into the small intestine near the stomach are two small tubes or ducts. One of these comes from the *liver* and its reservoir, the *gall-bladder*. The liver is the largest gland in the body and weighs from three to four pounds. It is reddish-brown in color, firm in consistency but easily torn, and lies across the body at the level of the lower ribs. It has several im-

portant functions, two of which are related to digestion. It serves as a storehouse for the excess sugar found in the blood coming from the intestine during digestion, and as a factory for the making of *bile*. The bile is a thin yellow-green alkaline liquid, which is secreted continuously and is stored in the gall-bladder when digestion
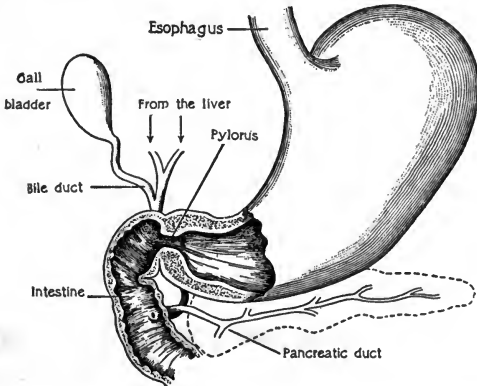
Fig. 73. Stomach, beginning of small intestine, and entrance of bile and pancreatic duct. (Hough and Sedgwick.)

is not going on. When the acid chyme enters the intestine, it causes a reflex contraction of the gall-bladder, which thereupon pours out bile through its duct. Unlike the saliva, the gastric juice, and the intestinal juice, bile has no specific action upon starches, sugars, or proteids. It is of great use, however, in the digestion and absorption of fat.

Pancreas.—The other of the ducts opening into the small intestine comes from a long gland, the *pancreas,* which lies at the lower edge of the stomach and along a portion of the intestine. The same stimulation by the acid chyme which causes the gall-bladder to contract and force out the bile, also causes the cells of

the pancreas to secrete its juice. The *pancreatic juice* is a thin clear liquid containing several ferments. One of these ferments acts upon proteids and aids in finishing the digestion of any part of them not completed by the gastric juice of the stomach. Another finishes the digestion of starch begun in the mouth by the saliva and continued in the stomach until stopped by the acid of the gastric juice. A third ferment acts upon fat, which cannot be acted upon by either the saliva or the gastric juice.

Digestion of fat.—The fat in animal tissues is in the form of drops of oil which are stored up within the cells of the connective tissue. The walls of these fat cells
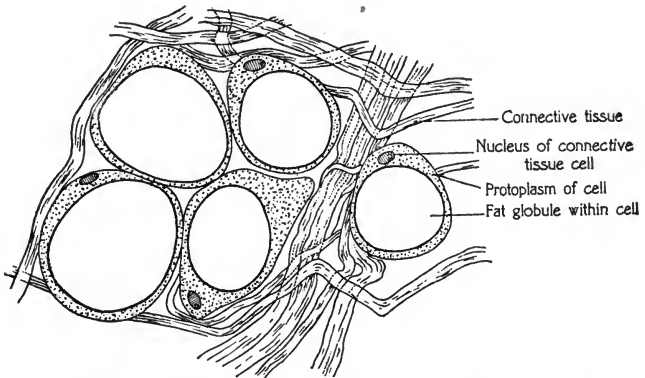
FIG. 74. Diagram showing storage of fat within connective tissue cells.

are digested in the stomach by the gastric juice, so that the fat is free when it enters the intestine. As a result of the action of the pancreatic juice upon it, assisted by the alkaline bile, the fat is so changed that it can be readily absorbed through the walls of the intestine. The action of the pancreatic juice is not com-

pleted immediately but takes place gradually as the food contents are slowly churned forward through the small intestine by the contractions of its walls.

Chyle.—The bile and the pancreatic juice, when mixed in the intestine with the grayish chyme, make of the fat a soapy solution, or emulsion, and thereby change the chyme into a white alkaline mixture known as *chyle.*

Villi.—Up to this point, only a small amount of food has been absorbed through the walls of the mouth and
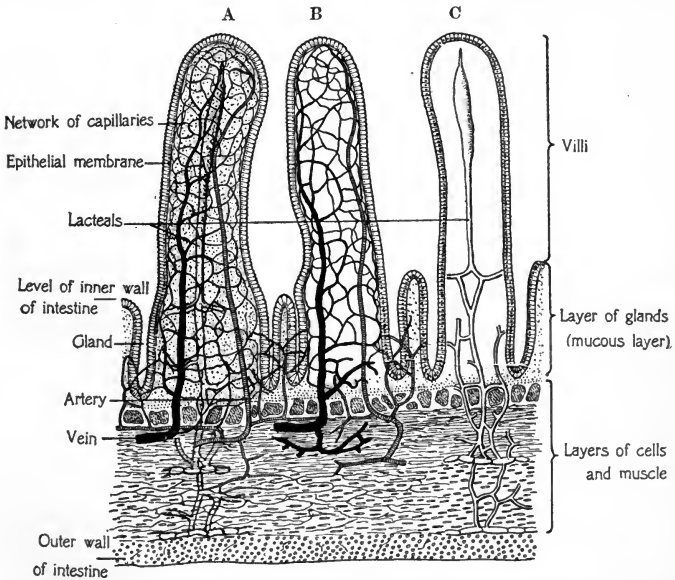
Fig. 75. Small section of wall of intestine showing three villi. In A, artery, vein and lacteal with their branches are represented; in B, artery, vein and branches; in C, the lacteal only. (Diagrammatic.)

stomach into the blood-vessels. The small intestine has a special mechanism by means of which practically all of the digested material in the chyle is absorbed into

the body before the residue passes into the large intestine. This mechanism consists of minute finger-like processes, the *villi,* which project from the inner wall of the intestine into its cavity, where they are bathed by the chyle. The villi are covered with a continuous layer of cells. Within this wall of cells lies a network of connective tissue cells, muscle fibres and blood-vessels. Scattered among these are irregular spaces, into which open the mouths of tube-like channels, called *lacteals.*

Absorption of food.—The solutions of food materials absorbed by the villi from the chyle pass into the body in two ways. The peptones and the sugars diffuse directly into the fine blood-vessels in the villi and are thence carried in the blood stream to the liver. The fats, which remain in the villi after the peptones and sugars have been absorbed, are pumped by them into the lacteals, which in turn take them into the blood but not by way of the liver.

In this process of absorption, it is difficult to see how the solutions get through the cells which form the membrane covering the villi. Experiments show conclusively that the cells must have the power of passing the solutions of peptones and sugars and the emulsion of fat through themselves. It is true that peptone and sugar can diffuse through animal membrane, but, unless they were assisted by some action of the cells themselves, it would be at a much slower rate. Fats do not seem to be able to pass through animal membranes even slowly and therefore their absorption certainly requires the active assistance of the cells. Indeed, it is probable that the cells even change the fats into soaps in order to facilitate their passage.

Food after absorption.—As the digested food passes through the membrane covering the villi, its character

is once again changed. In the blood, peptone is not found, but in its place appear certain forms of albumin and other proteids peculiar to the blood. The emulsion of fat becomes again ordinary fat. The maltose, the special form of sugar derived from the starches and sugars eaten, alone remains as maltose. When this reaches the liver, however, most of it also is changed back into a form of starch, the so-called liver or animal starch known as *glycogen*. Thus we see that the main purposes of digestion are to change the food so that it can be readily absorbed and then manufactured, in the case of proteids and fats, into the forms peculiar to the blood.

Undigested residue.—After the chyle has been absorbed from the small intestine, there still remains a certain amount of undigested material. This ordinarily consists of the cellulose from the vegetables and grains eaten, of the connective tissue from meat, and of any digestible matter which has escaped the action of the various digestive juices. This residue is passed from the small intestine into the large intestine through the connecting *ileocecal valve*. Occasionally, when masses of indigestible material are unable to pass readily through this valve, a pronounced distention of the intestine results, producing the pain known as colic.

Large intestine.—The *large intestine* is about five feet long in an adult and varies from one and a half to two and a half inches in diameter. Its walls are made up of a series of pockets, the partitions of which serve to prevent its contents from passing forward too rapidly. In it, a certain amount of digestion and absorption, especially of water, still goes on. As a result, the mass of undigested food and waste becomes firmer and dryer. It passes forward around the partitions in the walls and

is finally caught as a semi-solid mass in a sharp curve which lies in the left groin. From this, it is ejected at intervals.

<center>EXPERIMENTS AND DEMONSTRATIONS</center>

<center>*The Alimentary Canal*</center>

Materials: Sound and diseased natural teeth such as can be obtained from a dentist; dilute hydrochloric acid or vinegar; rabbit such as can be bought at a market; a short piece of the small intestine of a recently killed calf or sheep; alcohol, 50 per cent strength; normal salt solution; sheet of fine emery cloth; microscope; fine saw; hand lens.

1) *Teeth:* Soak sound teeth in warm water for one or two days; saw some lengthwise, others crosswise, and smooth on emery cloth.

a) Examine the structure.

b) Demonstrate decayed teeth.

c) Test the effect of an acid upon a tooth.

2) *Salivary glands:* Dissect away the skin from the whole ventral aspect of rabbit and note salivary glands:

a) Below and back of the ear, the pink mass of the *parotid gland.* (It is difficult to trace the duct which has its outlet on the inside of the cheek).

b) Just inside the angles of the lower jaw, the rounded masses of the *submaxillary* glands.

c) Farther forward, under the tongue, the narrow *sublingual* glands.

3) *Mouth and throat:* Examine the muscles moving jaw. Cut away the muscles on one side of mouth and neck, exposing cavities of mouth and throat. Identify and sketch the following:

a) Teeth; tongue; and hard and soft palates.

b) Cavity at back of mouth and its connection with nasal cavity; tonsils; muscular walls of pharynx; larynx; epiglottis; and the opening into esophagus.

4) *Esophagus, stomach and intestines:* Carefully cut away the front walls of chest and abdomen. After examining and

sketching the larynx, trachea, lungs and heart, remove them by freeing blood-vessels and other attachments:

a) Trace and sketch the esophagus, stomach, liver and intestines, disturbing their natural positions as little as possible.

b) Turn liver out of the way and follow esophagus to stomach:

Note form of stomach; its projection (*fundus*) to the left of esophagus; its great and small curvatures; its narrower pyloric portion on the right, from which the small intestine proceeds.

Notice a thin membrane (the *omentum*) attached to stomach and hanging down over the abdominal contents, ordinarily loaded with fat.

c) Follow and unravel the coils of small intestine, spreading out as far as possible the delicate membrane (*mesentery*) which suspends it from the upper dorsal part of the abdominal cavity.

Note the blood-vessels and lacteals running in the numerous bands of fat in the mesentery.

d) Cut open the side of large intestine opposite entrance of small intestine:

Note the termination of small intestine in the ileocecal valve; the *cecum* or blind end of large intestine, projecting beyond the ileocecal valve.

Compare the position of *vermiform appendix* and cecum with that in the human body. See pp. 97, 105.

Follow large intestine through ascending, transverse, and descending colon, sigmoid flexure, and rectum, to its end at anal aperture, cutting away front of pelvis to follow terminal portion.

e) Spread out the portion of mesentery lying in the concavity of the first coil (*duodenum*) of small intestine:

Note the pancreas, a thin, branched, glandular mass; the portal vein entering the under side of liver by several branches which drain the intestinal tract; near it the gall duct, formed by the union of two branches and proceeding as a slender tube to open into duodenum about $1\frac{1}{2}$ in. from pyloric orifice of stomach.

f) Cut off esophagus and rectum, remove the whole alimentary canal, cut away mesentery, and spread the canal out at full length:

Note the relative length and diameter of its various parts and determine the ratio of its length to the length of body.[1]

g) Open stomach along its greater curvature:

Note character of mucous membrane.

Examine under water the surface of lining membrane with microscope.

h) Remove liver:

Note its general form and relation to body as a whole, to stomach, and to intestine, with special reference to veins and bile duct.

Scrape its cut surface and examine cells in normal salt solution under microscope.

Find gall-bladder and trace out its ducts.

i) Cut out piece of intestine (also of calf or pig), wash inner surface gently with normal salt solution, and examine in the solution with a hand lens.

j) Place pieces of small intestine in 50 per cent alcohol for 24 hours. Then open and examine villi under water with a hand lens.

Digestion

Materials and apparatus: Sugar; salt; raisins, grapes, cranberries and other fresh fruits, with skins and stems uninjured; corn or arrowroot starch; olive oil; blood fibrin either fresh or dried and softened in warm water,—or egg albumin coagulated by slowly pouring white of egg, which has been cut up with scissors and forced through cheese cloth, into boiling water acidulated with vinegar; meat juice; milk; bile of pig or other animal, obtained from butcher; glycerole pepsin, Parke, Davis & Co.; pancreatic extract made by dissolving in 2 oz. warm water, 15 grs. dry extract obtained from druggist; saliva collected by chewing paraffin or a piece of rubber and filtered; hydrochloric acid, 2 per cent solution made by adding 1 teaspoonful commercial hydrochloric acid to 1 qt. water; sodic hydrate solution; copper sulphate solution; water bath for holding test tubes (a deep tin containing a wire test tube rack, nearly

---

[1] It must be remembered that the rabbit is herbivorous and therefore has an alimentary tract quite different in certain particulars from that of man. The alimentary canal of a cat or dog more nearly resembles the human.

filled with water and kept at a constant temperature of about 99° F. will answer); thermometer with scale on stem or in glass tube; wire test tube racks, each with a capacity of 3 doz. test tubes; one wooden test tube rack with holes and pins for each pair of students; dialyzer, which may be made from a lamp chimney, the large end being covered with bladder, intestine, or moist parchment paper; funnels 2 in. in diameter for students' use; funnels 6 or 8 in. in diameter for preparing material; six 6 in. test tubes for each student; nests of 3 beakers of from 4 to 6 oz. capacity; filter papers, 1 package 3½ in. in diameter, a few, 6 or 8 in.; litmus paper.

Experiments[1]*:*

1) *Penetration of membranes by crystalloids (sugar, salt) and by peptone:*

a) Place dialyzer obliquely in a glass, so that the membrane-covered end does not rest on the bottom. Carefully pour the solution to be tested (1 teaspoonful sugar, or salt, to ½ cup water) into open end of dialyzer so that no particle of it is spilled. Pour pure water into the glass to exactly the same level as solution in dialyzer and allow to stand over night. Test the water in glass by taste or chemically.

b) Test peptone and other solutions similarly.

[1] Use a test tube for each experiment beginning with 4. Identify them by slipping bits of paper containing names of students and contents into the open ends. Place the test tube for all digestion experiments in that portion of the water bath reserved for each student. It is best to use small amounts of substances for digestion, to fill the test tubes about two-thirds full of the solution, and to shake frequently. Two or three drops of the solutions of pepsin and of pancreatic extract are sufficient. The digestion ordinarily requires some time, and it may be necessary in certain cases to prepare the solutions, put them in the water bath, and leave them until the next day for examination. If the test tubes are shaken every few minutes, the digestion of starch and of fibrin (or egg albumin) is so rapid that it may be possible to get the proper reactions in half an hour. If the laboratory section extends for two hours, the digestions will be sufficiently completed at the end of that time for all characteristic tests. It is best to have the pupils prepare the digestion test tubes first, then to have the demonstrations and experiments which can be accomplished immediately, and to leave the examination of digestion products until the last.

2) *Non-penetration of membranes by colloids (starch, albumin) except peptone:* Proceed as in 1).

3) *Absorption (Osmosis):*

a) Place 2 grapes, 2 raisins, 2 cranberries or other similar fruit into glasses containing hot water and allow to stand for an hour. Compare the fruits with untreated specimens.

b) Prepare a syrup of 2 parts of sugar to 1 of water, bring to a boil, and stir in fruit as in a). Let stand for an hour; compare with a) and with untreated fruits. (If difference is not sufficiently obvious, allow to stand over night.)

Note in both a) and b) changes in size and consistency, and infer what has caused results in each case. Record all observations in schedule form, using the following signs: diminution ($-$); increase ($+$); no change ($=$); solution in water (dissol.).

	In water	In syrup
Raisin		
Grape................................		
Cranberry		

4) *Effect of saliva:*

a) Prepare proteid, fat, and boiled and raw starch paste, by mixing in test tubes with water to which 1-3 in bulk of saliva has been added. Place in water bath, shake frequently, and watch progress.

b) Mix a little saliva with 3 or 4 volumes of thick starch paste and note its immediate effect.

c) Test results of salivary digestion in a) for starch,[1] sugar and peptone.[2]

5) *Effect of artificial gastric juice:*

[1] Test by putting 1 drop of solution on a white plate and adding a drop of the iodine solution. A brownish color indicates *dextrin*, a partially digested starch.

[2] *Biuret test for peptones:* Put ½ in. of solution to be tested for peptone into a test tube. Add an equal amount of sodic hydrate solution, mix thoroughly, and then add 1 or 2 drops of very dilute copper sulphate solution. Violet color indicates peptone.

a) Make gastric juice by adding a few drops of glycerole pepsin to 0.2 per cent hydrochloric acid. Prepare digestion test tubes by adding ½ test tube of solution to small amount each of egg albumin (or fibrin) and starch.

b) Test results of gastric digestion in a) for peptones by means of *biuret test*.

6) *Effects of pancreatic juice and bile:*

a) Shake sweet oil with an equal amount of solution of pancreatic extract.

b) Prepare as in a) and add a few drops of bile. Compare with a). Examine a drop under microscope and compare with a drop of milk.

c) Moisten with bile a filter paper stretched across top of a funnel and add a teaspoonful of oil. Moisten with water another filter paper similarly placed, and apply the same amount of oil. Note comparative rapidity of penetration.

4) Make soap by boiling fat or oil with a strong solution of caustic soda. Test result by shaking a few drops with water.

CHAPTER XI

THE HYGIENE OF DIGESTION

Food in relation to age.—The amount of food sufficient for the body's needs varies with age and with activity. The active growing child requires food not simply to produce energy but to build up his tissues. He therefore requires more food in proportion to his weight than the adult, who needs the food principally for the production of energy. The aged person, whose activity is slight and whose tissues are changing but slowly, needs but comparatively little food.[1]

To health.—The amount of food required also varies with the general condition of the body, that is, whether it is healthy or ill. In illness, not only is muscular activity less, but the ability to digest may be so far reduced

[1]Influence of age on diet	Proteins		Fats		Carbohydrates		Calories energy
Children to 1½ years	28 20-36	gms. "	37 30-45	gms. "	75 60-90	gms. "	770
Children 1½ to 6 years	55 36-70	"	40 35-48	"	200 90-250	"	1423
Children 6 to 15 years	75 70-80	"	43 37-50	"	325 250-400	"	2048
Women with light exercise................	80	"	80	"	300	"	2308
Aged women...........	80	"	50	"	260	"	1867

The heat units used represent the amount of heat necessary to raise certain amounts of water one degree Centigrade.
1 Calorie　　　= 1 kilo water, 1° C.　　= 1 lb. water, 4° F.
1 calorie　　　= 1 gram water, 1° C.　　= 0.001 lb. water, 4° F.
1 micro-calorie = 0.001 gram water, 1° C. = 0.000001 lb. water, 4° F.
1 Calorie is equivalent in mechanical energy to 1.53　　　foot-tons.
1 calorie "　　　"　　"　　"　　　"　　" 3.06　　foot-pounds.

that certain foods cannot be used at all. The diet, therefore, which is proper for a person in good health may be most injurious for one who is ill.

To activity.—Another important factor in determining the amount of food necessary for the body is the amount of muscular activity. Of two healthy adults of the same weight and age, the one who is active requires more food than the one who is not, because the former is constantly having to oxidize food materials for the production of energy.[1] If the inactive man should eat and absorb as much as the active one, instead of oxidizing it all, he would store the excess as fat.

Variations in diet.—Between the amount of food required by the body and the amount actually eaten, there is often a wide divergence. If a person's appetite is good or if he can afford to tempt it with luxuries, he may overeat; if poor, he may fail to have enough to eat. It is probably true that many persons eat too much proteid, especially in the form of meat. Proteid can be stored in the body but slowly, even during the growing period of youth. In adult life, only a comparatively small amount is needed to make good the wear and tear of the active tissues. Since the greater part of it cannot be stored, it is immediately oxidized for the production of energy, and its waste products of urea and uric acid are removed by the kidneys. Up to a certain point, the kidneys are able easily to do this. If the proteid

[1] Effect of activity on diet	Proteins	Fats	Carbo-hydrates	Energy in calories
Man at light in-door work......	110	60	390	2,645
" " " out-of-door work..	110	100	400	3,063
" " moderate out-of-door work......	125	125	450	3,568
" " hard out-of-door work	150	150	500	4,120
" " very hard out-of-door work in winter........	180	200	600	5,026

taken is excessive, however, the kidneys may become
overburdened, especially if they are weak or diseased.
The waste products then tend to clog or even to poison
the body.[1]

Times for meals.—The hours at which food is taken
depend a good deal upon the habits of peoples and of
individuals. In America, it is customary to have three
quite substantial meals a day. In determining what
practice is best for a given individual, the amount of
physical work to be done is the main factor. For the
man who is to do a morning's hard muscular work, a
substantial breakfast is essential, whereas lighter work
requires less food. The test in any case of whether
enough food has been taken is the person's condition
previous to the next meal. If he feels faint and ex-
hausted, with possible headache and even nausea, it
shows that his breakfast has been too scanty. He should
either have eaten more or have had a luncheon between
the two meals. If, on the contrary, he feels dull and
sluggish with little appetite for the next meal, he has
eaten too much. The same rules apply to the midday
meal. If a person is dull and sleepy after it, he should
eat more sparingly. At night, the meal should be com-
paratively light for children who go to bed soon after
it, in order that they may sleep soundly. For those who
are active for three or four hours afterwards, a hearty
meal may be necessary. The test of whether or not
the proper amount is eaten is the soundness of sleep
and the appetite for breakfast.

Appetite as a guide.—For those who are active the
appetite is a guide as to when food should be taken and

[1] Experiments have shown that men can work to advantage on
about half as much proteid as the foregoing tables show, that is,
on from 50 to 70 gms. per day of dry proteid, which is the equiva-
lent of 200 to 300 gms. or 7 to 10 oz. of meat.

how much. Under ordinary conditions, however, the appetite is for various reasons often misleading. Appetite itself is a diffused sensation of discomfort, which is caused partly by the failure of the tissues to receive as much food as they need and partly by the failure of the stomach to be adequately filled with the food which it has been trained to expect. For the appetite to be a reliable guide, it must be aroused only when the tissues need food and the stomach needs filling. If a person is habitually overeating, the stomach trained to expect food at given intervals, gives the signal through the appetite that it is time for more food, in spite of the fact that the tissues do not need it and so must store the excess as fat. If, on the contrary, a person habitually eats too little, the stomach accustomed to expect and to take care of but small amounts, may fail to produce the appetite for food, although the tissues are actually in need of it.

Its unreliability.—Another factor which contributes to the unreliability of the appetite is that it often outlives its cause and so leads to the taking of a larger amount of food than is necessary. The stomach may be filled sufficiently by a meal to satisfy the needs of the tissues and yet the appetite persist, especially if the food has been swallowed without much chewing. If the appetite is further reinforced by pleasure in eating, the probability of overeating is greatly increased. To avoid this, food should be eaten slowly, that the appetite for it may tend to cease when enough has been eaten.

A third most important cause of an unreliable appetite is eating between meals. This practice not only interferes with the rest which the stomach needs but also prevents the proper recurrence of appetite. When for

any reason, as in illness, a proper amount of food can-
not be taken at the regular times, the intervals between
the meals should be shortened but still kept regular.

Composition of food.—That food may fully nourish
the body, it must not only be taken at the proper time
and in the proper amount but it must also be of the
right composition, that is, it must combine the right pro-
portions of proteid, carbohydrate and hydrocarbon. The
amount of proteid which is needed daily by the body has
been shown by investigation to be fairly constant and
smaller than was formerly thought. The proper amount
of carbohydrate and hydrocarbon varies with our ac-
tivity. Muscular energy may come from the oxidation of
either the carbohydrates or the hydrocarbons, although,
as a matter of fact, it is usually derived more largely
from the carbohydrates since the fats are ordinarily
eaten in much smaller amounts.[1] They are both oxi-
dized and their waste products removed in the same
way. If taken in excessive amounts, they may both
give rise to indigestion.

Necessity for variety.—The kinds of food which con-
tribute the proteids, carbohydrates and hydrocarbons
are important, since their proportion may be right and
yet the monotony of the food be distinctly injurious,
especially if there is a tendency to overeating. Loss
of appetite and failure of digestion may result from an
unvarying diet. It is necessary therefore to plan to
have the kinds of food changed frequently enough to
avoid monotony.

Importance of good teeth.—However carefully we
may determine the amount and kind of the food which

[1] In cold climates and in cases of poor nutrition and of tuber-
culosis, much larger amounts of fats may sometimes be taken with
benefit, provided they are not used in such a way as to make other
foods indigestible, as in frying.

we eat, we cannot be sure of a good digestion unless we take care of such of the digestive organs as are under our control. Of these, the most important are the teeth. Unless our food is adequately chewed, indigestion almost surely follows. The influence of bad teeth upon the general health has been shown to be so marked that the importance of keeping them clean and of having all cavities, even in the first teeth, attended to by a dentist, cannot be overestimated. Decayed teeth interfere with proper chewing, and act as lodging places for microbes, which not only make the breath foul but may also infect the glands of the jaw and neck. To keep the teeth clean, they must be brushed after each meal with a good tooth powder or paste. The brushing should be up and down and not across the teeth, as the latter method wears the teeth unnecessarily and does not clean between them. A strong silk thread should also be used to remove any particles of food that may have lodged between them. If the thread is moistened and covered with tooth powder, it will keep the sides of the teeth polished and tend to prevent the deposit of tartar. Any discoloration or deposit should be removed by rubbing the teeth with powdered pumice upon the end of a moistened pointed stick.

CHAPTER XII

THE BLOOD

THE products of digestion are received and carried to the tissues by the blood, a red salty liquid which constitutes about eight per cent of the total weight of the body. Upon exposure to the air, the blood quickly
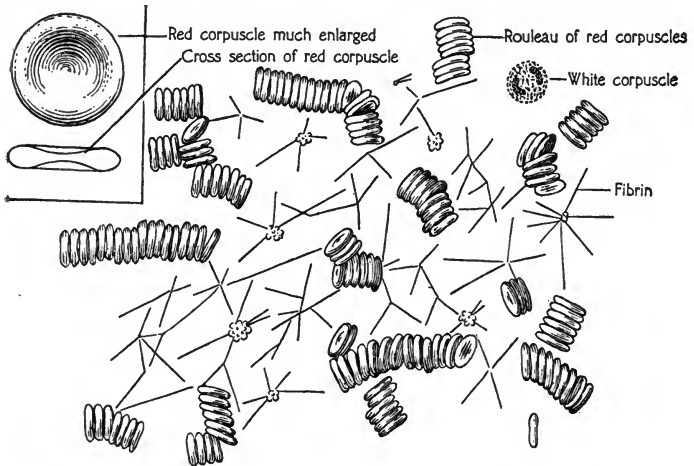
FIG. 76. Coagulated blood (highly magnified).

becomes sticky and jelly-like through the formation of clots. When examined under the low power of a microscope, blood is seen to consist of a clear colorless liquid, the *plasma,* which is thickly packed with small rounded particles, the *corpuscles,* the majority of which are a pale yellowish-red. When examined under a higher power, the corpuscles are seen to have several different forms. Those which are yellowish-red appear as flat-

tened discs. Others which are translucent or "white," are globular and have one or more small rounded granular bodies, the *nuclei*, within them. Still others are smaller transparent discs.

Red blood corpuscles.—The blood owes its red color to the yellowish-red discs, which are therefore called *red blood corpuscles*. They consist of a clear jelly-like substance, *hemoglobin*, which readily absorbs oxygen. Their shape makes it possible for them quickly to take up oxygen from the air and give it off to the tissue cells, since they are so flat and broad that each one of them exposes a comparatively large surface for absorption. It has been calculated that in an adult there are 25,000,-000,000,000 red corpuscles and that their total surface equals about 35,000 square feet. In a healthy person, 5,000,000 red corpuscles are contained in a drop of blood no bigger than a pin head (1 cu. mm.).[1] In bulk, they constitute one-half of the blood. They are developed in the red marrow of the bones and when full grown are set free in the blood current, in which they are carried to all parts of the body. They are destroyed in the liver and spleen.

White blood corpuscles.—The *white blood corpuscles* consist of granular protoplasm containing one or more nuclei. They are nourished by the blood and lymph and behave very much like amebæ, in that they are able to change their form and to lead an essentially

[1] In cases of anemia (literally, lack of blood), their numbers may be diminished to two-thirds or one-half of this. Consequently, the amount of oxygen necessary for full activity cannot be carried to the tissues, and the result is pallor and weakness. In hookworm disease, which is common in the South and other warm countries, the anemia due to the sucking of blood by parasitic worms in the intestinal wall, may be so great that there are but 1,000,000 cells in a cu. mm. of blood.

independent life. They make their way through minute openings in the walls of the blood-vessels and wander through into the spaces between the cells of the tissues without doing them any harm. By eating up microbes and small particles of foreign matter, they act as scavengers in the body. They are developed in the lymph glands [1] and spleen, from which when mature they are set free in the lymph and blood.
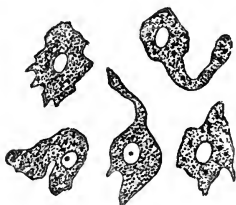
FIG. 77. A white blood-corpuscle sketched at successive intervals of a few seconds to illustrate the changes of form due to its ameboid movements.

The white blood corpuscles are present in the blood in the proportion of one white to five hundred red. In certain diseases, however, their number is often increased and as a result they are better able to combat the invasion of the harmful microbes to which the disease is due. In abscesses and pustules, many white corpuscles die, either overwhelmed in their attempt to destroy the microbes or smothered as a result of their own overcrowding in the inflamed tissue. The "matter" from abscesses is made up almost entirely of these corpuscles.

Platelets.—A third kind of blood corpuscle, the *platelet*, resembles the red blood corpuscle in form but it is smaller, more transparent and so exceedingly delicate that it breaks up almost instantly when blood is shed. Practically nothing is known of its functions, except that it assists in causing the blood to clot.

Plasma.—When the corpuscles are removed, the fluid of the blood, the *plasma*, remains as an almost colorless sticky liquid, composed of ninety per cent water and

[1] See pp. 132, 150.

ten per cent solids. The solids consist chiefly of proteids, together with fat and other organic substances, salts, and a small amount of fibrin-forming substance.

Fibrin.—Blood plasma upon its escape from the blood-vessels becomes very quickly a jelly-like mass, or clot, by the rapid formation of a close tangle of slender fibres, known as *fibrin*. When taken singly, these fibres are so delicate that they can be seen only through a microscope. When fresh blood is whipped with a bundle of twigs, the fibrin is caught on the twigs, where it forms very elastic white threads. Since the blood which remains does not clot, it is proved that its coagulation depends upon the formation of these threads, which, although constituting but one two-hundredth part of the blood bulk, are yet so numerous that they completely entangle the water and other constituents of the blood and hold it as a firm, fairly dry jelly. That the blood should be able to coagulate is most important, since thereby a vein or small artery when cut is quickly plugged and severe bleeding prevented. If a larger artery is cut, however, the force of the blood is so great as to prevent plugging by the formation of a clot.

Blood as a common carrier.—The general work of the blood is that of a common carrier and as such it furnishes the only means of transport within the body. It carries in solution to all the tissues their supply of food, which has been absorbed from the digestive tract, and gathers up from the special organs their secretions, which it distributes to all parts of the body. It also collects from the cells the waste products of oxidation and carries them to such organs as the lungs and kidneys for disposal.

Blood changes.—Because of these exchanges with the various tissues of the body, the blood is constantly

changed in character. For example, the bright red blood which comes from the lungs is rich in oxygen and fairly poor in carbon dioxide. After its contact with the tissues, the amount of oxygen is diminished, whereas the carbon dioxide has increased. As a result, the blood becomes a dark bluish-red. This blood again passes through the lungs, where it replenishes its supply of oxygen and loses much of its carbon dioxide, thereby regaining its brilliancy.

Food elements.—The character of the blood is also changed by the rapid absorption of food materials when we eat and drink. Some of these it stores up and later doles them out to the tissues as they need them for their activity.

Carbohydrates.—In the storage of the sugar absorbed, the blood is assisted by the liver. The liver takes from the blood the excess sugar which the blood absorbed in the villi during digestion and stores it in its cells in the form of a starch, called *glycogen*. As the blood becomes poor in sugar through loss to the tissues, the liver changes the glycogen once again into sugar and restores it to the blood. In this way, the supply of sugar in the blood is kept fairly uniform, provided that meals are taken regularly.

Hydrocarbons.—The fat absorbed into the blood after each meal remains there until removed by the tissues and oxidized. If, however, an excessive quantity of fat is eaten, the blood is assisted in taking care of it by the various cells of the body, especially those of the connective tissue, which store it within themselves in the form of fat globules.

Proteids.—The proteid material which is absorbed during digestion is retained in the blood until given up to the tissues for repair, growth, or oxidation. Dur-

ing growth a part of the proteid material is built into the developing tissues; the remainder is quickly oxidized for the production of energy. After growth ceases, the majority of the proteid eaten is oxidized, since none is needed for the building of tissue and but little for tissue repair.

Water.—Water, when absorbed from the intestinal tract, dilutes the blood temporarily, but is quickly removed by the kidneys. When water is taken in excessive amounts, there may also be a considerable temporary storage of it in the cells of the tissues.

Storage of excess food.—If food is taken at regular intervals, the blood is able to supply the tissues with the nourishment which they need in adequate amounts during the intervals between meals. If excess food is regularly taken, the tissues by preference oxidize the proteids and carbohydrates, with the result that the fat is left as a permanent storage.

Starvation.—If too little food is taken, or, as in starvation, none at all, we find a marked effort on the part of some of the tissues to keep up the normal composition of the blood. Not only are the stored supplies of fat and carbohydrate gradually returned to the blood, but additional proteid material is furnished by the sacrifice of the less active tissues themselves.[1] These actually convert themselves into food material for the tissues which must be active in order to preserve life, such as the heart and nervous system. These are thus enabled

[1] Total loss of various tissues in starvation:

Fat	97.0%
Liver	54.0%
Muscles	30.5%
Lungs	18.0%
Bones	14.0%
Nervous system	3.2%
Heart	2.6%

to continue their activity and the life of the individual is considerably prolonged.

Internal secretions of glands.—In addition to the food materials, the blood also carries the various products manufactured by the different cells and organs of the body. These materials, although in many cases the waste products of their activity, are yet essential to the health of the other organs and cells to which the blood carries them. Thus the pancreas not only discharges through its duct the pancreatic juice externally into the intestinal tract, but also gives directly to the blood passing through it an *internal secretion* which enables the cells of the body to oxidize and utilize the sugar brought to them as food by the blood. The kidney also probably does a double work of supplying an internal as well as an external secretion, which it gives to the blood for the benefit of the rest of the body.

Other internal secretions are those which come from ductless glands such as the *thyroid gland*, which lies in the neck; the *adrenal bodies*, which lie just above the kidneys; and the *pituitary body*, which lies at the base of the brain. These secretions have been shown by careful experiment to be of the utmost importance to the health of the other cells of the body.

Spleen.—Secretions are also probably contributed to the blood by the *spleen*, an organ lying in the left side of the abdominal cavity. Its exact functions, however, are still open to dispute, since it can be removed without serious consequences. The main function clearly belonging to it is the removal from the blood and the subsequent destruction of red blood corpuscles.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Alcohol; nitric acid; defibrinated blood; blood clot or fresh liver; serum; chisel-pointed needle; test tubes; blotting paper; microscope with powers up to 450; 2 fruit jars; bundle of twigs or wires; tumbler; platinum foil; alcohol lamp or Bunsen burner.

1) Get a drop of blood from lobe of ear or side of finger by rubbing vigorously, washing with a little alcohol, and piercing when dry to a depth of $\frac{1}{8}$ in. with a needle sharpened to a chisel point, soaked in alcohol, and dried. (No pain results from piercing.) Spread a drop of blood on a piece of glass, put on a cover glass, and examine under microscope. Note form, size and color of red blood corpuscles; method of clustering; color, form, size and relative number of white blood corpuscles.

2) Obtain a large drop of blood as above (1) described. Note its physical characteristics (color, opacity, etc.) when it flows from the wound; its apparent change of color when it is spread very thin on the glass and held over a sheet of white paper; its color when mixed with a teaspoonful or more of water in a test tube; its change of consistency when a drop of nitric acid is added and test tube is heated.

3) Place another large drop of blood on a clean glass plate. To prevent its drying, cover by inverting over it a glass lined with wet blotting paper.

In 4 or 5 minutes, remove glass and note condition of blood when manipulated with a needle.

Replace moist glass and in half an hour examine again.

Additional Demonstrations at Option of Teacher:

1) Collect blood at butcher's in a glass jar; set aside until blood clots and carry without shaking. Observe clot and serum next day. Carefully pour off serum for subsequent tests.

2) Collect fresh blood in a pail and beat it vigorously with twigs for 3 or 4 minutes. Note quantity of stringy elastic material (*fibrin*) collected on twigs.

Wash fibrin thoroughly in running water and note its color.

3) Take some of serum and note its physical characteristics.

Heat it in a test tube and note change.

Apply Xantho-proteic test.

4) Place a small quantity of whipped blood on a piece of platinum foil. Heat in alcohol or gas flame and note that after the drop dries it blackens, showing that it contains much organic matter.

Continue heating until this is burned away; examine residue of white ash, consisting of mineral constituents of blood.

CHAPTER XIII

THE CIRCULATION OF THE BLOOD

System of tubes for the blood.—In order that the blood may surely find its way from tissue to tissue in the body, a system of tubes and special organs has been developed. This system has a central pumping station, the heart, which furnishes the power by which the blood is pushed forward. A system of tubes, the arteries, veins and capillaries, leads from the heart to the tissues and back to the heart again. These tubes are so constructed and arranged that, although the blood is carried to all parts of the body through their many branches, yet it is all gathered together again and returned to the heart.

Greater and lesser circuits.—The blood leaves the large cavity on the left side of the heart and goes to the tissues through thick walled tubes, the *arteries*. It returns by larger and thinner walled tubes, the *veins*, to the right side of the heart. It is then sent through another set of arteries to the lungs, whence it again returns to the left side of the heart through a second set of veins, and is once again ready for a repetition of its journey to the tissues. There is thus the main circulatory route to and from the tissues comprising the *greater,* or *systemic, circuit;* and a secondary route to the lungs and return, which is known as the *lesser,* or *pulmonary, circuit.* Neither of these circuits is in itself complete, since the blood after returning from the tissues can reach the starting point in the heart for its next trip to the tissues only by way of the pulmonary route.

Heart.—To provide the power required to drive the blood through the arteries, its pumping organ, the *heart,* is a strong hollow body, whose thick walls are made up entirely of muscular tissue. In order to keep separate the blood in the two circulatory systems, the heart is divided into two parts with no direct means of communication between them. In each part are two chambers, an *auricle* and a *ventricle,* separated from each other by swinging doors, the *valves,* which by opening only in one direction prevent the blood from flowing backward.

Heart muscle.—The muscle which produces the power to push the blood forward, is arranged so as to form the

Aorta
Cavity of auricle
Auriculo-ventricular valve
Chordae tendinae
Cavity of ventricle
Papillary muscle
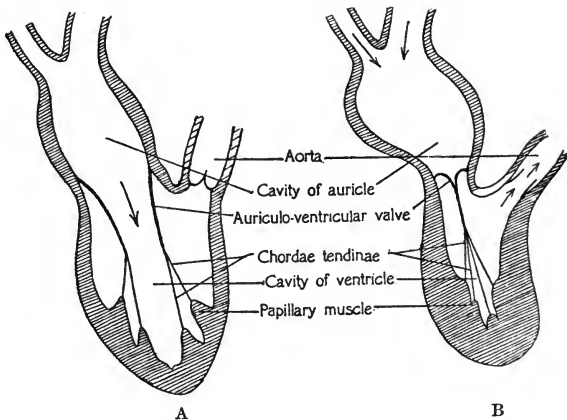
FIG. 78. Diagram of heart during relaxation and contraction: A, auricle contracting to fill ventricle; B, auricle filling, ventricle emptying into aorta.

walls and main partitions of the heart. The pumping action consists in the contraction of the muscular walls of both chambers when they are full of blood, until they become so small that the blood is forced out through the open valves. The valves then close and thereby pre-

vent its return. As soon as the blood is forced out, the muscle relaxes and allows another supply of blood to flow in and fill the chambers. This contraction and relaxation are repeated one or more times a second throughout life and cause the *heart beat,* which can be readily felt on the left side of the front of the chest.

Muscle cells.—The heart of a human being when contracted, is about the size of his clenched fist; when distended with blood, it is nearly twice as large. When it contracts, the pressure which it ordinarily exerts is sufficient to push the blood to a height of about eight feet. At times of severe effort, as in heavy lifting, it may even be much greater. The heart has therefore to be built in such a way that it is strong enough to generate this amount of power, and firm enough to prevent any of the blood on which it contracts from tearing a way through its walls. For these reasons, its walls are built of short powerful muscle cells, which are striated like those of the voluntary muscles, but differ markedly from them in that they have squared ends, each of which is ce-

FIG. 79. Muscle cells of heart.

mented fast to the ends of the adjoining cells, and lateral branches similarly cemented to other cells. This method of building affords a wall with an interlacing muscular meshwork which cannot be split apart by the blood in its attempt to escape as the heart contracts upon it.

Ventricles.—Each half of the heart is divided, as we have seen, into two chambers, the thick walled *ventricle* and its ear-like appendage, the *auricle.* Of the two ventricles, the left pushes the blood into a large artery, the aorta, which leads from it. The left ventricle has to exert great pressure and its walls are therefore thick. The right ventricle, on the contrary, has the lesser work of sending the blood through the lungs and its walls are correspondingly thinner.
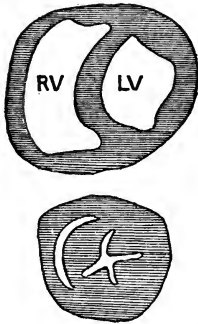
Fig. 80   Transverse section through the middle of the ventricles of a dog's heart when full and when contracted.

Auricles.—Of the two auricles, the left receives the blood from the lungs; the right, from the systemic veins. They then push it forward into their respective ventricles when these are relaxed to receive it. The auricles serve mainly as reservoirs for holding the blood while the ventricles are contracting. As they have to do but little work, their muscular walls are comparatively thin.

Auriculo-ventricular valves.—Lying between each auricle and its corresponding ventricle, there is a strong thin flexible partition which is attached by its outer edge to the wall of the ventricle. It is divided into three flaps on the right side of the heart, into two on the left. Slender tendons arise from the free edges of the flaps and are attached by means of muscular projections, the *papillary muscles,* to the inner walls of the ventricles. The purpose of these tendons is to hold the flaps in place, so that they will act as valves to prevent the blood from going back into the auricle when the ventricles contract. When the ventricles relax, they

offer no resistance to the movement of the blood from the auricles into the ventricles. Because these valves lie between the auricles and the ventricles, they are called the *auriculo-ventricular valves.*

Exit valves from ventricles.—Leading from each ventricle is a large artery. At the beginning of each
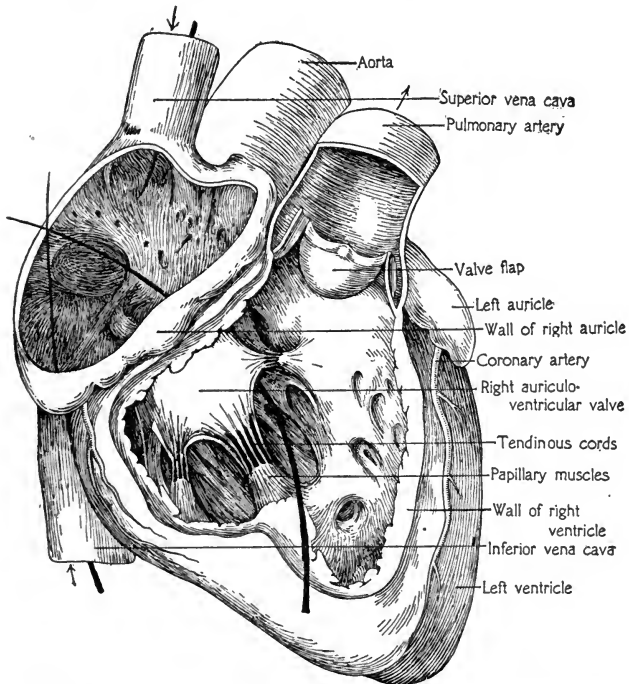
FIG. 81. Heart, with portion of right auricle and right ventricle cut away to show interior. Bristles show passage ways.

of these two arteries, there is also a valve to prevent the blood from flowing back into the relaxed ventricle. Each valve consists of three thin tough pockets, or valve flaps, which lie flat against the walls of the artery when

the blood is passing into it from the ventricle. When, however, the ventricle is emptied and relaxes so that the blood tends to return to it from the artery, they swell

Right carotid artery
Thyroid gland (in front of larynx)
Right vagus nerve
Vein from the thyroid gland
Trachea
Artery to right shoulder and arm
Vein from head, shoulder and arm
Pleura

Left carotid artery
Left vagus nerve (to heart, stomach, etc.)
Left phrenic nerve (to diaphragm)
Thoracic duct
Artery to left shoulder and arm
Vein from head shoulder and arm
Pleura

Arch of aorta

Superior vena cava

Left branch of pulmonary artery
Left bronchus
Tip of left auricle
Pulmonary artery
Left coronary artery
Left ventricle

Right auricle

Right coronary artery

Right ventricle

Right ventricle

Inferior vena cava

Aorta

FIG. 82. The heart and connecting blood-vessels.

out with the backward movement of the blood and close the opening.

Arteries.—Of these two large arteries, one, the *aorta,* leads from the left ventricle, and its branches reach all parts of the body. The other, the *pulmonary artery,* leads from the right ventricle, and its branches reach all parts of the lungs. Both the aorta and the pulmonary artery are tough gristly tubes with highly elastic walls.

EXPLANATION OF PLATE IV.

The Circulatory Organs.

The arteries (except the pulmonary) and the left side of the heart are colored red; the veins (except the pulmonary) and the right half of the heart, blue. On the limbs of the left side the arteries are omitted and only the superficial veins are shown.

1. Aorta, near its origin from the left ventricle of the heart.
2. Lower end of aorta.
3. Iliac artery.
4. Femoral artery.
5. Popliteal artery; the continuation of the femoral which passes behind the knee joint.
6, 7. The main trunks (anterior and posterior tibial arteries into which the popliteal divides).
8. Subclavian artery.
9. Brachial artery.
10. Radial artery.
11. Ulnar artery.
12. Common carotid artery.
13. Facial artery.
14. Temporal artery.
15. Right side of heart, with superior vena cava joining it above, an l inferior vena cava (16) passing up to it from below.
17. Innominate vein, formed by the union of subclavian and jugular veins. The right and left innominate veins unite to form the superior cava.
18. Left internal jugular vein.
19. Axillary vein.
20. Basilic vein.
21. Cephalic vein.
22. Median vein.
23. Radial vein.
24. Ulnar vein.
25. Median vein.
26. Iliac vein.
27. Femoral vein.
28. Long saphenous vein.
29. The kidney: attached to it are seen the renal artery and vein.
30. Branches of the pulmonary arteries and veins in the lung.
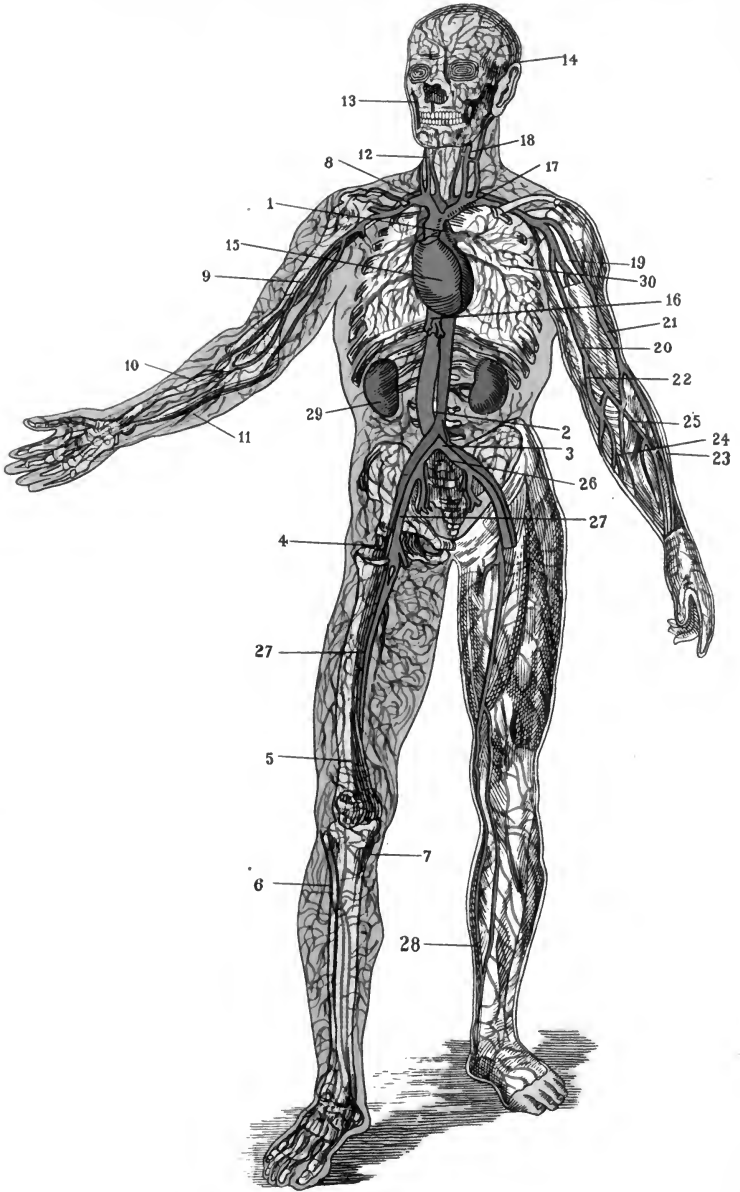
PLATE IV.—THE CHIEF ARTERIES AND VEINS OF THE BODY.

Their numerous branches differ from them mainly in being smaller.

Functions of arteries.—The arteries form smooth channels through which the blood is guided to all parts of the body. When the left ventricle contracts and pushes the blood into the aorta, the walls of the aorta are stretched out by the extra supply of incoming blood. The elastic recoil of the walls squeezes the blood forward through the branches of the arteries. Before the arteries have a chance to push all the blood that is in them forward, they are again filled by the contraction of the left ventricle. The right ventricle also contracts at the same instant and sends its blood into the pulmonary artery, which by its elastic contraction forces it through the lungs.

Structure of arterial wall.—The elastic recoil of the walls of the larger arteries is due to a special form of highly elastic tissue which resembles rubber in its action. Thin overlapping layers of this material lie in the arterial walls. When the arteries are stretched out by the blood pumped into them, the elastic tissue makes them recoil so that they press upon the blood and thereby push it along. Obviously, the pressure exerted upon the blood is greater when they are distended than when they are but partially filled. As we shall see, this is an important factor in the circulation of the blood.

Control of blood supply.—In addition to the elastic tissue, the walls of the arteries also contain encircling muscular fibres, which are especially numerous in the very small arteries, the *arterioles*. These muscular fibres are all of the non-striated variety and are slow in contraction. In the arterioles, their function is to control the amount of blood passing through them to the tissues. For example, if a tissue is active, these small muscle

fibres, which are usually slightly contracted, relax and thus permit the arterioles to become larger and more blood to pass. If, on the contrary, the tissue's activity
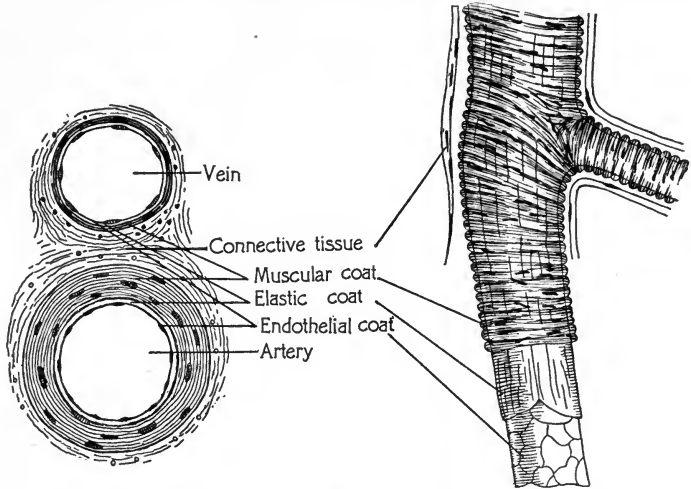
FIG. 83. Artery and vein, showing structure of walls.

is diminished, they contract so that only the small amount of blood necessary to supply the resting tissues is allowed to pass through. These muscle fibres, under the control of their nerves, thus automatically adjust the supply of blood to the needs of the tissues.

Branching of arteries.—The arteries divide into smaller and smaller branches and their number becomes very great. Eventually, they are so small and numerous that they can penetrate nearly every particle of tissue in the body.[1] As the arteries become smaller, their walls also become thinner and the elastic tissue

[1] The only exceptions to this are cartilage and certain transparent parts of the eye. In these, sufficient nourishment reaches the very inactive cells by means of the lymph which soaks through from cell to cell.

diminishes until in the arterioles it disappears completely. The proportion of muscle fibre, on the contrary, increases until the arterioles are reached, when it in turn decreases until none is left.

Capillaries.—The smallest branches of all, the *capillaries,* which are only about half a millimeter in average length, have neither elastic tissue nor muscular fibres. They are the smallest, the most delicate, as well as the most numerous of all the bloodvessels. The finest needle point can penetrate scarcely any part of the body without severing some of them. Their walls consist of an exceedingly thin membrane, which is made up of flat cells placed edge to edge to form a continuous tube. Their thinness permits the blood to come into close contact with the tissue cells, without, however, allowing the red blood corpuscles to escape. The required amount of oxygen freely passes from the red corpuscles to the tissue cells, and the plasma of the blood containing the food material in solution also oozes through in sufficient quantity to nourish them. The blood in the capillaries receives in exchange from the cells their waste products, including carbon dioxide, which pass readily through their walls into the blood stream.

FIG. 84. A, diagram of branching capillaries, showing how they are made up of a single layer of cells, the edges of which are cemented together to form tubes. B. Cross section of same, showing nuclei in walls.

Veins.—The capillaries join together at their farther ends to form a second system of larger tubes, the *veins.*

The veins continuously increase in size as they diminish in number, until finally there are but two large tubes which receive the blood from all the others and pour it into the right auricle of the heart. This second system is known as the *venous system.*

Blood flow in the veins.—In structure, the veins closely resemble the arteries, except that their walls are much thinner, since they do not have to stand any considerable pressure. The pressure which in the arteries served to push the blood forward, is not ordinarily transmitted to the veins, because it is largely blocked by the contraction of the arterioles. If it were transmitted, the delicate walls of the capillaries would be overstretched or even burst by the high pressure of the arterial system. The propulsion of the blood back to the heart through the veins must therefore be accomplished by a different mechanism from that which pushed it from the heart through the capillaries. The veins have numerous valves which are readily pushed open by the blood flowing from the capillaries toward the heart but are closed against its return toward the capillaries. The veins are thus converted into a series of short sections separated by valves. Each section is emptied by the external pressure exerted by the muscles, the skin, and the pulsations of the arteries which lie close to it. As a

FIG. 85. Diagram showing the bending of red blood corpuscles and the rolling of white blood corpuscles in the capillaries of a frog.

White corpuscle

Red corpuscle

Red corpuscle caught at branch

result, the blood is pushed forward from one section to another on its way to the heart. The largest veins of the trunk, however, do not have valves. In them, the forward movement of the blood is largely due to the variations in pressure exerted upon them by the movements of the chest in breathing.

General function of blood-vessels.—The work of the arterial system as a whole is thus seen to be to carry the blood in adequate amounts to the capillaries. The work of the capillaries is to get the blood into such close contact with the cells of the tissues that oxygen and nourishment may be given to them and waste products removed from them. The work of the venous system is to return the used blood back to the opposite side of the heart, ready to start on its pulmonary circuit.

Pulmonary circulation. — In the pulmonary system, the structure and relation of the arteries and veins are similar to those in the systemic. The capillaries in the lungs, however, differ from the systemic capillaries in that they are larger and have a dif-
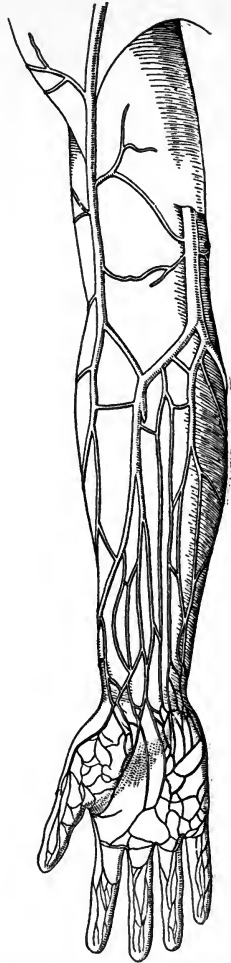
FIG. 86. Superficial view of right arm showing the fascia and veins, and the method of branching of the veins by which many other paths are open to the returning blood in case of obstructing pressure or injury to the direct path.

ferent arrangement. They cover the walls of the tiny air sacs in the lungs so thickly that they expose to the purifying and enriching action of the air a layer of blood the thickness of a capillary and about eight hundred square feet in extent.

Travels of a drop of blood.—Through this double system of heart, arteries, capillaries and veins, we may trace the course of a drop of blood as follows: Starting in the left ventricle of the heart, the drop of blood passes through the aortic valve into the aorta. It quickly flows down the aorta into one of its numerous arterial branches and finally reaches the capillaries, for example, those in a leg muscle. Here a certain amount of plasma and perhaps a few of its white corpuscles pass through the

Fig. 87. Diagram of valves of veins: A, valve opened by blood passing forward toward heart; B, valve closed by attempted return of blood; C, vein opened to show arrangement of valves.

walls of the capillaries into the spaces between the muscle cells. Its red corpuscles give up some of their oxygen to the muscle cells and its plasma receives carbon dioxide and other waste matters. Thus changed and slightly diminished by its losses, it returns by way of the veins into the right auricle of the heart. It then passes through the right auriculo-ventricular valve into the right ventricle. From here, it is pushed by the contraction of the ventricle through the pulmonary artery and its branches into the capillaries of the lungs which surround the air sacs. Here, some of its carbon dioxide escapes to the air and a fresh load of oxygen

is taken on. Thus renewed, it passes through the pulmonary veins to the left auricle of the heart. Upon
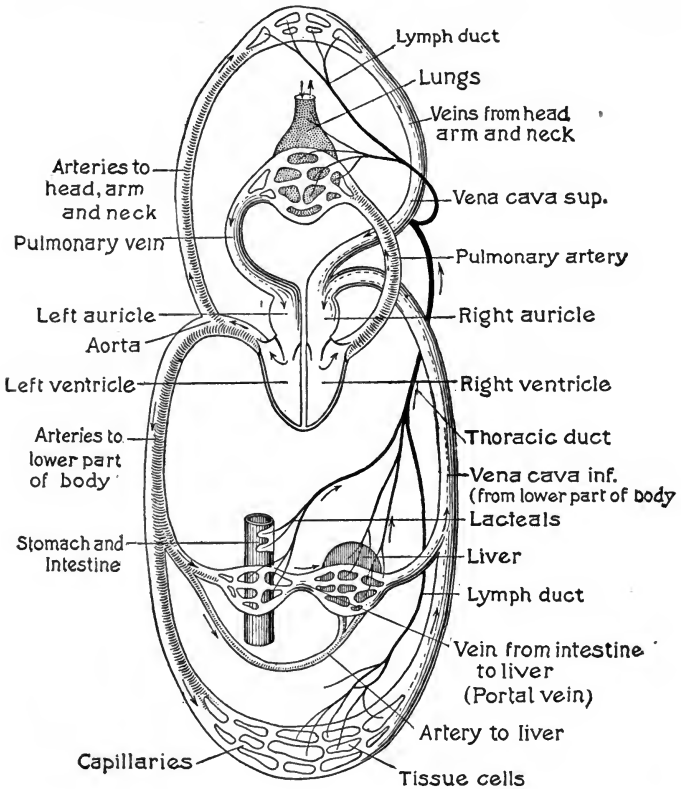
FIG. 88. Diagram of the circulation of the arterial and venous blood and the lymph. (Arteries have transverse shading; veins longitudinal shading. Lymphatics are represented by black lines.)

the relaxation of the left ventricle, it enters once again through the left auriculo-ventricular valve and

thus completes the circuit. The shortest time that a drop taking the shortest route can make the circuit is estimated at fifteen seconds. Between one and two minutes is required for all the blood in the body to pass once through the left ventricle.

Lymphatics.—The small portion of the blood comprising the plasma and the white blood corpuscles, which, as we saw, escaped from the capillaries into the space

White corpuscle penetrating wall of capillary

White corpuscle in tissue

Red corpuscle

From artery

To vein
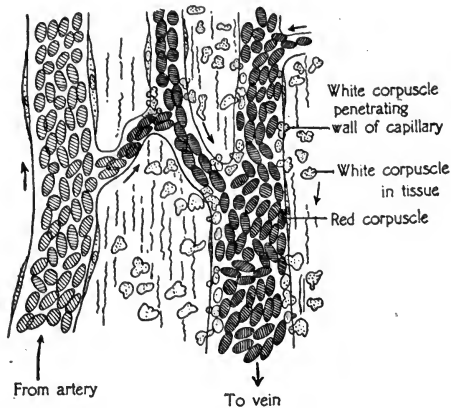
Fig. 89. Migration of the white blood corpuscles from the capillaries of a frog into the tissues during inflammation. (After Warren).

between the muscle cells alone remains to be accounted for. After leaving the capillaries, the plasma and white blood corpuscles are known as lymph,[1] because of their clearness and lack of color. The spaces between the cells into which the lymph escapes are irregular in size and shape and have no definite boundaries. They blend together to form communicating spaces of considerable extent. The lymph in these intercellular spaces is con-

[1] Lymph may be seen characteristically under the skin in the form of "water blisters."

A GENERAL VIEW OF THE LYMPHATIC OR ABSORBENT SYSTEM
OF VESSELS.

At e is seen a portion of the small intestine from which lacteals or chyle-conveying vessels, d, proceed; at f the *thoracic duct,* into which the lacteals open. This duct passes up the back of the chest, and opens into the great vein at g, on the left side of the neck: here the chyle mingles with the venous blood. In the right upper and lower limbs the superficial lymphatic vessels $l\ l\ l\ l$, which lie beneath the skin, are represented. In the left upper and lower limbs the deep lymphatic vessels which accompany the deep blood-vessels are shown. The lymphatic vessels of the lower limbs join the thoracic duct at the spot where the lacteals open into it; those from the left upper limb and from the left side of the head and neck open into the thoracic duct at the root of the neck. The lymphatics from the right upper limb and from the right side of the head and neck join the great veins at n. At $m\ m$ are seen the enlargements called lymphatic glands, situated in the course of the lymphatic vessels.
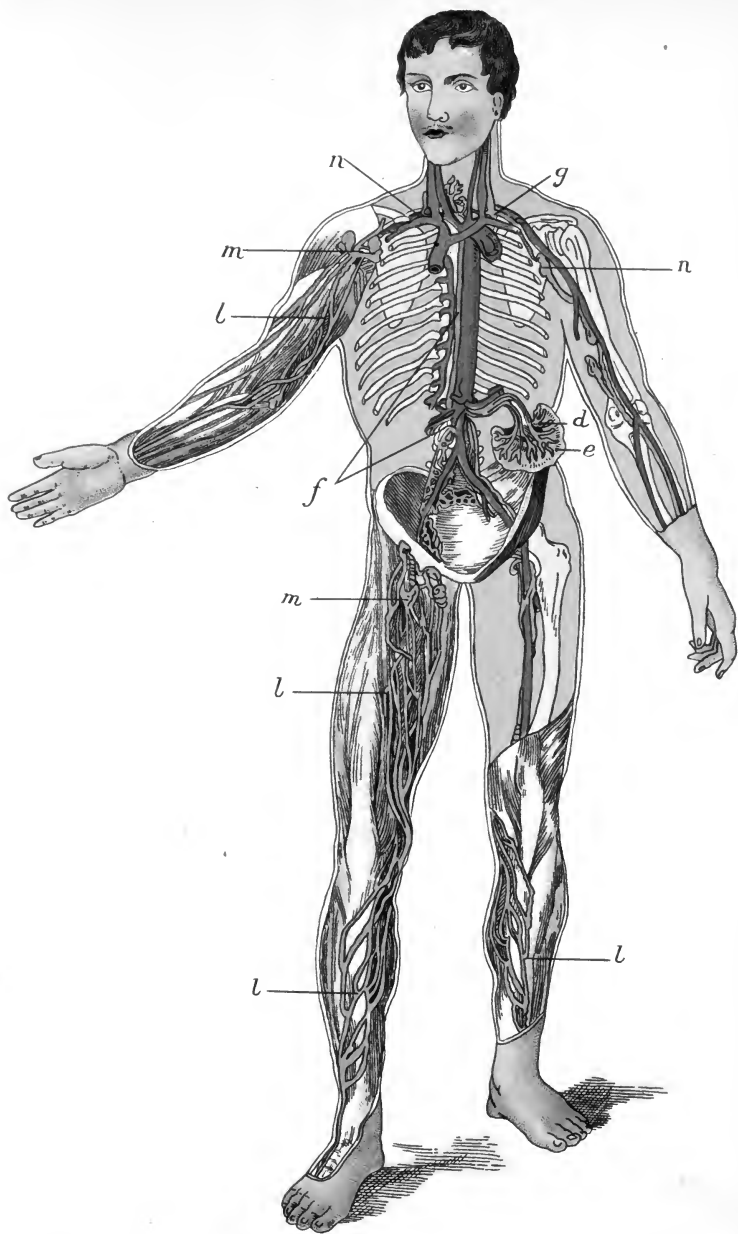
PLATE III.—A GENERAL VIEW OF THE LYMPHATICS OR ABSORBENTS. That portion of them known as the lacteals is seen at *d*, passing from the small intestine *e* to the thoracic duct *f*.

stantly drained away by delicately walled tubes, the *lymphatics,* whose expanded mouths open into them. The lymphatics join together to form larger lymph canals, very much as the capillaries unite to form the veins. The flow of lymph through the lymphatics is brought about by the external pressure due to the activity of the muscles and other tissues lying near them.

The two large lymphatic ducts which result from the union of all the smaller branches, pass respectively into the two large veins under the collar bone on the sides of the neck, through o p e n i n g s protected by valves, so that the blood cannot pass back through the lymphatics. Of these ducts, the left is much the larger and carries, in addition to the lymph, the lacteal flow from the intestinal tract. The total amount discharged from the lymphatics into the veins is estimated to be more than two quarts in every twenty-four hours.

FIG. 90. Lacteals and thoracic duct.

Function of lymphatic system.__The function of the lymphatic system is twofold. It brings the plasma of the blood containing the dissolved food materials into closer contact with the cells than is possible when the plasma is within the capillaries. By means of the lymph, the tissue cells are bathed in a constant and fresh stream of food-containing fluid, from which they can

readily absorb what they need. Secondly, it takes away
some of the waste products from the active tissues. This
it accomplishes in part by the activity of the white

Lymphatic
ducts
supplying
gland

Lymph gland

Lymphatic ducts
draining gland

Nodes of ducts (valves)
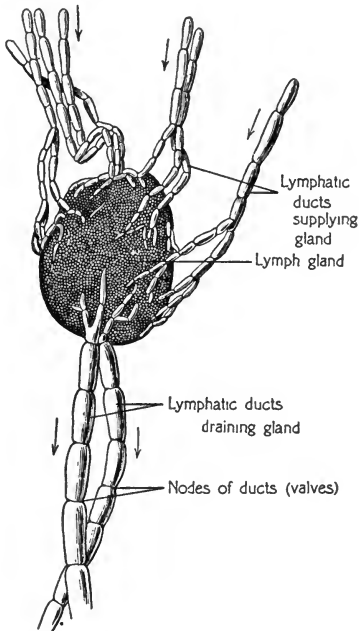
Fig. 91. Lymph gland and connected lymphatics.

corpuscles which are carried about in it and are
thereby enabled thoroughly to explore the tissues of the
body.

Lymph glands.—The work of drainage is further ac-
complished by the establishment of filtering stations
called *lymph glands.* The lymph glands vary in size
from a hemp seed to a bean and are scattered at various
points along the lymph canals. They are made up of

masses of small cells, the function of which, like that of the white blood corpuscles, is to destroy microbes and other foreign substances. They are so constructed that no portion of the lymph can escape passing between a large number of their cells and being exposed to their influence before it continues on its passage towards the veins. If microbes are present in overwhelming numbers, the cells of the first protecting lymph gland may not be able to kill them all or even prevent their development, which then takes place in the overcome gland itself. In this case, the lymph glands next in order in the course block the progress of the microbes and continue to the limit of their ability the good work of exterminating them. In extreme cases, however, an invasion of microbes may overcome gland after gland in the course of the lymphatics until finally they enter the blood stream and are scattered to all parts of the body. The result is a general infection, or blood poisoning, which always constitutes a grave menace to life. In this way, an infected scratch or cut may eventually have serious results.

Control of blood supply to tissues.—In order that the tissues may receive as much food and oxygen as they need when active and yet the total amount of the blood be kept as small as possible, the blood is sent to them copiously during activity and sparingly during rest. To accomplish this, a definite and accurate control of the distribution of the blood is required. Certain of the nerves are sensitive to the activity of the tissues and control the muscle fibres in the walls of their arteries. When tissue cells, because of their activity, require more food and oxygen, the nerves cause the muscle fibres in the walls of their arterioles to relax, thus allowing more blood to pass through them. When, on the contrary, the tissues become quiet and so require less food and

oxygen, the nerves cause the muscle fibres to contract.
The arterioles as a result become smaller and less blood
is allowed to pass. The nerves which control the relaxa-
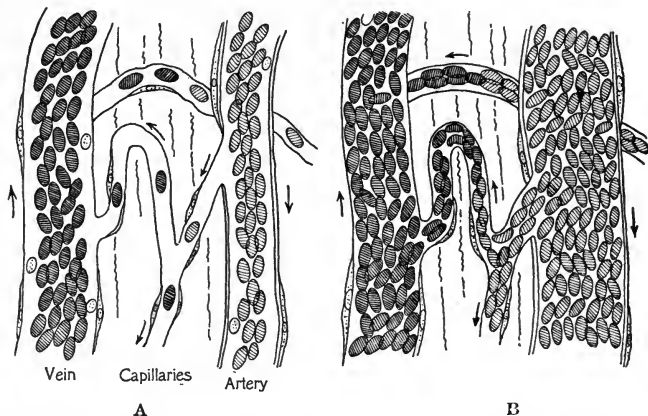
FIG. 92. A, Diagram of circulation from artery through capillaries to vein of
frog. The darker corpuscles show change to venous blood. B, Diagram of cir-
culation in congestion, showing dilatation of blood-vessels and crowding of
corpuscles. (After Warren.)

tion and contraction are known as the *vasomotor nerves.*
They are a part of that branch of the nervous system
which, because it works automatically, is called the
sympathetic system.

EXPERIMENTS AND DEMONSTRATIONS

Anatomy of the Heart

Materials: Sheep's heart with pericardium unpunctured;
rabbit, freshly killed if possible; glass tube ¼ in. diameter, 12
in. long; scalpels; scissors; forceps.

1) Demonstrate in rabbit, which has been prepared [1] by cut-

[1] If the chest is carefully punctured with the points of scissors,
previous to the removal of the ribs, the entrance of the air will
allow the lungs to collapse, so that they will not be injured by
subsequent cutting.

ting away front of chest with scissors, the relation of diaphragm, heart, lungs, trachea and esophagus.

2) Expose trachea in neck, cut, and insert glass tube, tying on if necessary. Inflate lungs to natural size, and note their relations to ribs, heart, diaphragm and abdominal organs.

3) Carefully manipulate heart and lungs:

a) Find vena cava inferior on under (abdominal) side of diaphragm; thence follow it until it enters pericardium.

b) Trace out veins which vena cava inferior receives from liver, spleen, kidneys and diaphragm.

c) Trace out superior vena cava and its branches.

d) Notice between ends of two venæ cavæ the right pulmonary veins proceeding from lung and entering pericardium.

4) Turn lung and heart back to their natural positions. Trace out aorta, its arch and branches; pulmonary artery dorsal to aorta, and its branches into lungs; pulmonary veins.

5) Slit open pericardial sac.[1] Note character of lining membrane of cavity; and character and amount of fluid present.

6) Cut away pericardium carefully from various vessels at base. Note general form and position of heart and location of vessels connected with its base.

7) Carefully dissect out entrance of pulmonary veins into heart.[2] Note on exterior the left and right auricles; the band of fat running around top of ventricles and its offshoot running obliquely down front of heart, thence passing to right of its apex. (This indicates position of partition, or septum, between two ventricles.)

8) Dissect away fat around origins of great arterial trunks and around base of ventricles. In fat will be found two coronary arteries arising from aorta close to heart, and the coronary veins which accompany them.

9) Open right ventricle by passing blade of scalpel through its wall about 1 in. from upper border of ventricle and on right of band of fat, and cut down toward apex. Make a corresponding cut through wall of same venticle on its other side. Raise

---

[1] The following dissections are much better carried out upon the sheep's heart owing to its larger size.

[2] It will probably seem as if the right pulmonary veins and the inferior cava opened into the same auricle, but it will be found subsequently, (14), that such is not really the case.

point of wedge-shaped flap and expose cavity. Cut off pulmonary artery about an inch above its origin and open right auricle by cutting a piece of its wall at left of venæ cavæ.

a) Pass handle of scalpel from ventricle into auricle, and also from ventricle into pulmonary artery. Study out relations of these openings.

b) Slit open auricle. Note fleshy projections on its walls; character of interior surface; apertures of venæ cavæ; and entrance of coronary sinus below entrance of inferior cava.

c) Pass probe through aperture along sinus and slit it open. Note muscular layer covering it.

10) Raise by its apex the flap cut out of ventricular wall, and if necessary prolong cuts toward base of ventricle until divisions of tricuspid valve come into view. Note fleshy columns on wall of ventricle; muscular cord (not found in human heart) stretching across its cavity; and prolongation of ventricular cavity towards aperture of pulmonary artery.

11) Cut away right auricle. Examine carefully tricuspid valve, composed of three membranous flaps, thinning towards their free edges; and tendinous cords which connect flaps to muscular processes (papillary muscles) of wall of ventricle.

12) Slit up right ventricle until origin of pulmonary artery is disclosed. Looking carefully for flaps of semilunar valves, prolong cut between two of them so as to open pulmonary artery and spread it out. Note valves; pouch made by each flap; and slightly dilated wall of artery behind each flap.

13) Open left ventricle and left auricle similarly. Cut aorta off about ½ in. above its origin. Note aperture between auricle and ventricle; passage from ventricle into aorta; entry of pulmonary veins into auricle; septum between auricles; and septum between ventricles.

14) Pass handle of scalpel from ventricle into auricle; another from ventricle into aorta; also pass probes into points of entrance of pulmonary veins. Trace possible movements of fluid through auricle, ventricle and aorta, with reference to position and character of valves.

15) Compare auricles and ventricles as to character of their walls.

16) Carefully raise wedge-shaped flap of left ventricle, and cut toward base of heart, until valve (mitral) between auricle

and ventricle is brought into view. Note that one of its two flaps lies between auriculo-ventricular opening and origin of aorta.

17) Slit aorta between two semilunar valve flaps:

a) Compare aorta with pulmonary artery and with larger veins, with special reference to thickness, texture and elasticity.

b) Note coronary arteries opening into dilatations of aortic wall above semilunar flaps.

Heart Action

Materials and apparatus: Frog; 2 sheep's hearts; a piece of sheet cork or of thin board with ½ in. hole cut in it; microscope; circulation apparatus made from bulb syringe; funnel of glass or tin; 2 feet of ¼ in. rubber tubing; 10 inches of 1 in. sap tubing; several feet of glass tubing, some ¼ in., some ½ in.; glass nozzle made of glass tubing drawn out in flame; a piece of sheet lead such as comes in tea chests; dissecting instruments; a circular piece of glass 1½ in. in diameter, cemented into a short tin tube to form a window; 2 basins.

1) Wrap frog in damp cloth and then in tea lead, leaving one foot outside of lead. Fasten it to perforated sheet cork or board and tie toes to pins so that web foot is spread over hole. Clamp in place on microscope stage and focus carefully on web. Note movement of blood corpuscles; arteries, through which blood is passing toward thin-walled capillaries; veins into which blood from capillaries is passing; rapidity of movement of red blood corpuscles,[1] their position in blood stream and bending at arterial branches; movement of white blood corpuscles and their behavior in blood stream.

2) To demonstrate pumping action of heart, carefully remove sheep's heart from pericardium.

a) *Aortic valve:* Cut off aorta 1 in. above valve. Tie into it a piece of glass tubing, down which pour water. Note efficiency of valve.

Tie a glass or tin funnel into one pulmonary vein and close the other by tying it. Fill funnel with water. Squeeze ventricles with hand and note results.

---

[1] The frog's red blood corpuscles differ from the human in that they are oval and have very large nuclei.

b) *Mitral valve:* Tie glass window into left auricle and watch appearance of mitral valve as ventricle is squeezed and released.

c) *Mitral and tricuspid valves:* Cut auricles away, taking great care not to injure valves. Hold ventricles apex down, and pour water into them from pitcher held about a foot above. Note movement of valves.

Cut cords attached to edge of one mitral valve and repeat.

3) *Effect of elasticity of blood-vessels and of change in resistance of arterioles:* Take bulb syringe [1] and fit outflow tube to receive both a piece of glass tubing about 2 ft. long and a piece of sap tubing; also prepare nozzle with a hole about $\frac{1}{64}$ in. in diameter, which is fitted to distal ends of glass and sap tubes.

a) Put intake tube of syringe into a basin of water, fill syringe, and attach glass tube. Squeeze and release bulb every 2 seconds, noting character of outflow.

b) Attach nozzle to end of glass tube, pump regularly as before, and note character of outflow.

c) Remove glass tube and attach sap tube. Pump as before, and note character of outflow.

d) Attach nozzle to sap tube and test as in b). Compare d with a, b, and c, and determine factors contributing to uniform flow.

---

[1] Instead of this, the more elaborate circulation scheme of Prof. W. T. Porter may be used. It is obtainable from the Harvard Apparatus Co., Medfield, Mass.

CHAPTER XIV

THE HYGIENE OF THE CIRCULATION

Vasomotor control of blood distribution. — The blood in the human body amounts, as we have seen, to only eight per cent of its weight, and yet it is so accurately distributed to all its parts that each of its tissues never fails of getting the right amount at the right time, in spite of the fact that it wants now more, now less, as its activity increases or diminishes. To accomplish this, two methods are employed. The first is the vasomotor adjustment, by which more blood is allowed to escape into the active tissues through the arterioles which are opened more widely for this purpose. As a result, the distention of the arterial walls is decreased and consequently their pressure upon the blood which remains within them is lowered. Less blood therefore is forced through them to the inactive tissues of the body. It is conceivable under this arrangement that so many large organs might be actively at work at the same time that a large proportion of the blood in the arteries would escape to them. Such a big reduction in the blood pressure might result that the other organs of the body would receive less blood than they needed. This would be especially true of the brain, to which the blood has to be sent uphill.

Control by heart beat.—In order to give complete control of the circulation, the vasomotor control is supplemented by variations in the frequency of the heart

beat.   As the pressure in the arterial system is lowered by the draining away of blood through the active organs, the heart is made to work more quickly, in order to pump the blood faster into the arteries.   The arteries are thereby kept well filled and the blood pressure maintained at a height sufficient to drive the blood through all the tissues in adequate amounts.   In this way, the adjustment of the blood supply to the needs of all the organs, including the brain, is made possible within the limits of normal activity.

Faulty distribution.—When, however, the body's normal activity is exceeded, as when large numbers of muscles are used at once, both of these methods of adjustment may be inadequate and the blood may be drained out of the arteries faster than the heart can pump it in.   The blood pressure then becomes so low that the blood is not forced in sufficient amounts to the brain.   The result is *dizziness* and *faintness*.   Such faulty distribution undoubtedly accounts for the fainting of athletes after a hard run or row.   In cases of stomach and intestinal irritation which leads to the abnormal dilatation of the abdominal blood-vessels, the arterial blood pressure is similarly lowered, and as a result faintness and dizziness are common accompaniments of these illnesses.   Similar effects are also produced by considerable losses of blood, or hemorrhage.

Effects of eating.—These facts make it clear why it is unwise to attempt severe brain or muscular work after a hearty meal.   The drowsiness which accompanies the brain work shows that the brain is not getting its full share of blood because of the activity of the digestive organs.   In the case of hard muscular work, the reverse is true.   The muscles draw the blood to themselves and so digestion is delayed.

Causes of sleeplessness.—Sleeplessness, on the contrary, has been shown to be due to an overactive circulation in the brain. The remedy is to reduce by one means or another the amount of blood flowing to the brain. A light meal which draws a portion of it to the stomach, exercise which distributes it to the muscles, a hot water bag which tends to open up the blood-vessels in the feet are all methods of accomplishing this.

Effects of alcohol.—Another factor which may seriously interfere with the economical distribution of blood is the use of alcohol. As a beverage alcohol dilates the blood-vessels in the skin and as a result the blood goes to the skin in larger amounts. In cold weather, this effect opposes the natural adjustment by which the blood within the body is kept away from the skin, in order to protect it against a too rapid loss of heat. Although there is a superficial feeling of warmth from the alcohol because of the rush of blood to the skin, yet the total amount of heat in the body is quickly diminished. Many lives have been lost by freezing under these circumstances, and many more by pneumonia and other diseases induced by the severe chill.

External pressure.—The proper distribution of the blood is subject also to local interference by external pressure, such as that exerted by tight circular garters. External pressure ordinarily interferes with the circulation in the lymphatics and veins rather than in the arteries. Unlike the arterial blood, the lymph and the venous blood have not the high pressure necessary to force themselves forward under an obstruction. As a result, the part becomes cold and swollen and the nutrition of the tissues is often interfered with. When tight garters are worn, the veins become unduly dilated so

that the valves do not close the tubes, and consequently the venous circulation in the legs becomes poor. If persisted in, especially in later life, the veins become enormously swollen and sometimes even burst through the skin.

Injuries.—Further instances of local interference with the proper distribution of the blood are seen in such injuries as *bruises, sprains* and *fractures.* Small bloodvessels are broken, and bleeding into the tissues occurs; lymph vessels are also broken, so that the normal return of the lymph is checked. The collection of the blood and lymph in the tissues causes swelling. Further, as a result of the irritation of the injury, the arterioles in the injured part become dilated so that greater quantities of blood go to them, thereby increasing the swelling and causing throbbing pain. In sprains and bruises, the swelling and discoloration may be largely prevented by working the excess of blood and lymph out through the lymph channels by means of gentle rubbing, or massage. In this way, the force necessary to push the blood and lymph which have escaped from their torn vessels back into the circulation through the lymph channels, is artificially given. Less effective treatment for swelling is heat, which causes contraction of the blood-vessels; cold (ice), which has a similar although less marked effect; or elastic pressure obtained by bandaging the injured part.

Inflammation.—In *inflammation,* as in boils and abscesses, the blood-vessels are dilated by the irritation of the microbes which have invaded the tissue. Because of this dilatation, the lymph and white blood corpuscles escape more freely into the tissues, where they collect in such great numbers as to clog and distend them. The swollen tissue presses upon the blood-vessels so strongly

as to stop the circulation in the central part of the inflamed area. The white blood corpuscles are thus deprived of nutriment and oxygen by being shut off from the fresh blood and become so weakened that they cannot overcome the invading microbes. As a result, they frequently die in great numbers, together with the tissue in which they are lodged. The white corpuscles, the dead tissue and the microbes are then thrown off as pus. The clogging of the tissue by the white corpuscles has a beneficial result, however, in that it shuts off from the general circulation the microbes which have caused the disturbance. It is usually considered wise to cut into an actively inflamed area early, in order to get rid of the microbes. The destruction of good tissue and the formation of a large scar are thereby avoided.

Bleeding from arteries. — In accidents where large arteries are cut, the bleeding is copious because of the high pressure which pushes the blood out in strong spurts. In the case of a large cut in a fair-sized artery, the whole arterial system may empty itself

Fig. 93. Diagram showing where important arteries come near enough to surface to have pressure applied.

in a short time and death result. The bleeding can best be stopped by applying pressure to the artery at some point where it comes near the surface in its course from the

heart to the cut. A large pebble or a strip of cloth made into a hard roll, if applied over the artery so as to press it against the bone and then held in place by a tight
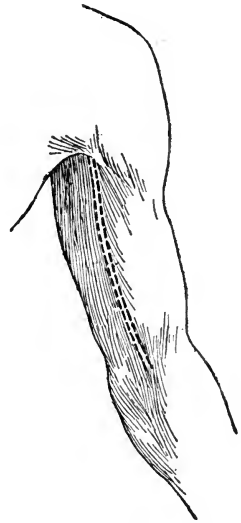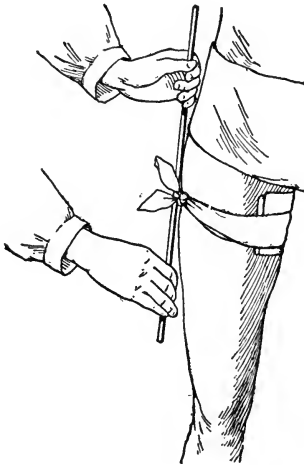
FIG. 94. Compression of femoral artery.   FIG. 95. Course of artery in arm.

bandage, will entirely stop the flow of blood through the artery. The points where pressure can be advantageously applied are shown in the accompanying illustrations. They should be carefully learned by repeated practice, as death has often resulted through the lack of such knowledge.[1]

From veins.—In the case of a vein, the loss of blood is much slower and will ordinarily cease through the

[1] In order to develop one's ability to check arterial bleeding, a student should practise finding the pulse in the ankle and wrist and then should press upon the artery above these points until the pulse is stopped.

coagulation of blood in the cut. Bleeding can always be stopped by a light pressure over the wound itself, and can be temporarily treated in an emergency by bandaging a small pad firmly over the cut.

"Poor" circulation.—In many persons, the circulation of the blood is said to be poor, because of a tendency to cold hands and feet. In most cases, this is due to the fact that not enough exercise is taken for the production of heat in the body, that clothing warm enough to protect the body against too great a loss of heat is not worn, or that there is some nervous disorder which leads to a disturbance of the vasomotor control. Whatever the cause, the result is a chronic spasm of the arterioles, which shuts the blood out of the extremities, leaving them cold. The remedy depends upon the cause. In many cases, the wearing of warm woolen underclothing is effective, especially if supplemented by frequent periods of brisk exercise and by plenty of good fresh air and wholesome food.

Fainting.—The circulation may also be temporarily disturbed, especially in weak persons, by such causes as nervous shock, the close warm air of a crowded room, or severe pain. In these cases, the nerve control of the heart is so deranged that the heart beats less forcibly and less blood is pumped into the arteries. The blood pressure in them is then too low to push the blood up to the brain against the downward pull of gravity, and the person becomes dizzy or even faints. The simple remedy is to place the person thus affected with the head lower than the body and to supply fresh cool air for breathing, cold water for bathing the face and stimulants such as aromatic salts.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Roller bandages of cheese cloth, 2½ in. wide, 3 yds. long, tightly rolled; triangular [1] or handkerchief bandage.

1) Locate pulse in wrist; in upper arm at inside edge of biceps muscle; at back of and below bony prominence of ankle on inside; behind knee; at inner upper part of thigh; at side of larynx in neck; in front of ear; and behind collar bone.

2) Practise shutting off blood current.

a) In arm, by applying pressure upon arteries in upper arm and back of collar bone. Test effectiveness of pressure by obliteration of wrist pulse.

b) In leg, by pressure upon large artery in thigh and back of knee. Test effectiveness by obliteration of ankle pulse.

3) Practise bandaging a pad or stone over pressure points for shutting off arterial blood supply to arm and leg. Test efficiency as in 2).

4) *Adjustment of circulation to activity as shown by heart beat:* Test and record rate of pulse on awaking before rising; on first sitting up before standing; on standing; after dressing; seated at table before breakfast; after breakfast while still seated; before and after climbing a flight of stairs; and before and after running.

5) *Action of valves in veins:*

a) Find large veins on back of hand, and stroke slowly with moderate pressure toward wrist and toward knuckles. Note changes.

b) Place one finger on end of a vein toward knuckles, and with another finger stroke same vein toward wrist. Carefully compare results with a). Make diagram of veins showing location of valves and direction of action.

---

[1] Each pupil should be encouraged to get the printed cloth bandage known as Esmark's Triangular Bandage, for sale at 10 cents, by the Society for Instruction in First Aid to the Injured, 105 East 22d Street, New York, or by the Health Education League, 113 Devonshire St., Boston.

CHAPTER XV

RESPIRATION

Air supply of the body.—As we have seen, the venous blood on its return from the tissues must come into contact with the air in the lungs, in order to get
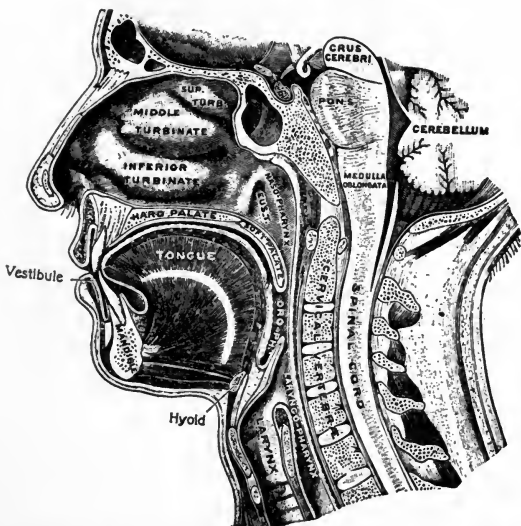

FIG. 96. Section of face and neck showing passages of nose, mouth and throat. (Testut.)

a fresh supply of oxygen and to remove its burden of carbon dioxide. It is of the utmost importance, therefore, that the air in the lungs should not fail in purity or abundance. We can live without food for many days,

and without water for a considerable number of days, because of storage within the body; but without air, life is limited to minutes.[1]

Nose as an air passage.—The mechanism for supplying oxygen to the blood consists of two elastic bags or reservoirs, the lungs, which lie within the chest walls and are entered by way of the mouth and nose and the wind-
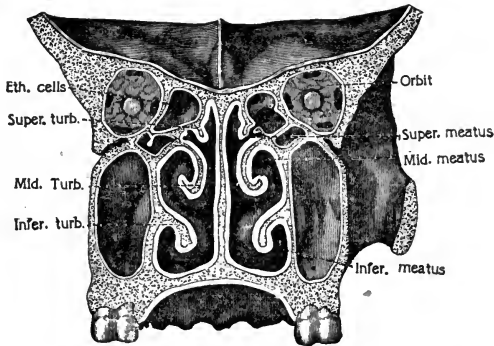
Fig. 97. Section through nose, showing how the turbinate bones are arranged to increase the surface over which the air must pass. (Testut.)

pipe, or trachea. So far as breathing is concerned, the *mouth* and *nose* act mainly as canals through which the air passes to the trachea. They are lined with a moist membrane which catches the dust and thus helps to prevent the entrance of irritating particles into the lungs. This membrane also warms and moistens the air, that irritation of the lungs by extreme cold and dryness may be avoided. The nose is especially planned to serve this purpose, in that it is provided with projections, the *turbinate bones,* which divide the nasal passage into several smaller passages and thus greatly increase the wind-

[1] The longest recorded period of being under water with subsequent recovery is about fifteen minutes.

surface of warm moist membrane over which the air must pass.

Trachea.—The windpipe, or *trachea,* begins at the lower end of the *pharynx,* that wide shallow chamber at the back of the mouth into which both nose and mouth open. The trachea lies in front of the esophagus and is shut off from it by a lid, which closes during swallowing to keep out particles of food. It is an elastic tube with hoops of cartilage in its walls. The ends of these hoops do not quite meet and tend constantly to spring apart. As a result, the trachea is held widely open so that the air can always pass through it easily.

Larynx.—As in every other part of the body each mechanism is made to serve as many purposes as possible, so in the trachea we find the passage of air through it used for the production of voice. A special chamber, the walls of which are stiffened with cartilage, lies near the top of the trachea. It has two membranes which can be made to stretch tightly across the air passage, so as to meet at their edges and shut off the air. When the air passes between their edges, these membranes vibrate and thereby produce sounds which constitute the voice.[1] This chamber is called the *larynx* and causes the prominence in the throat known as "Adam's Apple."

Bronchial tubes.—At its lower end near the heart, the trachea divides into two short branches, the *bronchi,* one of which goes toward the right side of the chest, the other toward the left, to connect respectively with the right and left lung. The bronchi are equipped with cartilaginous hoops to keep them open. Upon entering the lungs, they at once multiply into an immense number of smaller branches, the *bronchial tubes,* which in turn divide into smaller ones and thus penetrate to every part of

the lungs. All of these which have a diameter of more than one-fortieth of an inch are equipped with cartilaginous rings. They have in addition a certain number of smooth muscle fibres in their walls. Their lining, like that of the trachea, consists of a mucous membrane made up
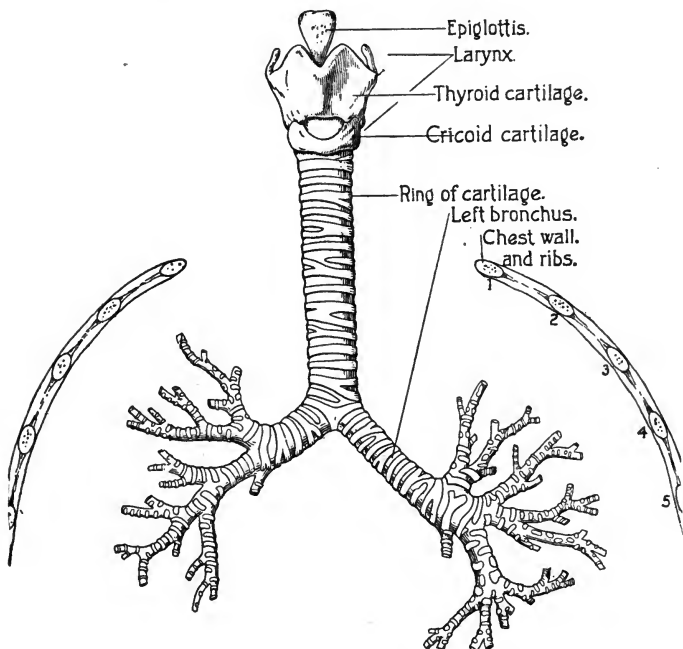

FIG. 98. Front view of the trachea and its branches.

of elongated cells, the exposed tips of which carry many cilia for the purpose of whipping dust and mucus out of the lungs. They are also furnished with cells which secrete mucus and thereby keep their surface moist.

When the bronchial tubes have become as small as one-fortieth of an inch, their walls lose their carti-

laginous rings and acquire additional muscle fibres. The lining mucous membrane also loses its cilia and consists of thin broad flat cells. The bronchial tubes

FIG. 99. Two alveoli of lung, considerably magnified. *b, b,* air sacs ; *c, c,* terminal branches of bronchial tube.

themselves are very thin-walled and each leads to several expanded funnel-shaped soft-walled passages, which serve as entrances to numerous rounded cavities, the *air sacs.*

Air sacs.—The thousands of air sacs with their connecting passages make up the main bulk of the expanded lungs. In an adult, they contain when normally expanded about three quarts of air, but are so elastic that they can be stretched to hold one or two quarts more. They have a lining membrane made up of very thin broad cells, which is an extension of that in the bronchial tubes. Under this lining membrane, there is a close meshwork of capillaries, which is so arranged as to expose the largest possible surface [1] of blood to the air contained within the air sacs.

[1] About 800 sq. ft. in extent.

Structure of lungs.—Besides the capillaries with their connected arteries and veins, the air sacs and their connecting passages, the bronchial tubes and bronchi, the lungs consist of but little more than a strengthening framework of soft elastic connective tissue, which holds all the parts together and forms a strong yet highly
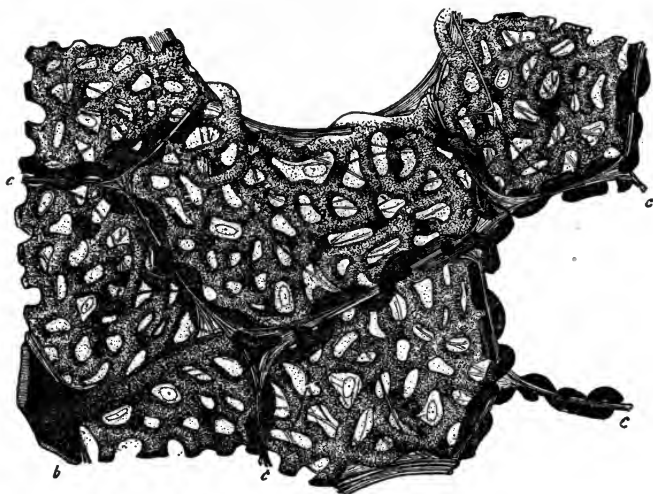
Fig. 100. Section of lung with distended blood-vessels, highly magnified. *c, c,* partitions between air sacs; *b,* small artery giving off capillaries to walls of air sacs.

elastic spongy mass. The bulk of this mass when empty of air occupies but a small fraction of the space which it fills in the chest cavity during life. In other words, the main bulk of the lungs is due to the air which fills the air sacs.

Membrane covering lungs.—The lungs have for outside covering an exceedingly thin membrane formed of flattened cells, which also lines the chest cavity within which the lungs lie. This membrane, known as the

pleura, is very smooth and under normal conditions is made slippery by means of a fluid very similar to the synovial fluid of the joints. The two pleural surfaces,

Labels (clockwise from upper left):
Superior vena cava
Sternum
Outline of heart (auricles)
Boundary between auricle and ventricle
Carotid artery
Jugular vein
Arch of aorta
Outline of heart (ventricles)
Lungs
Portion of heart not covered by lungs
Stomach
Large intestine
Small intestine
Lungs
Top of diaphragm
Liver
Gall bladder
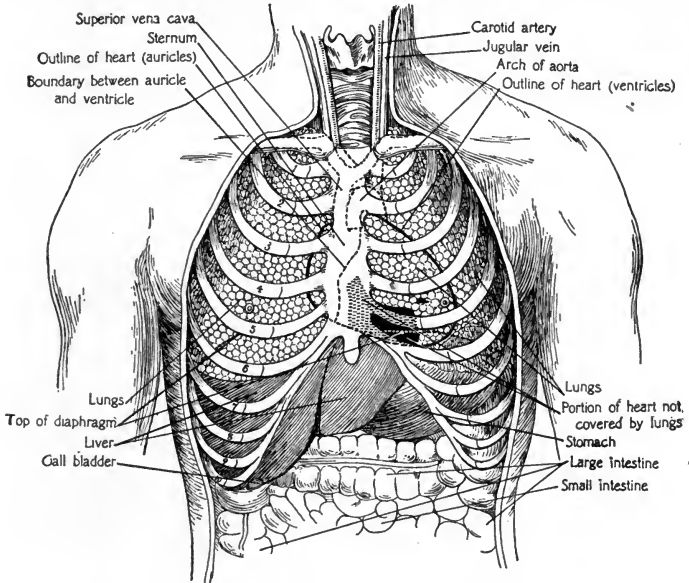
FIG. 101. Chest, showing position of organs.

which normally are in contact, are thus made to slip easily over each other during the enlargement and reduction of the chest cavity in the movements of breathing. The inflammation and roughening of these surfaces are what give rise to the discomfort and pain of *pleurisy.* As a result of pleurisy, the surfaces sometimes grow together, so that the lungs can no longer slip up and down.

Relation of lungs to chest cavity.—Under the normal conditions of life, the lungs fill all the cavity of the

chest not occupied by the heart and its connected blood-vessels and supporting tissues, by the esophagus and the trachea. As we have seen, the walls of the lungs are in close contact with the inside walls of the chest cavity. Below they are in similar contact with the *diaphragm,* a partition made up of muscle and tendon, which separates the chest cavity from the abdominal cavity. All outward and inward movements of the chest wall and

FIG. 102. Front view of the diaphragm and its attachments.

downward and upward movements of the diaphragm, are accompanied by an equal enlargement and reduction of the lungs, so that there is never any separation of the pleural surfaces.
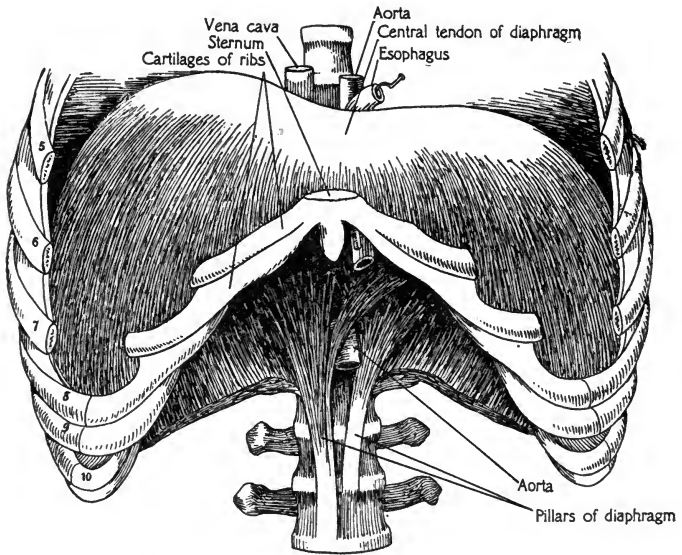
Air movement.—Associated with each enlargement of the lung there is an intake, or *inspiration,* of air; and

with each inward or diminishing movement there is a corresponding output, or *expiration,* of air. This air movement is called *respiration,* and takes place only when the chest wall, or diaphragm, or both are moved.

Inspiration.—The enlargement of the chest in inspiration is caused by the contraction of the muscles which lead from the ribs to the shoulder girdle and to the neck and head. The chest wall is readily lifted by these muscles, because its stiff framework of ribs is jointed at the spine. Moreover, the ribs are connected by thin layers of muscle and connective tissue; hence, when one rib moves, the others are carried with it. The ribs are slanted forward and downward so that, when they are raised by the contraction of the muscles, the chest cavity is enlarged at the sides as well as in the front. As the chest enlarges,

FIG. 103. Diagram illustrating the position of the chest in expiration (A) and inspiration (B).

the lungs follow, and their air cavity is correspondingly increased. The enlargement of the chest cavity in inspiration is further increased by the downward movement of the dome-shaped diaphragm, due to the contraction of its muscle fibres.

Expiration.—In expiration, the reverse process takes place. The muscles which lifted the chest relax and allow the ribs to descend. Their descent is greatly aided by the weight of the chest walls and shoulders, and, especially in the case of stout persons, by the weight of the abdominal walls. The diaphragm also relaxes and
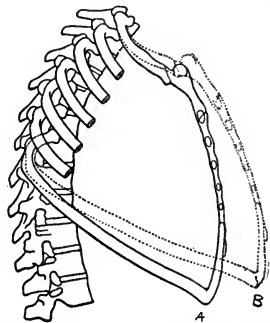
allows the abdominal contents to push upward against the base of the lungs.

In forced expiration, as in shouting or blowing upon a horn, the abdominal muscles also contract. They pull down on the ribs and push the abdominal contents with the diaphragm up into the chest cavity, thus strongly pushing the air out of the lungs.

Amount of air breathed.—The difference in the size of the lungs between an extreme inspiration and an extreme expiration is measured by the amount of air which can be blown out after the fullest inspiration.[1] It varies much with the size of the individual and the flexibility of his chest wall. It may be as much as two quarts, and as little as two pints if the chest walls are extremely rigid.

Lungs filled by air pressure.—The entrance of the outside air into the lungs and its exit from them is in accordance with the physical laws governing the movement of all gases. It must be remembered that, since we are living at the bottom of a sea of air, we are exposed to a constant atmospheric pressure due to the weight of this air of nearly fifteen pounds to the square inch. When the air presses equally upon all side of an object, as upon a thin sheet of rubber, the pressures completely neutralize each other. As a result, the rubber is flaccid and apparently without pressure. If, however, the rubber is held tightly over the open mouth and inspiration is attempted, the rubber is seen to be pushed inward. This is due to the pushing in of the outside air to fill the increased space made by the enlargement

---

[1] Of course it must be borne in mind that the amount blown out does not represent the total actual capacity of the lungs, since, even after they have been emptied as completely as possible, they still contain two or three pints of air. They are never normally collapsed during life.

of the chest.   Just as the air pushes the rubber in, so the air pushes its way through the air passages, distends the walls of the lungs, and presses them against the receding chest wall.

In expiration, the relaxing muscles permit the ribs to drop, the chest cavity becomes smaller, the elastic lungs contract, and the excess of air in them is pushed out.

Rapidity of breathing.—Owing to the large bulk of air required to furnish the oxygen necessary for the body's activity and to remove waste products, amounts sufficient for more than a moment's use cannot be stored up in the body.   As a result, constant and fairly rapid breathing is necessary.   Its rapidity varies somewhat with age and sex.   Women breathe more rapidly than men, and children more rapidly than either.

Effects of exercise.—Exercise causes a great increase in both the depth and the rate of breathing, because the additional amount of energy expended means a corresponding increase in the body's demand for oxygen as well as for the removal of its waste products.   If the exercise is mild, an increase in the depth of breathing may at first give all the air necessary.   If, however, the exercise is continued and severe, the respiration usually becomes rapid as well as deep, since to get all the air necessary from mere depth of respiration would require such extensive chest movements as would interfere with the exercise itself.   Thus, when exercise becomes too severe, one has to stop to take breath, since the demand for air becomes so imperative and gives rise to so much distress that it cannot be disregarded. The body is thus automatically protected from an inadequate supply of oxygen and from poisoning by an accumulation of waste products, as a result of too great activity.

Effects of severe exercise.—For those who are weak and habitually inactive and unused to hard work, this feeling of respiratory distress during unusual and severe exercise may be associated with much strain and consequent injury to the heart because of its increased labor. The lungs themselves are but rarely injured in this way, although the distress is felt to be respiratory, because
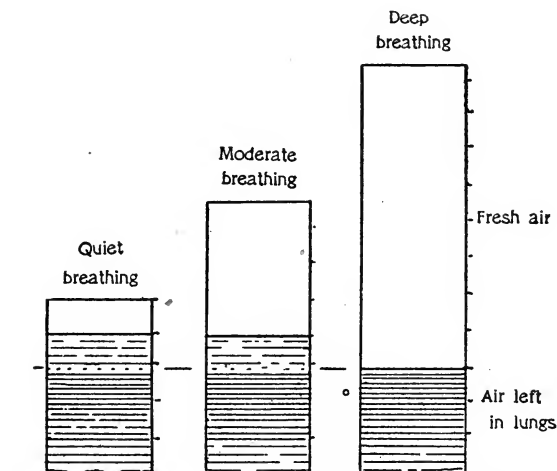
FIG. 104. Diagram showing relative amounts of fresh and stale air in lungs at different depths of breathing.

of the close relation between the nervous control of circulation and respiration.

Adjustment of respiration and circulation to exercise.—When muscles work, the blood coming from them is, as we have seen, richer in waste products, especially carbon dioxide, and poorer in oxygen and food materials. This change in the blood is directly proportional to the work done by the muscles. The amount of blood thus affected depends on the size and

number of the muscles at work. When many large muscles are hard at work, as in running or walking upstairs, a comparatively large amount of blood is affected. If under these conditions a more rapid exchange of waste products were not possible, the blood supply of the entire body would speedily become impure. To avoid this, there is a nervous mechanism by which the condition of the blood is constantly tested to determine its quality. If the quality falls below the standard, this nervous mechanism has the power of quickening both the respiratory movements and the heart beat. In consequence, the blood not only gets more oxygen and is more quickly freed of its waste, but it is also sent around faster to supply the larger amounts demanded by the muscles. To aid the heart in the work of pumping this increased amount of blood, the arterioles in the active muscles are, as we have seen, relaxed, the blood escapes more freely from the arterioles, the blood pressure in the arterial reservoir is lowered and the left ventricle of the heart has to overcome less resistance in opening the aortic valve and emptying its content of blood into it. The work of the heart in pumping the increased amount of blood is thus diminished, and the heart itself is saved from quick exhaustion.

Effect of training.—In athletes and in those used to hard work, the nervous control is so perfectly trained for its work that it enables the muscles to exert their greatest effort with little or no strain of the heart. In untrained persons, on the contrary, the automatic mechanism lacks the skill which comes with practice and so may overdrive the heart in attempting to bring about the proper adjustment between the circulation and respiration and the muscular activity. This is especially the case in youth, and as a result athletic contests are

frequent sources of heart strain. They should be indulged in but moderately and under medical advice, at least until the heart is so far developed that its ability safely to do work under conditions of strain has been proved.

As the perfection of the adjustment between circulation and respiration is entirely automatic and beyond the control of the will, the training necessary to attain such perfection can only be gained by frequent active work and exercise. For this reason, during the period of growth and development, children should have much physical activity, in order not only to perfect this control but also through it to attain full development of the heart, lungs and blood-vessels.

EXPERIMENTS AND DEMONSTRATIONS

Anatomy of the Respiratory Tract

Materials: Sheep's lungs with wind-pipe and heart attached (to prevent puncturing of lungs through careless removal of heart); rabbit, cat, or rat; frog; normal salt solution; glass and rubber tubing about ½ in. diameter, 12 in. long; some small object, as a piece of cork or rubber; microscope.

1) Examine wind-pipe of sheep and trace its division into bronchi. Notice in its wall rings of cartilage, so arranged that dorsal aspect of tube (which lies against esophagus) has no hard parts in it.

2) Slip rubber tube on end of glass tube and insert other end of glass tube into trachea; tie firmly; blow up lungs and pinch rubber tube to keep distended.

Note extensibility and elasticity of lungs; their size and form when distended; concavity of their lower (diaphragm) surface; lobes; pleural membranes; and space occupied by heart.

3) Trace one bronchus to its lung.

a) Cut through lung tissue and follow branching bronchi. Note cartilage rings, and lining mucous membrane.

b) Wash surface of mucous membrane with normal salt

solution; gently scrape with scalpel and examine scrapings under microscope.

4) Remove from rabbit its abdominal viscera, cutting away liver and stomach with especial care. Examine vaulted diaphragm and through it the lungs.

5) Seize diaphragm by its centre and pull it down, imitating its respiratory movements.

6) Make a free opening into first one and then the other side of chest and note effect upon lungs.

7) Cut away front of chest and observe tendinous centre of diaphragm; its muscular periphery; and attachment of pericardium to its thoracic side.

8) Place a recently killed frog on its back; fasten lower jaw wide open.

a) Place small object on roof of mouth near nose and note movement.

b) Examine scrapings from roof of frog's mouth in normal salt solution under microscope.

9) Remove as much of esophagus as possible; split it open and pin out.

a) Place small object upon it near mouth and note behavior.

b) Set esophagus aside under moist glass and note position of mucus on surface at end of half an hour.[1]

Respiration

Materials:

Blood clot, defibrinated blood, or piece of liver; lungs of rabbit, cat, or rat; phenolphthalein (a few drops 1 per cent solution); lime water; thermometers in tin cases; mirror; tape measure; wide-mouthed bottles; bottle of 1 gal. capacity; pan for water; test tube; glass tubes; rubber tubing; bell jar of 2 qts. capacity; heavy pure gum sheet rubber, to tie over bottom of bell jar; pinchcock; rubber stopper with double perforations, to fit bell jar; 2 pieces of glass tubing, to fit perforations of stopper; water-valve respiration apparatus for carbon dioxide.

1) Note the effect of breathing on bulb of a thermometer; on a mirror, knife blade, or other polished metallic surface.

---

[1] Cilia are present in the respiratory passages but not in the esophagus of man.

2) Measure the girths of chest and abdomen at end of inspiration; at end of expiration.

3) Measure amount of air which you can blow out after deepest inspiration, by blowing through a piece of tubing into a large bottle filled with water and inverted in a pan of water.
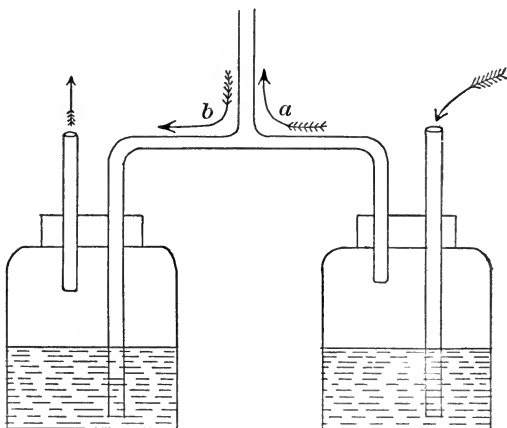

Fig. 105. Apparatus to demonstrate carbon dioxide in expired air. *a*, inspiration; *b*, expiration.

4) Determine the rate of breathing, that is, the number of inspirations per minute, upon awaking in the morning; upon rising; after dressing; after eating; and after running.

5) Demonstrate by means of the water-valve respiration apparatus (fig. 105) the relative amounts of carbon dioxide in atmospheric air and in expired air, by partly filling bottles with lime water and breathing in and out through mouth tube.

6) Blow breath through a weak solution of lime water colored with phenolphthalein.[1]

7) Cut open blood clot or piece of liver.

a) Compare freshly cut surface with surface previously exposed to air.

b) Place freshly cut pieces of blood clot or liver in a bottle containing oxygen.   Or·

[1] Phenolphthalein is pink in alkaline solutions; colorless, in acid.

b') Shake defibrinated blood in bottle containing oxygen. Note result (oxyhemoglobin).

8) *Respiration apparatus:* Tie trachea of cat or rat on piece of glass tubing which is then passed up inside bell jar through one of perforations in stopper.   Seat stopper firmly in mouth of bell jar.   Stretch piece of sheet rubber over
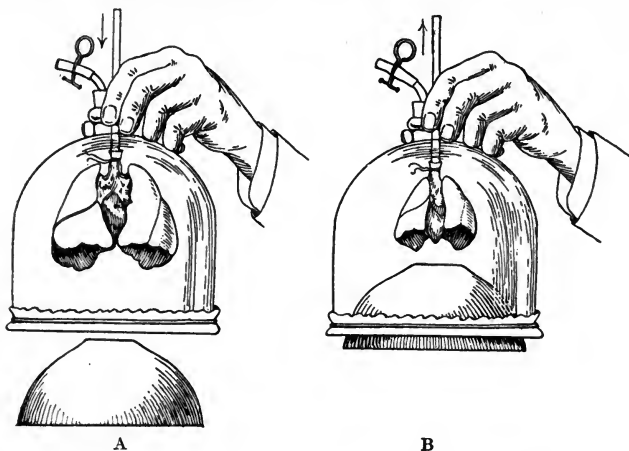
FIG. 106.   Diagram of apparatus to demonstrate the action of the diaphragm. **A,** in inspiration diaphragm flattened by contraction ; **B,** in expiration diaphragm relaxed and pushed upward by abdominal contents.   Note changes in fullness of lungs.

larger end of bell jar and tie firmly in position.   Press this rubber membrane down on top of bowl and close free rubber tube with pinchcock.

a) To represent inspiration, lift bell jar from bowl, allowing rubber membrane to flatten.

b) To represent expiration, press membrane down over bowl.

c) To represent effect of puncture of chest wall, remove pinchcock from tube and lift jar from bowl.

CHAPTER XVI

THE HYGIENE OF RESPIRATION

WE have seen how dependent the animal organism is upon the air as a source of oxygen and as a means of getting rid of carbon dioxide and other volatile products of the body's activity. In order to serve this purpose, the air breathed must be both rich in oxygen and poor in carbon dioxide. These conditions would be perfectly fulfilled, if we lived constantly in the open air. The necessity of protecting ourselves from cold and wet, and the consequent living in closed spaces, such as the modern dwelling house, have, however, made it more diffcult to get a constant and pure supply of air. Indeed, in many cases, no attempt at all is made to get it.

Effects of respired air.—A study of persons who constantly live and work in close rooms shows that they are pale, weak, with poor appetite, and in a large percentage of cases, with marked tendencies to consumption, whereas those who work out-of-doors are ruddy and strong. Experiments on animals have also shown the same results from breathing air made impure by respiration. For example, a series of cages for mice was arranged with tight sides, so that the only air which reached them came through one end of the series and made its exit at the other. It was found that the animals in the first cages were perfectly well and strong, while those in the others showed weakness and other signs of poisoning, which increased in degree with their distance from the source of the fresh air supply. In the instance of the Black Hole of Calcutta, where a large

number of prisoners were crowded into a dungeon with but one window, all of the men, except those few who were able to crowd close to the window, were found dead in the morning. The effects of bad air are further shown by the wonderful improvement in health and strength which a change to out-of-door life in the pure air makes among those who have been confined in close rooms. Even when consumption has obtained a foot-hold, the fresh air life not only stops the progress of the disease but even cures it.

Odor a test of impurity. — Careful studies have shown that whenever the air of an occupied room has a close or offensive odor to a person coming into the room from the outside air, it is unwholesome and even poisonous to those breathing it, however unconscious they may be of it. Indeed, the worst danger of bad air lies in the fact that its effects are so general in char-acter and accumulate so slowly from day to day that its victims do not know why they are weak, pale and gen-erally miserable.

Amount of fresh air required. — Many chemical tests have been made of the air of crowded rooms, halls and shops, in which the occupants were sleepy, list-less and given to headaches. The air has invariably been found to be offensive to a person entering from the outside air and to contain large amounts of carbon dioxide from the breath. The presence of 2 parts of

TEST BY ODOR OF AIR OF AN OCCUPIED ROOM

	Fresh	Slightly close; per-ceptible odor	Close; disa-greeable	Very close; offensive
Parts CO_2 in 10 000 vols. air....	6	8	10.5	13
Parts CO_2 due to respiratory impurity....	2	4	6 5	9

respiratory [1] carbon dioxide in 10,000 parts of air indicates that the air is as bad as can safely be tolerated by human beings. As expired breath contains 4 per cent of carbon dioxide, or 400 parts in 10,000, each breath must be diluted with at least 200 parts of fresh air to make it safe for breathing. Since the amount of air expired by one person in an hour [2] is 15.6 cubic feet, it is evident that each person in a room must be supplied every hour with about 3,000 cubic feet of fresh air, if he is to avoid the debilitating effects of bad air.

Ventilation.—To supply this amount of fresh air economically is the problem of ventilation. In summer, ventilation is not difficult because the windows can be kept open so that the air can circulate throughout the rooms of a house. Under these circumstances, all the air of a room can be changed as frequently as once a minute. In cold weather, when the windows cannot be freely used in this way, special provision has to be made to get rid of the bad air and to introduce in its place air that is fresh and pure. In addition, the air which is thus introduced must be warmed, so that it is customary to consider heating and ventilation together and to provide for them at one and the same time.

[1] By respiratory carbon dioxide is meant that which is added to atmospheric air by the breath. Atmospheric air itself contains from $3\frac{1}{2}$ to 4 parts of carbon dioxide in 10,000 parts. For example, when by test 10 parts of carbon dioxide in 10,000 are found in a school-room, 4 parts are the atmospheric carbon dioxide, and the remaining 6 parts are respiratory carbon dioxide. In this case, it is evident that there is being supplied to the room only $\frac{1}{3}$ the amount of air which is necessary.

[2] In a year, each adult breathes about 10,000 lbs. of air. From it, he takes 657 lbs. of oxygen, and to it he gives 730 lbs. of carbon dioxide.

Heating.—There are two methods of heating generally in use. The *direct method* of heating is by a stove or fireplace, or by a radiator for steam or hot water. The *indirect method* is by means of a stream of hot air from a furnace or steam coil in the basement.

Direct method.—The direct method by means of a stove or fireplace gives better ventilation than when a radiator for steam or hot water is used, since the rapid movement of hot air up the chimney draws an equal amount of air into the room through the cracks around the windows and doors, and in the walls and floor. If the house is tightly built, however, or if more than one or two persons are in the room, this amount of fresh air is not ordinarily sufficient and must be supplemented by a proper opening of the windows and doors. If the direct method of heating by means of a radiator is used, no air is drawn out of the room and consequently but little enters through the cracks, unless a heavy wind is blowing. The windows and doors must therefore be used more or less continuously, in order to insure adequate ventilation.

Use of windows for ventilation.—If windows are to be depended upon for ventilation, they must be intelligently used with this end in view. When the wind is blowing, the windows upon the windward side of a room will give entrance to the air because of the wind pressure. These windows should be opened more or less, as determined by the force of the wind, and preferably at the top, in order that the air entering may mix with the warm air of the room and not settle as a cold draft near the floor. If there is no fireplace or other means of exit for the air, one or more windows should also be opened at the bottom on the leeward side of the room, to permit the vitiated air to go out. When, as rarely

happens, the wind is not blowing at all, there is, of course, no particular reason for opening one window rather than another.

When the air of a room is too hot, the windows should be opened at the top on the leeward side of the room, to allow the hot air, which tends to rise, to escape; and at the top on the windward side, to allow the cold air to enter in its place. In this way, the air of a room may be quickly changed and cooled, and yet the floor not be chilled.

Indirect method.—With indirect heating, ventilation is much easier, since the stream of air which carries the heat may and should be a stream of pure fresh air from the outside, which has been carefully kept from contamination with bad air, dust, or other impurities. The stream of warm pure air is best admitted near the top of the room so that it will not be mixed with the colder impure air but will spread out and fill the upper part of the room because of its greater lightness. The lower stratum of air should be drawn off by fireplaces or ventilating flues as large or larger than the hot air flues. The openings of these flues should be placed as near the floor as possible, in order to get rid of the colder impure air of the floor.

Humidity.—Aside from the freshness of the air, two of the most important factors in ventilation are the temperature of the air and the amount of moisture contained in it, that is, its *humidity*. The humidity of any given amount of air depends upon its temperature. The more it is warmed, the more moisture it is able to take up; and, conversely, the colder it becomes, the less moisture it can hold. Thus moist foggy air at 32° F. becomes very dry air at 70° F.; suddenly cooled to zero, its moisture is so much in excess of what it can hold

that it is precipitated as snow. Very dry air takes the moisture from our bodies more rapidly than that which is humid. Thus we feel chilly in winter when in a dry indoor air at 75° or 80° F.; in summer at the same temperature we feel oppressively hot in the moisture-laden air of the dog days. In the one case, the air is so dry that it takes the body's moisture rapidly enough to chill it; in the other, the air is so full of moisture that it will not take the moisture which, if evaporated, would cool it. It is therefore obvious that a person's comfort depends quite as much upon the humidity as upon the temperature of the air.

Relation of humidity to ventilation.—In cold climates, such as that of the northern part of the United States, the warming of the air for ventilation often gives it a parching dryness which may equal that of the Sahara desert. Because this excessive dryness causes the moisture on the body's surface to evaporate rapidly, the body is chilled unless the temperature of the room is kept as high as 75° or 80° F. The eyes and the mucous membrane of the respiratory tract also become irritated by undue drying of their surfaces. By adding moisture to the air so as to raise its humidity from 25 or 50 per cent to 70 or 75 per cent, the air may be made very comfortable at a temperature of 65° F. and its irritating effects removed. The addition of moisture not only makes the air more wholesome but saves expense in heating.

In moist climates, such as are found in coast regions, where the ordinary winter temperature is above freezing, the addition of moisture may not be necessary, except in cold dry weather. It is undoubtedly on this account that in England 60° to 65° F. is accepted as the normal temperature for comfort indoors.

In the New England coast regions, where the extreme ranges in humidity and temperature make the climate like that of almost all other countries in rapid turn, it is necessary to supply moisture only in the clear cold weather when the natural moisture of the air is frozen out.

Drafts.—One of the greatest difficulties in the way of proper ventilation is a very prevalent fear of drafts. This fear has survived in undiminished strength in spite of the fact that many diseases, notably pneumonia, which were formerly thought to be directly traceable to them, have been proved to have quite a different origin in the invasion of the system by microbes. It is probably true that the exposure to a draft of a limited portion of the body's surface, such as the back of the neck, the wrist, or the ankles, may result in a catarrhal condition of the mucous membranes, especially of the nose and throat, and the development of microbes on their surface be favored thereby. There is every reason to believe, however, that in many of these cases the results are due not so much to exposure to drafts as to the irritation from breathing microbe-laden dust.

Relation of clothing to ventilation.—Even were drafts, however, responsible for all the ills attributed to them, the sensible thing to do would be to protect the body by proper clothing so that we could have fresh air without injury. In recent years, there has been a growing and most unfortunate tendency in quite the opposite direction. Women and girls especially are dressing more and more thinly, in total disregard of season or climate, and, as a result, they are forced for comfort to keep their houses overheated. Adequate clothing is a most important aid to ventilation. It is the cheapest way of securing comfort with proper ventilation in cold

weather, and it has the further advantage of enabling one to avoid the depressing and weakening effects of overheated rooms.

Night air.—Another difficulty in the way of adequate ventilation, which is fast being overcome, is the fear of night air. Years ago, many persons were accustomed to shut their sleeping rooms up tightly, lest "the poison of the night air" should harm them. To-day, however, it is recognized that the night air is as wholesome as that of the day, from which it differs only in temperature. The restfulness and recuperation of sleep depend very largely upon having the freshest air possible in the sleeping room, in order to furnish the tissues with all the oxygen that they need for repairing the inroads which the day's activity has made upon them. For this reason, the bed should always be far enough from the wall to permit the free circulation of air about it, and the windows should be wide enough open to admit perceptible currents of air. In cold weather, the old-fashioned nightcap is most useful, since it protects the head from the drafts which are inseparable from a well-ventilated sleeping room.

Malaria.—Malaria, which was formerly attributed to the night air, is now known to be due to the transmission of disease germs by the bite of a certain mosquito, the *anopheles*, which is active at night. The moral, therefore, is not to keep out the night air but to protect against insects.

Dust, a source of disease.—Our present knowledge of the way in which disease is spread, has shown us that one of the great menaces to health is the breathing of dust-laden air. The dusty air of cities is so contaminated by the dried excretions of animals and of human saliva that it is undoubtedly responsible in thousands

of cases for the spread of disease. In this way, we are exposed to hordes of disease germs, which are constantly lodging in the mucous membranes of nose, throat and lungs. If we are fortunate, they are thrown out by the cilia or destroyed by the white blood corpuscles. If not, such diseases as colds, consumption, pneumonia and diphtheria result. The problem of diminishing the amount of dust in cities is therefore exceedingly important.

Coughing.—In addition to the dried particles of microbe-laden sputum and other excretions, air also contains at times particles of moisture which are projected into it by those who cough. These particles are so fine that they quickly dry and float about for some time before settling. Careful examinations have shown that they carry such disease germs as exist in the mucus covering the air passages of the lungs, the bronchi and trachea, the pharynx, nose and throat of those who are coughing or sneezing. Many diseases are directly transmitted in this way from diseased to well persons. Thorough ventilation and covering the mouth when coughing reduce the danger of their transmission very materially, although they do not remove it entirely. Only by the isolation of those diseased, can the danger be eliminated.

Sewer gas.—Sewer air, which is disagreeable chiefly because of its odor, is not necessarily poisonous, although it may contain poisonous gases such as coal gas and illuminating gas. As we have seen, both coal gas and illuminating gas contain the deadly carbon monoxide (CO), which has been generated by burning carbon at too low a temperature for complete oxidation.

Care of nose.—In addition to providing the organs of respiration with as pure air as possible for breathing,

we have to bestow upon them a certain amount of care and attention that they may do their work properly. The nose is exposed to all the microbes and dust contained in the air breathed. These are caught upon its moist surface and removed by the cilia. If the mucous membrane is not sufficiently moist and the cilia active, or if the dust is excessive or especially irritating, the mucous membrane becomes swollen from the irritation, and secretes large amounts of mucus in its effort to wash the irritating dust away. This constitutes what is popularly called a head cold. It is important, therefore, that those who are subject to head colds should remove the dust by spraying the nose with a mild antiseptic solution [1] after such exposure.

Catarrh. — Persons with sensitive membranes, who have frequent head colds, are liable to get a chronically thickened membrane, which secretes mucus in copious amounts, that is, they have *catarrh*. Catarrh is not only a very disagreeable ailment in itself but it indicates conditions in the nose which may extend to the tube connecting the throat with the middle ear and produce partial or complete deafness. Head colds, therefore, should be prevented whenever possible, and should receive careful medical attention.

Adenoids.—In the nasal cavity, the mucous membrane is so delicate that constant irritation, especially by dust, often causes it to become so swollen that it blocks the passage of air through the nose. Repeated irritation tends to produce soft masses of tissue, called *adenoids,* which are especially frequent in children and make it necessary for them to breathe through their mouths. The closure of the nose and breathing through the mouth

[1] A proper atomizer and Dobell's solution can be bought at any druggist's.

lead to narrowing of the nasal passages and upper jaw, and eventual closing of the tube to the ear, which results in defective hearing. It is therefore important that adenoids should be removed before the deformities have time to develop. Whenever mouth breathing is habitual or head colds with closure of the nose are frequent, the presence of adenoids should be suspected and a physician consulted.

Enlarged tonsils.—The throat is affected by much the same conditions as the nose and requires much the same treatment. The tonsils frequently become chronically enlarged, sometimes so much so that swallowing and breathing are difficult. When markedly enlarged, they should be removed, since the general health may suffer greatly through them.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Whips or light rods, 5 to 6 ft. long; down or delicate feathers; spool "A" sewing silk; ball of lead weighing about 1 oz.; dry and wet bulb thermometers (psychrometer); [1] [Fitz CO_2 apparatus [2]].

1) *Test of purity of air:*

a) By odor: Make an independent test of the air of 2 occupied rooms by entering them from outside fresh air and

[1] Select cheap tin-cased thermometers by noting that the three scratches on side of glass stem of each coincide respectively with the graduations for 32°, 62° and 92°. Match them by putting them into a glass of water of about 60° temperature and selecting the pairs which register the same. A slight variation may be adjusted by sliding one stem up or down on its scale the required amount. Slip thermometers out of tin cases and secure each stem in its proper position on scale by means of sealing wax, applied to back of scale where tip of glass stem projects through. Carefully cut off lower portion of metal scale where it surrounds bulb and fasten thermometers to a grooved piece of wood, as shown in fig. 107. Upon bulb of one, tie a piece of thin linen cloth and attach a stout cord 12 in. long to top of wooden support so that it can safely be whirled.

[2] L. E. Knott Apparatus Co., 15 Harcourt Street, Boston, Mass.

noting presence of odor as none, faint, marked, or strong. Record size of room in cu. ft., number of persons occupying it, method of heating and ventilating, number of ventilators open (windows, doors, registers, transoms, etc.) and movement of air through each as to direction [1] and strength. Make diagram of essential features.

[b) By chemical analysis: Use CO_2 apparatus according to directions accompanying same.[2] Make plans of rooms and carry out as in a).]

2) *Air currents:*[3]

a) *Direction:* By means of the suspended tuft of down, determine the direction of air movement in various parts of a room. Indicate currents upon diagram of room by means of arrows.

b) *Velocity:* Determine by measuring distance in feet that a tuft of down will move with air current in 1 second.[4]

c) *Amount:* Determine by measuring areas of air inlets and outlets in square feet and multiplying this by the air velocity in feet per second.

d) *Adequacy of air supply:* Add together amounts of air entering inlets of room; divide result by total number of occupants; compare with standard requirements ($\frac{5}{6}$ cu. ft. per sec.).

3) *Humidity of air:* Moisten cloth on bulb of psychrometer and whirl in air until readings of 2 thermometers are constant.

---

[1] The best method of detecting currents of air at ventilators is to attach a bit of down or a feather on a silk thread 15 in. in length to the end of a whip or stick long enough to reach to the top of the room. This will indicate even a slight draft and show whether it is inward or outward. If the draft is very slight, a candle flame or smoke from a joss stick affords the best means of detection.

[2] This method is simple and reliable and does not require a knowledge of chemistry.

[3] Since the currents of air in a room determine the distribution of the incoming fresh air, their study is important to determine whether the air is distributed evenly throughout the room.

[4] The seconds are easily measured by means of a metronome or by a pendulum consisting of a small lead weight suspended by a cord 39 in. long from point of suspension to centre of weight, and should be indicated by tapping, so that the one watching the movements of the down may not have his attention distracted by the necessity of watching the pendulum as well.

Record temperatures and subtract the reading of wet bulb from that of dry.

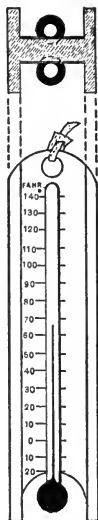By reference to table, find relative humidity corresponding to

FIG. 107. Wet and dry bulb thermometers arranged for whirling (Psychrometer) to get quick readings.

air temperature as given by dry bulb thermometer, and to difference between readings of 2 thermometers.

Difference between wet and dry bulbs.	Air temperature (Fahrenheit).							
	10°	20°	30°	40°	50°	60°	70°	80°
1	80	86	90	92	93	94	95	96
2	60	72	79	84	87	89	90	92
4	21	44	58	68	74	78	81	83
6		16	38	52	61	68	72	75
8			18	37	49	58	64	68
10				22	37	48	55	61
12					8	26	39	48	54
14					16	30	40	47
16						5	21	33	41
18							13	26	35
20							5	19	29

Repeat test at various times, indoors, outdoors, and at home, making careful notes as to weather conditions.

4) *Heating and ventilating plant:* Examine and make sketches showing method of ventilating and heating school; home.

CHAPTER XVII

THE REMOVAL OF WASTE PRODUCTS

As we have seen, the volatile waste products of the body's activity are constantly removed from the blood by the air in the lungs. The non-volatile waste products which are in solution in the blood cannot, however, be got rid of in this way, since they are incapable of passing from the blood to the air. To dispose of them, special organs have been developed, notably the kidneys.

Kidneys.—The *kidneys* are two rounded bodies, one of which lies on each side of the spine in the upper part of the abdominal cavity just under the lowest ribs. In size, they are nearly five inches long, two and three-quarters inches wide and one and three-quarters inches thick, and weigh about four ounces each. They are reddish-brown in color, of firm consistency and covered with a smooth membrane.

Blood supply.—Each kidney contains two complete systems of tubes. One is made up of the branching arteries, capillaries and veins, which carry the arterial blood from the aorta into, through and out of the kidneys. On leaving the kidneys, the blood enters the large abdominal vein which returns it directly to the heart. Thus a part of the arterial blood is constantly passing through them.

Structure.—The other system of tubes consists of a very complex meshwork called *renal tubules,* which begin as tiny cups surrounding tufts of capillaries.

These cups are drained by tubes which follow winding paths through the kidney tissue. At one point in their course, they are surrounded by a fine network of capil-
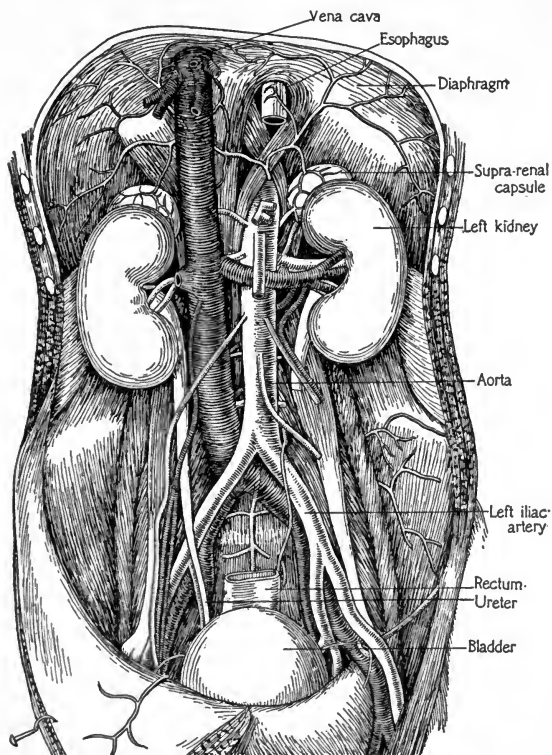

FIG. 108. The kidneys and principal blood-vessels of abdomen, as seen when intestines are removed.

laries. They ultimately join together to form large drainage canals, which empty into a cavity on the inner or concave side of each kidney. This cavity is connected by means of a slender tube, the *ureter*, with an elastic

reservoir, the *bladder*. At both points of contact between the capillaries and the renal tubules, water and certain waste substances in solution are removed from the blood.

Excretion.—Since the waste products taken from the blood are to be ejected from the body, the process of removing them from the blood is called *excretion*. The
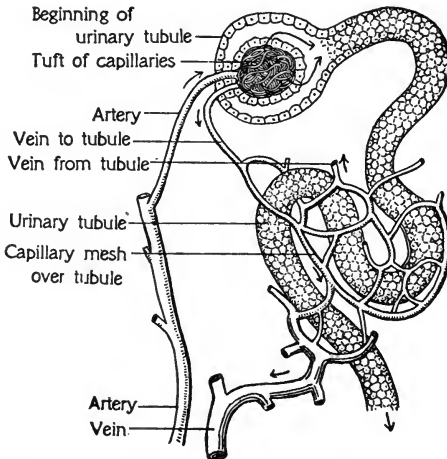
Fɪɢ. 109. Structure of kidney, showing the secreting mechanism (diagrammatic). The arrows indicate the direction of flow of the fluids.

excreted fluid [1] is constantly drained from the kidneys into the bladder, where it is temporarily stored. The amount secreted by the kidneys in twenty-four hours is normally about three pints.

Effect upon blood.—The kidneys, through their power of eliminating water from the blood, prevent the blood

[1] The total amount in 24 hours is 1500 grams. Its composition is water, 1440 gms.; total solids, 60 gms. (consisting of urea, 35 gms.; uric acid, 0.75 gms.; sodium chloride, 16.5 gms.; and other substances as salts of potassium, magnesium and calcium, 7.75 gms.).

from being long overdiluted by too much water. If, for any reason, water is drunk in such small quantities that the blood has but little to spare, the amount of water excreted by the kidneys is correspondingly reduced.

Importance of the kidneys.—The importance of the work of the kidneys is most clearly seen when through disease their action is impeded or stopped. The consequent accumulation of waste substances in the blood results in headache, convulsions and even death.

Excretion by the skin.—The skin, as well as the kidneys, removes a certain amount of waste products in the form of *perspiration.* The perspiration when analyzed is shown to contain a considerable amount of various salts, especially sodium chloride, some fat and minute traces of other substances which are also found in the kidney excretion. Its bulk consists of water, which under normal conditions is being constantly eliminated in this way throughout life. When, through disease, the kidneys fail to do their work, the urinary substances are found in much greater amounts in the perspiration. Their excretion may be further increased by inducing copious perspiration through hot air baths. The failure of the kidneys may thus be partially neutralized by the increased activity of the skin as an excretory organ.

Uses of perspiration.—Perspiration serves a threefold purpose. It not only aids in removing the excess of water from the blood, but it also keeps the skin both moist and cool, even when the perspiration is so slight in amount that it evaporates as quickly as it is secreted and so is not perceptible or "visible." When perspiration fails for any reason, as in fever, the skin becomes dry and harsh and the body is no longer properly cooled.

CHAPTER XVIII

THE SKIN

The skin, a protection.—Besides aiding in the excretion of certain waste products from the body, the skin serves to enclose the body and thus to protect its more delicate tissues from harmful contact with surrounding objects. For this purpose, it is tough and elastic, and has the power of becoming still thicker and tougher when habitually exposed to hard contact, as in the soles of the feet and the palms of the hands.

The skin, a sense organ.—The skin is richly supplied with nerves, by means of which information is given of the objects with which contact is made, so that the individual knows not only when an object is touched but also whether it is warm or cold, large or small, rough or smooth. He is thus able to recognize in general whether the objects touched are harmful or not and to act accordingly.[1]

Structure.—The skin is built up of several layers, of which the outermost, the *epidermis,* is solely protective. The epidermis consists of numerous layers of cells, the surface layers of which are flat and scalelike, while the deeper ones are more spherical. The layers of cells on the surface are constantly being worn away and are as constantly being replaced by new cells from the lower layers, which on approaching the surface become flattened and scale-like.

[1] For a further discussion of the skin as a sense organ, see p. 247.

Pigment cells.—In the deepest layers of the epi-
dermis are cells containing more or less coloring matter
or pigment, which intercepts the rays of the sun and
thus prevents irritation.   In the colored races, these
cells are more numerous and contain darker pigment
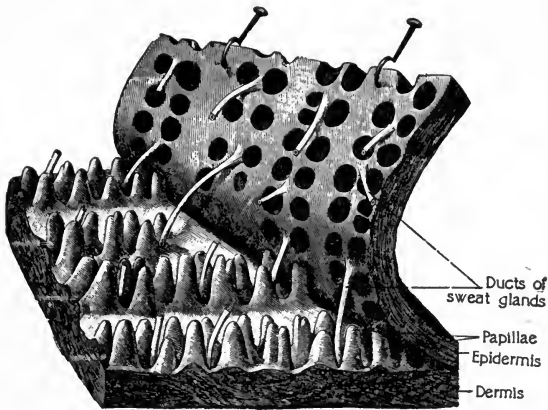than in the case of the white races.   They are therefore

Fig. 110.   Papillæ of skin, as seen when epidermis is stripped from dermis.

much better adapted to hot climates.   Among the white
races, exposure of the skin to sunshine leads the cells
to protect themselves and the body by a rapid increase
in the deposit of pigment, which may be uniformly dis-
tributed as in tanning, or scattered as in freckling.
Freckling is much more common among blondes than
among brunettes, because many of their cells have not
the power to develop the protective pigment.

Color of the skin.—The color which results from
the presence of pigment must not be confused with the
warm glow which is the characteristic color of the skin
in health and is due to the color of the blood showing

through the translucent skin. It is greatly heightened
when the blood-vessels dilate in blushing, in exercise,
or as a reaction to the cold. A sudden pallor is due
to a contraction of the blood-vessels from cold or to
a lowering of the blood pressure associated with fear
or faintness. Persistent or chronic pallor is frequently
due to a chronic contraction of the blood-vessels in the
skin, or to a deficiency in. the red corpuscles of the
blood. The gaining of a good color, therefore, is often
dependent upon improving the health by fresh air and
exercise, which enrich the color of the blood itself.

Dermis.—Below the epidermis, we find the true skin,
the *dermis,* which is also made up of numerous layers
of cells. The cells of the upper layers are compactly
joined together, whereas the deeper ones shade off into
soft fibres which blend with the underlying tissue. The
dermis is richly supplied with blood-vessels, and con-
tains the nerve terminals which receive the impressions
of touch. It also contains in part the ducts of the
sweat glands and the hair roots.

Connective tissue layer. — Underneath the dermis,
there is a less well-defined layer, consisting largely of
loose connective tissue, the spaces of which are more or
less filled with fat cells. This layer is of considerable
thickness in stout persons. It is made distinct from the
underlying muscles and other tissues by a loose mesh-
work of connective tissue, such as was found between
the large bundles of muscles. Its purpose is to permit
the skin to slip freely over the underlying parts, so that
it will not interfere with the contraction of the muscles
and the bending of the joints. The thickness of the skin
when picked up between the thumb and finger is mainly
due to this fatty layer, the other layers being com-
paratively thin.

Fat is placed in this lower layer of the skin apparently for the double purpose of serving as a storage for food supply which can be utilized when needed, and also of forming a thick layer of non-conducting material for the protection of the body against a too rapid loss of
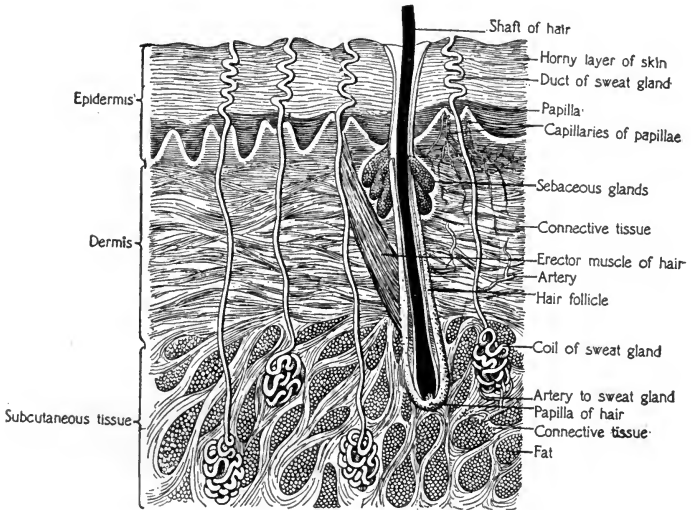

FIG. 111. Section of skin, considerably magnified.

heat in cold weather. When the partial or complete starvation of prolonged illness, or the partial failure of digestion and assimilation, as in old age, has caused this supply of fat to be used up, the skin is no longer filled out and becomes wrinkled. It is for this reason that age shows itself most quickly in those who are thin.

Hair.—In this fatty layer are embedded folds of the epidermis and dermis in which lie the roots of the hairs and nails. The hairs pass from the surface into the fatty layer through tiny canals slightly larger than the hairs

themselves. Here, there is a small root from which the hair grows. When a hair is pulled out, the portion which is not alive separates from the living root, which remains and builds a new hair.

Connected with each canal through which a hair passes are several minute glands, the *sebaceous glands,* which secrete an oil for making the hair glossy and waterproof. Since the hair tends to collect dust and dirt, it should be washed with warm water and mild soap. The natural oil which is removed in washing can be restored when necessary by rubbing a small amount of vaseline into the roots before the hair is dried.

Nails.—The nails, like the hair, are special modifications of the epidermis. They serve to protect the sensitive tips of the fingers and toes, and consist of a translucent horny layer of closely compacted broad cells. They take root in folds of the dermis and epidermis, which dip down through the fatty layer nearly to the bone. The nail is slowly developed and pushed out until it overhangs the end of the finger or toe to which it is attached. When a nail is torn off, a complete new nail is built out from the root in about six months, unless the root itself has been destroyed.

Since the edges of the nails afford natural lodging places for all kinds of dirt and microbes, it is important from the standpoint of health as well as of beauty that they should be kept clean. They should be trimmed carefully and the crevices around and under them should be cleaned with a pointed stick rubbed in soap.

Sweat glands.—The sweat glands of the skin have their mouths in the tiny ridges on its surface. Their ducts penetrate in the form of a spiral through the epidermis and dermis into the subcutaneous fatty layer. Here each duct becomes twisted upon itself, and forms

a knotted mass, the *gland*, which is about one-sixtieth of an inch in diameter.

Secretion.—The sweat glands are scattered thickly in the skin, especially in the palms of the hands and the soles of the feet. Their total number is estimated at about 2,000,000, and their total secretion in twenty-fours hours may be as much as a quart. In warm weather, as a result of vigorous exercise, the secretion may be two or three times as much. It consists normally of water containing a small amount of salt. It is ordinarily more or less mixed with the secretions of the sebaceous glands. When the kidneys are not able adequately to do their work, the sweat becomes much richer in the waste products usually eliminated by them.
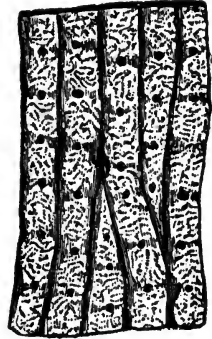
Fig. 112. Magnified view of the epidermis, showing mouths of the sweat glands.

"Pores" of the skin.—The mouths of the sweat glands are popularly known as the *pores* of the skin, and are said to open and close. As a matter of fact, they are always wide open. Occasionally, it is true, a few of them may be clogged with dirt, with resulting pimples or "black heads." The semi-solid contents of these can be emptied by gentle pressure. The popular term, "opening the pores of the skin," really means increased activity in these glands and visible perspiration, or the dilatation of the blood-vessels lying under the skin.

Inadequacy of the skin's protection.—The unbroken skin, even when as delicate as in man, forms ordinarily an adequate protection against the invasion of the body

by disease-producing germs. This protection would be more complete, were it not for the openings of the sweat glands and hair roots, which occasionally afford them entrance and permit their development in the form of small abscesses, *pimples*, or large abscesses, *boils*.
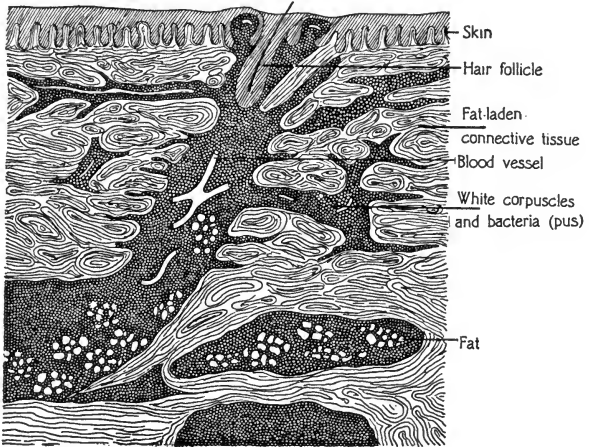

FIG. 113. Section of the skin and underlying tissue of the back, showing the spread of pus in a carbuncle. (After Warren.)

These ordinarily remain in the skin and do not penetrate into the tissues below. They tend to work outward, destroying the skin as they go, until finally they break through the surface. Sometimes, however, when the invading microbes are of a very active form or when they develop in very tough skin, such as that on the back, they tend to work inward and form large spreading abscesses called *carbuncles*. When the skin is broken, microbes are able to find their way into the lymph spaces, where they have a chance for development, provided that they can resist the attacks of the white blood corpuscles.

Necessity for cleanliness.—By its own secretions, the skin increases the danger of contamination through microbes by furnishing a surface to which they adhere and on which they develop. The safeguard against this is cleanliness. An efficient method of cleaning the skin is by thorough washing with warm water and soap. The soap is dissolved by the warm water and in turn dissolves the oil and grease found upon the skin. Microbes and other impurities which have been held to the surface by the oiliness of the skin are in this way carried away by the water. It has been found by tests that this form of cleansing, if followed by rinsing in running water, is ordinarily effective against the transfer of even contagious diseases. Such thorough washing of the hands is a precaution which should always precede eating.

Bathing.—Washing of the whole body, or bathing, is valuable not only for cleansing the body but also for giving a wholesome stimulation to the nervous system. For this purpose, cold or cool baths are preferable to warm, which have a more relaxing or sedative effect unless immediately followed by a cool shower or sponge bath. To be stimulating, a bath need not be colder than 70° F. Bathing in water colder than this has its dangers, chief among which is its liability to increase any tendency to pain or stiffness in the joints. Cold baths should be avoided by those who fail to get a vigorous warm reaction or glow after them.

Sea bathing.—One of the most popular and beneficial forms of cool bathing is sea bathing, principally because of the exercise in the fresh air and sunshine associated with it. Its value, however, is frequently lessened and even changed to actual harm, if prolonged beyond the five or ten minutes which is a safe limit for cool water.

This is especially true if one is fatigued, as then one is liable to cramps of the muscles.

Soaps.—Some skins are more sensitive than others and become roughened by much washing, especially with strong soaps which contain enough free alkali to be irritating. This can be avoided if care is taken to use a neutral soap, such as a good castile, and to replace the oil of the skin by diluted glycerine or other emollient.[1]

Skin parasites.—The skin is sometimes irritated by parasites of both animal and vegetable nature, which, when once established, are difficult to remove. It is therefore important to be cleanly oneself and to avoid contact with those who are not, that such parasites may not get a foothold.

Skin eruptions.—A number of contagious diseases, such as *measles, scarlet fever, small-pox* and *chicken-pox*, are accompanied by eruptions of the skin. All eruptions, therefore, which appear suddenly and are accompanied by such other symptoms of illness as headache, chills, cold in the head and sore throat, should be looked into at once. The person should be isolated, especially from children, until it has been definitely determined by a physician that the cause is not a contagious disease.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Piece of glass; ink roll, or dabber; printers' ink; dull and sharp knives; stiff nail brush; soaps—soft, yellow, castile, etc.; vinegar; various kinds of leather; hair of dog, horse, etc.; fur of cat, rabbit, etc.; feathers; fish scales; microscope; magnifying glass [2]; litmus paper.

---

[1] Glycerine should be used in a solution of about three or four parts of water to one of glycerine. Emollients are best applied at night, while the skin is still moist after bathing.

[2] In the following experiments, all examinations should be made, if possible, with both a magnifying glass and a microscope.

1) Examine skin of hand. Compare skin on back with that of palm. Note character of surface and markings, especially on balls of fingers.

2) Make finger print by rolling ball of finger on a piece of glass upon which a thin film of printers' ink has been spread by roller or dabber. Apply finger to smooth white paper.

a) Examine print with magnifying glass and note white dots (mouths of sweat ducts) on ridges.

b) Compare patterns of markings [1] of different fingers of same individual and of different individuals.

3) Moisten back of hand and repeatedly scrape surface with edge of dull knife, as table knife. Collect detritus, place upon glass slide with drop of water, and apply cover glass. Examine under microscope and note flattened cells.

4) With sharp knife or razor, slice off a thin slip of skin over a callus on palm. Moisten and examine under microscope. Note mouths of sweat ducts and horny character of skin. Distinguish separate cells after prolonged soaking.

5, a) Make parings of nail,—a narrow strip to show edge, one broad to show surface. Examine under microscope dry and after soaking in water.

b) Compare shape and general structure with nails of various animals, as dog, cat, cow, fowl, bird, horse, etc.

6, a) Pull out hair and examine shaft and root in drop of water under microscope. Note that root is incomplete.

b) Compare with hair of dog and horse, with fur of cat and rabbit, with feathers, with scales of fish, etc.

7) Compare human skin with that of various animals, as to general character, texture, thickness, etc. (Make use of such leather [2] as is obtainable, as cow, sheep, pig, horse, alligator, snake, etc.)

9) Dissolve in separate test tubes pieces of various samples of soap, the size of a lima bean, by shaking gently in 2 teaspoonfuls of hot water.

---

[1] Finger prints are so characteristic and so constant as to furnish one of the best means of identification.

[2] Leather is skin which has been tanned. The tanning process consists in treating the leather with such chemicals as the tannin of tan bark, which make insoluble the tissues of the skin.

a) Test each solution with red litmus paper to determine whether neutral or alkaline.

b) To determine amount of alkali in each soap, pour tablespoonful of vinegar into glass of water, add slowly to soap solution and gently shake, noting amount required to change soap solution from alkaline to acid. A piece of litmus paper should be floating in each test tube and its change of color carefully watched.

CHAPTER XIX

THE HEAT OF THE BODY

Warm and cold animals.—The heat of the body results from the oxidation of food materials in its tissues. The unicellular and lower forms of animals have no means of retaining the heat which they generate within their small bodies, as their skins are so thin and moist as readily to transmit it. Indeed, in many cases, there is but little heat for retention, as their movements are so infrequent or sluggish as to call for but little oxidation of food material. As a result, their temperature corresponds to that of the air or water in which they live. They must therefore depend for their warmth upon such external sources as the sun, air and water. In warm-blooded animals, on the contrary, the body is kept at a fairly uniform temperature partly by means of the protective skin and partly by means of the vasomotor mechanism.

Heat control.—When too much heat is generated during muscular activity and the temperature of the body tends to rise, the excess heat is taken up by the blood, carried away from the active tissues and glands, and distributed throughout the body. In the course of its circulation, the blood reaches the special nerve centre in the upper end of the spinal cord which has to do with the regulation of heat in the body. If, in spite of its distribution, the blood still contains too much heat, this centre at once actively arranges for the removal of the superfluous heat by causing the arterioles

of the skin to relax. As a result, much more blood is
allowed to pass to the surface of the body, where it can
be quickly cooled by contact with the air. If the blood
is not sufficiently cooled in this way, the sweat glands
are also stimulated to activity and secrete a copious
amount of perspiration, which they pour upon the sur-
face. The heat of the blood then disappears much more
rapidly because it is doing the work of evaporating the
moisture. In health, the temperature of the body, even
in severe exercise, never rises much above the normal
point of 98.4° F.

Loss of heat.—The heat-controlling mechanism has
to provide not only against a possible increase of body
temperature but also against a too rapid loss of heat
from exposure to cold. When there is but little activity
on the part of muscles and glands and the air is cold,

the heat centre causes the
arterioles of the skin to
contract, so that compara-
tively little blood passes
through them to be chilled
at the surface. This with-
drawal of blood from the
body's surface is in a meas-
ure equivalent to putting on
an overcoat, since it shuts
the heat inside the fatty
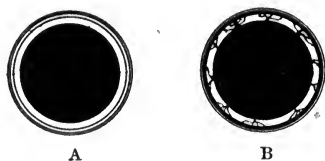
FIG. 114. Diagram to show distribution
of blood in the body when heat is
being saved (A), and is being thrown
off (B). The black areas represent
the parts containing blood. The
innermost white area represents the
layer of subcutaneous fat; the outer,
the epidermis.

layer of the skin. In case this is not sufficient to maintain
the normal temperature, the arterioles in the feet and
hands, and even those in the legs, arms, ears and nose, also
contract to shut the blood within the trunk and thus pre-
serve life, even at the sacrifice of these parts by freezing.[1]

[1] Those who habitually suffer from cold hands and feet simply
demonstrate the efficiency of this control and prove that they have

Clothing.—In cold climates, the heat-regulating mechanism receives great assistance from such further protection of the body as is afforded by clothing. Of the various materials employed for clothing, the skin of animals was probably the first used. With the development of weaving and the consequent manufacture of fabric, it became possible to utilize the softer fibrous substances such as the various forms of hair from animals, feathers from birds, silk from the cocoons of worms, and cotton and linen from plants.

Wool.—Of these materials, hair or its softer finer form, wool, was developed by nature as an outgrowth from the skin to give added protection to animal life. From an evolutionary standpoint, therefore, we are forced to regard wool as the best material which nature was capable of developing for that purpose. Thousands of years of use by man has proved its undoubted claims to superiority as a protection from wet and cold. This superiority seems to be largely due to the fact that the fibres do not soften and become matted down by moisture, but retain their elasticity. As a result, the fabric never loses its porous quality which enables it to remove by absorption a large amount of moisture. By this absorption and removal of moisture from the body's surface, it prevents the chill so noticeable when cotton and linen are used. Wool is the only material which has proved effective for workmen who when wet from perspiration are constantly exposed to cooling drafts, as, for example, iron workers and coal stokers. These men wear wool all the year around. Those among them who have attempted to substitute cotton have almost invariably become crippled by rheumatism. Under such trying con-

not sufficient food or exercise to generate a proper amount of heat, or clothing enough to retain it.

ditions as these, therefore, the advocates of wool as the most adequate protection against both heat and cold, are fully justified.

Leather and furs.—The skins of animals, although a most satisfactory protection against wind and cold, lack the power of absorbing moisture and of permitting its evaporation without chill. Instead, they tend to keep the perspiration upon the surface of the body with the result that the clothing worn beneath them becomes wet. Much of this bad effect can be avoided, however, if they are worn loosely enough to permit beneath them the ventilation which will allow for the evaporation of the moisture.

Thin or thick clothing.—The method of wearing clothing is quite as important as the materials used. Its object is to economize the body's heat and yet permit the perspiration to evaporate freely. To accomplish this in the most wholesome way, several layers of thinner clothing are preferable to an equal amount in one thick layer. This is especially true if, as is customary, the clothing is worn somewhat loose so that a certain amount of air is enclosed between each layer. The enclosed air warmed by the body not only permits the evaporation of moisture from the body's surface, but also serves in itself to retain the heat. For the same reason, porous underclothing is far superior to that which is tightly woven, since it allows a sufficient change of the enclosed air to permit the evaporation of moisture.

Bed clothing.—Clothing for sleep is in some measure even more important than that for daytime use, since it cannot be as readily adjusted to sudden changes of temperature. The bed clothing for cold weather should consist, in addition to sheets, of wool blankets of mod-

erate thickness, or of puffs filled with lamb's wool,
eiderdown, or feathers. These should be as light and
porous as possible, since heavy clothing is oppressive
and interferes with the restfulness of sleep. For this
reason, cotton, whether used as blankets or as filling for
puffs and quilts, is much less satisfactory than wool.

Arrangement of bed clothing. — For getting the
greatest warmth out of the least bed clothing, a sleep-
ing bag such as hunters use is most effective. Indeed,
for children who toss about in bed, several sleeping
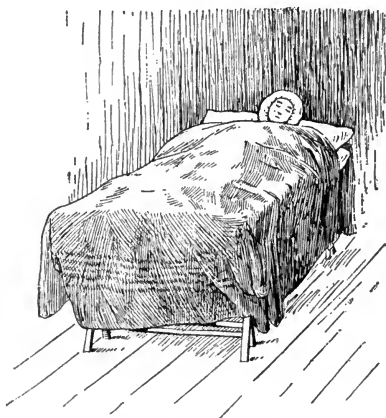
Fig. 115. Sleeping in an open shack in cold weather. (Boston Children's Hos-
pital Report.)

bags one over another are the only adequate protection.
The ordinary bed clothing can be made to imitate a
sleeping bag by having it tucked in only at the foot of
the bed, and allowing the sides to rest in loose folds
closely about the person. The lower part of the body
should ordinarily have about twice as much clothing
as the upper half, since the feet are most apt to become

cold.[1] In general, the shoulders and neck should be but
lightly covered. Properly to protect the head, a light
covering in the shape of a thin hood is also desirable,
especially for children, who often cover their heads with
the bed clothes to keep them warm and so half smother
themselves.

Fall in body temperature.—When the body has been
exposed to cold or wet without proper protection, the
loss of heat may be so great that in spite of the body's
effort to increase its heat production, its temperature
falls to 94° or even 90°. When the body is chilled, the
blood-vessels in the skin and the extremities contract.
The extra blood which no longer circulates freely in the
exposed parts collects in the large veins, especially those
of the abdomen. Under these conditions, the tempera-
ture of the skin may be almost if not quite at the freez-
ing point, since its sole supply of warmth, the blood, is
withdrawn. The quickest relief is afforded by a hot
drink, such as soup, tea, coffee, chocolate, or hot milk,
which adds heat to the body and stimulates the nerve
control to relax the blood-vessels of the skin and ex-
tremities. The warm blood passing freely to the skin
raises it at once to a more normal temperature. The
nerve ends in the skin are also warmed by the return-
ing blood current, and as a result, the person feels warm
and comfortable.

Alcohol.—Alcohol is sometimes used to overcome chill,
but, unlike a hot nutritious drink, it has no heat to fur-
nish the body. Moreover, it dilates the blood-vessels in
the skin, and as a result the blood rushes so strongly to
the surface of the body that a false sense of warmth

---

[1] This leads to curling up in bed, which in children frequently
results in such bodily deformities as round shoulders, flat chests,
or even spinal curvature.

and comfort is produced. In reality, even the body's reserve heat is being lost through this rush of blood to the surface, and if the exposure to cold continues the subsequent chill is often fatal.

Freezing.—A similar feeling of warmth comes to a person who is on the point of freezing. As a result of the extreme cold, the heat-controlling mechanism apparently becomes fatigued in its effort to retain the blood within the trunk. Consequently, the blood rushes to the surface and gives to the person who has been vigorously struggling against freezing a grateful feeling of warmth, comfort and drowsiness. If he yields to it and stops the exertions upon which his supply of heat depends, he quickly freezes to death.

Owing to the exposed condition of the fingers, toes, nose and ears, and to the tendency of their blood-vessels to contract in the cold, they are especially liable to be frozen. Before they are actually frozen, vigorous rubbing will frequently restore the circulation. When frozen, they should be thawed out as soon as possible by applications of very cold water, melting ice, or melting snow. After being thoroughly thawed, the cold applications should be continued, in order to restrain the intense inflammatory reaction which may lead to extensive sloughing of the skin and even to a loss of the frozen parts. The use of warm applications under these conditions serves to aggravate the subsequent inflammation and is therefore most harmful.

Rise in body temperature.—In fever, we have, instead of a decrease in the body's temperature, an increase which in extreme cases amounts to as much as seven or eight degrees. This seems to be due both to an increase in the generation of heat by the tissues of the body and to a derangement of the heat-controlling

mechanism. More heat than usual is generated in the body because of the poisonous substances developed by the microbes which are responsible for the fever. Because of the derangement of the heat-controlling mechanism, the secretion of perspiration fails and the blood cannot therefore be cooled by its evaporation. There is therefore an excess of heat to be removed and a defective mechanism to accomplish its removal. As a result, much of the heat remains in the body and raises its temperature.

Since fever has a most harmful effect upon the body, especially upon the nerves and brain, it is important that the body temperature should be kept down as much as possible. To accomplish this, it is customary to give a person with pronounced fever, cooling drinks, applications of ice, and cold baths, in order to aid in removing the excess heat from the body.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Clinical thermometer; dairy thermometer; pieces of wool, linen, cotton and silk; ice; microscope.

1) *Skin temperature:* Place bulb of dairy thermometer on back of hand and cover with piece of dry woolen cloth. Watch mercury column and when it no longer rises (5 or 10 min.) record temperature.

2) *Internal temperature:* a) Having carefully shaken mercury column of clinical thermometer below 98° F., place bulb under tongue and close lips. Read temperature at end of 5 min.

b) Hold piece of ice in mouth for a few minutes. Having shaken mercury column down to 90° F., take temperature of mouth.

3) Examine under microscope fibres of pure linen, silk, cotton and wool. Observe and sketch characteristic appearances.

CHAPTER XX

THE NERVOUS SYSTEM

General arrangement.—Although there are millions of separate cells in the human body, each doing its individual task, yet they all work together harmoniously.
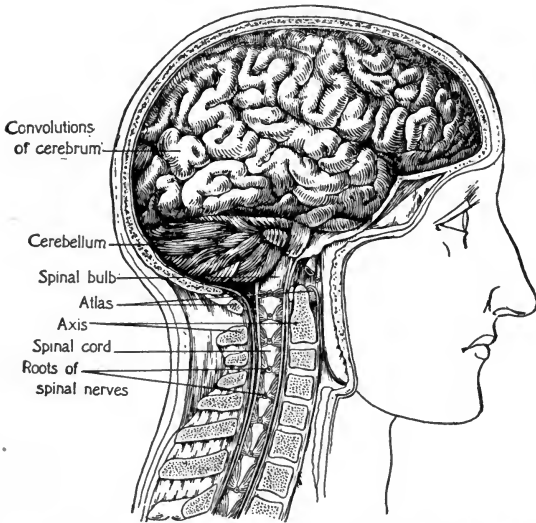
FIG. 116. Right side of brain and upper portion of spinal cord.

The co-operation of all these minute activities is made possible by means of a master tissue, the *nervous system.* By its many branches, the nervous system reaches every cell to detect its needs and control its activity. Like the circulatory system, the nervous system consists of
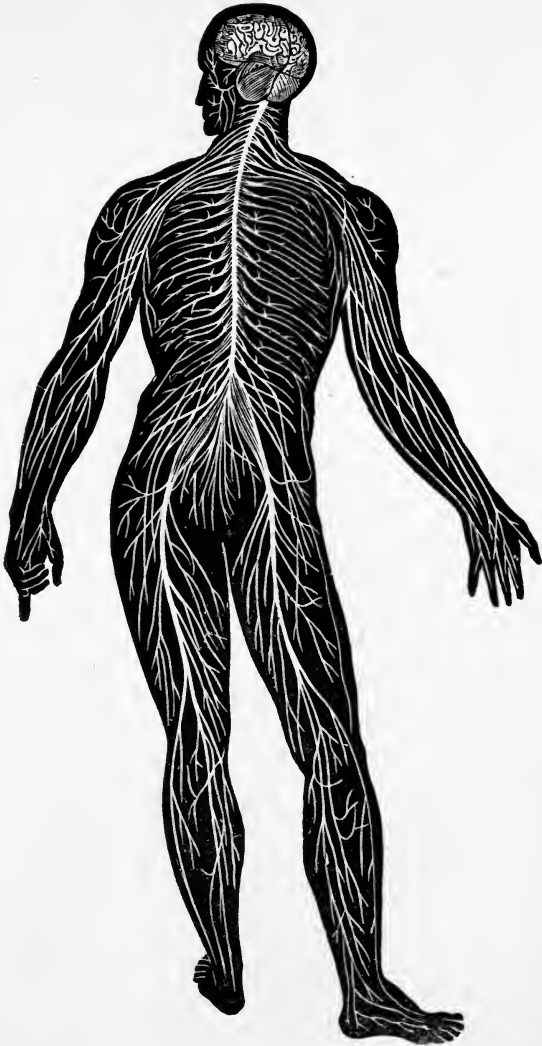
Fig. 117. Diagram illustrating the general arrangement of the nervous system.
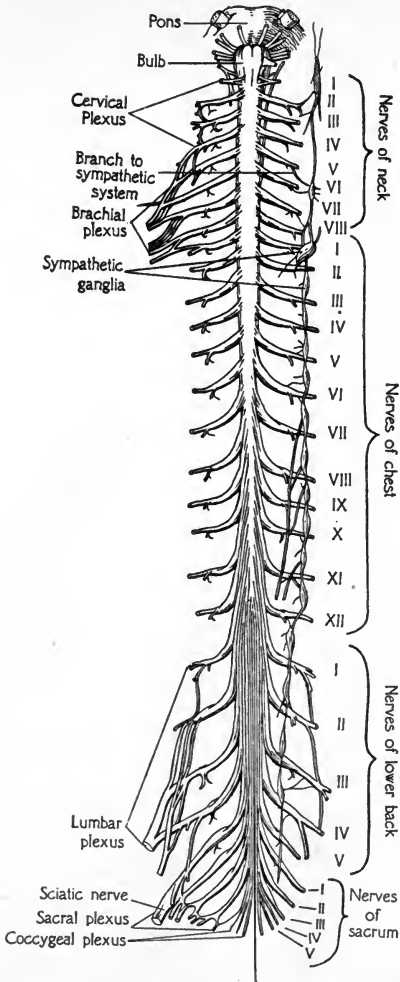
FIG. 118. Diagrammatic front view of spinal cord and bulb, showing spinal nerves, one side chain of sympathetic ganglia, and some of cranial nerves.

a central organ, the brain and spinal cord, and of numerous distributing branches, the nerves, which radiate

from it to all parts of the body. In the limbs and to a less extent in the trunk, the larger nerves follow nearly the same courses as the blood-vessels. They can be readily distinguished from them because they appear as solid white cords of considerable strength.

Nerves.—When the course of any nerve is traced from its termination in a cell inward toward the brain, it is seen to start as a very fine thread, or nerve fibre, visible only under the microscope, which quickly joins with similar fibres from other cells. Together they form the bundle of fibres known as a *nerve*. As the nerve passes inward, it constantly grows larger through the addition of many branches until a large nerve, or *nerve trunk*, is formed.

Spinal nerves.—All the nerves in the body, with the exception of those of the head, are finally united into sixty-two nerve trunks, which on approaching the spinal column are called *spinal nerves*. Two spinal nerves, one upon each side, pass into the spinal column at each of its joints. These constitute a pair of spinal nerves, there being thirty-one pairs in all.

Ventral horn

Ventral root

Ganglion

Dorsal root

Dorsal horn
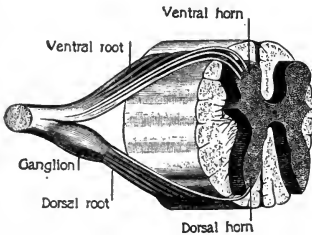
Fig. 119. Formation of a spinal nerve. (Testut.)

After passing between the joints of the spinal column, the spinal nerves enter the neural canal formed by the arches which spring from the bodies of the vertebræ. Here they split into two parts, or *roots*, and enter the much larger white tough flexible cord, the spinal cord, which nearly fills the neural canal. The nerve fibres of the spinal cord serve to connect the spinal nerves with

a large grayish mass of similar composition but of much more delicate structure, the brain, which is enclosed within the bony cavity of the skull at the top and back of the head.

Nerve structure.—When a nerve is examined under a microscope, it is seen to consist of a large number

B — Connective tissue support
Sheath of nerve fibre
Fatty layer
Nerve fibre (axis cylinder)

Connective tissue

Bundle of fibres in a nerve

A
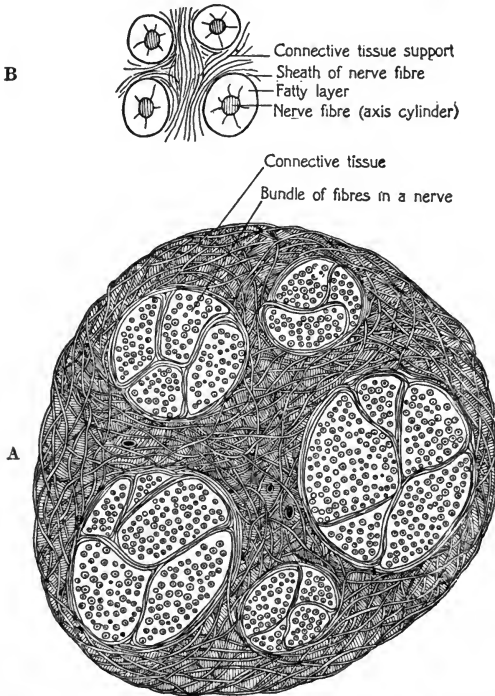
Fig. 120. A, cross section of a nerve, showing 5 bundles of fibres and the supporting tangle of connective tissue fibres penetrated by blood-vessels. B, 4 fibres much more highly magnified.

of very small tubes, or *sheaths,* which contain fat and carry in their centres the delicate threads which are the true nerve fibres. The sheaths with their fat are

but a means of protecting and strengthening the central nerve fibres. In all nerves, the fibres form the central line, or axis, of the cylindrical sheaths and are therefore known as *axis cylinders*. They reach the cells of the various tissues of the body by branching into fine
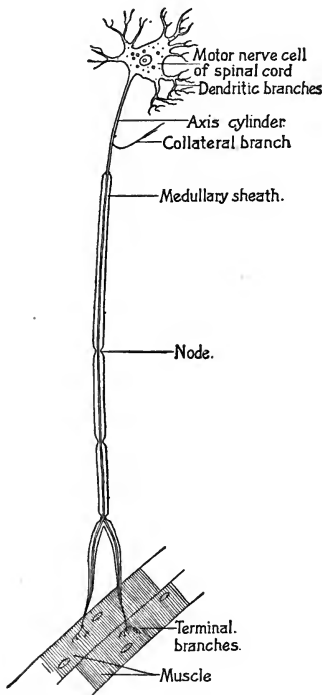
FIG. 121. Diagram of a motor nerve cell from the anterior horn of the spinal cord, and its branches connected with a muscle (highly magnified except as to length).

short *filaments*, one of which ordinarily passes into each cell. The filaments in turn split up into such fine and delicate branches that it is difficult to distinguish them from the cell structure itself, even with the most powerful microscope. Each axis cylinder controls by means of its branches the activity of a small group of cells.

Course of a motor nerve. —If we select the axis cylinder of a small group of cells in a muscle and trace its course inward, we find that it passes along through its fatty sheath in complete isolation from the many accompanying axis cylinders in their sheaths, which are packed with it in the nerve. It finds its way along the nerve of which it is a part up to the point where the spinal nerve forms two roots to enter the spinal cord. It then passes through the ventral root into the ventral

portion of the spinal cord, where it is seen to be an out-growth from a comparatively large cell. This cell, and not its branch, the axis cylinder, is the real centre of activity, as is shown by the fact that when the axis cylinder is cut off from the cell it dies, whereas the cell lives on and may even produce a new and complete axis cylinder.

Neurons.—From this nerve cell there are also tree-like branches which serve to bring the cell into close relation with other cells. Each cell and its branches, including the axis cylinder, form one unit of the nervous system, a *neuron,* of which there are many millions in the brain and spinal cord.

Motor neurons.—The neurons which terminate in the cells of muscles or glands, control their activity. The contraction of every muscle, the secretion of every gland, is directly due to the stimulations developed in the large central cells of the neurons. These stimulations, or *nervous impulses,* are transmitted along the axis cylin-ders of the neurons to the muscles or glands. The neu-rons are therefore called *motor neurons,* since upon them all activity depends. If motor neurons are injured, as for example by cutting the ventral root of a spinal nerve, the cells of the muscle or gland supplied by their fibres become paralyzed. In other words, the cells are powerless to act, because they have ceased to receive nervous impulses. Unless the motor neurons recover so that communication with the cells is restored, the cells of the muscle or gland themselves waste away, since with-out the nerve stimulation they are unable even to take the food which they need from the blood.

Course of a sensory nerve.—If, instead of selecting an axis cylinder going to a muscle, we had chosen an axis cylinder from the cells in the nearby skin and had traced

it inward, we should have found that it followed a course similar to that of the motor fibres, perhaps even in the same nerve and nerve trunks, until it reached the neural canal of the spinal column. Here, instead of passing through the ventral root of its spinal nerve, it passes into the dorsal root and thence by a short right-angled branch to the nerve cell of which it is a prolongation. This nerve cell is situated in an enlargement, or *ganglion*, of the dorsal root of the spinal nerve, which also contains the other cells belonging to the similar fibres of this spinal nerve. Each of these ganglion cells sends inward to the spinal cord a branch, which, after entering the spinal cord, divides into numerous branches. Each ganglion cell with its branches also forms a neuron. These neurons have quite a different function from the motor neurons, in that they are responsible not for our activities but for our sensations. Along them travel the nervous impulses which arise in the skin and which result in our sensations of touch, pressure, heat and cold. They are therefore called *sensory neurons*. If sensory neurons are injured, as for example by cutting the dorsal root of a spinal nerve, there is an immediate loss of sensation in the part to which the cut nerves go. That part of the skin may even be pricked or burned, but the person will feel nothing.

Direction of nervous impulses.—In the case of sensation, the nervous impulses start in the skin and pass inward along the sensory nerves to the spinal cord and thence to the brain. In the case of muscle and gland stimulation, on the contrary, the nervous impulses originate in the brain and spinal cord and pass along the motor nerves outward.

Spinal cord.—The spinal cord is thus seen to contain the inner ends of both the motor and sensory neu-

rons. It also contains still other neurons which are distributed up and down its length. The latter serve to connect the more distant sensory and motor neurons with those which lie in the upper portion of the spinal cord and in the brain. In this way, both sensory and motor nervous impulses are carried to and from the great centre of nervous activity, the brain.

Motor impulses from sensory.—The spinal cord forms a distinct portion of the nervous system which is responsible for certain activities. If, for example, we accidentally touch a hot object, the irritation of the ends of the nerves in the skin starts nervous impulses, which pass inward along the sensory fibres, and thence along the dorsal root of the spinal cord into the branches of the neurons which lie in the cord itself. They then pass along these branches to their many-branched tips, where they come into close relation with many motor cells, which they arouse to activity. The impulses started in the motor cells are then transmitted outward along the motor fibres to the groups of muscle cells controlled by them. As a result, the muscles are caused to contract and the hand is snatched away from the hot object.

Reflex action.—This kind of nerve activity is called *reflex action,* and takes place when the sensory impulses are so strong that on their way to the brain they excite the motor nerves in the spinal cord which lie within reach of their branches. Reflex action is involuntary, for the reason that it takes place before the brain has time to know about it and to aid or interfere with it. It is so rapid that the time which elapses between the touching of the skin with a hot object, for example, and its withdrawal is only about six- or seven-hundredths of a second. If touching the object had not been painful and the reaction had not been reflex, the time taken

to withdraw the hand under the direction of the brain, that is voluntarily, would have been from twelve- to eighteen-hundredths of a second.
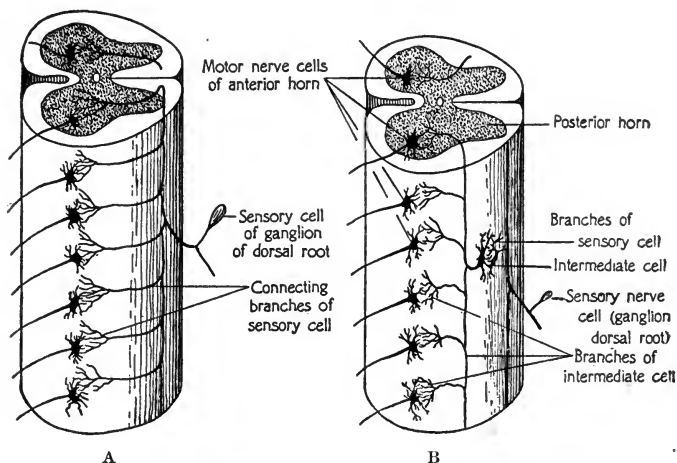
FIG. 122. Diagram of the spinal cord, showing the mechanism of reflex action : A, shows how a sensory cell, by means of its branches, may influence many motor cells directly; B, how an intermediate cell, may serve to connect a sensory cell to motor cells, thus making possible more complicated reactions. (After Kölliker.)

Its characteristics.—As we study reflex action in its control of muscles, we find that the movements are in general planned to take the part of the body threatened away from danger. For example, the hand is never thrust against the hot object, but always definitely and accurately removed from it. This is true regardless of whether the object is under, above, or on either side of the hand. This means that each sensory nerve is connected by its branches with the particular motor nerves which will cause the proper protective movement and with no others. Thus there is never an opportunity for an irritation to start the wrong movement, but

a given irritation is invariably followed by the correct protective movement.

Branches of spinal nerves.—In addition to the system of spinal motor and sensory nerves, there is another system of branches from the spinal nerves which have charge of the parts of the body not under voluntary control, that is the viscera. These branches leave the spinal nerves near the spinal cord and pass into the
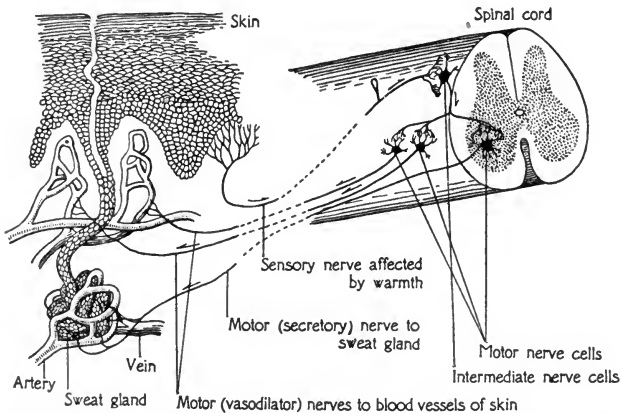
Fig. 123. Diagram showing a part of the reflex mechanism by which heat when applied to the skin results in the dilatation of the blood-vessels in the skin and in the secretion of perspiration.

chest and abdominal cavities. Here they join a chain of ganglia which lie close to the back wall of these cavities. From the ganglia issue many nerve branches which pass to the heart and blood-vessels, the lungs, stomach, intestines and other organs of the chest and abdomen.

Sympathetic system.—This system of nerves is known as the *sympathetic system,* because it controls the activities of the viscera automatically through its sensitiveness to their needs and the needs of the body. For
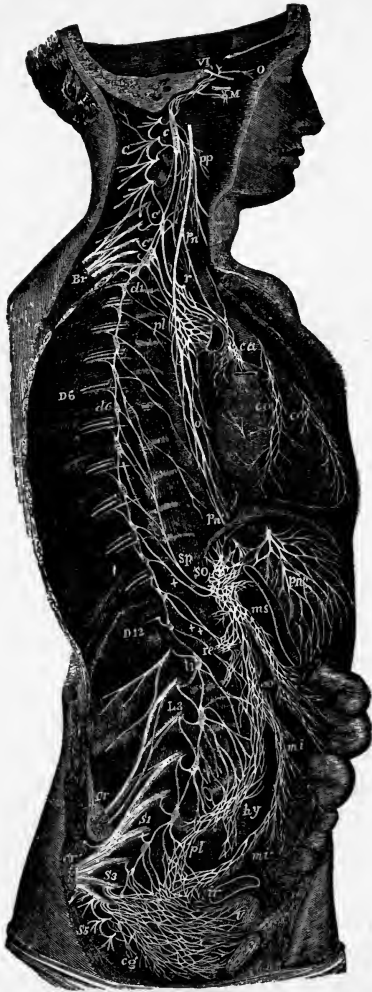
Fig. 124. The sympathetic system of nerves as connected with the spinal nerves and distributed to the various organs. (Quain.)

example, when a muscle is active, the sympathetic system dilates the blood-vessels in the muscle so as to allow more blood to go to it than when it is at rest; when the blood pressure falls, it makes the heart beat faster; when the pressure rises, it makes it beat more slowly; when the skin is hot, it dilates the blood-vessels

Olfactory nerve
Forebrain (hemispheres)
Midbrain (optic lobes)
Hindbrain (cerebellum)
Afterbrain (Medulla oblongata)
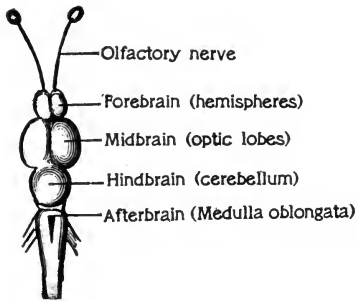
Fig. 125. The brain of a fish. (After Steiner.)

and starts the secretion of perspiration; when food enters the stomach, it stimulates its glands and muscles to activity; and so on throughout the unconscious adjustments made in the organs of the body.

Spinal bulb.—In its upper part, the spinal cord is enlarged into the *spinal bulb,* or *medulla oblongata.* The spinal bulb contains several important nerve centres which aid in controlling certain of the vital organs, as the heart. Since the spinal bulb lies entirely within the skull and its structure is much more complex than that of the cord, it is considered to be a part of the brain. As a

Olfactory nerve
Forebrain (hemispheres)
Pineal body
Midbrain (optic lobes)
IV
Hindbrain (cerebellum)
V
VII and VIII
Afterbrain (spinal bulb)
IX
X
XII
XI
Spinal cord
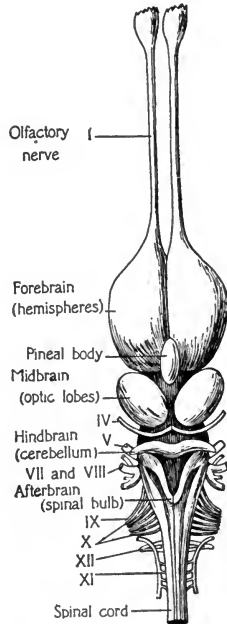
Fig. 126. The brain of a lizard, with the cranial nerves indicated by numerals. (After Wiedersheim.)

matter of fact, however, the brain itself is really but an
enlarged and specialized development of the end of the
spinal cord and is found fully developed only in the
higher animals. The spinal cord may therefore be con-
sidered as projecting into the skull and there forming
the axis from which the various parts of the brain arise.

Cerebellum.—
Springing from this
axis and covering the
spinal bulb is a large
gray mass, the *cere-
bellum,* the surface
of which is broken
up into many ridges.
When cut open, it is
seen to consist of a
thin layer of gray
material, which con-
tains nerve cells, and
a much larger inner
white portion made
up of nerve fibres in
their fatty sheaths.

Olfactory lobe

Forebrain
(hemispheres)

Midbrain
(optic lobe)
Hindbrain
(cerebellum)
V
VII
VIII
IX
X
Afterbrain (spinal bulb)
XI

Spinal cord
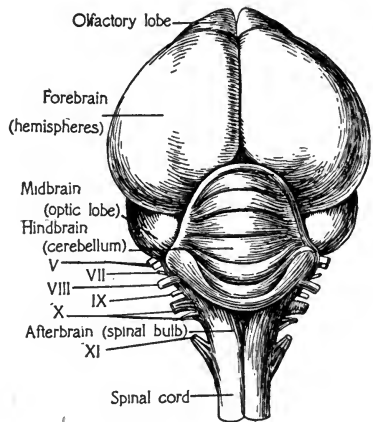
Fig. 127. Brain of a pigeon, with the cranial
nerves indicated by numerals. (After
Wiedersheim.)

Cerebrum.—Arising from the same axis, a short dis-
tance in front of the cerebellum, are two large masses
of soft gray tissue, the *hemispheres,* which together con-
stitute the largest part of the brain, the *cerebrum.*
When the cerebrum is cut through, the outer gray por-
tion, or *cortex,* is found to be about one-eighth of an inch
thick and to be made up of nerve cells. Beneath this is
white matter made up of nerve fibres in their fatty sheaths.

Brain convolutions.—In the case of the higher ani-
mals, the extent of the gray matter is greatly increased
by furrows, which dip deeply into the brain substance

and form the intricate *convolutions* found upon the brain's exterior. The intelligence of animals has been found to depend more or less upon the number of the convolutions, that is, upon the number of nerve cells contained in the gray matter of the cortex.

Gray matter.—The gray matter is made up mainly of two kinds of cells, the true nerve cells, and the smaller connective tissue cells, the *neuroglia,* which by their close meshwork support the nerve cells. The nerve cells are connected with one another and with other cells in various parts of the brain and the spinal cord, either directly by means of their tree-like branches and axis cylinders, or indirectly by means of intervening neurons.

White matter.—The white matter of the brain consists, as we have seen, mainly of axis cylinders and their sheaths, together with a certain amount of connective tissue to support them. The axis cylinders tend to follow parallel courses and thus form definite bundles of nerve fibres or tracts of communication.

Protection of brain.—The brain is protected from external injury by the bony case, the skull, in which it lies. It is protected from contact with the skull by a small amount of fluid and by

FIG. 128. Diagram of cortex (gray matter) of brain, showing nerve cells and their connections.

several membranes that both cushion it and help to supply it with blood-vessels for its nutrition.

Cranial nerves.—From the under side, or base, of the brain are given off twelve pairs of nerves, which supply the two sides of the face and its various organs and muscles, such as the nose, ears, eyes, mouth, teeth, tongue, pharynx and the muscles which control them. Two of them also aid in supplying and controlling the organs
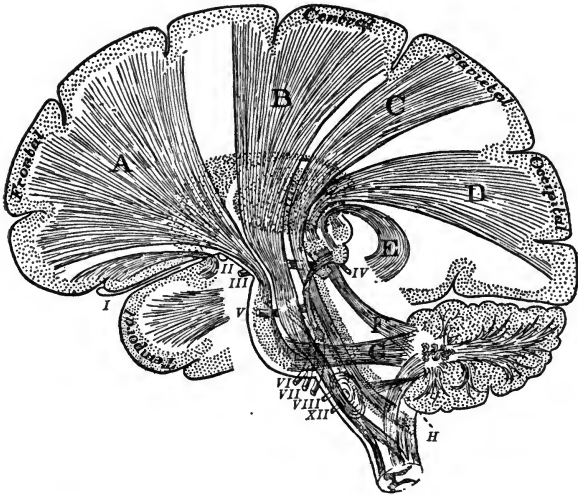
FIG. 129. Diagram illustrating the course of nerve fibres within the brain. (After Starr.) A, track of nerve fibres running from the frontal convolutions to the pons and thence to the cerebellum; B, motor tract; C, sensory tract for touch; D, visual tract; E, auditory tract; F, G, H, tracts to cerebellum. Numerals indicate the cranial nerves. Dotted areas represent the cellular, or gray, matter.

of the chest, and the stomach and liver. Since they are entirely within the skull, or cranium, they are called the *cranial nerves*. Each pair of cranial nerves is named according to its function, as, for example, the pair which supply the nose are called *olfactory;* those which go to the ears are *auditory;* those to the eyes are *optic;* and those to the tongue, *gustatory*. Some of the cranial nerves are purely sensory, others purely motor, and still

others are mixed. For example, the cranial nerves by means of which we get the nervous impulses which give rise to the sensation of sight are sensory, while those which control the muscles of the eyes are motor.
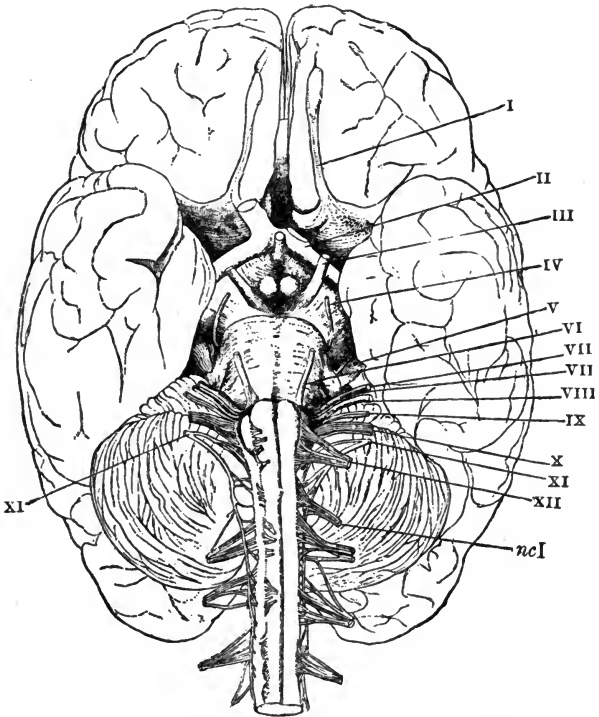
FIG. 130. The base of the brain and the cranial nerves.

Reflex action.—The cranial nerves, like the spinal nerves, act reflexly as well as voluntarily. For example, if an object touches an eyelash, the lid is instantly closed. The nervous impulses originated by the pressure upon the lash, travel inward along the sensory nerves to

the branches of the neurons which lie in the base of
the brain. They then pass along these branches to their
fine many-branched tips, where they come into close
proximity with the branches of motor neurons. Here,
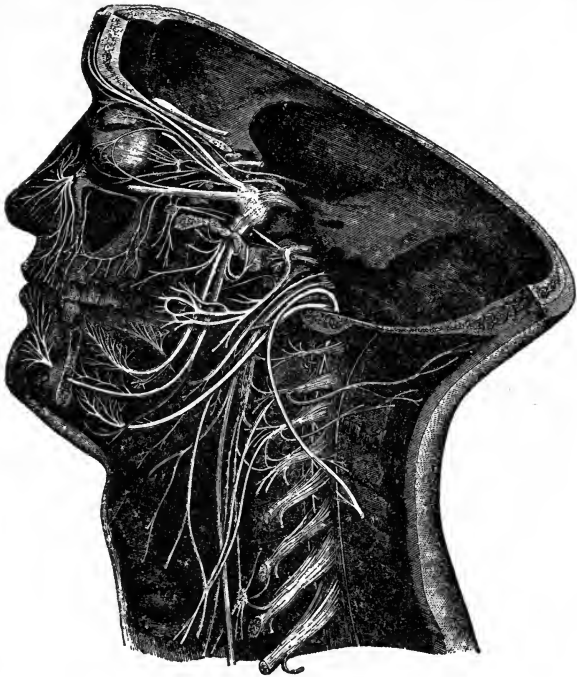
Fig. 131. The cranial nerves. (Quain.)

as in the case of the spinal nerves, the nervous impulses,
although on their way to higher sensory centres in the
cortex of the cerebrum, are strong enough to excite im-
pulses in the nearby motor neurons. These impulses are
then transmitted outward along the motor fibres to
muscle cells. As a result, the muscles controlled by

them, in this case the muscles of the lid, contract and the eyelid winks, thus protecting the eyeball from the object in the shortest possible time.

Voluntary action.—In case the sensory impulses are not strong enough to produce reflex movement, they pass without overflow to the cortex of the brain. There they excite certain of the higher nerve centres, and as a result we are conscious of sensations. These nerve centres in turn excite still other nerve centres, until eventually motor nerve centres are stimulated and motor impulses are transmitted to the muscles, thereby producing movement. For example, as we sit at the breakfast table, the waves of light reflected from a glass of water pass into the eyes and there start up sensory nervous impulses which travel along the optic nerves to the portion of the cortex known as the visual centre. This nerve centre is excited, with the result that sensations are aroused, that is, we see a glass of water. The sensory impulses from the visual centre may then be communicated through associative nerve fibres to other centres, the excitation of which results in our desiring the water. Thereupon the proper motor nerve centres are stimulated and in consequence we reach for the glass of water. This kind of action which involves the higher nerve centres of the cortex, is called *voluntary action*, in contrast with reflex action, which results from the stimulation of motor neurons in the spinal cord or base of the brain because of the overflow of exceptionally strong impulses.

Habits.—If a voluntary act is repeated many times, it tends to become habitual. The same sensory impulses excite the same nerve centres and the same movements result, until finally it is difficult for them to act in any other way. In other words, a *habit* has been formed.

Habits, which form so large a share of our daily life, are thus seen to be nothing more nor less than the customary way in which our brain centres act. We do a thing in a given way to-day because we have done it so often in just that way in the past that our brain cells are used to no other way of doing it. We can thus see why it is that habits once formed are hard to break. To change our habits means to change the way in which nerve cells have been trained by constant repetition to work together. If our habitual way of doing things is the best way, habits are our powerful servants, in that through them we can do things easily and quickly. If the opposite is true, they may be evil masters, wasting our time and energy.

EXPERIMENTS AND DEMONSTRATIONS

Anatomy of the Nervous System

Materials: Frog; ether; fresh calf's or sheep's head; piece of spinal cord of lamb, pig, calf, or beef; alcohol, 50 per cent; small saw; stout scissors; bone forceps; microscope.

1) Kill frog with ether; open abdomen and remove viscera.

a) Note at back of abdominal cavity a bundle of white cords (nerve trunks) passing to each hind leg.

b) Trace sciatic nerve into which they unite and dissect it out along its course until it ends in fine branches in muscles.

2) With stout scissors cut carefully bodies of vertebræ (which will be seen projecting in middle line at back of abdominal cavity), until neural canal is laid open and spinal cord exposed. Note a) Origin of nerves from spinal cord.

b) Their division into ventral and dorsal roots before they join cord.

c) Ganglionic enlargements on posterior roots.

3) Turn frog upon abdomen and remove skin and muscles on dorsal side of spinal column. Carefully cut away upper ⅔ of neural arches of vertebræ. Then remove upper half of

skull. Gently raise brain and spinal cord, divide nerves which spring from them, and lift out whole cerebro-spinal system and place it in alcohol for 24 hrs.[1] Note a) Origin of nerves from both brain and cord. b) Union of brain and cord.

4) Cut across spinal cord at various levels. Note a) Arrangement of gray matter. b) Arrangement of white.

5) After having hardened spinal cord of lamb or pig in alcohol for 24 hrs., cut thin transverse slices and examine with microscope.

6) Dissect away skin and muscles covering cranium of calf's or sheep's head. With small saw [2] carefully cut bones in circular direction, so as to loosen top of skull. Carefully remove top of skull, without injuring the tough protecting membrane, the dura mater.

Demonstrate dura mater enveloping brain.

7) Cut dura mater away and note processes which it sends between cerebral hemispheres and between them and cerebellum.

8) Cut processes away and note a) Glistening inner surface. b) Membrane covering brain and full of blood-vessels (pia mater).

9) Put specimen aside in alcohol or formalin solution for a day or two. When brain has become somewhat hardened, dissect away pia mater on one side and show, a) Cerebral hemispheres and their surface convolutions. b) Cerebellum and its foldings. c) Spinal bulb beneath cerebellum.

10) With bone forceps cut away remainder of sides and roof of skull. Find a) Nerves to eyes. b) Nerves to nose.

11) Raise brain in front, cut through vessels, nerves, etc., which attach it to base of skull cavity, and remove it from skull cavity. Note a) Cerebral hemispheres. b) Midbrain. c) Stumps of cranial nerves.

12) Make sections across brain in different directions and note a) Gray matter spread over most of its surface. b) White matter forming most of its mass. c) Nodules of gray matter imbedded in white, especially in base of brain.

----

[1] The specimen may preferably be hardened and preserved in a solution made of formalin, 2 parts; alcohol, 20 parts; water, 78 parts.

[2] The skull can be cracked with a light hammer and pieces removed, without injury to brain.

Nerve Action

Materials: Frog; feather; watch with second hand (preferably stop-watch).

1) *Reflex Action:* a) Feign blow at a person's eye, having warned him that he is not to be struck. b) Tickle inside of nose with feather.

2) *Voluntary Reaction:* a) Arrange class in a circle so that a signal may be passed from one to another by touching hands. Let instructor, as member of circle, give signal by touching hand of neighbor, who transmits it to next, and so on. Finally, instructor receives signal and determines time of transmission. This time, divided by number in circle, gives average reaction time of its members.

b) Repeat with such modifications as shutting eyes; whispering a sound instead of touching; dividing class into competing halves, etc.

3) Place live frog on table and note its reactions (breathing, winking, jumping, etc.) to varying stimulations (touching, turning, feeding, etc.).

CHAPTER XXI

USE AND CARE OF THE NERVOUS SYSTEM

Activity of the nervous system.—By means of the nervous system, we get all our information as to the outside world in the form of a constant stream of sensations pouring in through each of our sense organs. By means of it, also, our activities from the least to the greatest, from the secretion in a tiny gland to the putting forth of great muscular or mental effort, are started and guided. During our waking hours, there is no second of time when millions of neurons are not actively at work. During our sleep, there is no time when all the neurons are at rest, for the vital processes of the body, the beating of the heart, the movements of breathing, the activity of many glands, the resupplying of tissues with food materials and the clearing away of waste, must all be carried on. The nervous system must therefore, in spite of its sensitiveness, be long enduring, and it must further be cared for in such a way as to keep it strong and efficient. Like all the other tissues of the body, it develops strength through use and thrives on good hard work, provided only that the conditions under which it works are wholesome and the work is not too long continued.

Value of sleep.—The most fundamental condition for the health of the nervous system is sufficient regular sleep. Sleep is more important even than food or drink, since without it life more quickly becomes impossible.

Although during sleep the lower nerve centres, especially those of the sympathetic system, are active, the higher centres of the cerebrum are largely at rest. They are both avoiding exhaustion by further work and recovering from the work already done by storing up a fresh supply of food and eliminating waste products. Sleep is thus a period of relaxation from outside work, of cleaning up and setting to rights of each cell's household, and of laying in fresh stores of fuel for the morrow's demands. To deprive the nerve cells of sleep is therefore not only to prevent each cell from recovering its normal amount of strength, but to make it grow weaker and weaker from overwork. To such abuse there can be but one outcome. Inevitably the nervous system must grow gradually less and less efficient until finally it breaks down.

Amount of sleep.—Although sleep is required to keep the nervous system in order, yet it has been found that too much sleep is almost as bad as too little, since it results in the nervous system becoming sluggish and inefficient through too little exercise. The cells seem to accumulate an oversupply of food materials and thus become so clogged up that they work much less quickly and easily. The amount of sleep which each person needs depends less upon personal peculiarities than is generally thought. Rather does it depend upon how old a person is and how hard he works. In early infancy when the brain and other tissues of the body are least developed and are growing most rapidly, the baby spends a very large part of the twenty-four hours in sleep. Gradually the amount of sleep taken grows less, until at the end of a year the child requires but thirteen or fourteen hours. This amount is further diminished until at ten years of age eleven hours are

enough; at twenty years, from nine to nine and a half; and in adult life, from eight to nine.

Habits of sleep.—The nervous system tends to adapt itself to whatever habits of sleep one acquires. Persons who have accustomed themselves to short sleeping hours are apt to feel that they are exceptions to the general rule in that they require less sleep than the majority of persons. It is, however, a matter of fact that those who have regularly eight or more hours of sleep out of the twenty-four rarely break down nervously, whereas those who get less than eight hours, and especially those who get less than seven, are very apt to break down under mental strain. The safe rule, therefore, is not to stint the nervous system in the hours of repair and recuperation.

Nervous breakdown.—Curiously enough, one of the early symptoms of the failing strength of the nervous system is its apparent ability to do hard brain work on but little sleep. Soon, however, as the habit of sleeping less and less increases, the ability to work hard decreases. Finally, sleeplessness becomes so marked that, in order to avoid a complete breakdown, a rest of months and even of years may be necessary. The nervous system has made a brave attempt to adapt itself to the hardship of too much work and too little rest and has failed.

Value of work.—Next to sleep, the most important condition for the health of the nervous system is good wholesome work. Like all the tissues of the body, the nervous system is developed by exercise, without which its growth and power are stunted. To this exercise, all the activity of the body contributes. Even the higher centres of the cortex, which are concerned with the more purely intellectual forms of our activity, with our will-

ing and thinking, are also trained by the work which we do with our muscles. This is especially true of the early years, when the growth of nerve control is entirely dependent upon physical activity. The apparently aimless kicking and tossing of a baby and the vigorous play of young animals and children are nature's provision to ensure the development of the nervous as well as of the muscular system.

Amount of work.—Work, whatever its nature, should not be continued after a certain degree of fatigue is felt, since the more the nervous system is exhausted, the more uncertain becomes its recovery during rest. For this reason, periods of concentrated study should be made short and be relieved by periods of rest and recreation. The majority of the work should also not be of so exacting a nature that the labor of holding the attention to it is exhausting. The test in any case of whether work is excessive, is the ability of the nervous system fully to recover from its effects by ordinary sleep.

Method of work.—The way in which we do our work is quite as important for the health of the nervous system as its character and amount. The same piece of work, whether mental or physical, may result in benefit or harm. If we do it with a happy confidence that, since we are doing our best, it must come out well in the end, the effect upon the body and mind is one of exhilaration and strength. The breathing is deeper, the blood courses more vigorously through the vessels, the brain gets a full supply, and every cell of the body is in a condition to do its best work. If, on the contrary, we do our work unwillingly, fretting lest it take too long and not come out right in the end, the effect upon the body and mind is one of depression. The tissues do not

get as much blood, the breathing is not so deep, the cells are not so well able to work, and the work done is usually less in amount and poorer in quality, while the nervous system is exhausted rather than strengthened by the exercise.

Meaning of pain.—When the body is not receiving proper care, the nervous system gives danger signals in the form of pain. The pain may come from a definite point, as in earache, and its cause be easily determined. At other times, as in a headache, it may be due to one or more of a number of causes, as eye strain, stomach upset, sleeplessness, or fever. In any case, it is a most important means of guiding us in our care of our bodies and should never be ignored. It indicates that something is out of order, and it is fortunate for us that we are made increasingly uncomfortable until we are forced to remedy it. If pain, or fear of pain, had not tended to keep the human race in the straight and narrow path of health, we should probably not be in existence to-day.

CHAPTER XXII

THE SPECIAL SENSES

Evolution of the special senses.—In the simple forms of animal life, the special senses of taste, sight, smell and hearing are either lacking entirely or are most rudimentary. The sense of touch, on the contrary, is found in all animals, however simple in structure, and may therefore be considered the fundamental sense from which all the others have been developed. In the next higher forms of animal life, the senses of taste and smell are added to touch, as they require but a fairly simple nervous structure. It is difficult to say at what stage of animal evolution sight and hearing begin. Rudimentary organs are found which are probably capable of perceiving noise and light. Hearing and sight of the perfect kind which the higher animals possess is clearly impossible for them, however, since the structure of their ears is too simple to enable them to perceive pitch and quality of sound, nor can their rudimentary eyes build up perfectly formed and colored images of external objects.

Special senses. — Five distinct or special senses, namely, touch, taste, smell, sight and hearing, have always been recognized. The sensations included under touch have been shown by experiment, however, to consist of at least four distinct and different kinds, those of contact or touch, of pain, of heat and of cold.

246

THE SENSE ORGANS OF THE SKIN

Touch.—Of the four senses of the skin, *touch* alone has a relatively simple mechanism. It consists of special nerve endings, many of which are located within rounded elongated masses called *touch corpuscles*. Each touch corpuscle is made up of a large number of layers, somewhat after the fashion of an onion, within which are the terminal branches of the nerve. It is about one-twelfth of an inch in length and one twenty-fourth of an inch in diameter, and so very elastic that the slightest touch tends to change its form. The touch corpuscles are found all over the body in

Fig. 132. Section of skin showing two papillæ of dermis and some deeper cells of epidermis. At left side are nerve fibres leading to corpuscle.

the papillæ of the dermis and are especially numerous on the palms of the hands, on the soles of the feet and on the tongue.

The touch corpuscles are not the only terminal organs of the sense of touch. Where there are hairs, for example, the touch corpuscles are much less frequent, since the hairs themselves serve to transmit pressure to the ends of the nerves, the branches of which surround their roots. It has been estimated that there are 500,000 points sensitive to touch, including the hairs and the touch corpuscles, scattered over the body's surface. In addition, smaller bodies very similar to the

touch corpuscles are found in such structures as the muscles, tendons and internal organs, and serve the same purpose.

When pressure is applied to the skin, the elastic touch corpuscles are so pressed out of shape that they press upon the nerve ends. Nervous impulses are thereby started, which pass up the sensory neurons, until on reaching the cortex they excite certain of its nerve cells and thus give rise to sensations of touch.

Other dermal senses.—Although we do not understand the mechanisms by which sensations of *heat*, *cold* and *pain* are produced, yet the sensations themselves are so definite as to leave no doubt that each has a special end organ which responds to the application of heat or cold or harmful contact. Distinct points in the skin have been found which, when touched with a cold object or even when pressed, give a sensation of cold. Others when touched with a warm object give a sensation of heat; and still others when firmly pressed give a sensation of pain. So definite and specific are these points that pressure by a warm point upon a "cold spot" will produce a sensation of cold.[1]

FIG. 133. Diagram of a piece of skin showing arrangement of cold spots (circles); hot spots (crosses); and pressure spots (dots).

Fatigue.—As in all the special senses, these mechanisms are so delicate that they quickly get tired out and do not respond to stimulation. For example, a feeling of cold or chilliness may be experienced by one who is constantly overclothed, apparently because the heat

---

[1] The heat spots are much more difficult to locate than the cold.

centres are so fatigued that they no longer respond. The cold centres, on the other hand, have had so little use that they are oversensitive and respond to the slightest change of temperature. This is frequently spoken of as a nervous chill and is best corrected by a course of training with cold sponge baths, which serves to restore the equilibrium of the oversensitive nerve ends. In like manner, the nerve end organs of pain may become oversensitive. This should be corrected by vigorous exercise and massage.

THE MUSCULAR SENSE

The means by which we are enabled to judge of the direction, rapidity and extent of movement, the position of the moving parts, the amount of force exerted, and the weight of objects lifted are grouped under the term, *muscular sense.* They are supposed to arise from nerve terminals and bodies resembling touch corpuscles in the muscles, tendons and joints.

SENSE OF PAIN

The sensations called *pain* which do not arise in the skin, are so general that they cannot be localized and the mechanism by which they are produced is not known.

THE SENSE OF TASTE

End organs.—The special end organs of *taste* differ markedly from those of touch, inasmuch as they have to do not with physical contact with external objects, but with substances in solution. The end organs of taste consist of groups of specialized cells, the *taste buds,* which are distributed over the top and sides of the

tongue around the large papillæ found there. The dissolved substances come into contact with the exposed portions of the taste buds and cause nervous impulses to start inward along the cranial nerves of taste. These
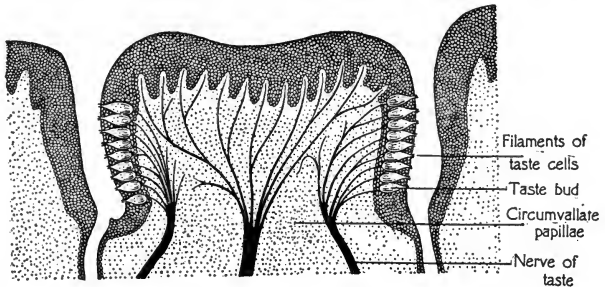
FIG. 134. A circumvallate papilla. (After Testut.)

impulses eventually reach the centres in the cortex of the brain and give rise to sensations of taste.

Kinds of taste.—Careful experiments made by drying the tongue and applying to its surface solutions of different substances, have shown that there are really four different tastes, each of which probably has a different kind of end organ. These tastes are *sweet, bitter, sour* or *acid,* and *salty.* The tip of the tongue is more sensitive to sweetness, the sides to acidity, and the back to bitterness. Sweetness is the most powerful of the tastes and is able to overcome the others. For this reason, we take bitter medicine in a sweet syrup and put sugar into lemonade.

THE SENSE OF SMELL

Structure.—The sense of *smell* is closely associated with that of taste. The surface which contains the cells sensitive to odors, the *olfactory cells,* is situated in the

upper part of the cavity of the nose, one half being on each side. It is made up of elongated cells, among which are the pointed olfactory cells, containing the

Skull bones
Olfactory bulb
Olfactory nerve
Olfactory nerve branches
Nerve ganglion
Nerve supplying nose palate and pharynx
Eustachian tube
Hard palate
Soft palate
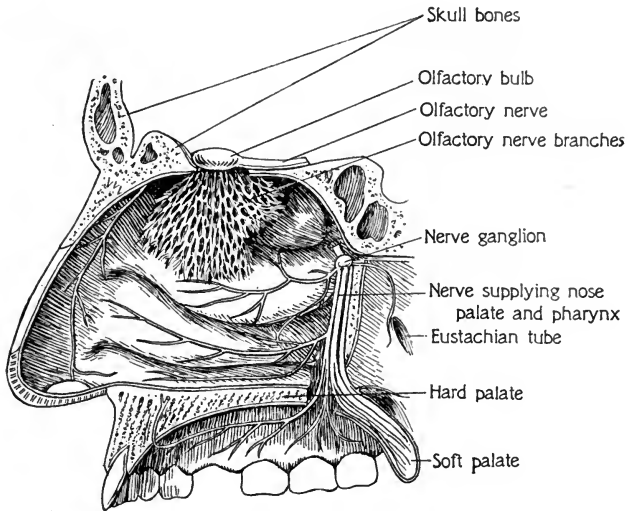
Fig. 135. Diagram showing distribution of olfactory nerve on outer side of nasal cavity.

ends of the olfactory nerves. When stimulated by volatile particles of substances, the olfactory cells start the nervous impulses which pass up the olfactory nerves to the higher centres in the cortex, thereby producing sensations of odors.

Influence upon taste.—How much the sense of smell has to do with the flavor of food is readily appreciated when the nose is closed by pinching the nostrils or by a head cold. Even such a highly flavored food as an onion cannot be distinguished under these circumstances from a turnip; and other foods, except those

which are sweet, bitter, sour, or salty, become similarly tasteless.

THE SENSE OF HEARING

External ear.—Much more complex than the mechanisms for touch, taste and smell, is that of *hearing*. Within
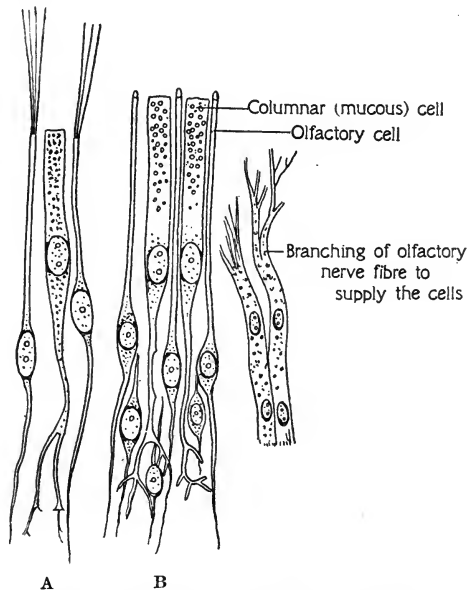
FIG. 136. Cells from the olfactory surface: A, of the frog ; B, of man.

each of our ears there is a small complicated structure, which is sensitive to sound vibrations. Although it contains thousands of nerve fibres and terminals, it is only the size of a large pea. It is well protected by its position within one of the hardest bones of the skull and the sole entrance to it from without is a crooked passage, the *auditory canal*. This canal leads from the vibration-

gathering shell-like *external ear* to a membrane, the ear drum or *tympanum*, which entirely shuts off the inner end of the auditory canal from the next cavity, the middle ear. The tympanum has a diameter of about a
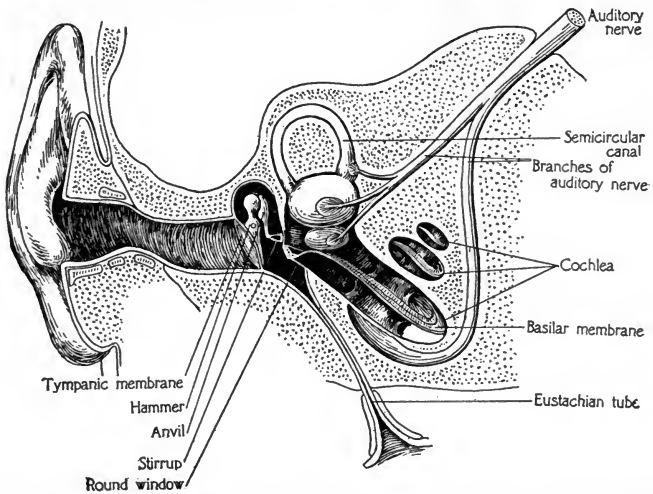
Fig. 137. Diagram of a section through the ear, showing the arrangement of its various parts.

quarter of an inch, is thin, and receives the vibrations of the air in the canal.

Middle ear.—Imbedded in the tympanum is one end of a tiny bone, the *hammer*, which is the first of a train of three bones crossing the cavity of the *middle ear*. These bones, the *hammer, anvil* and *stirrup*, are called the *ear bones*. The innermost one, the stirrup, lies against a thin membrane which closes a small opening, the so-called *oval window*. This window opens into a bony case which contains the real or inner ear. The vibrations of the tympanum are thus transmitted by the ear bones to the inner ear.

Eustachian tube.—The cavity of the middle ear is connected with the pharynx by a passageway called the *Eustachian tube,* through which it is filled with air under the same pressure as the outside air. Strain of the delicate tympanum by air pressure from the outside is thus avoided, and it is free to move with the slightest air vibration. Sometimes, however, the Eustachian tube is closed by the swelling of the mucous membrane of the pharynx. The air supply of the middle ear is thus cut off and the air which it already has is gradually absorbed. As a result, the pressure of air upon the inner surface of the tympanum becomes less than that upon its outer surface; the tympanum is consequently pushed inward and loses some of its sensitiveness to air vibrations. This is the reason why with a head cold we may become temporarily more or less deaf. If the Eustachian tubes are permanently closed for any reason, chronic deafness results.

Inner ear. — The bony case in which the *inner ear* lies is coiled like a snail-shell and is therefore called the *cochlea* or *bony labyrinth.* The cochlea contains a small amount of fluid, the *perilymph,* and floating in this fluid, an inner case, shaped like itself but made of membrane, the *membranous labyrinth.* The entrance to the membranous labyrinth for vibrations is through the oval window against which, as we have seen, the stirrup lies. The vibrations of the tympanum are thus transmitted through the ear bones, through the oval window, through the perilymph to the membranous labyrinth.

Receiving apparatus.—The membranous labyrinth is itself filled with a thin watery fluid, the *endolymph.* Stretched across it lies the receptive membrane for the vibrations, the *basilar membrane,* to which the vibrations of

the air are transmitted by the tympanum, the ear bones, the perilymph, the labyrinth and the endolymph. The basilar membrane is a long strip of thin membrane, broader at one end than at the other, coiled in a spiral form, and stretched between the bony walls of the labyrinth. Its tension and width are so varied that some portion of its length between the broad end and the narrow tip will vibrate sympathetically with all rates not lower than twenty per second and not higher than thirty thousand.

Sensation of sound.—Standing upon the basilar membrane are various complicated structures. Prominent among these are certain slender highly sensitive cells, the *auditory cells,* in which the fibres of the *auditory nerve* start. Whenever any part of the basilar membrane is set into vibration, the auditory cells of that part are stimulated to activity. As a result, nervous impulses start inward along the nerve fibres of the auditory nerve to the brain cells in the cortex, and a sensation of sound results. If the vibrations of the air are made up of a number of different rates of vibration, as is usually the case, not one but several regions of the basilar membrane will be agitated, and a corresponding number of nervous impulses and of blending sensations will result.

SENSE OF EQUILIBRIUM

Semicircular canals.—In close connection with the internal ear are found the *semicircular canals.* In each ear, there are three of these canals filled with fluid. They are so arranged that any movement of the head will cause movement of the fluid over the surface of the wall containing it. This makes the fluid press upon

the hairs of sensitive cells lying in the wall. Nervous impulses are thereby started which result in our having a sense of the direction and rapidity of the movement of the head.

THE SENSE OF SIGHT

Nature of light.—Light, upon which our sensations of sight depend, resembles sound in that it is a form of vibration. The vibration, however, is not of the air but of the ether, a gas so extremely thin that it penetrates bodies and fills all space. Light itself in all its variety of color consists merely of vibrations of ether which pass from luminous objects at varying rates of speed. Ordinarily, it is a mixture of many different rates which blend together to give us white light. When one rate of vibration prevails in the light which reaches the eye, we perceive the color characteristic of that rate, as red when the rate is three hundred and ninety-two trillions of vibrations per second, or violet when it is seven hundred and fifty-seven trillions.[1]

General structure.—The mechanism of the eye consists essentially of two parts. The first part is an optical instrument corresponding to a camera with lens and screen. Rays of light from external objects are focused upon a screen, the retina, at the back of each eye. The second part is a nervous mechanism in the retina by which the rays of light thus focussed give rise to nervous impulses, and these in turn to our sensations of sight.

[1] The colors lying between the two extremes of red and violet are orange-red, orange, orange-yellow, yellow, yellow-green, green, green-blue, blue and blue-violet. Vibrations which are slower than those giving red or faster than those giving violet are not perceived by the eye, although experiments have proved that they exist.

Detailed structure.—The eye is an elongated ball about an inch in diameter, which is covered by a tough coat made up of several membranes. The outer membrane forms the white of the eye and covers it except in front, where a transparent membrane, the *cornea,* per-

Conjunctiva
Cornea
Anterior chamber (aqueous humor
Iris
Ciliary muscle
Suspensory ligament
Lens (within its capsule)
Tendon of internal rectus muscle
Vitreous humor
Optical axis (line of vision)
Layer of nerve fibres
Retina
Choroid
Sclerotic coat
Central Artery
Optic nerve
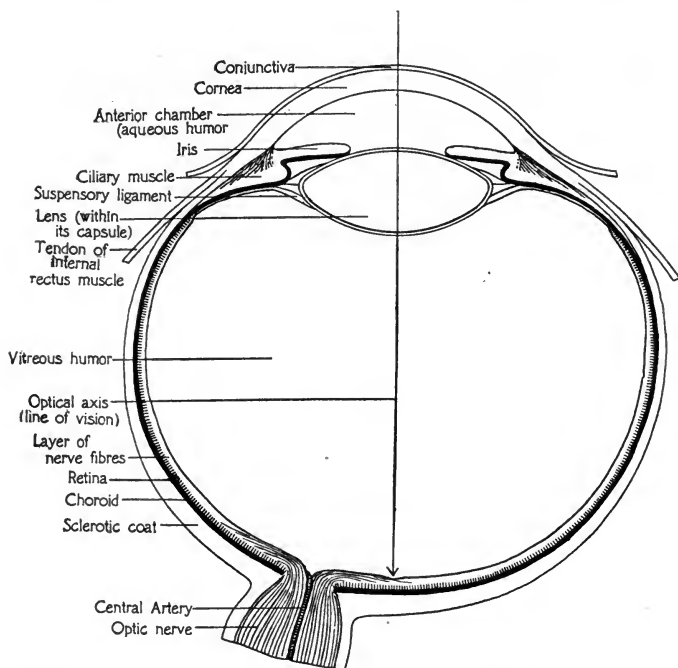
Fig. 138. The right eye cut horizontally, viewed from above (somewhat diagrammatic).

mits light to enter it. After passing through the cornea, the light enters a transparent liquid, the *aqueous humor,* which fills the front of the eyeball. It then passes through a hard transparent mass, the *lens,* into a stiff jelly-like transparent substance, the *vitreous humor,*

which fills the larger part of the eyeball. It next falls upon the sensitive screen, the *retina,* which forms the lining coat of the eye.

Formation of image.—In order that we may get a perfect image of an object, it is necessary that the eye should act as a lens to focus upon the retina rays of
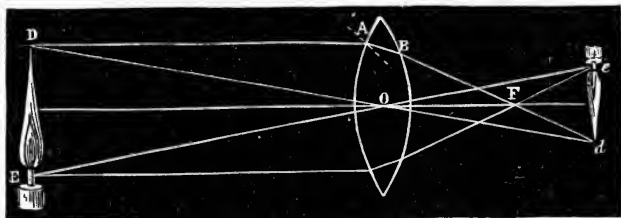
FIG. 139. The formation behind a convex lens of a diminished and inverted image of an object placed in front of it.

light from the object. The cornea receives the rays and makes them converge enough to bring them to a focus behind the retina. The lens then completes the work by focusing them upon the retina. For this purpose, the lens must be relatively flat if the rays do not require much bending because they come from a distance, or quite convex if they come from nearby objects and so require considerable bending.

Adjustment of lens.—To enable the lens thus to adjust itself, there is a circle of elastic fibres which radiate out from its edges. These are constantly pulling the edge of the lens outward and thereby flattening its front surface. In addition to the elastic fibres, there is a ring of muscle fibres which encircles the edge of the lens. These muscle fibres, by contracting, relieve the lens of the pull of the elastic fibres and so make it more convex. The muscle fibres are controlled automatically

through their nerves, so that any object upon which we direct our attention is automatically brought into focus.

Flexibility of lens.—In childhood, the lens is very flexible and can be made so convex as to focus objects
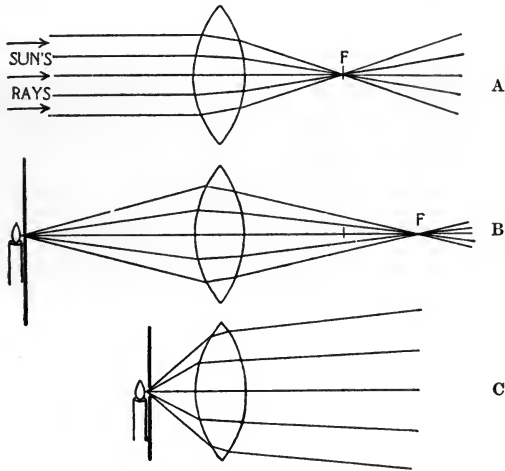
FIG. 140. Diagram illustrating the effect of a convex lens upon rays of light: **A**, when parallel rays are brought to a focus (*principal focus*); B, when rays from a near object are brought to a focus beyond the principal focus; C, when rays from an object nearer than the principal focus continue divergent.

but three or four inches from the eye. As one grows older, the lens gradually loses its flexibility and tends to become rigid in its flattest form. As a result, we gradually lose the power of seeing near objects clearly because their light rays are not brought to a focus on the retina. Ultimately, between the ages of thirty-five and fifty years, a normal person is usually unable to read or thread a needle without strain. He is therefore forced to aid his eyes by the use of glass lenses, which by their convexity assist the cornea and lens in

bringing the rays of light from nearby objects to a focus upon the retina.

Far- and near-sight.—Flatness of the lens, which brings the rays of light from near objects to a focus beyond the retina, gives rise to *far-sight*. It can be
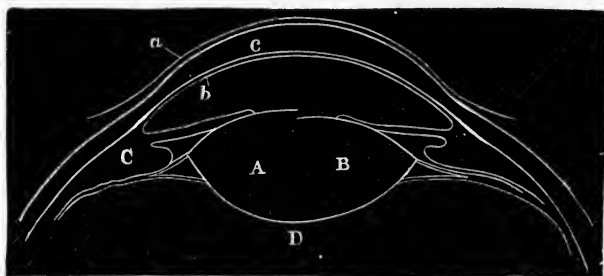
FIG. 141. Section of front part of eyeball showing the change in the form of the lens when near and distant objects are looked at. *a, c, b,* cornea; A, lens when near object is looked at; B, lens when distant object is looked at.

corrected by convex glasses, which make up the deficiency of the eye and bring the rays to a focus on the retina. In case the eyeball itself is so long that the rays of light from distant objects are focused before they reach the retina, we have a condition of *near-sight*. Near-sight requires for its correction a concave lens, in order to throw the focus back to the retina. While some eyes are near-sighted from birth, others acquire this condition by being used too much upon near objects in childhood. Too early and too long continued attempts at sewing and reading are often responsible for the development of this unfortunate condition.

Adjustments to intensity of light.—Varying distance is not the only condition to which the eye must be adjusted. Light itself is ever varying in intensity, and the eye must be at once so sensitive as to see ob-

jects in a dim light and so protected that it will not
be injured by a bright light. To adjust the eye to the
strength of light, there is stretched in front of the lens
a muscular curtain, the *iris*, which gives to the eye its
characteristic color. In the centre of the iris is an
opening, the *pupil*, through which all the light which
enters the eye must pass. The iris is capable of con-
tracting to make the pupil smaller or of dilating to
make it larger. In this way, just enough light is admit-
ted to the interior of the eye to give the best vision,
but not enough to injure its more sensitive portions.

Purpose and structure of retina.—When the rays of
light from objects are focused upon the retina and have
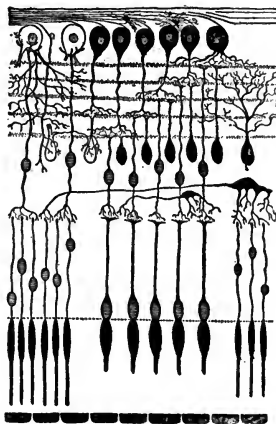
Fig. 142. Diagram of a section of the retina, showing groups of rods and cones
and their nerve connections.

built upon it, as upon a screen, a reduced and inverted
picture, no more has been accomplished than is done by
the lens and screen of a camera. It still remains to
translate this image on the retina into sensations of
sight. The retina consists of several layers of nerve

and other cells with their branches, a layer of special-
ized structures called *rods* and *cones,* which are thought
by many to be the real terminals of the nerves, and,
deeper still, a layer of dark coloring matter which pre-
vents the light from entering the eyeball anywhere
except through the pupil and also shuts off reflections
within the eyeball itself.

Optic nerve.—The nerve fibres from all points of the
retina pass over its inner surface and converge at one
point where they unite to form the *optic nerve.* The
optic nerve then passes out through the wall of the
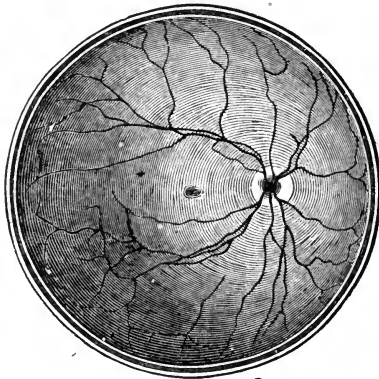
$$\frac{2}{1}$$

Fig. 143. The right retina as it would be seen
if the front part of the eyeball with the lens
and vitreous humor were removed. The
white disk to the right marks the entry of the
optic nerve (blind spot); the lines radiating
from this are the retinal arteries and veins.
The small central dark patch is the yellow
spot, the region of most acute vision.

eyeball to the brain.
At the point of exit
of the nerve there is
no retina, and rays
of light falling up-
on it excite no ner-
vous impulses. It is
therefore called the
blind spot. Since the
blind spot in the
right eye cuts out a
portion of the field
of vision to the right
of the centre, and in
the left eye to the
left of the centre, we
can see with one eye
what we cannot see
with the other. Vision

with two eyes is not, therefore, impaired.

Sensation of sight.—The excitation of the retina by
the exceedingly rapid vibrations which constitute light,
excites the rods and cones and the nerve structures

connected with them into activity. As a result, multi-
tudes of nervous impulses pass through their nerve fibres
and thence along the optic nerve to the centre of sight

FIG. 144. To find blind spot, hold in front of right eye and close left eye; looking
steadily at cross, move book nearer and farther from eye until white circle is
made to disappear.

in the cortex of the brain. Here they cause the activity
of the nerve cells and as a result we have sensations
which we call sight.

Acuteness of vision.—When we consider the extent
of the field of vision pictured upon the small surface
of the retina, the delicacy of detail which we perceive
seems marvellous. For example, a white thread can be
seen on a black blackground at a distance of sixty feet.
Since the combination of cornea and lens is equivalent
to a lens of about three-quarters of an inch focus, the
image of the white line upon the retina must be about
one two-thousandth of a millimeter in diameter. The end
organs of the nerves upon which the image falls must
therefore be of extreme fineness and efficiency.

Defects of vision.—Although the eye serves us so
wonderfully well, yet as an optical instrument it has
certain marked defects, which are more exaggerated in
some persons than in others and are especially noticeable
in those who continually use their eyes for close work.
In a faint light, as in twilight, when the pupil is large,

so much of the lens is uncovered that its defects due to irregularities of curvature and of adjustment become apparent and we can no longer see clearly.

Eye strain.—As long as the adjustments of the eye are reflex and take place accurately enough to give a fair degree of vision, they ordinarily give rise to little or no trouble either directly or indirectly. When, however, they are put to severe use, the attempt to make, in spite of their defects, the constant and complete adjustment necessary for good vision gives rise to *eye strain*. Eye strain seldom or never shows itself by discomfort about the eyes, but rather causes such symptoms as nervous irritability, headache, dizziness and nausea, which for years may fail of being traced to the eyes. As a result, the nervous system often suffers seriously, even to the point of a breakdown.

Astigmatism.—In addition to far- and near-sight, another defect which causes much eye strain is *astig-*
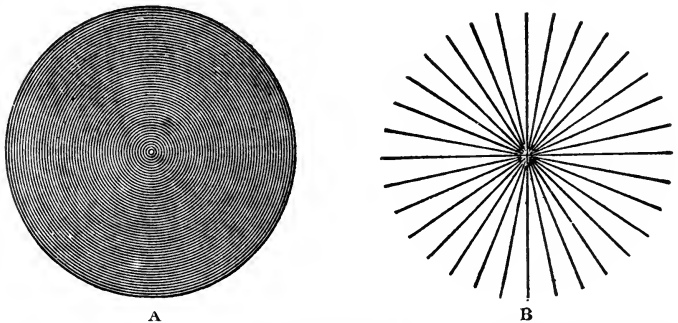
Fig. 145. If certain of the lines or portions of the circles appear blacker than others, astigmatism is present. The test should be made by shutting one eye and then the other.

matism. Astigmatism results when either the cornea or the lens has not a perfectly spherical surface but tends to become curved in one diameter more than in another.

Some rays are brought to a focus before others and a partial blurring results. Astigmatism may be remedied by glasses of a slightly cylindrical form, which make good the general defect of curvature in the lens.

Perception of distance.—For the perception of color and form, one eye is enough, but to accurately determine the distance of objects, two eyes are necessary. With two eyes, we look a little farther around an object on each side and thereby make it stand out in relief. Besides this, since near objects require a greater convergence of the eyes than distant objects, the amount of movement necessary to make the convergence helps us to estimate the distance.

Binocular vision.—That we may see but one object with the two eyes instead of two, it is necessary, first, that the eyes should be controlled so as to converge ac-

Pulley of upper rotating muscle
Part of skull (eye socket)
Muscle of upper lid

Upper rotating muscle
Muscle turning eye upward
Muscle turning eye outward
Muscle turning eye downward
Bone of socket
Optic nerve
Lower rotating muscle
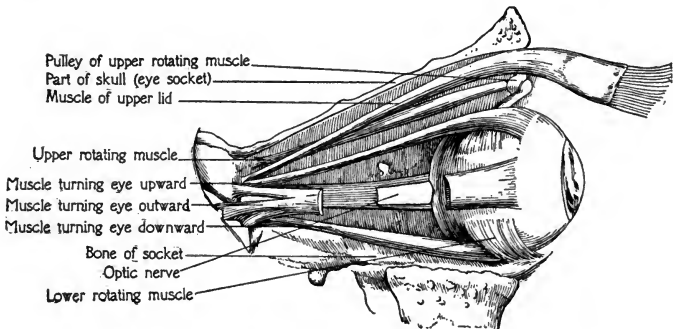
FIG. 146.   The eye and its muscles.

curately upon an object. To accomplish this, there are muscles which pass from the sides of the eyeballs at the front to the back of the eye-sockets. By their contraction, they are able to move the eyes so that they can converge upon an object in any direction. It is further

necessary that the retinas of the two eyes should corre- spond so exactly that the corresponding fibres in each retina may receive the light from exactly the same point in the object. The nervous impulses will then blend in the brain to form a single sensation, that is, we shall see but one object in spite of the two images on the retinas.

Double vision.—Where the eyes fail to work together and two images are seen, the fault is probably due to an imperfect control of the convergence of the eyes by their muscles. Extreme instances of this are seen in *cross-eyes* and in *diverging eyes*. In all such cases, con- siderable nerve strain may result from the attempt to make the images coincide, and the defect should there- fore be remedied by glasses, or, in more extreme cases, by operation upon the eye muscles.

EXPERIMENTS AND DEMONSTRATIONS

Dermal Senses

Materials: Drawing compasses (any form, not too sharp, may be used); scale graduated to millimeters; vessels of cold, lukewarm and hot water; fine horsehair or straight human hair; pencil; forceps.

Experiments (2 students working together):

1) Take straight piece of hair in forceps and, by ascertain- ing greatest length which will give rise to sensation of pressure, determine relative sensitiveness of palm; back of hand; fore- head.

2) Determine least distance that two points of compasses may be separated and still be recognized as two when applied to finger tip; back of hand; back of neck; tongue, etc.

3, a) Determine sensations caused by slight pressure of pen- cil point on back of hand.

b) Determine if cold points are constant in their position by testing from day to day.[1]

[1] Care should be taken not to exhaust the sense organs by over- stimulation.

c) Study similarly painful points and warm points, using a heated point of pencil or wire for latter.

4, a) Put finger of right hand into warm water and finger of left hand into cold water. Note immediate sensations; changes in sensations after fingers have remained some time in water.

b) Withdraw fingers and plunge both immediately into vessel containing lukewarm water. Compare sensations of two fingers.

Taste and Smell

Materials: Sugar; salt; dilute vinegar; quinine; dilute ammonia, one drop of strong ammonia in glass of water; cabbage; onion; carrot.

Experiments (2 students, one as blindfolded subject, other as experimenter):

1) Dry tongue, and determine taste of dry sugar. Compare with taste of moist sugar. Determine most sensitive part of tongue.

2) Test similarly with salt and other substances, closing nose to avoid odor.

3) Determine which have odor.

4) Determine relative proportions of taste and odor.

Hearing

Materials: Tuning fork and its resonance chamber; violin or stretched cat-gut; violin bow; [apparatus for manometric flame].

1) Pluck violin string and note dependence of sound upon vibration.

2) Strike tuning fork and note dependence of volume upon amplitude of vibrations of prongs.

3) Place finger on middle of violin string, thus doubling rate of vibration. Pluck string and compare pitch with that of whole string.

4) Strike tuning fork and hold prongs over its resonance chamber.

5) Test acuteness of hearing by determining how far off a watch can be heard.

6) Test accuracy of sense of direction as determined by hear-
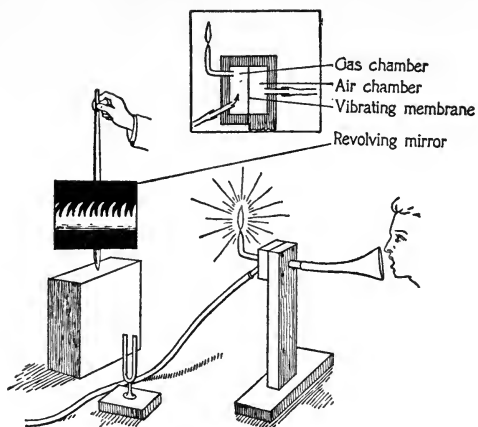
Fig. 147. Apparatus for analyzing sound by means of manometric flame.
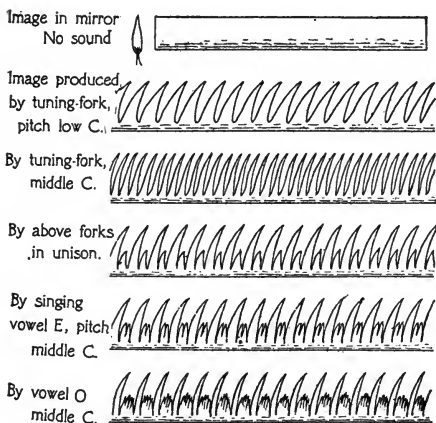
Fig. 148. Analysis by means of manometric flames, of the vibrations producing certain sounds.

ing, by having blindfolded subject point in direction of sounds heard. Close one ear and repeat.

[7] Demonstrate graphically the varying characteristics of sound waves by projecting tones of voice and cornet into speaking tube of apparatus, at same time that revolving mirror is whirled to separate the tongues of flame produced by sound waves.]

Vision

Materials: Color top with color disks; set of worsteds for testing color blindness; small glass prism, 60° angles; camera with ground glass, or ordinary magnifying glass with cardboard diaphragms having central openings of $\frac{1}{4}$, $\frac{1}{2}$ and 1 in.; spectacle lenses, concave and convex of varying strengths; candle; screen, a piece of cardboard placed in a vertical position on a base; [sharp scalpel; curved scissors; forceps].

1) Demonstrate formation of image by lens. Use camera with ground glass, or ordinary magnifying glass, and receive image on paper. Note a) Relative sizes of images of near and far objects. b) Relative lengths of focus for near and far objects.

2) Test effect of different-sized diaphragms on brightness and sharpness of images.

3) Analyze white light (sunlight) by means of prism throwing spectrum on white paper.

4) Mix colors by means of color top:

a) Black with white in different proportions (grays).

b) Various colors with white (tints).

c)   "   "   " black (shades).

d)   "   "   " each other.

5) *Color blindness:* Give to pupil a set of standard colors and their tints and shades. Hold up in succession different colors and ask for selection of all pieces resembling them.

6) *Near-sight:* Place candle on table; two feet distant, set screen. Place magnifying glass between, so as to throw focus on screen. Move screen away from lens until image is blurred, to imitate the elongated eye of near-sight. Take small piece of paper and locate focus by moving it between lens and screen until image on it is distinct.

Apply in front of magnifying glass the proper spectacle lens to bring focus to screen.

7) *Far-sight:* Place candle, glass and screen as in 6), for focusing on screen. Move screen toward lens until image is blurred, to imitate the focal condition of far-sight.

Apply in front of magnifying glass the proper spectacle lens to bring focus to screen.

8) *Sharpness of vision:* a) Determine farthest distance at which white thread on black card can be seen, using one eye; using both eyes.

b) Determine farthest distance when card is 10° and 20° from line of vision.

9) *Change in iris* (2 working together): a) Have subject sit facing window; cover one eye with hand for 1 min. Quickly uncover eye and note changes in pupil.

b) Compare size of pupil when looking at distant object with that when looking at object 6 in. away.

10) *Blind spot:* Determine distance from eye at which large spot on p. 263 disappears when one looks at cross with right eye.

11) *Accommodation:* Determine greatest and least distances at which objects can be seen clearly with left eye; with right eye.

12) *Binocular vision:* a) Hold 2 pencils vertically in front of eyes, one at distance of 1 ft., other at 2 ft. When you look at either one with both eyes open, what is appearance of other, and why? Show by diagram.

b) Under what conditions do you see "single" when using both eyes?

13) Determine movements of eyes in changing from far to near vision.

14) Test visual judgment of

a) Sizes of disks of equal diameters but of different colors (black on white, white on black, red on white, etc.).

b) Lengths of vertical and horizontal lines which appear of same length.

c) Two halves of a line, one of which is crossed by several short lines.

15) *Fatigue of color sense:* a) Place a piece of bright red paper upon sheet of white paper and gaze at it steadily for

half a minute. Then look steadily at a white surface and note any color changes which appear upon it.[1]

b) Repeat using other colors.

[16) *Anatomy of eye:* a) Demonstrate muscles of sheep's eye, coats, optic nerve, cornea, iris and pupil.

b) Cut eye open with scalpel from front to back. Demonstrate aqueous humor, anterior chamber, iris, lens, ciliary process, vitreous humor, retina and blind spot (optic nerve).]

[1] The color which appears is *complementary* to the original color. White is made up of the three fundamental colors red, green and violet. When the retina is fatigued for any one of these, the other two preponderate and tinge the white.

CHAPTER XXIII

THE CARE OF THE SENSE ORGANS

Means of protection.—The sense organs because of their delicacy have been given careful protection by nature whenever possible. This protection is usually afforded by their location, as in the case of the organs of smell, of taste and of hearing. In the case of the eyes, however, the range of vision is so important that they must be located on the surface of the body. They therefore have a special covering, the lids, which act as shutters, to be opened for vision and closed for protection.

Care of the ear.—The ear would seem to be adequately guarded by its location in a very deep bone of the skull, where it can be reached only through a long and crooked canal. This canal, however, must be kept open so that sound waves may pass through it, and thus it is the ear's weak point. Through the canal insects may pass and objects may be thrust[1] in spite of the protection afforded it by the growth of hairs. Insects are easily removed by a drop of oil or water. The entrance of objects we ourselves can control. The drum is so delicate that, were it not for the sake of cleanliness, we might lay down the rule that we should permit nothing whatever to be introduced into its canal.

---

[1] Recent investigations have shown that many prairie animals, as wolves and coyotes, are deaf because of injury to the ear by the entrance through the canal of the heads of certain grasses. These have actually penetrated the drum and caused an inflammation which has destroyed the inner ear.

Method of cleaning.—To clean the canal of the ear, a rounded object such as the closed end of a hairpin, should be covered with several folds of soft cloth moistened in soapy water. This should be rotated in the canal so gently that there is no feeling of pressure. No attempt to remove the deeper layers of wax should be made, since in normal quantities it is beneficial, not harmful. When excessive, it usually works out of itself and can then be easily removed.

Removal of objects.—When an object has become lodged in the canal, no attempt to remove it should be made, since even a slight touch may drive it through the drum. A physician should be consulted immediately.

Earache.—Another danger to which the ear is exposed arises from the necessity for a canal to the middle ear from the pharynx. This canal may permit inflammation of the membrane of the nose and throat to spread to the middle ear. Such an inflammation of the Eustachian tube closes it, with the result that the fluid caused by the inflammation swells the drum out and may ultimately burst through it. The earache which accompanies this inflammation should lead one to consult a physician at once.

Effect of noise.—Blows upon the ear and loud noises, such as the explosion of firearms near the ear, are another source of danger, since they may bring such a sudden pressure upon the ear drum as to burst it.

Eyes.—The organ of sight, being at once the most delicate and the most exposed of the special organs, requires the most care from us. The dangers to which the eyes are exposed are manifold. Dust,[1] cinders and

---

[1] The irritation due to dust can be relieved by dropping into the eyes a small amount of a weak solution (10 grs. to 1 oz. pure water) of boracic acid.

insects find an easy entrance to them, in spite of the quick closure of the eyelids.[1] The light may be so strong as to irritate them or so weak as to make the effort to see, a strain. The nature of the work they are called upon to do may be too exacting and the hours of work too long.

Removal of objects.—Dust, cinders and other foreign bodies are usually washed out by the copious flow of tears which their irritation causes, especially if the lid is raised so as to free the object from the pressure between lid and eyeball. If the object is not thus removed, it is a simple matter to pull down the lower lid, in case it is lodged there, and wipe it off with the moistened corner of a clean handkerchief. If it is under the upper lid, the lid can be turned back by taking the eyelashes between thumb and finger, raising the edge of the lid outward, upward and finally backward, and at the same time pressing down against the centre of the lid with some slender object, as a match, in order to make the inner surface of the lid turn outward. The object is thus exposed to view and can be removed with the moist corner of a handkerchief. If, in spite of these attempts, the object still remains, a physician should be consulted.

Effect of strong light.—The eye is protected against too strong a light by the reflex turning of the head or shutting of the lid, which gives the iris time to contract and thus make the pupil small. Any light which remains disagreeably bright after this adjustment harms the eye and should be carefully avoided. To look continuously at any bright object, as a lamp or an electric

---

[1] The muscles controlling the eyelids act more quickly than any others in the body. It takes only about 0.05 of a second to close the lid. If any object touches the tip of an eyelash, therefore, it can get into the eye only if it is going faster than 10 feet per second.

light, may result in serious damage to the eye. To look at the sun steadily may actually destroy the spots on the retinas on which its rays are focused.

Weak light.—Dim light is not in itself harmful to the eye. Only when we attempt to read, sew, or do other fine work, does it do harm. Under these conditions, the iris is so wide open that the imperfections of the cornea and lens make it much more difficult to see clearly and therefore add greatly to the strain.

Proper use.—Under the present conditions of civilized life, so much work is exacted of the eyes that they should be favored in every way possible, especially during the developing period of childhood. Too early or too long continued use of the eyes for near and fine work, as reading, writing and sewing, should be avoided, since it often produces near-sight. Such work should be done only under the most favorable circumstances. The light should be neither too bright nor too dim; and it should come from the left, in order not to fall directly into the eyes nor to cause a reflection from the page into the eye, as well as to avoid the shadow of the active hand upon the work. The eyes should also have frequent rest by being closed or by being allowed to look at distant objects, that the muscles of accommodation may be relaxed. Improper use of the eyes often shows itself, not by discomfort of the eyes themselves, but by headache, sleeplessness, nausea and other forms of distress. Under such circumstances, therefore, the eyes should be tested by an oculist to learn if they are at fault.

CHAPTER XXIV

THE VOICE AND SPEECH

Sound as a means of communication.—Because sound penetrates space so rapidly and is so easily produced, it is used by many kinds of animals as a means of communication. The sounds thus used range from the shrilling of insects through various inarticulate cooings, gruntings and squealings up to the articulate speech of human beings. The mechanism by which these sounds are produced varies markedly in different animals. Many insects, as the katydid, use their wings by rubbing them against the sides of their bodies. Others, as the locust and cricket, use their legs in a similar fashion. Most of the higher animals, however, including the birds, use for this purpose the air currents produced by respiration. For this, they have a special organ developed in the trachea for the production of voice, the larynx.

Larynx and vocal cords.—The *larynx* is situated in the upper part of the trachea, and, as we have seen, is a hollow tube or box made up of several pieces of cartilage, through which the air passes on its way to and from the lungs. Across the larynx are stretched two membranes known as *vocal cords*. The vocal cords are attached in front and at the sides to the larynx. At the back, they are attached to two small pieces of cartilage which are freely moved by muscles. For the production of voice, these pieces of cartilage swing al-

most together and carry with them the vocal cords,
which are thus stretched tightly across the larynx.   In
this position, they nearly close the air passage through
the trachea and are made to vibrate by the air as it
passes over their edges on its way from the lungs.   These
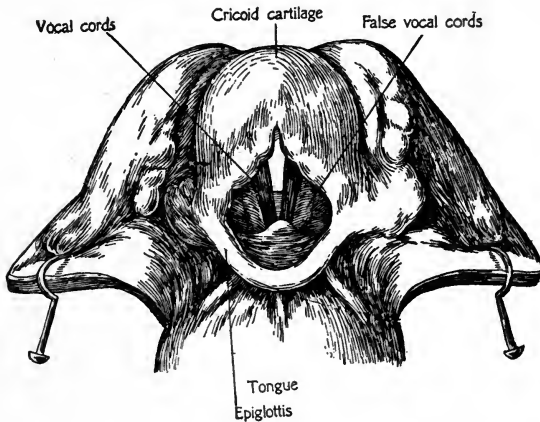
Fig. 149. View of larynx from above, showing position of vocal cords.

vibrations cause the air in the larynx to vibrate, and
its vibrations are directly transmitted by the air in the
throat and mouth to the external air.   All the vibrations
of which the vocal cords are capable are of a rapidity
that comes within the range of the ear and they are
therefore perceived by us as sound.

Volume.—The loudness, or *volume*, of the sound **pro-**
duced by the vocal cords depends upon the force with
which the air of the lungs is pushed out between them.
A gentle voice is the result of very little pressure,
whereas a shout requires a sudden vigorous contraction
of the expiratory chest and abdominal muscles.

Pitch.—The *pitch* of the voice depends upon the tension of the vocal cords. If they are made very tense

Arytenoid cartilages

Position for a high note in singing

Vocal cords

Position in quiet breathing

Position in rapid inspiration
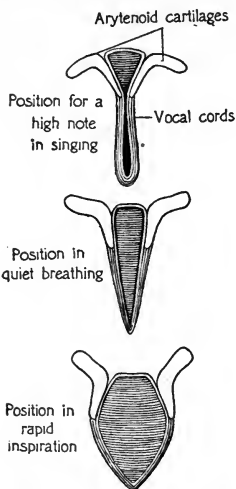
FIG. 150. Diagrams showing various positions of the vocal cords and their adjustment by the muscles controlling the arytenoid cartilages.

by their adjusting muscles, the voice is of high pitch. If, on the contrary, they are but slightly tense, the pitch is low. The range of pitch differs in different individuals. A large larynx with long thick vocal cords results in a deep bass voice; a smaller larynx with shorter thinner vocal cords results in a tenor voice. In women and children, the larynx is distinctly smaller than in men and their voices are of correspondingly higher pitch. In children, as the larynx increases in size, their voices, especially those of boys, become lower pitched.

Timbre.—The quality, or *timbre,* of the voice in contrast to its pitch, depends upon the fact that the vocal cords, like violin and piano strings, vibrate not only as a whole but in halves, quarters and even in shorter lengths. As a result, the vibration of the whole length, or *fundamental* vibration, is supplemented by the higher, or *overtone,* vibrations of the sections. These overtones are octaves of the fundamental tone. If the vocal cords are smooth and of the same weight and tension, the voice is greatly enriched by the overtones and is musical. If, however, the cords do not vibrate together because of inequality of weight or tension, the vibrations of the two cords do not coincide. In addition, their overtones, not

being true octaves, do not blend either with the funda-
mental tones or with each other.   Under these circum-
stances, the voice is unmusical and harsh.   An inflam-
matory condition of the throat, as in a cold, may result
in the swelling of the vocal cords (laryngitis), which
produces the same result.

Effect of air cavities upon the voice.—It has been
found by experiment that the various cavities of the
mouth, nose, trachea and lungs have a tendency to act
as organ pipes for the reinforcement or increase of the
vocal sounds, in just so far as the air within them tends
to vibrate in unison with the fundamental vibrations of
the vocal cords and of their overtones.   In this way, the
quality of the voice is made richer and its volume
greater.   The assistance given by the cavity of the nose,
for example, may be readily appreciated by contrasting
a person's ordinary voice with the voice produced when
the nose cavity is closed by pinching the nostrils or by
a head cold.   The nasal twang of many voices is due
to the fact that the nose is not properly open.

Vowels.—Besides the increase and reinforcement of
the vocal sounds by the air in the various cavities, cer-
tain parts of the throat, tongue and lips modify and
interrupt the sounds produced.   When the air passages
are unobstructed so that the movement of the air is
continuous, the sounds made are called *vowels*.   One
can readily observe with a mirror the changes involved
in the production of the sounds *a, e, i, o* and *u*.

Consonants.—The *consonants,* on the contrary, are
produced when the air passages are partially or com-
pletely obstructed, as by the lips and tongue.   If the
closure is complete and then is suddenly overcome by
air pressure, we get an explosive articular sound, such
as is required for the pronunciation of the consonants

b, p, t, d, k and *g*. If the closure is not complete, the result is a hissing sound called an aspirate, as in pronouncing *f, v, w, s, z, l, sch, th, j, ch* and *h*. Still other sounds, as *r, m, n* and *ng,* are produced by the vibration of the tongue or by the resonance of the nose.

Whispering.—In *whispering,* the larynx is not used, but instead the resonance chambers of the nose together with the articular movements of the lips, tongue and palate, produce the sound.

CHAPTER XXV

HEALTH AND DISEASE

Health.—We have seen that the ability of our bodies to live and to work depends upon the condition of the millions of cells, the activities of which constitute our life. When each cell adequately does its share of the work of the body, directed and guided by the nervous system, our physical life runs smoothly and we are said to be in good health. If, on the contrary, any of the cells act sluggishly or fail in any way to do their work, the balanced working of the body as a whole is more or less disturbed, its smooth running ceases and a condition of ill-being or disease exists.

Conditions of health.—In order that the cells may be in good health, they must inherit a tendency to grow and develop normally and in addition they must be given proper exercise and wholesome conditions. In other words, the body as a whole requires for its perfect health an abundance of good invigorating exercise, of wholesome food and of pure air. In just so far as any or all of these are lacking, the health of the body suffers. Instead of being vigorous and enduring, it is weak and easily succumbs to one or another of the outside influences which stand ready to change weakness into disease.

Disease.—Whenever a tissue is injured or its proper working interfered with, there is said to be *disease*. Nearly all disease can be traced to some external cause.

The cause may be purely mechanical, as in the case of a blow which bruises tissue or breaks bone. It may be chemical, as when a poisonous gas is inhaled or a poison is eaten or drunk. Or it may be some one of the many forms of disease-producing organisms which invade the body and, if the conditions found there are favorable, multiply rapidly as poisonous parasites.

Microbes, a cause of disease.—The living organisms which are responsible for our infectious diseases, as
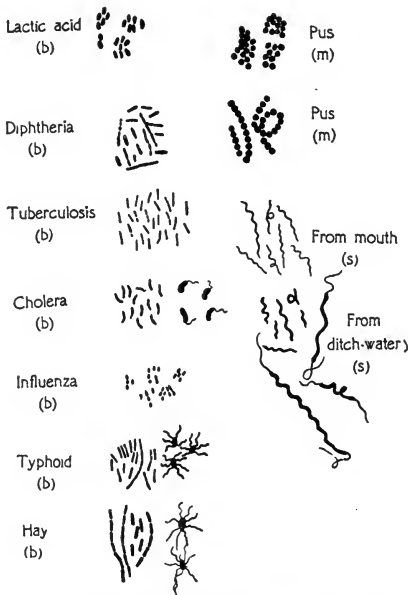
Fig. 151. Various forms of bacteria, highly magnified, some of which have flagella or cilia: b, bacilli; m, micrococci; s, spirillæ.

consumption, cholera, typhoid fever, diphtheria and *malaria,* come from either the vegetable or the animal kingdom and are so small that they can be seen only

with a high-powered microscope. On this account, they escaped detection until recently, and the ravages due to them were ascribed to mysterious or supernatural causes.[1] By means of the microscope, aided by modern methods of investigation, we now recognize many of these organisms and associate them with the diseases which they cause.

Bacteria, protozoa and molds.—Each well-defined infectious disease is in all probability caused by its special microscopic organism, or *microbe,* although in some diseases the particular kind has not as yet been discovered. The microbes which come from the vegetable kingdom and are minute one-celled plants of varying forms are called *bacteria.* Those which come from the animal kingdom and also consist of single cells of varying forms, are known as *protozoa.*[2] In addition to bacteria and protozoa, certain higher forms of vegetable and animal life are responsible for disease. They are chiefly certain kinds of *molds* and various forms of animal *parasites,* as the tapeworm and trichina.

Exposure to disease.—To many of these varying kinds of disease-producing microbes we are more or less exposed at all times. They may be present in the dust of the air which we breathe, on the food which we eat, or in the water which we drink. They may lurk upon the skin and in the various cavities of the body. In many cases, however, they are harmless because of the body's ability to destroy them as fast as they find entrance to it. When the body has been weakened, however, or when the invading microbes are very numerous and virulent, they are able to invade it and to multiply

---

[1] Defoe's "History of the Plague" gives a vivid picture of the old attitude toward infection.

[2] Literally, "first animal."

within it. For example, the special bacterium of pneumonia is found in almost every one's mouth, where it remains as a harmless parasite, totally unable to force an entrance into the body because of the vigilance of the white blood corpuscles. When, however, through extreme fatigue or a severe chill, the power of the blood corpuscles is greatly reduced, the bacteria find their entrance but weakly contested by them and so are able to enter and multiply. The result of their activity is the disease of the lungs known as pneumonia.

Generation of toxins.—Like all unicellular organisms, microbes multiply by division. The process of division goes on so rapidly that under favorable circumstances one microbe requires but a few hours to become millions. As they increase in numbers, they generate the most active poisons known, the *toxins*. These poisons are absorbed by the lymph and carried all over the body, with the result that the body is prostrated.

Antibodies.—In spite of its prostration, the body sets about to resist the poison of the infecting microbes. It is stimulated to increased activity by the toxins, as shown by the fever which is the usual accompaniment of disease. As a result of this activity, there is developed a substance called *antibody* or *antitoxin,* which has a threefold power. It neutralizes the poisonous effect of the toxin; it weakens the invading organisms; and it stimulates the white blood corpuscles to destroy them more actively. If the body is able quickly to develop a large amount of antibody, the disease runs an unusually short course and is said to be aborted. If, on the contrary, the infecting microbes are of overwhelming strength and numbers, the body has little or no chance to develop an antibody before it is overcome by the

destruction of its tissue and the poison of the toxin. As a result, it quickly succumbs to the disease.

Four stages of disease.—The ordinary course of any disease is dependent upon the conditions of the invasion and the resistance of the body to it. It has four distinct stages. First there is a period of incubation, during which the microbes are gaining strength by multiplying in numbers. This period begins at the time of exposure, that is, at the time of the first entrance of the microbes into the body, and ends at the first symptoms of disease, as nausea, headache and fever. The second stage is a period of development of the disease, due to continued activity and multiplication of the microbes. During this period, the resistance of the body is beginning. During the third period, the fight between the microbes and the body is raging. If the body is able to make a good resistance, the disease ceases to increase and maintains a level. At the end of this period, which may be short or long as determined by the nature of the disease and the body's power of resistance, the fourth period commences. The disease either begins to abate, if the body has been successful in its manufacture of antibody; or to increase, if it has been unsuccessful. The decline of the disease may be sudden, as in the crisis of pneumonia, in which case the microbes seem to be speedily and completely overwhelmed; or the decline may be slow, as is much more usual.

Individual differences in resistance.—The power of the body to develop antibodies to meet disease varies greatly in different individuals. This difference is shown especially in the attitude of the white blood corpuscles toward the invading microbes. In some persons, they seem to be indifferent to them; in others, they seize

upon and destroy them with the greatest eagerness. The latter are those whose cuts heal quickly and who are not troubled with boils and abscesses.

Immunity.—Certain diseases,[1] as *smallpox* and *scarlet fever,* never attack the same person twice, no matter how often he may be exposed to them. From this fact, we infer that the antibodies developed during the disease persist throughout his life. Consequently, the microbes of the disease can never again gain a foothold and he is said to be *immune* to the disease. In smallpox, immunity can also be gained by *vaccination* with the microbes derived from a modified and much milder form of the disease, *cowpox* or *vaccinia.* Such immunity, however, is limited to a period of from six to fifteen years. In such diseases as diphtheria, on the contrary, the immunity acquired by the reaction of the body lasts but a few weeks after the disease has run its course.

Tuberculosis.—In contrast to these diseases in which the body has the power of curing itself, is that most common disease, *consumption* or *tuberculosis.* In consumption, the growth and multiplication of the microbes are so slow that they do not give off enough toxin to arouse the body to manufacture an adequate supply of antibodies. The white blood corpuscles seem to remain more or less indifferent to the infecting organisms, and as a result they are not destroyed. If, however, the person is in a condition of very robust health or acquires such health by invigorating out-door life, the body is stimulated to develop antibodies in sufficient amounts and the course of the disease is thereby checked.

Artificial development of antibodies.—By experiments upon animals, it has been found possible to de-

[1] The microbes which cause these diseases have not as yet been established beyond question.

velop antibodies similar to those developed by the body in its struggle with disease. For example, if small doses of the toxin developed by the bacteria of *diphtheria* are repeatedly injected into a well horse, his tissues will develop the antitoxin which antagonizes diphtheria, so that he will quickly become immune to the disease while retaining perfect health. If this process is continued until the maximum amount of antitoxin has been developed, the blood of the horse becomes richly supplied with it. It may then be used to supply antitoxin to a person stricken with diphtheria. The destruction of tissue which goes on while the body itself is preparing antitoxin is thus avoided, and its presence in sufficient amounts immediately insured. In this way, the microbes are overcome before they have time to overwhelm the body or to cause serious destruction of tissue. As a result, the fever goes down and the person quickly recovers.[1]

In consumption.—In diseases like *consumption*, where the disease is of such slow progress as to be chronic, there is sufficient time to stimulate the body to produce antibodies. In addition to such improvement in general health as can be brought about by fresh air and good food, the production of antibodies may be further stimulated by the actual injection into the patient of toxins in the form of the dead bacilli of the disease. The increased amount of toxins in the body stimulates it to make enough antibodies to overcome them.

Infection.—A disease, to be *infectious,* must be produced by a microbe which has the power of invading the body, of multiplying therein and of giving rise to

[1] Thus far the method of producing antibodies has been discovered for only certain of the infectious diseases, but it is undoubtedly only a question of time when the list will be greatly extended or even made complete.

symptoms of disease. The transmission of an infectious
disease from one person to another is brought about by
the transference of microbes either directly by contact
from person to person; or indirectly, through common
contact with intermediate objects, as door knobs and
furniture, or through inoculation by the bites of in-
fected insects. For example, a person with diphtheria
may transmit the microbes directly by coughing into
another person's face or by touching some part of his
skin; or he may transmit them indirectly by leaving

Anopheles (malaria)

Anopheles (malaria)   Culex (common)   Stegomyia (yellow fever)
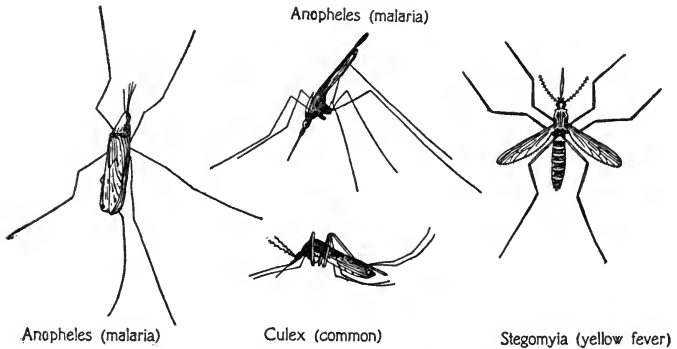
Fig. 152. Various types of mosquitoes. (After Howard and Underwood.)

some of them upon a door knob or chair back which the
other person subsequently handles. Had the disease
been malaria or yellow fever, the person might have
transmitted the microbes indirectly through the bite of
a mosquito. The microbes thus transmitted are in a
position to enter the body of the well person, provided
that they can find a cut in his skin or are conveyed
to his mouth. In the case of the insect's bite, they are
actually injected under the skin.

Entrances and exits for microbes.—The main en-
trances by which infecting microbes enter the body of a

well person are the nose and mouth, for the reason that streams of air containing microbes are continually passing through them. The food entering the mouth also forms an excellent means for conveying them into the stomach, provided that the food itself is infected. The main exits for infecting microbes from the body of the diseased person are the discharges from that person, including those of the nose and mouth, as in coughing and sneezing.

Prevention of disease by personal care.—Since the microbes from one case of infectious disease may so readily be transmitted to a great number of persons, it is essential that the person infected should exercise the greatest care to avoid spreading his disease, and that those who are well should similarly exercise the greatest care not to become infected. If each person would follow certain simple rules of hygiene, the number of cases of infectious diseases would be greatly diminished. The more important of these rules may be formulated as follows.—

Avoid unnecessary contact with others, when either they or you are suffering from any acute illness.

So dispose of all excreta and discharges that no one else can come into contact, even remotely, with them. The best methods are burning, disinfecting with strong disinfectant solution before putting into sewage, and deep burial (in the country) at a distance from wells and other water supplies.

Burn or disinfect whatever clothing has come in contact with the disease.

Protect against insects, particularly mosquitoes and flies.

Protect food and drink against all insects, since they may carry infection upon their feet.

Do not let any one who is ill assist in preparing food.
Do not eat or drink from utensils used by others.
Wash the hands immediately before eating.

Keep the general health good through proper exercise,
fresh air and wholesome food.

Disinfection.—Since all the microbes producing disease are living organisms which must have favorable conditions for their growth and development, it is possible to provide the unfavorable conditions which will check their growth or even kill them outright. When the microbes are in the body, this is done, as we have seen, by the development or injection of antibodies. When, however, the microbes are outside of the body, as, for example, in excretions and on clothing and furniture, much more immediate and vigorous measures can be used. The most effective of these is moist heat in the form of steam, especially if the steam is under pressure.[1] A few minutes' exposure to such steam is sufficient to kill all microbes. Next to steam in efficiency is boiling in water in a closed vessel. For all microbes except those of consumption, ten minutes or so of boiling is sufficient; for the bacilli of consumption, an hour is necessary. Objects which cannot be either steamed or boiled, have to be treated with such chemicals as will kill the microbes on them. Of these, formaldehyde [2] is the most effective, both in its gaseous and liquid forms.

Prevention of disease by municipal hygiene.—No matter how much care the individual exercises, it is not possible for him fully to protect himself against the possibility of infection, since in every community

[1] That is, in a steam-tight vessel.
[2] Formalin candles can be obtained of any druggist and when used according to directions afford a most effective and simple means of room and clothing disinfection, provided that penetration of thick clothing, etc., is not required.

some of its members are so careless as to expose others.
Moreover, many cases of contagious disease cannot be
easily recognized as such in the beginning. Conse-
quently, a number of persons may be exposed without
knowing it. Against the carelessness of its members,
the community as a whole can take certain measures of
protection, since no one member has a right to endanger
the lives of others. It can, for example, demand the
isolation of all cases of contagious disease; the quaran-
tine of all those who have been in contact with the
disease until it has been proved that they have not caught
it; and the disinfection of the premises at the end of an
illness. It can guard against epidemics [1] by such pre-

[1] *Influence of vaccination upon smallpox:*

Before vaccination	Population Boston	Cases	Deaths
1721	11,000	5,989	850
1730	15,000	4,000	509
After vaccination			
1811-1830		14	

Annual rate of cases per million of inhabitants:

	Before	Optional	Compulsory
Sweden	2,045	480–155	5–0.2
England	2,000	417	53
Prussia	2,000	300	4
Spain		12,050	
Porto Rico		600	0

Smallpox cases and death rates per 1,000 persons in Sheffield,
Eng., epidemic:

	Cases	Deaths
Not vaccinated	94	51
Once vaccinated	19	1
Twice vaccinated	3	0.08
Children under 10 yrs.		
Not vaccinated	101	44
Vaccinated	5	0.09

Influence of antitoxin treatment upon diphtheria (at Boston
City Hospital):
Annual death rate per 1,000 cases for 6 yrs. previous to in-
troduction of antitoxin (1894) 400
Average death rate for 1904 (excluding cases which died
within 24 hrs.) 69.5

ventive measures as vaccination in the case of small-pox. It has, further, the right to guard its water supply from all sources of contamination and to make and enforce laws insuring the purity and healthful-ness of all foods put on sale. It can protect the general health by laws regulating labor in shops and factories, that the conditions of work may be healthful and the hours not excessive. It can institute health inspection in schools, that the spread of contagious diseases may be avoided and such deficiencies as eye and ear trouble be discovered and remedied. It can establish parks, playgrounds and gymnasia, that each one may have the fresh air, sunshine and exercise which might otherwise be denied him. In short, the community can help to protect its members from infection by destroying the sources of disease and by making them better able to resist its attacks. If both the community and the indi-vidual do their duty loyally, the ravages of disease will be lessened with each succeeding year and the horror of epidemics be made impossible.

EXPERIMENTS AND DEMONSTRATIONS

Materials: Cake of compressed yeast; bread; cheese; molasses; raw meat; hay; test tubes; perforated stopper for test tube; delivery tube for perforation in stopper; cotton-bat-ting; dairy or chemical thermometer; ice box; warm box; 12 test tubes of gelatine culture medium, obtained from a dealer in bacteriological supplies; 6 Petri dishes thoroughly cleansed, covers applied, and baked for ½ hour in a hot oven, before using for culture experiments (dishes should not be uncovered except as indicated in experiments).

1) *Fermentation by means of yeast:*

a) Put into a test tube 1 part of molasses to 9 parts of water. Add a little compressed yeast rubbed in water. Set aside in a warm place (not above 100° F.) and observe it at intervals for 24 hrs., noting carefully its appearance.

b) At end of 24 hrs., examine some of sediment[1] under microscope, using the high power.[2] Note yeast cells with their buds. Make sketches of characteristic forms and compare with forms in the yeast cake.

c) Collect gas given off by fermentation, by closing mouth of test tube with a cork in which is inserted a bent glass delivery tube, and identify it.

2) *Influence of temperature upon activity of yeast:*

a) Prepare a test tube similar to 1, a), but put it upon ice for 24 hrs. Compare with 1, a), and note differences.

b) Prepare 3 test tubes similar to 1, a). Place one in water at 150° F. for 10 min.; label and place with 1, a). Place second in water at 175° F. for 10 min.; label and place with other two. Boil third gently for 10 min.; label and place with others. At end of 24 hrs., compare 3 test tubes of this experiment with test tubes of 1, a) and 2, a).

3) *Presence of yeast in air:*

a) Prepare 3 test tubes similar to 1, a), except that no yeast is added. Put tubes uncovered in various parts of room and leave uncovered for a day or two. Note whether there is any fermentation. When bubbling begins, examine sediment under microscope, to detect yeast.

b) Examine also squirming rods and other forms of microbes present.

4) *Putrefaction through activity of microbes:*

a) Place in a test tube a small piece of raw meat. Add some cold water and set aside in a warm place for 2 or 3 days, noting changes from day to day. At end of time, note odor and appearance of both meat and fluid.

b) Examine sediment under microscope and note various forms and degrees of activity of microbes present.[3]

---

[1] The sediment is best obtained by introducing into the liquid a glass tube drawn out to a moderately fine point at one end.   Hold the other end closed with the finger until the fine end reaches the sediment.   Then allow the air to escape from under the finger tip. The sediment will then enter the small tip.

[2] The best results are obtained by using a $\frac{1}{12}$ in. oil immersion objective, which can probably be borrowed, if necessary, from a physician.

[3] To stain these microbes, which are chiefly bacteria, in order more clearly to show their forms, various coloring fluids may be

c) Compare putrefaction with fermentation as to odor and general characteristics. It will be found that carbohydrates ferment through action of yeasts and that proteids putrefy through activity of bacteria.

5) *Hay bacillus:*

a) Cut hay into short pieces and pour boiling water upon it. Cover and set aside for several days. Observe carefully from day to day cloudiness and formation of scum, indicating multiplication of bacteria.

b) When scum is developed, examine under microscope and note many rod-like bacteria (hay bacilli).

6) *Molds:*

a) Moisten pieces of bread and of cheese, put on plates and cover tightly with tumblers. Leave for several days, observing growth at intervals.

b) When molds are well developed, examine under microscope and note their characteristic forms.

c) Take up some of mold on point of a needle and touch it to several points on surface of a fresh piece of bread. Moisten and set aside under tumbler, as before. Note whether mold develops more quickly at points touched than elsewhere.

7) *Determination of number of microbes by culture:*

a) Melt 6 test tubes of gelatine by placing in water at a temperature of about 120° F. When thoroughly melted, remove the cotton from test tube and, by means of a small glass tube which has been sterilized by boiling or heating in a flame and then cooled, introduce 1 cu. cm. of well or tap water. Replace cotton and mix water thoroughly by shaking but do not get it upon cotton. Remove cotton and pour into sterilized Petri dish. Cover dish immediately and allow to stand at room temperature for from 24 to 48 hrs. Observe contents of dish from time to time without uncovering it.

b) When small white dots representing colonies of microbes, each of which has grown from a single microbe, are distinctly visible, count them and thus determine number of microbes in cu. cm. of water used.

used, such as methylene blue and methyl green. The blue or green is dissolved in a drop of water, which is then allowed to flow under the cover glass into the sediment. A small piece of blotting paper placed upon the opposite side of the cover glass will assist the flow.

c) Repeat experiment, using 1 drop of milk (about $\frac{1}{20}$ cu. cm.).

d) Melt 2 tubes of gelatine and pour into Petri dishes.   Expose one to air at beginning of school; the other, after sweeping or dusting.   Cover and allow to develop as before.

e) Prepare 2 Petri dishes and allow to cool.   Touch to surface of gelatine in one dish some part of skin, as a finger tip, which has not been washed for several hours.   Touch to surface of gelatine in other dish the same finger tip immediately after it has been washed in soap and warm water.   Compare the growth after 24 and 48 hrs.

8) *Effect of heat (sterilization) upon bacteria:*

a) Cut some raw meat into small bits.   Place a few pieces in a test tube and cover with 2 in. of lukewarm water.   Plug it with a tuft of cotton and set aside in a warm place.

Place an equal number of pieces in another test tube and boil briskly for a half minute.   Plug and set aside with former test tube.

At end of 24 and 48 hrs., compare the 2 tubes and note effect of heat.

b) Place in 2 test tubes 2 in. of milk.   Boil one by placing it in a small vessel of boiling water for 5 min.   Plug both tubes with cotton and put together in a warm place.   Compare at end of 24 and 48 hrs., testing acidity and odor.

9) *Effect of disinfectants upon bacteria:*

a) With scissors cut the white of an egg into 10 times its weight of water. Put 2 in. of the solution into each of 14 test tubes.   To No. 1, add nothing.   To No. 2, add 4 grs. of salt; to No. 3, 15 grs.   To No. 4, add 15 grs. of sugar; to No. 5, 45 grs.   To No. 6, add 2 drops of 1 to 1000 corrosive sublimate solution; to No. 7, 6 drops.   To No. 8, add 1 drop of formalin, 40 per cent solution; to No. 9, 2 drops; to No. 10, 3 drops.   To No. 11, add 2 grs. of borax; to No. 12, 4 grs.   To No. 13, add 4 drops of 5 per cent carbolic acid solution; to No. 14, 10 drops.

Shake the 14 test tubes carefully to mix contents, plug firmly with cotton, and set aside in a warm place.   Examine daily and note changes in each, in order to determine relative effectiveness of different mixtures as preservatives.

CHAPTER XXVI

STIMULANTS AND NARCOTICS

Definition.—Aside from the ravages of disease, one of the greatest dangers to human health is the use of certain substances which are not required by the body as food but are taken solely because of the pleasure which they give. These substances are known as stimulants and narcotics because they either produce a feeling of increased vigor, or partial or complete insensibility. The stimulants most commonly used are alcoholic beverages, tea and coffee. The narcotics are the various preparations of opium with its most important derivative morphine, and chloral, cocaine, tobacco and chloroform.

Proper use of narcotics.—Many of the narcotics, such as morphine, chloral and cocaine, have long been recognized as having valuable medicinal properties when given to weak and suffering persons by a cautious physician who fully recognizes their dangers. They are then used for a short time only to tide over an emergency. Their use is distinctly the choice of the lesser evil, since, although their after-effects are known to be injurious, yet they are not so injurious as the condition which they correct. For example, a person in intense pain would be injured more by sleeplessness and exhaustion than by the after-effects of the narcotic, which, by dulling the pain, brought sleep. In all such cases, however, these substances must be used with ex-

treme caution and their prolonged use for chronic conditions avoided. Otherwise, the headache, nervous depression and exhaustion, indigestion, constipation and weakness of heart and blood-vessels which follow their continued use, may easily become so serious that the original trouble seems trivial by comparison. This is especially true when by their continued and prolonged use the body has so adapted itself to their influence that it demands them. The body is then pledged, as it were, to its own destruction. It is being ruined by their use, and yet so intense is the craving for them that to give them up means intolerable mental and physical distress.

Improper use.—In view of the danger lurking in the use of the stronger narcotics, it may be said that for a person to give such a narcotic to himself in any form is in itself improper. The first step in this direction seems most innocent. The person feels that a few doses can make no difference and that in any case he himself will be strong enough to resist their effects. In this, he is very apt to overestimate his own strength and underestimate that of the drug. Each dose is building up within his body an appetite, a craving for the next dose, and in some moment of pain and depression he may be reasonably sure that he will take that dose. As time goes on, the moments of pain and depression become more frequent and the doses necessary to overcome them become larger. The more frequent and larger doses create more terrible fits of depression, a more irresistible craving for the drug, a weakened resistance to its use. The man has now become the victim of the drug. Without it his life is unbearable because of the weakness, pain and depression, which are, in turn, largely the result of its use. The man can no longer live without it, yet its use means his mental, moral and physical ruin.

Legal restrictions.—Morphine, chloral and cocaine have claimed so many victims that the law recognizes their danger and limits their use as much as possible by restricting their sale except upon a physician's order. The physician in turn limits his order to the least amount necessary to tide over the emergency which necessitates its use. He further so words his prescription that it is difficult for the patient to know what has been given him or to get a second supply, except upon a new prescription.

Tobacco a narcotic.—Although of much milder form than the drugs which we have been considering, tobacco has, nevertheless, their narcotic characteristics. It is a sedative, allaying nervousness and to a certain extent pain. It produces in habitual users a distinct craving, which is satisfied only by itself. It is not a food and is taken solely for the pleasure which its use gives.

Method of use.—The physiological effects which tobacco produces depend upon the manner and extent of its use and the susceptibility of the user. In smoking, the *nicotin,* which is the essential poison of the drug, is volatilized from the tobacco by the heat. It is then condensed upon the surface of the mouth, or, in the inhalation of cigarette smoking, upon the surface of the throat and bronchi as well. A part of it is lost by burning. In chewing, the nicotin is dissolved by the saliva and absorbed by the mucous membrane of the mouth. In snuff-taking, it is dissolved by the secretions of the nose and is absorbed by its mucous membrane. There is little fundamental difference between these methods, so far as the effects of the drug upon the body are concerned. In each, a certain amount of the nicotin is absorbed into the system, where it produces its characteristic effect.

Presence of carbon monoxide (CO).—In smoking, there are added to the effect of the drug itself the fumes from the ingredients of the tobacco other than the nicotin, and these are also absorbed into the system. It is supposed that one of these, carbon monoxide, generated because of the low temperature at which the tobacco is burned, is responsible, in part at least, for the great weakness and deranged heart action which confirmed smokers, especially of cigarettes, experience.

Extent of use.—The extent to which tobacco is used is much more important from the standpoint of health than the mode of its use. As in other narcotics, the habit grows fast with repetition. As the habit strengthens, the size of the dose required to satisfy the desire tends to increase. Owing to the adaptation of the body to its influence, a dose which in the beginning would cause nausea, headache, dizziness, prostration and even death, is often required after a year or two of use to satisfy the daily craving for it. Although the bad effects of its use have thus become less apparent, it cannot be said that they have ceased. Irritation of the mucous membrane lining the throat and mouth, more or less dyspepsia, increased nervous irritability and impairment of the heart action are very apt to accompany its persistent use, especially in young persons.

Individual susceptibility.—The injury which the use of tobacco causes varies greatly with individuals, some being much more susceptible to its use than others. This holds true, however, only of those who have passed the developing period. During youth, all are highly susceptible to it. The poison of tobacco is especially injurious to the developing nervous system, the heart and blood-vessels, the lungs and stomach. It not only interferes with their growth but even tends to exert first

an irritating and then a paralyzing influence upon their functions. As a result, the boy who smokes is apt to be stunted in growth, nervous and lazy. He is poor in his studies and of but little use in athletics. He is indifferent to the wholesome ambitions of boyhood and tends to seek the companionship of those who like himself are principally occupied in trying to have a good time in a more or less questionable way. In short, he is taking the quickest and surest way of ruining his health and his future prospects and of cheating his children of their right to wholesome bodies and minds.

This has been scientifically demonstrated in studies made by Dr. Seaver of Yale University and by Dr. Hitchcock of Amherst College, upon the growth of students. These showed that non-smoking students were markedly taller and had larger chest girth and greater lung capacity than those who smoked. As to their mental attainments, the Hon. Andrew J. White, formerly president of Cornell University, says:

I never knew a student to smoke cigarettes who did not disappoint expectations, or to use our expressive vernacular, "kinder peter out." I have watched this class of men for 30 years, and cannot recall an exception to this rule. Cigarette smoking serves not only to weaken a young man's body, but to undermine his will and to weaken his ambition. In colleges having a large percentage of these futile personages they too often give the student tone; they set the fashion; the fashion of overexpenditure, of carelessness as to the real aim and glory of college life.—*Cornell Sun,* November 11, 1891.

Stimulants: tea and coffee.—Besides narcotics, the most important substances which are often taken for the feeling of well-being and strength which they give, are stimulants in the form of alcoholic beverages, tea and coffee. As we have already seen in our discussion of food materials, tea and coffee may be occasionally used

with benefit to tide over an emergency which involves unusual nervous strain. They give a temporary increase of strength, which is later followed by weariness and depression, because they have spurred the tissues to an activity which results in their more complete exhaustion. When taken habitually, each period of stimulation is followed by a period of greater exhaustion,[1] so that the individual's 'plane of strength is constantly being lowered. The more he depends upon them for stimulation, the weaker he really becomes, until his nervous system may become more or less shattered and his digestion seriously upset.

Formation of habit.—As with narcotics, the use of tea and coffee easily becomes a habit, since to leave them off at any time means weakness, restlessness and depression. A user of tea and coffee can readily estimate how much he is depending upon them by leaving them off for a few days. If he feels less energetic and comfortable, it means that his nervous system has suffered from their use. It is then for him to determine whether he wishes to continue the habit at the expense of his nervous system, or to regain a more wholesome condition where the feeling of well-being is not dependent upon artificial stimulation but upon proper amounts of food, exercise, work and sleep.

Alcohol.—Alcohol differs from tea and coffee, in that like food it is oxidized in the body, thereby producing heat and energy. It cannot, however, be ordinarily considered as a food for the reason that even in small doses it produces a serious effect upon the nervous system. It cannot therefore be safely used in sufficient amounts to get any food value from it.

[1] This is frequently exaggerated by the substitution of tea or coffee for food.

Production of alcohol.—Of all forms of drugs, with the exception of tea and coffee, alcohol is the most generally used, doubtless for the reason that it is easily and cheaply made from such common materials as grains and fruits, by the ordinary processes of fermentation or by distillation from the products of fermentation. When crudely made, however, and not sufficiently aged, the alcoholic beverages from fermentation and especially from distillation contain in addition to ethyl alcohol other much more dangerous forms of alcohol, as fusel oil.

Various beverages.—The alcoholic beverages in common use are of two distinct types, being produced either by fermentation or distillation. Those produced by fermentation, as beer, cider and wine, contain from two to twelve per cent of alcohol. Those produced by distillation, as whiskey, brandy and rum, contain from forty to sixty per cent. Certain wines, as port, are strengthened by the addition of alcohol and are known as fortified wines. The alcohol·in all cases is the result of the fermentation of sugar, which is present in such fruits as grapes and apples, or is obtained by a malting process from the starch of grains.

Effects of alcohol.—The effects of alcohol upon the body and especially upon the nervous system depend upon the form, amount and frequency of its use and upon the susceptibility of the individual. In general, its first effect is that of stimulation and excitement. The person's face becomes flushed, his eyes brighten, his reserve is lost, he becomes animated, confident and talkative. In a later stage, the flush becomes more marked, the lack of reserve shows itself in silly loquacity, control of movement is lost and the stagger of drunkenness develops. In a still later stage, the full effects of the

poisoning are seen in stupor and inability to move. This last stage may continue for a number of hours or may end in death.

Alcohol, a narcotic poison.—From a physiological standpoint, alcohol in its effects seems rather to resemble a narcotic than a true stimulant, inasmuch as the period of exhilaration produced by its use appears due not to a stimulation of the brain but rather to a paralysis of its higher functions of caution and judgment. It would further seem that all of its effects are due to a gradual paralysis, first of the higher and then of the lower brain centres, until finally all voluntary action is lost. The automatic processes of organic life, as the beating of the heart and breathing, alone continue and even these feel the paralyzing effect of the poison.

Chronic effects upon structure.—When alcoholic beverages are used habitually and frequently, other and more chronic effects may be produced, especially if the alcohol is in the concentrated form of wines and liquors. The mucous membrane of the stomach tends to become irritated, producing dyspepsia. The liver, which receives the blood immediately after its absorption from the stomach and intestine, is also irritated. This irritation causes an overgrowth of the connective tissue which forms the framework that supports its cells. As a result, its active cells are so pressed for room that they become smaller and less able to do their work. In extreme cases, the cells even disappear to a considerable extent, leaving only the connective tissue in their place. This results in so serious a reduction in the amount of work which the liver can do that the person dies. In such cases, the liver when examined is found to be hard and tough and is covered with small projecting knobs due to the contraction of the masses of connective tissue.

Such a liver is called the hobnailed or gin-drinker's liver, because it is rarely found except among hard drinkers.

Effect upon heart.—The heart as well as the liver may be more or less seriously influenced by the frequent and regular use of alcoholic beverages. The more concentrated beverages tend to produce deposits of fat about the heart which interfere with its action. Sometimes even, they give rise to a fatty degeneration of its muscles. The more dilute beverages, as beer, when taken in excessive amounts throw such an undue bulk of fluid into the circulation that the heart is overtaxed.

Upon blood-vessels.—The blood-vessels are also frequently affected by chronic alcoholism. Their walls may become so weakened that they are unable to withstand the pressure of the blood. This is especially true of the brain, where their bursting results in apoplexy and paralysis. Dilatation of the veins, especially of the face and nose, is also one of the effects of alcoholism, although it is not infrequently due to other causes.

Upon nervous system.—Whereas the heart, liver and blood-vessels are injured only by the prolonged use of alcohol, the nervous system shows the immediate poisonous effects of a single dose, as well as the chronic effect of its continued use. The immediate effect, as we have seen, is largely one of paralysis. The chronic effects are far-reaching and much more serious. They may show themselves as acute pain, due to the inflammation of the nerve tracts; as acute mania with hallucinations, that is, as delirium tremens; as epilepsy; or as insanity. Often, however, the chronic effects are so intangible that they do not appear until after the system has been weakened by disease. This is especially true in the case of habitual moderate drinkers, who often seem to have escaped all bad effects from the use

of alcohol until an illness or accident brings them to light.

Systemic effects.—Alcohol not only injures the special organs and tissues of the body but in addition it produces certain more general effects. It is frequently noticed that the powers of resistance to disease in habitual moderate users are markedly lessened. Their powers of recovery after accidents or illnesses are also decreased and in some cases entirely destroyed. These effects vary greatly with different persons. Some deteriorate rapidly under the influence of very small amounts, whereas others are seemingly able to withstand large amounts for long periods with but little apparent effect. The latter are simply examples of exceptional resistance to its influence and cannot be cited to prove that alcohol has no injurious effects. One might as well argue that scarlet fever is not contagious because a certain number of persons, although frequently exposed, have failed to catch it. Unfortunately, these resistant cases are rare, whereas the number who bear witness to its injurious effects is overwhelming.

Longevity.—The effect of the use of alcohol upon length of life is conclusively shown by the statistics of the various life insurance companies, which consider the subject from the unbiased point of view of business. Between the years 1875 and 1889, the Mutual Life Insurance Company found that upon the lives of those who had declared themselves to be total abstainers when applying for their policies, the maximum expected loss was $5,455,-669, and the actual loss was $4,251.050. Upon those who acknowledged themselves users of alcoholic beverages the maximum expected loss was $9,829,462, and the actual loss was $9,469,407.

The experience of the Sceptre Life Assurance Society,

Ltd., of London, for the twenty years from 1884 to 1903, inclusive, gives the following figures: For abstainers, expected deaths, 1,440; actual deaths, 792; being 55% of the expected. Non-abstainers, expected deaths, 2,730; actual deaths, 1,880, or 79% of the expected.

The experience of the Scottish Temperance Life Assurance Company, Ltd., for the twenty years from 1883 to 1902, inclusive, gives the following figures: Abstainers, expected deaths, 936; actual deaths, 420, or 45% of the expected. Non-abstainers, expected deaths, 319; actual deaths, 225, or 71% of the expected.

There are many other testimonies [1] to the effect that the use of alcoholic stimulants produces an increase in the rate of mortality. So destructive has been their effect upon the lives of the North American Indians, that under United States law it is a penal offense to sell alcoholic beverages to an Indian. The mortality among Africans and South Sea Islanders has also been so increased by the use of alcohol, that simply as a matter of humanity the civilized nations of the world have united in their efforts to stop the sale of liquor in the Congo and in certain islands of the Pacific. While it is doubtless true that the deleterious effects of alcoholic beverages are more apparent among black men and red men than among white men, yet, as we have the assurance that all nations are of the same blood, what is injurious to one cannot be beneficial to another.

As further proof of the injurious effect of alcoholic beverages, as shown in the death rate, I would refer to the statistics which have been published from time to time, showing the percentages of mortality in the various occupations. These statistics have invariably shown a higher death rate among those engaged in the liquor business, from brewers down to bartenders, than among those engaged in other occupations, except such as are clearly defined as specially hazardous. The higher death rate among liquor dealers is so universally recog-

[1] Effects of Total Abstinence on the Death Rate, by Joel G. Van Cise, Actuary of the Equitable Life Assurance Society of the United States.

nized by life assurance companies that a number of them will not issue policies, even on the lives of the richest brewers, upon any terms, and not one of the companies, to my knowledge, admits liquor dealers upon as advantageous conditions as those engaged in other ordinary occupations.

As an example of the restrictions in this respect, I would quote the rules as given in a circular sent to the agency force of a prominent United States company. This circular reads almost like a temperance document, and yet it is simply sent out as a matter of business, because statistics show that owing to what might be called the very atmosphere by which liquor dealers are surrounded, the mortality among them is higher than among those engaged in occupations which do not involve the handling of alcoholic beverages. This circular reads as follows:

"The number of applications received from persons engaged in the sale or manufacture of liquor has increased so rapidly that we find it necessary to call the attention to the rule on page 345 of the 'Blue Book' regarding this class of business, in order that unnecessary declinations may be avoided. This rule is as follows:

Bartenders	Not Taken.
Saloon keepers, generally, not taken, but best of this class may be accepted on 10 or 15 Year Endowments only.	
Commercial Travelers (Salesmen)	$5 per thousand extra.
Brewers (unless seldom at their breweries)	$5 per thousand extra.
Employees in breweries..........	$5 per thousand extra.
Wholesale dealers, if apparently unaffected by their business.....	Free.
Restaurant keepers and waiters selling liquor.................	$5 per thousand extra.

(In this whole class the habits, past and present, and appearance will be carefully considered.)

Please note that bartenders are *positively not taken,* and saloon keepers *tending bar occasionally* are therefore unacceptable. Only saloon keepers of the best class, very temperate in their habits, not tending bar, and enjoying the best moral surroundings which the business permits, will be taken at all, and only on 10 and 15 Year Endowment G. C. V. policies. It is useless to present cases not falling within these limits, as not only will the applications be declined, but the cost of medical examination may be charged against the agents for their failure to observe the rule.

It is also noted that there is a growing tendency to present the applications of brewery employees for acceptance without extra premium. In order that there may be no misunderstanding on this subject, agents are hereby informed that the only persons employed directly in connection with breweries who will be accepted without extra premium are the financial officers or officials seldom at the breweries, and employees such as book-keepers, etc., whose work is performed in a building apart from the brewery proper, or the place where the product is stored or kept in bulk.

General store-keepers everywhere, handling liquor at retail as part of their business, if taken at all, will hereafter be limited to dividend accumulation Endowment policies with not more than 20 years to run, but no policies with return of premium or with the Indemnity or Mortuary dividend feature will be issued to this class of applicants. This limitation is made necessary by the very excessive rate of mortality found to exist among persons so employed."

Experimental proof.—The effects of alcohol upon animal life have been experimentally studied by a number of scientists. One of the most interesting of these studies is that made by Professor Hodge of Clark University. He selected four healthy dogs and for four years allowed two of them to have regular doses of alcohol. The results showed conclusively that the use of alcohol made the dogs weak and timid. They fell ready victims to an epidemic, which they survived only by the most careful nursing. Of their twenty-three

puppies, but four lived to grow up, the rest being born dead or deformed. In marked contrast to them were the other two strong, happy, courageous dogs. When the epidemic came, they were not even ill enough to lose their appetites. Of their forty-five puppies, none were born dead, but four were slightly deformed, while the remaining forty-one were fine and normal. A study by another scientist of ten alcoholic and of ten non-alcoholic families showed that the same conditions held for human beings as for dogs.

In writing of a somewhat similar experiment upon kittens, Professor Hodge says: "In beginning the experiment, it was remarkable how quickly and completely all the higher psychic characteristics of both the (alcoholic) kittens dropped out. Playfulness, purring, cleanliness and care of coat, interest in mice, fear of dogs, while normally developed before the experiment began, all disappeared so suddenly that it could hardly be explained otherwise than as a direct influence of the alcohol upon the higher centres of the brain. They simply ate and slept, and could scarcely have been less active had the greater part of their cerebral hemispheres been removed with the knife." [1]

Practical studies.—Further proofs of the bad effects of alcohol are to be found in the experiences of men who have watched its use by large numbers of persons. For example, a writer in Manila has remarked pointedly concerning the health of the American troops: " 'It is not so much the climate as the glass bottle which injures people out here,' which statement is corroborated by another who had seen actual service as a member of a company,

---

[1] The Physiological Aspects of the Liquor Problem, Committee of Fifty.

many of whose members were total abstainers and the rest made up of moderate drinkers and those prone to excesses, the latter constituting 20 to 25 per cent of the whole. Of the latter class, only two returned home in approximately the same condition of health which they enjoyed at the time of enlistment. Of the moderate drinkers who confined themselves to malt liquors, a large majority suffered more or less impairment of general health. But the total abstainers returned almost to a man in excellent health, having endured the same hardships of an active campaign. The same correspondent, speaking of the far greater harm induced by the stronger alcoholic drinks, relates that he had repeatedly seen American soldiers, after spending several hours under shelter, drinking round after round without perceptible harm, fall over with all the symptoms of sunstroke as soon as they stepped into the glaring rays of the hot sun."[1]

Another man who was in the Civil War gives the following results of his observation of the soldiers who, as prisoners, were deprived of alcoholic beverages: "During the war I was a prisoner for thirteen months in Louisiana and Texas. Among the prisoners were many men, soldiers and sailors, but chiefly sailors, who had been addicted to drink. For four or five months the conditions of life were fairly sanitary. On the one hand, the prisoners were in roomy, well-ventilated barracks; they had to police and keep clean their quarters and grounds under their own officers, acting with the coöperation of the Confederate authorities; they had sufficient food and sufficient means for cooking it properly; they had saved their clothes when captured; they were allowed to go out

[1] Practical Hygiene, Harrington.

and cut their own wood; they were marched across Texas from Hempstead to Shreveport, and from Shreveport back to Tyler. On the other hand, there were the confinement and depression of imprisonment, the lack of regular work; a climate they were not accustomed to, and some malarial influences. Notwithstanding the latter conditions these men improved physically and mentally in such a marked degree that other officers agreed with me, at the time, that enforced total abstinence was the very best condition that could be imposed upon them.

"And in confirmation of the above, I repeatedly observed that many of these men, after they had returned to their homes with all the advantages of civilized life, had run down and did not appear either physically or mentally to be as fair specimens of manhood as they did while inmates of a Confederate prison camp." [1]

This opinion was further borne out during the same war by the experience of the Federal Authorities. "A daily issue of a gill of whiskey to each officer and man of the Army of the Potomac was ordered, half to be given out in the morning and half in the evening. This was brought about by the fact that for several weeks the men had been subjected to unusual hardships and extra duty, and were breaking down under the strain. The issue, which was to continue 'until further orders,' was greeted with enthusiastic appreciation of the farsightedness of the authorities responsible for it. 'Until further orders' proved to be exactly one month, and hot coffee was substituted for the whiskey, the issue of which was ordered to be '*immediately discontinued.*' During the month, the general condition of health of the troops was not only in no way improved, but became markedly worse,

[1] The Physiological Aspects of the Liquor Problem, Committee of Fifty.

while drunkenness, with its attendant evils, became much more common.'' [1]

That the bad effects of alcohol are not limited to the strenuous life of the soldier but are to be found equally among men in the more peaceful walks of life is borne witness to by a physician of many years' standing, who says: ''From my experience during a very active life of twenty-six years of medical practice, I have reached the conclusion that the regular consumption of a moderate or even small quantity of whiskey, wine, or beer is not conducive to the most perfect health or the highest working power in my profession or in any walk in life. In the conditions of life in cities, I believe the most effective work is performed by total abstainers from alcohol, but that the greatest harm is done to men of sedentary pursuits, and to those who through the stimulus of alcohol consume a larger quantity of nitrogenous food than they would otherwise take. . . . Leaving out of consideration all the harm done by alcohol in excess, the injury done by moderate regular indulgence is incalculable. Almost all the ill health in men beyond forty is associated with alcoholic indulgence and with imprudent or excessive eating in association with it.'' [1]

A man who for many years has had daily evidence of the effects of alcohol, adds his testimony as follows: ''From a large experience with drinking men in a line of work for their rescue, covering many years, I find that the drink habit is one that they have formed not through predisposition, but during the years of eighteen to twenty-four from so-called good-fellowship and treating; then, having acquired a habit, and their system craving

[1] The Physiological Aspects of the Liquor Problem, Committee of Fifty.

alcohol, it became the old story of an uncontrollable appetite. This applies to the millionaires and the sons of the same—who have the means to gratify their wants, and do so till their systems refuse, when mania and death follow—as well as to the gutter-snipe who burns for rum and dies the death of a neglected drunkard. Rum levels them both and affects them in the same way—here and hereafter. The curse is in the abuse, but the man, as a rule who is abusing the use of it, does not consider that it applies to himself, but to the other fellow, and will sympathize, and sometimes remonstrate with him in his being a slave to drink.'' [1]

Economic effects.—If the effects of alcohol were limited to physical and moral degeneration, the spectacle would be pitiable enough, but it further brings economic evils in its train. The expense connected with its use is enormous. The sums of money spent in buying it, although amounting to hundreds of millions yearly, are yet but a small item in the final bill of costs against it. In that must be reckoned the diminished or even destroyed earning power of those who use it, which, if it could be reckoned, would be beyond belief. To its account must also be charged a proportion of the cost of maintaining poorhouses, courts, reformatories and prisons, which are necessitated in part by the crimes committed under its influence. If alcohol could be abolished from the world and this immense sum of money spent for the families of its present victims, the world would have made a marvellous step toward the elimination of misery and crime and the development of a more uniformly wholesome, strong and intelligent race.

[1] The Physiological Aspects of the Liquor Problem, Committee of Fifty.

THE GROWTH OF PLANTS AND ANIMALS

Food of plants.—As plants grow, they are constantly taking material from the world about them and building it into themselves. The most common source of material for their use is that sea of air called the atmosphere, at the bottom of which they live. In it are found mainly oxygen, nitrogen and carbon dioxide, with slight amounts of such other gases as ammonia and coal gas.

Oxygen (O).—Oxygen is an invisible gas which forms about 20 per cent of atmospheric air. It is capable of union with other substances, thereby producing light and heat. This union is called combustion or *oxidation*.[1] Oxygen is given off to the air by plants when, in order to get the carbon and hydrogen which they need, they separate the carbon dioxide (CO_2) of the air into carbon and oxygen, and the water (H_2O) into hydrogen and oxygen. Oxygen is thus a waste product from plant growth.

Nitrogen (N).—Nitrogen is an invisible gas which forms about 80 per cent of atmospheric air. It serves to dilute the oxygen of the air and thereby prevents over-rapid combustion, which otherwise would mean the destruction of all things. Plants unite nitrogen with carbon, hydrogen and sulphur, and thereby build up the flesh-forming food of animals. Nitrogen as found in

---

[1] The chemical compounds formed by oxidation are called *oxides*. Water (H_2O) is an oxide of hydrogen; carbon dioxide (CO_2), of carbon; and iron rust (Fe_2O_3), of iron.

nature cannot be used by animals but must first be built into other compounds by plants.

Carbon dioxide (CO₂).—Carbon dioxide consists by measure of one part of the solid, carbon, and two parts of the gas, oxygen, and is present in fresh air only in minute quantities. The burning of coal, wood and oil, and the decay of animal and vegetable substances mean that the oxygen of the air is uniting with the carbon in these substances to form carbon dioxide. It is also generated in the bodies of animals when the food which they eat unites with the oxygen which they breathe. In animals, it is a waste product given off by the breath, but for plants it is a most important building material or food.

In the remote geologic ages before plants had taken the carbon dioxide from the air and stored up the immense quantities of carbon now found in coal and oil fields, the amount of carbon dioxide in the air was much greater than at present. It is probable, however, that the burning of the large quantities of coal and wood now in use is increasing the proportion of carbon dioxide in the air. The air of cities has distinctly more of this gas (0.06 per cent) than that of the country (0.04 per cent), while the sea air contains even less (0.025).

Carbon monoxide (CO).—Carbon monoxide is an invisible gas which is very poisonous for both plants and animals. It is produced when there is too little oxygen present to furnish the two parts of oxygen to one of carbon necessary for complete combustion into carbon dioxide, or when the temperature is too low to permit of complete oxidation, as in the case of wood or charcoal burning without a flame. It is commonly found in large amounts in illuminating gas, especially in the so-called "water gas," and in the fumes from

stoves, furnaces, charcoal-heaters and from tobacco as ordinarily smoked.

Water (H₂O).—Of not less importance than air to plants and animals is water. It is formed during the combustion of coal, wood and oil when the hydrogen in them unites with the oxygen of the air. It is also formed in the bodies of animals when the hydrogen in the food which they eat unites with the oxygen which they breathe. Water is of great importance for both plants and animals because it dissolves food and waste materials, so that they can be readily carried to and from all parts of their structure. Moreover, it is only when dissolved that food is capable of nourishing them and of undergoing the various changes necessary for growth and the production of energy by oxidation in animal tissues.

The demand of living organisms for a definite amount of water is so urgent that animals will seek for it at any cost of exertion or danger. Plants in their helplessness can only wilt and die.

The amount of water in the body of a man who weighs 150 pounds is about 87 pounds. The daily loss which requires to be made good is about 6 pounds or 6 pints. Of this, 3 pints is usually taken as drink, and the remainder as liquid food.

Soil.—In addition to air and water as sources of food supply for plants, there is the soil. Besides furnishing a firm support for them, the soil is so fine of texture, so filled with decaying organic matter and so well shaded by vegetation that it holds the moisture given it by the rain and gives it back to even the smallest plants. The soil further supplies substances needed by plants of both organic and mineral nature. In it are found the minerals potassium, calcium, magnesium and phos-

phorus, together with iron, sulphur, chlorine and sodium. They are found, however, only in comparatively small amounts, about 2 to 4 per cent of the plant weight, and constitute the ash or unburned portion of the plant.

Plant growth.—The most fundamental form of growth, upon which depends the food supply of all animals, is that which takes place in green plants. These require for their growth certain substances as carbon, hydrogen, nitrogen and oxygen. By means of the energy of the sun's light and heat, they are able to separate carbon from its union with oxygen in the carbon dioxide of the air. In the same manner, they are able to separate the hydrogen in water from its union with oxygen. The carbon, hydrogen and oxygen they then transform into such entirely new and complex substances as starch,[1] woody fibre or cellulose, and sugar.

Non-destructibility of matter.—When plants decay or are burned up, the starch, cellulose and sugar are again converted into the original simple substances from which the plants formed them. For example, the carbon in the starch again unites with the oxygen of the air to form carbon dioxide; the hydrogen and oxygen in the starch form water.[2] We thus see that the substances used by the plants for their growth and development are not destroyed even by burning or decay, but are used over and over again for thousands of years and will continue to be so used as long as plants grow.

Conservation of energy.—In the growth of plants, energy is required to separate out the materials which they use and to build them into their proper places in

---

[1] Growth: Carbon dioxide + water = starch + free oxygen
$$6 \ CO_2 + 5 \ H_2O = C_6H_{10}O_5 + 6 \ O_2$$
[2] Decay: Starch + oxygen = carbon dioxide + water
$$C_6H_{10}O_5 + 6 \ O_2 = 6 \ CO_2 + 5 \ H_2O$$
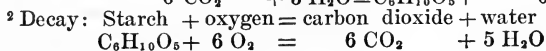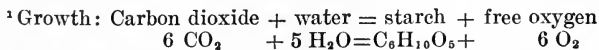
the plant's tissues. This energy is furnished by the sun in the form of light and heat. The same amount of energy which is given by the sun to the plant is again given out quickly and intensely if the plant is burned, or slowly and imperceptibly if the plant decays. During the growth of the plant, the energy is being stored up. The storing up of energy in this way so that it is not lost, although for a longer or shorter time it may seem to disappear, is an example of the natural law known as the *conservation of energy*.[1]

Transformation of energy.—Energy, like matter, can never be destroyed. If, for example, the wood from a tree, which has been built up of carbon and hydrogen obtained by the use of the sun's energy, is burned under a boiler, the energy set free by the burning of the wood causes the little particles of water in the boiler to take on so violent a motion that in their effort to escape from confinement they press upon the piston of the engine and drive it vigorously back and forth. As a result, an entirely different form of energy, namely, mechanical energy, is developed. The engine may in turn run a sawmill, a piledriver, or a dynamo for the generation of electricity. In any case, there is an exact equality,[2] or *correlation*, between the original heat from the sun, the force developed in the engine and the work done

[1] Similarly, the labor (energy) expended in raising building materials to their positions in a building, although seemingly lost for many years, again becomes active when the materials ultimately fall to the earth.

[2] All of the sun's heat is not made productive, since a part of it escapes as hot gases up the chimney, a part is radiated from boiler and engine, and a part is neutralized by the friction in the bearings of the engine and machinery run thereby. The losses in the ordinary boiler and steam engine amount to about 85 per cent of the heat generated by the burning fuel. Thus only 15 per cent of the energy developed from the combustion of the fuel is utilized in useful work.

by the sawmill, piledriver, or dynamo. In other words, one form of energy, the sun's heat, has been converted through the processes of growth, burning and the use of machinery, into other forms, such as mechanical and electrical energy.

The animal body, an engine.—The animal body in its relation to the plant world is in some respects quite in the position of the engine. It too is largely dependent upon plants for the fuel, or food, which is necessary for the development of its energy for growth and work. For example, starch when eaten by animals is burned [1] in the tissues for the production of heat and muscular energy.[2] In this process there is just as much energy developed in the form of muscular work and heat as could be developed were the starch burned as fuel in the most perfect steam engine. In fact, the animal body is able to utilize in the form of muscular force, not 15 but 30 per cent of the total energy set free. The remaining 70 per cent takes the form of heat and serves to maintain the temperature of the animal's body.[3]

As the muscular work done by animals increases in severity, the amount of heat generated by the oxidation increases in the same ratio. The result is that more heat is generated than is necessary to maintain the body's temperature, and the individual feels uncom-

---

[1] That is, *oxidized*, since all burning, whether rapid as in a fire or slow as in decay, is due to the union of the oxygen of the air with the carbon and hydrogen of the fuel (food).

[2] Starch + oxygen = carb. diox. + water + heat + musc. energy
$$C_6H_{10}O_5 + 6 O_2 = 6 CO_2 + 6 H_2O + \text{``} + \text{``} \text{``}$$
In other words, 1 molecule of starch acted upon by 6 molecules (12 atoms) of oxygen forms 6 molecules of carbon dioxide and 6 of water, and heat or heat and muscular energy are set free in the process.

[3] In man, the normal temperature is 98.4° F.; in the horse, about 104° F.; in the ox and dog, 101° F.; in the sheep and pig, 103° F.; and in the hen and pigeon, 107° F.

fortably warm. This excess of heat is thrown off by wetting the surface of the body with perspiration. Here again is another example of the conservation of energy, since the heat is made to disappear as heat in doing the work of changing the liquid water of the perspiration into water vapor.

EXPERIMENTS AND DEMONSTRATIONS

I

Materials: Cellulose in the form of large slivers of soft pine wood; wide-mouthed bottles with tin or glass covers; matches; litmus paper, blue and red; saturated solution of lime water, filtered or cleared by settling; test tube; 12 in. piece of glass or rubber tubing, with about $\frac{1}{16}$ in. bore; 12 in. piece of glass tubing, $\frac{1}{8}$ in. opening, bent to S shape and fitted to a rubber stopper; hydrochloric acid, 1 part to 10 parts of water; sheet zinc; small deep tin pan with perforated tin shelf to serve as pneumatic trough; soap; ammonia; soda; cream of tartar; sweet and sour milk.

1) *Acid and alkaline reaction with litmus paper:*

a) Moisten both blue and red litmus paper with dilute hydrochloric acid. *Acid reaction.*

b) Moisten blue and red litmus paper with lime water. *Alkaline reaction.*

c) Moisten blue and red litmus paper with water. *Neutral reaction.*

d) Test various substances, as soap, ammonia, soda, cream of tartar and sweet and sour milk with litmus paper; arrange according to their reactions as acid, alkaline and neutral.

2) *Carbon dioxide manufacture:*

a) Burn cellulose in a wide-mouthed bottle by thrusting the lighted slivers under its partially raised cover, keeping the bottle covered as closely as possible in order to avoid the escape of the gas. Continue combustion until the wood will no longer burn. Remove sliver and cover bottle tightly. Note carefully every change taking place and write out observations.

b) Moisten with water a piece of blue litmus paper and drop it into bottle a). Note the change and make inference.

3) *Carbonate of lime manufacture:*

a) Pour a tablespoonful of lime water into the bottle of 2, b) and shake vigorously, keeping the bottle tightly covered. Note the changes and write out observations.

b) Pour 1 oz. of clear lime water into a clean bottle and blow the breath through it by means of a piece of small tubing. Or, blow breath into the bottle, cover and shake, repeating if necessary until the effect is produced.

4) Pour carefully a small amount of hydrochloric acid into bottles 2) and 3), so that it will run down their sides. Note the formation of bubbles of carbon dioxide again set free through the decomposition of the carbonate by the acid.

5) *Hydrogen manufacture:*

Place closely coiled strips of sheet zinc in a test tube until it is half full. Cover with dilute hydrochloric acid. Close with a perforated stopper containing S tube. Collect the hydrogen gas in an inverted bottle on the tin shelf of the pneumatic trough. Withdraw the tube while the gas is still coming freely and touch a lighted match to the end of the tube. Note the character and heat of the flame. Hold a piece of cold glass a short distance above the flame and note the condensation of water. Open bottle and apply lighted match.

II

Materials and apparatus: ½ oz. powdered chlorate of potash; ½ oz. manganese dioxide; sulphur; small piece of light iron wire or watch spring (broken springs from jeweller); small bits of magnesium, copper and zinc; splinters of pine wood; lime water; stick of phosphorus ½ to 1 in. long; matches or candle; ice or cold water; samples of soil; 6 wide-mouthed bottles about 8 oz.; 6 test tubes with 1 perforated cork or rubber stopper; several pieces of strong glass tubing, ⅛ in. opening, 12 in. long, bent to S shape and fitted to stopper; small deep pan with perforated tin shelf, to serve as a pneumatic trough; tin cup; scales capable of weighing ¼ grain or 1 centigram (decimal weights preferred); alcohol lamp or Bunsen burner; sheet tin.

1) *Oxygen manufacture:*

Put ½ teaspoonful each of chlorate of potash and manganese dioxide into test tube. Mix and close tightly with stopper carrying bent glass tube. Have ready pneumatic trough filled with water, in which several wide-mouthed bottles also filled with water are standing inverted over holes of perforated shelf. Place lighted lamp near trough. Gently heat lower end of test tube containing mixed chemicals over flame until gas begins to be given off. Insert open end of delivery tube under shelf of trough so that bubbles of gas will pass up into bottles and displace water in them. In this way, fill several bottles.

Caution: The heating must be continued uniformly, and when the gas begins to come very slowly the tube must be withdrawn from the trough quickly enough to prevent the cold water from being sucked back into the test tube.   The test tube should then be laid carefully upon something which it will not burn until it is cold enough to be washed out.

2) *Combustion in oxygen:*

a) Thrust end of a burning splinter of pine wood into one of bottles of oxygen covered with a piece of tin. Remove quickly, blow out flame and reintroduce wood with a live coal on its tip. Continue until wood will no longer burn. Test contents of bottle with lime water as in Exp. 3, a), part 1, and compare results with those previously obtained.

b) Heat end of iron wire and melt on it a drop of sulphur. Light sulphur and thrust it into a bottle of oxygen. Note rust (iron oxide) on sides of bottle.

c) Continue experiment by demonstrating combustion of small bits of magnesium, copper, zinc, etc.

3) *Nitrogen separation:* [1]

Make a wood float 1 in. by 1 in. by ½ in. thick. Upon this, place a sq. in. of sheet tin, on centre of which rest a piece of phosphorus the size of a pea. (The phosphorus should be cut under water and not handled.)   Float phosphorus boat on surface of water in pneumatic trough. Light phosphorus and immediately place over it upon tin shelf of trough an inverted

---

[1] This is really a method of oxygen elimination by phosphorus absorption. The oxygen combines with the phosphorus and the resulting oxide is absorbed by the water. The nitrogen is consequently left pure.

tumbler or wide-mouthed bottle filled with air, which should be steadied if it tends to tip. Note formation of phosphorus oxide (P_2O_5). Allow this to dissolve out, that nitrogen may be left pure. Then cover glass with tin, place it upright and test with lime water and with a burning stick. Compare with carbon dioxide.

4) *Water manufacture:*

Burn a match, or, better, a candle under bottom of a clean tin cup filled with ice water. Compare with result obtained in 5, part 1.

5) *Proportion of organic matter in soil:*

a) Weigh out 1 oz. of each sample of soil, as leaf mold and garden soil, and label each. Dry in oven for several hours, with heat low enough not to burn paper upon which they are placed. Reweigh and explain loss of weight.

b) Put dried samples in an iron spoon and place in a hot fire until samples have been at red heat for 5 or 10 min. Allow to cool and reweigh. What does loss of weight equal and of what does residue consist?

APPENDIX B

FIRST AID TO THE INJURED

Wounds.—Injuries which penetrate the skin in any way are called *wounds*. They should always be carefully dressed, since they remove the protecting coat of the body, the skin, and so afford entrance to the microbes which lie upon its surface or come into contact with it. These may be the microbes of such diseases as lockjaw (tetanus), abscesses and erysipelas. Many cases of tetanus arise each year as a result of some slight wound such as is often made by the exploding caps of toy pistols, which permits the tetanus germs lying upon the skin to enter. A wound, therefore, may not only be serious in itself but may produce serious results through the entrance of microbes.

The bleeding associated with wounds, if moderate in amount, is beneficial, since it washes away the microbes and has some power of checking their growth. Only, however, in case it is in sufficient amount can it be depended upon to protect the wound from germs. Even in this case, the skin about the wound may be the source of infection.

Treatment: The proper treatment of any wound involves, first, the stopping of the bleeding; and, second, the prevention of infection. If a large artery has not been cut, the bleeding should be stopped by applying a sterile compress (see Appendix C) and a firm band-

age, that the edges of the cut may be held close together. If a large artery has been cut, there should be immediately applied an elastic or other tight bandage between the wound and the heart at one or another of the points where the artery can be compressed (see p. 162). Unless it is certain that a wound is superficial, a physician should be called at once, since there may be internal bleeding of greater or less seriousness.

To prevent infection, it is necessary to get rid of the microbes lying upon the skin in the neighborhood of the wound. This is best accomplished by thoroughly scrubbing the skin with a clean brush and soap and then applying a disinfectant solution (see Appendix C). The person who bandages the wound should first have his hands similarly cleansed.

Bruises.—*Bruises* differ from wounds in that the skin is not broken. A combination of a broken skin and a bruise is called a *contused wound*. A bruise involves the crushing of tissues and blood-vessels with more or less internal bleeding. This usually works to the surface in a few hours and produces the dark color characteristic of a bruise. This changes to blue and gradually to yellow, as the pigment of the blood is absorbed.

Treatment: To prevent blood and lymph from collecting in the injured tissues and causing a swelling which retards healing, the bruised part should be immediately bound up tightly with a compress and bandage (see Appendix C).[1] Hot water or ice may be used as a partial substitute for the bandaging, since cold and especially heat cause contraction of the blood-vessels and thereby check bleeding. Gentle rubbing is also

[1] Care should be taken not to bind so tightly as to check the flow of blood in arteries and veins.

most effective in controlling the swelling, discoloration and pain, especially about the head and face.

Burns.—*Burns,* whether caused by fire, steam, hot water, acids and alkalies, or by cold, as in frost-bite, resemble wounds in that they remove the barrier to the entrance of microbes, by destroying the skin. They may also cause the irritation of extensive areas of nerve terminals and a consequently profound shock to the nervous system. There may further be an extensive absorption of the detritus of the wounded skin, through the lymphatics.

Treatment: In mild burns, where the skin is simply reddened, a moist paste of cooking soda is effective in relieving the pain. As a substitute, either a paste of starch or flour, vaseline, sweet oil, lard, or cream may be used. In more severe burns where the skin is blistered, the blisters should be emptied through small punctures made with the point of a knife or needle which has previously been sterilized.[1] The treatment should then be the same as for a mild burn. In still more severe burns where the skin is destroyed, the skin surrounding the burn as well as the hands of the operator should be disinfected. To allay the nerve irritation, soothing applications of sterilized oil should be used.

Acids and alkalies.—Burns by acids and alkalies require special treatment, because the acid or alkali may continue to destroy the skin if allowed to remain upon it. To remove these chemicals, water should be allowed to flow freely over the injured parts before any other treatment is attempted. As a further precaution in case of burning by an acid, it is well to apply a thin paste of cooking soda, that any remains of the acid may be

---

[1] Held in boiling water or in alcohol, or heated red hot in a flame and allowed to cool.

neutralized thereby. In case of burning by an alkali, vinegar should be substituted for the soda. The subsequent treatment should be that prescribed for burns.

Frost-bite.—The skin frozen by extreme cold should first be gently rubbed with water from melting ice or with melting snow. This treatment should be continued for several hours, in order to avoid the intense inflammatory reaction which is apt to follow freezing. If, in spite of this treatment, the skin becomes inflamed, it should be treated as a burn.

In all cases of severe burns, a physician should be immediately summoned, since a burn which involves as much as a quarter of the skin of the body may be quickly fatal.

Sprains.—*Sprains* are another frequent form of injury and are usually due to a wrenching force applied to a joint. As we have seen in our study of ligaments, a sprain usually involves some tearing of the ligaments about the joint. In severe cases, it may even involve the breaking off of portions of the bones to which the ligaments are attached.

Treatment: The immediate treatment for a sprain is in general similar to that for a bruise, as the laceration of the tissues leads to bleeding, swelling and pain. In addition to such treatment, a splint (see Appendix C) should be applied to the joint, to prevent pain and the possibility of further injury. Sprains should always be examined by a physician, that the extent of the injury may be definitely determined in the beginning. Serious disability has not infrequently arisen from a neglected sprain, especially of the ankle.

Dislocations.—*Dislocations* are ordinarily due to the same causes as sprains. The wrenching force must be

strong enough, however, to tear away sufficient of the protecting ligaments to allow the ends of the bones to slip by each other. Dislocation can ordinarily be easily detected by the deformity and stiffness of the joint.

Treatment: A physician should be called at once, as it usually requires experience to replace the bones. There should be no unnecessary delay, as the subsequent swelling makes the operation more difficult. Pending the physician's arrival, the dislocated joint should be protected by support upon a high pillow, in as comfortable an attitude as possible. If a physician cannot be got within an hour or so, and if the dislocation is fairly simple, as that of a finger, an ankle, or a shoulder, an attempt should be made to reduce it by pulling the limb, finger, or foot strongly in the direction of its length, with the injured part held in its normal position. Reduction takes place with a snap, which is easily recognized.

Fractures.—*Fractures* are more frequent than dislocations but ordinarily are not more serious. They usually involve the bones of the limbs, the collar bone, or ribs. Fractures of the spine, pelvis and skull are comparatively rare. A fracture can usually be easily recognized because the fractured bone becomes movable where there is no joint. The ends of the bones when moved upon each other give a characteristic grating feeling. Perforation of the skin may also be caused by the force which produced the fracture or by the projection of the bones through it, in which case the fracture is said to be *compound*. Compound fractures are usually much more serious than simple fractures, as there is a probability of infection.

Treatment: As in a dislocation, a physician should be called at once. The treatment depends largely upon

the nature, location and severity of the fracture and the surroundings of the patient. In general, the wounded part should be disturbed as little as possible, if a physician can be secured. For examination, the clothing should be cut, if to remove it means to disturb the injured part. The location and nature of the injury should then be determined by a careful and systematic comparison between the injured limb and its mate as to length, deformity and mobility. If, after the fracture has been located and the extent of the injury determined, it is considered necessary to move the patient, it should be done with the least disturbance of the fracture possible. If one of the legs is injured, the person should be placed upon a stretcher (see Appendix C), shutter, or door. If one of the arms is fractured, it should be supported by splints and put up in a sling (see Appendix C). If the collar bone is fractured, the arm on that side should be put up in a sling, in order to relieve the shoulder of its weight. A simple fracture of the ribs permits walking or riding, except where blood is coughed or spit. In that case, the broken rib has punctured the lung and absolute quiet is essential.

In case a physician cannot be secured, an attempt should be made to set the bone. In case of a simple fracture, the limb may be straightened to the length of its mate by pulling it very gently and evenly in the direction of the part nearest the body. It should then be carefully brought to a position as similar to the natural one as possible and supported by pillows. Temporary splints made of canes, laths, or umbrellas padded with cotton or cloth, may then be applied, or folded sheets or pillows bandaged on. In case of a compound fracture, there should also be antiseptic treatment, similar to that in the case of a wound. If there is bleed-

ing copious enough to show that an artery has been cut, it will be necessary to apply pressure to check it.

Poisons.—Another frequent source of injury to the tissues or of interference with their functions is found in certain substances which are commonly known as *poisons*. These may be taken into the body from with-out, as in the case of drugs and chemicals; or they may be developed in the body itself by the action of microbes, as ptomaines and toxins.

Drugs and chemicals.—Among drugs and chemicals, there are several types of poison which differ widely in their effects upon the body. Some destroy tissue, as strong acids and alkalies, and are called *corrosive* or *irritant* poisons. Others, as opium with its deriva-tives and alcohol, produce their harm by benumbing the nervous system and are therefore known as *narcotic* poisons. A third type, as strychnia, excites the nervous system so much as to destroy its control of the body and thereby cause convulsions. Poisons of this kind are therefore called *convulsive*. The effects of drugs and chemicals are sometimes very quick or again so slow as to extend over weeks and months, depending largely upon their nature and the quantities in which they are taken. Since many of the substances in common use in the household, such as disinfectants, insect powders and the like, are, when taken into the body, violent poisons, every one should be acquainted with them and their antidotes.

General treatment:

1) Send for the nearest doctor.

2) Produce vomiting by the use of:

Finger or feather for tickling the throat.

Mustard water, tablespoonful of mustard in tumbler of tepid water.

Salt water, tablespoonful of salt in tumbler of tepid water.

Copper sulphate, 10 grs. in 2 oz. of warm water.

Zinc sulphate, 20 to 30 grs. in half a tumbler of tepid water.

Ipecac, 2 tablespoonfuls of the wine or syrup.

Caution: Emetics are useless unless taken immediately after such substances as opium, morphine, carbolic acid, aconite, cocaine, or strong acids and alkalies, which either cause anesthesia of the throat and stomach or destroy their tissues.

3) Give antidotes:

Chemical (see Special Poisons), in order to destroy the power of the poison.

Physiological, in order to increase the power of the heart and to overcome weakness and depression:

a) Give stimulants, such as,

Aromatic spirits of ammonia or *common ammonia,* tablespoonful in half glass of water; frequent small doses.

Pure grain alcohol, 1 or 2 teaspoonfuls in warm water.

Coffee in strong solution.

Vapor of ether inhaled or 1 teaspoonful in warm water.

Tincture of nux vomica, 5 to 10 drops in water.

Strychnia, $\frac{1}{20}$ to $\frac{1}{60}$ gr.

Caution: Since stimulants are not absorbed from the stomach if there is much corrosive action, as in the case of strong acids or alkalies, they should be given by the rectum.

b) Apply heat by means of warm blankets, hot water bottles, bricks, etc. *Caution:* In case of loss of consciousness, be especially careful to apply nothing hot enough to cause a burn.

c) Give massage, rubbing toward the heart, in order to aid the venous return. Keep the patient in a horizontal position, or, in case of profound depression, with the head and chest lower than the rest of the body. Sudden raising of the head should always be avoided in anyone who is weak. *Caution:* In case of snake bite, avoid rubbing, since it tends to scatter the poison (see p. 335).

d) Give diluents, as water, or any harmless fluid, in order to dilute and thereby weaken the power of the poison as well as to delay its absorption.

e) Give demulcents, as milk, white of egg, or boiled starch, if the poison is corrosive or irritant, in order to coat over the

poison, to form a protective coating for the stomach, or to entangle the poison by coagulation.

COMMON POISONS AND THEIR ANTIDOTES:

Irritant poisons (more or less corrosive):

1) Arsenic (Paris green, Fowler's solution, arsenious acid, and certain vermin killers).

Antidote: Precipitated oxide of iron. If this cannot be immediately obtained, give moistened plaster of wall which will mix with the poison and serve to protect the stomach.

2) Phosphorus (matches, Rough on Rats).

Antidotes: Emetics and magnesia or plaster from wall. *Caution:* Do not give oily substances, as milk.

3) Corrosive sublimate (mercuric bichloride, bug poison).

Antidotes: Emetics and white of egg.

4) Iodine (tincture).

Antidote: Boiled starch, rice, etc.

5) Lead (paints, hair dyes).

Antidotes: Sulphates (Epsom salts, Glauber's salts, alum), emetics, etc.

Corrosive Poisons:

1) Acids (sulphuric, hydrochloric, nitric).

Antidotes: Emetics and dilute alkalies, such as lime water, soap solution, tooth powder, chalk, or plaster of wall, followed by demulcents.

2) Carbolic acid.

Antidotes: Emetics, water and sulphates (Glauber's or Epsom salts or alum).

3) Oxalic acid.

Antidotes: Lime or chalk with stimulants given as needed.

4) Alkalies (caustic soda, caustic potash, ammonia).

Antidotes: Dilute acid, vinegar, hard cider, lemon or orange juice, followed by demulcents.

Narcotics:

1) Opium [1] (laudanum, paregoric, morphine, black drops, soothing syrups, cholera mixtures, Dover's powder).

Antidotes: Solution permanganate of potash, 2 grs. dis-

---

[1] In opium poisoning, a distinguishing symptom is pin-head contraction of the pupils of the eyes.

solved in water; tannic acid; strong hot coffee; strychnia, $\frac{1}{20}$ to $\frac{1}{10}$ gr.

Keep awake by non-exhausting means, such as flicking with a damp towel, shouting in ear, and making walk. Keep warm with hot water bottles, blankets, etc. Perform artificial respiration, if necessary.

2) Chloral hydrate (chloral, knock-out drops).

Antidotes: Emetics, stimulants, ammonia.

Keep body warm with head low. Keep patient awake. Perform artificial respiration, if necessary.

3) Alcohol (drunk)[1]:

Antidotes: Hot coffee and dilute ammonia in small repeated doses. Apply first hot and then cold water. Keep patient warm.

Ptomaines and toxins.—*Ptomaines* and *toxins* arise, as we have seen, from the decomposition of animal and vegetable matter due to the activity of microbes. They may be found in food materials which have not been preserved by cold and even in some, as in ice cream, which have been so preserved. The symptoms of the poisoning are characteristic and include headache, purging and vomiting, fever and abdominal pain.

Treatment: A doctor should be called at once. The patient should not be allowed to eat but should have plenty of hot water to drink. If a doctor cannot be got without delay, 2 tablespoonfuls of castor oil, a dose of Epsom salts, or a Seidlitz powder should be given, in order to clean out the bowels and intestines. The doctor can then complete the treatment.

Stings of insects.—The poison injected by *insects* varies with the nature of the insect. In some cases, as in the stings of wasps and bees, the poison is irritant and results in pain and swelling but is not dangerous

---

[1] Wood alcohol and denatured alcohol, which contains wood alcohol, are extremely dangerous poisons.

when in moderate amount. In other cases, as with scorpions and tarantulas, the poison is often sufficiently virulent to be dangerous. In still others, as with certain mosquitoes, bedbugs and fleas, the poison may be in the form of microbes which infected the insect when it bit a diseased person.

Treatment: The treatment varies with each case. For the milder forms of insect bite, a strong solution of ammonia, if applied at once, is fairly effective. The more dangerous forms of poison introduced by scorpions and tarantulas, should be treated like poison from snake bites.

Snake bite.—Still another form of poison is that injected by certain kinds of *snake,* such as the rattlesnake, moccasin and cobra. The poison is especially virulent and takes effect so quickly that the treatment must be immediate.

Treatment: Tie a tight bandage around the limb just above the bite, to prevent the transmission of the poison through the body. In this way, the poison is localized in the limb and its effect upon the body as a whole is avoided. Freely slash the skin in which the bite lies, penetrating deeper than the wound, in order to induce a copious bleeding which will wash the poison out of the tissues; or, burn out the bite with a red-hot iron. Give stimulants as needed to support the strength and prevent shock, but be careful not to make the patient drunk with alcohol, as this tends to increase the paralyzing effect of the poison. A physician should of course be called as quickly as possible.

Dog bite.—The bite of a *mad dog* should have the same treatment as a snake bite.

Loss of consciousness.—*Loss of consciousness* is a common symptom for many conditions and injuries, such

as fainting, children's convulsions, epileptic attacks, apoplexy, sunstroke, injury of the brain, drowning, and poisoning by illuminating gas, carbolic acid, opium and alcohol. In order to assist a person who is unconscious, one must know the nature of the trouble. Ordinarily, it is possible to discover this and by rendering assistance to prevent more or less serious consequences.

Treatment: The general treatment for unconsciousness may be begun while an examination as to its cause is being made. A physician should be sent for at once. The patient should be placed upon his back and the clothing about throat and chest loosened. Give him plenty of fresh air and, if the breathing has ceased although the pulse is still felt, apply artificial respiration. Do not give stimulants if the face is flushed or the pulse is strong; in case of brain injury, they may even cause further injury of the brain tissue by continuing the hemorrhage. If the temperature of the body is raised, apply wet cloths or ice.

In making an examination, note if there is fracture of bones, including ribs, collar bone and skull. Run the fingers down the spine and determine whether there is dislocation or fracture. Lift the lids of both eyes and see whether they are dilated, contracted, or equal in size. In opium and morphine poisoning, they are contracted; in brain injury, they may be dilated or unequal in size. Determine also whether there is an odor to the breath which suggests alcohol, ether, or chloroform. Note whether there is any discoloration of the lips, showing the use of strong acids or alkalies.

Fainting.—In *fainting,* the face and lips lose their color and the pulse is weak.

Treatment: Place the patient upon his back, with the head and chest lower than the rest of the body. If there

is vomiting, place him upon his side. Apply smelling salts, or give ammonia or strong coffee. Insure plenty of fresh air by fanning, and avoid excitement.

Convulsions.—Children frequently lose consciousness through *convulsions,* as a result of improper diet, fever, worms, constipation, etc.

Treatment: Keep the child from injuring himself. Put him into a warm bath or wrap him in a blanket dipped in hot water. Keep the head cool by applying cold water or ice. If the convulsions continue, give an emetic, as a teaspoonful of syrup of ipecac, if the child can swallow. Assist vomiting by thrusting the finger down the throat or by using a feather. Give injection of soap and warm water, as the seat of irritation may be in the lower bowel.

Epileptic attacks.—*Epileptic attacks* may come on suddenly, or gradually with symptoms which the patient recognizes. Loss of consciousness may be accompanied by a peculiar cry, sudden pallor of the face and more or less stiffening of the body. The tongue is sometimes bitten and the eyes have a peculiar upward rolling motion. An attack usually lasts for a minute or two only, but several attacks may follow each other rapidly.

Treatment: Keep the patient from injuring himself, but do not struggle with him. Allow him to lie flat, and put a piece of folded cloth between the teeth to prevent biting of the tongue. The muscular contractions if prolonged give rise to exhaustion and lameness, but these may be lessened by putting the patient into a bath of warm water. After the attack put him to bed and if necessary use stimulants in small quantities.

These attacks are seldom serious, and it is usually unnecessary to do anything except prevent bodily injury.

Apoplexy.—*Apoplexy* is seldom found in persons under forty years of age. It is due to bleeding from a ruptured blood-vessel in the brain and consequent pressure of the blood upon the brain tissue. The nerve cells or nerve fibres when pressed upon, cease to perform their functions and more or less unconsciousness and paralysis result. The face is flushed, the pupils of the eyes more or less dilated and perhaps unequal in size, the breathing slow and noisy, the cheeks puffed out and drawn in with the air movement and the pulse slow and full. There may be convulsions and vomiting. An important symptom is one-sided paralysis. Notice whether the face is drawn to one side (away from the paralyzed side) or the head kept on one side.

Treatment: Keep the patient absolutely quiet, lying down, the head moderately raised. Apply cold water or ice to the head and heat to the lower limbs. If the patient can swallow, give castor oil or a dose of salts. The bowels may be emptied by giving an injection of soap and warm water. *Do not give stimulants.*

Sunstroke.—When working on a hot sunny day, or on warm days when the air is full of moisture, persons are sometimes overcome with the *heat,* having headache, weakness and difficulty of vision. The individual quickly becomes unconscious, and may even fall so as to be injured. The body is usually hot to the touch, the skin dry, the face flushed, the pulse full and rapid, but there may be coldness, pallor and weak pulse. Twitchings of the body may also be noticed.

Treatment: Reduce the heat of the body as rapidly as possible by throwing cold water over the patient and applying ice to the head. Strip the body and wrap it in a sheet kept wet by frequent applications of water. Continue until consciousness is regained or the temperature of the body is lowered. Do not send the patient

to his home or to a hospital until after the treatment has been begun. If the patient does not exhibit symptoms of high temperature, but shows pallor of face and weak pulse, do not use cold applications, but give rest, quiet, food and stimulants in cautious amounts.

Brain injury.—Any injury to the *brain* results in symptoms similar to those of apoplexy. In addition, there may be bleeding from one or both ears and even from the eyes, nose and mouth, due to the fracture of the skull. The *treatment* is also similar to that of apoplexy.

Suffocation and drowning.—Cases of *suffocation* and *drowning* can ordinarily be recognized as such and the proper measures for relief promptly undertaken.

Treatment: If the natural breathing movements have ceased, as is frequently the case when a person is rescued from drowning, artificial respiration should be applied at once. Turn the person on his face, clasp your hands under the lower chest and raise him from the ground; the pressure upon the lower chest will compress the lungs and tend to empty them of water. Repeat two or three times, taking care not to injure the face by rough handling. Do not, however, delay artificial respiration in the attempt to remove all of the water.

Artificial respiration.—*Prone pressure method (Schafer).*—Wipe out the patient's mouth. Kneel by the side of his hips and place hands over the lower ribs. Throw your weight forward so as to press strongly though gradually upon both sides of the lower ribs for a space of about 3 seconds. Remove pressure entirely for 3 seconds. Again apply pressure as before and release. Keep this up at the rate of 10 or 12 times per minute, until the patient shows signs of recovery. If, at the end of 2 hours or more, the patient does not recover and there is no perceptible heart beat, the case may be considered hopeless.

After 5 or 10 minutes of artificial respiration, it may be best, if in winter, to remove the patient to a warm place. During the time of removal continue, if possible, artificial respiration and especially rhythmic pressure in the region of the heart every 1 or 2 seconds, since this

FIG. 153. Prone pressure method of artificial respiration—showing, first, position of relaxation (inspiration); second, position of pressure (expiration). (After Schafer.)

may tend to keep the blood in circulation and carry aërated blood from the lungs to the tissues. Artificial respiration should be continued for 1 or 2 hours if necessary, as there is always hope of saving a person's life if the pulse or heart beat can be detected. Persons have been saved after being under water as long as 12 or 15 minutes.

In addition to artificial respiration, a hot water bottle may be applied to the heart to stimulate its action; and warm (105° F.) water may be injected into the rectum, to aid in restoring the heat of the body. Hot cloths, hot water bottles and hot bricks should be freely used as soon as possible, care being taken to avoid burns. Stimulants may be given by the mouth, if the patient is able to swallow; if not, they may be given by the rectum, in which case they will be absorbed and carried by the blood to the respiratory and cardiac centres.

After the crisis is past, shock should be avoided by keeping the patient quiet in bed, and his strength should be built up by the use of food and stimulants as needed.

Gas poisoning.—Poisoning by *illuminating* or *coal gas* results in headache, dizziness, ringing in the ears and gradual loss of consciousness. The skin is pale and bluish and the respiration irregular.

Treatment: Remove the patient into the fresh air. Dash cold water into the face, slap the chest, and tickle the nose. Hold ammonia under the nostrils or take the tongue in a dry handkerchief and every 4 seconds draw it out with moderate force. If these measures fail to re-establish breathing, artificial respiration must be immediately undertaken.

Choking.—Unconsciousness may further be due to *choking* or *suffocation.* Choking is usually due to the presence of objects too large to be swallowed, which become wedged against the larynx and thereby interfere with the passage of air. It may also be due to the presence of foreign bodies in the air passages, or to irritating gases the inhalation of which causes spasm. The result may be more or less complete but usually temporary suffocation. Distress and violent coughing are prominent symptoms.

Treatment: Strike the patient strongly with the flat of the hand on the back. Lay him on a bed or chairs with the head and upper part of the chest hanging over. Let him take a full breath and then press on his back as the air goes out. In a child, raising by the feet may aid in dislodging the object. If ineffective, do not waste time, but pass the finger down the throat, taking the precaution to insert a folded handkerchief between the teeth to avoid being bitten. An ordinary finger is long enough to reach to the larynx, and the object may be felt and removed. An emetic of mustard water is sometimes effective if the object has not passed too far. Avoid exhaustion of patient in the attempts at removal, since

objects which can pass through the esophagus by the larynx usually do no harm, if they are assisted in their passage by masses of food with large waste, as potato and turnip.

Croup.—At times, children are taken suddenly with *croup*,[1] the symptoms of which resemble those of choking. Give the child warm water, or, better, a teaspoonful of syrup of ipecac, and repeat until vomiting occurs. Apply hot water, ice, or mustard plasters to the throat. Send for the doctor.

[1] What used to be known as malignant croup is now recognized to be diphtheria.

APPENDIX C

PRACTICE IN FIRST AID

In order to render effective first aid, a certain amount of practice in the application of bandages, compresses, splints and slings and in the proper handling of the body when injured, is necessary. To this must be added a practical knowledge of the methods of disinfecting wounds.

Triangular bandage.—There are three principal forms of bandages with which a first-aid student should be familiar, namely, the triangular,[1] the roller and the four-tailed. The *triangular bandage* is made of fairly stout sheeting in the form of a triangle. The simplest way to make it is to take a piece of cloth from 30 to 36 in. square, and either to fold or cut it along the diagonal. This bandage is most useful as a protective bandage or to hold a compress in place but ordinarily is not very effective in applying pressure.

Roller bandage.—The bandage which applies pressure best is the *roller bandage*. This consists of a strip of cheesecloth 1 to 5 in. wide and from 4 to 10 yds. long, which is rolled tightly. To apply the roller, grasp it in the right hand so that the loose end points toward

[1] An excellent triangular bandage on which are printed the methods of applying, can be obtained for 10 cents from The Society for Instruction in First Aid to the Injured, 105 East 22d Street, New York, or from The Health Education League, 113 Devonshire Street, Boston. The directions for use are given so simply by means of illustrations on the bandage that they are omitted from this discussion. It is hoped that each pupil will own one of these bandages.

the left as it comes from underneath the roller. With the thumb of the left hand, gently hold the loose end upon the part to be bandaged. At the same time, run the roller around the limb and bring it firmly over the thumb which holds the loose end, so that when the thumb is withdrawn the loose end remains in place. Continue to roll the bandage upon the limb, keeping it taut so that it will not slip or give uneven pressure. After the bandaging is complete, double under the end and fasten

Fig. 154. A and B, Four-tailed bandage as applied to the head. C, Handkerchief bandage as applied to the chin in case of injury to the lower jaw.

it with a small safety pin, or split the end and tie the parts together around the limb. In applying the bandage, too severe pressure must be avoided, as otherwise the circulation may be stopped and even gangrene eventually result if the bandage remains on long enough. To test the amount of pressure, examine the limb after the bandage has been on for an hour or so. If it shows swelling beyond the bandage or is cold and bluish, the bandage is too tight and should be loosened. The roller bandage will be found to be more generally useful than any other.

Four-tailed bandage.—The *four-tailed bandage* is made of a piece of cotton cloth about 36 in. long and

from 6 to 10 in. wide, the two ends of which are slit equally toward the middle, leaving only about 6 or 8 in. intact. It is most useful for bandaging the head and should be applied as shown in the accompanying illustrations.

Compress.—*Compresses* are made of 10 to 15 layers of cheesecloth or soft sheeting, of the size necessary to cover the part, except in those cases where it is easier to use several compresses of a smaller size. They may be used dry for pressure, or moistened with hot water or antiseptic solutions. Compresses are used to apply pressure, heat, or medication to sprained joints or injuries where the skin is not broken. In case of wounds, the compresses may be freed from microbes (sterilized) by baking to a light brown in an oven or by steaming for fifteen minutes. They may then be safely applied to the cut surface to check bleeding and to prevent infection.

Splints.—*Splints* consist of light pieces of wood, cardboard, or any other stiff material. When bandaged on,
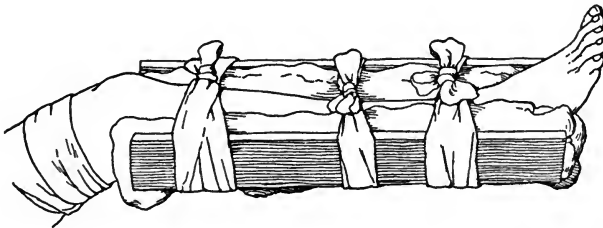
Fig. 155. Padded splints applied to fractured leg for temporary support.

they serve to hold broken bones and sprained or dislocated joints in place and thereby relieve pain and prevent further injury. The accompanying illustrations show several methods of utilizing splints. It will be

seen that the essential point is to give such full support
that the movements of the patient will not jar the in-
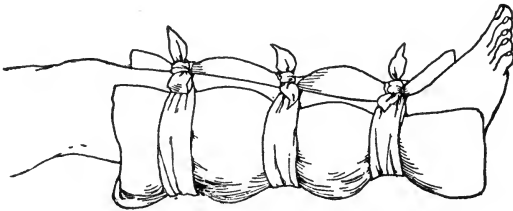
FIG. 156. Pillow used as an emergency splint.

jured part. In bandaging the splint, care must be
taken to avoid such pressure as would interfere with
circulation.

Sling.—When the arm or shoulder is injured, it is
important to support the weight of the arm. For this
purpose, a *sling* is used, which consists of a large tri-

FIG. 157. Sling as arranged for left arm.

angle of cloth of sufficient length to permit the forearm
to hang in a horizontal position. The middle of the
base of the triangle is placed at the finger tips, while
the apex lies behind the elbow. The long ends are then
carried around the neck, the outer one toward the farther

shoulder, and are tied behind the neck. The apex is pinned behind the elbow.

Stretcher.—A *stretcher* on which to carry an injured person may be made of two stout poles, 7 to 8 ft. long, slipped through hems in the sides of a piece of canvas 6 ft. long by 16 in. wide. As a substitute for the canvas in an emergency, two coats buttoned together over poles may be used. A wide board, door, shutter, or similar object may also be substituted. If nothing of this sort is available, it is possible for a number of persons so to carry an injured man as to avoid increased injury and pain. In this case, no part should be allowed to sag and there should therefore be as many supporting points as possible. The lifting should be done by all simultaneously, so that jar is avoided.

Disinfecting solutions. — For the *disinfection* of wounds, several antiseptics are available, such as *corrosive sublimate,* of the strength of 1 part to 1,000 parts of water; *lysol* in a 3 per cent solution, made by adding ⅔ of a cup of water to a teaspoonful of lysol; *carbolic acid* in a 3 per cent solution made similarly to lysol; *sulpho-naphthol* (*creolin*) in a 3 per cent solution, similarly prepared; and *peroxide of hydrogen* used full strength as sold by druggists. In the absence of other antiseptics, alcohol diluted with half as much water may be used. Washing soap is antiseptic to a certain extent and may be used in strong solution for thoroughly scrubbing around the wound.

Of these disinfectants, the best for use in wet compresses are corrosive sublimate, 1 to 2,000; lysol in a 3 per cent solution; and creolin, also in a 3 per cent solution. Carbolic acid should never be used, as it may exert corrosive action upon the skin.

APPENDIX D—TABLE OF INFECTIOUS DISEASES

	Incubation period av. ; range	Usual first symptoms	Cause (Mode of entry)	Length of quarantine (for schools[1])
Cholera[3]	3 ds.; 2-7 ds.	diarrhœa, weakness.	spirillum (food and water, carried by flies).	
Diphtheria[3]	2 ds.; 2-15 ds.	fever, pain on swallowing, whitish patches in throat, acrid discharge from nose.	bacillus (air, food, contact).	until 2 negative[2] cultures from nose and throat 48 hrs. apart.
Erysipelas	5 ds.; $\frac{1}{2}$ hs.-22 ds.	chill, fever, red swelling on face or neck.	streptococcus (wounds, etc.).	
Influenza	3 ds.; 1-5 ds.	fever, weakness, backache, etc.	bacillus (air, contact).	
Mumps	15 ds.; 7-30 ds.	swelling of parotid gland, fever.	unknown (air, contact).	1 week after all swelling and tenderness are gone.
Malaria	8 ds.; 4-60 ds.	chills, fever, sweating, and weakness every 1, 2, or 3 ds.	hæmatozoa (inoculated by mosquitoes).	
Measles	9 ds.; 4-14 ds.	head-cold, white blisters in mouth near molar teeth, eruption (blotches) on face.	unknown (air, contact).	after all peeling is over and bronchitis is cured.
Hydrophobia	40 ds.; 13 ds.-2 ys.	rigidity of neck and jaws, spasm on swallowing.	uncertain (wounds).	
Scarlet fever	4 ds.; 7 hs.-7 ws.	fever, sore throat, vomiting, eruption (scarlet flush).	uncertain (air, contact, wounds).	until all fever and all discharge from nose and ears have ceased.
Small-pox	12 ds.; 7-15 ds.	chill, fever, vomiting, headache, backache.	uncertain (air, contact).	until all crusts are gone.
Tetanus (Lockjaw)	2 ds.; $\frac{1}{2}$ hs.-35 ds.	chill, rigid neck and jaws.	bacillus (wounds).	
Typhoid fever[5]	14 ds.; 2?-21 ds.	weakness, nosebleed, headache, fever.	bacillus (food, water, carried by flies).	
Chicken-pox	14 ds.; 10-19 ds.	scattered eruption (pimples, then blisters) on face and scalp, fever, etc.	unknown (air, contact).	until all crusts are gone.

Disease	Incubation; Duration	Symptoms	Cause (Mode of transmission)	Length of quarantine[1]
Whooping-cough	8 ds.; 2-10 ds.	a cold with peculiar cough resulting in vomiting.	unknown (air, contact).	until cough has stopped.
Yellow fever	3 ds.; 2-6 ds.	chills, headache, fever, vomiting.	unknown (injected by mosquitoes).	
Tuberculosis	? long.	weakness, wasting, fever, cough (?), enlarged glands, chronic pimples, bone and joint inflammation.	bacillus (air, food, etc., wounds).	while cough persists.
Pneumonia	1 d.; ?-2 ds.	chill, fever, pain in chest.	coccus (air, contact).	until cured.
Dysentery[3]	6 ds.; 1-8 ds.	diarrhœa, pain in rectum.	ameba or bacillus (water and food, carried by flies).	until cured.
Conjunctivitis (Pink-eye)	short.	redness and discharge from eye.	various bacteria (air (?), contact, use of infected towels, etc.).	until cured.
Trachoma	long.	granulations of inner surfaces of eyelids.	unknown (contact, use of infected towels and clothing).	until cured.
Scabies (Itch)		itching and sores on skin from scratching	animal parasite (contact, use of infected towels and clothing).	until cured (whole family must be treated).
Pediculi (Lice)		itching, eggs on hairs, lice in hair.	animal parasite (contact, use of infected towels, clothing, brushes, combs, etc.).	until cured.
Ringworm		circular, rough, scaly patches on skin which spread at edges and clear at centre.	vegetable parasite (contact, use of infected towels and clothing).	until cured.

D=day; h=hour; m=month; w=week; y=year; contact may be either direct or intermediate (when objects infected by the touch of a diseased person are handled); air is contaminated by organisms carried in it as dust or by fine particles of discharges which float in it after coughing and sneezing.

[1] Lengths of quarantine as suggested by the Medical Committee appointed by the Massachusetts Board of Education, 1907.

[2] A negative culture is one in which no bacilli are found.

[3] A person who has this disease so lightly as to be able to be about or whose recovery has not been proved by negative cultures may through carelessness act as a "carrier" of the germs and thus infect others during a long period subsequent to apparent recovery.

INDEX