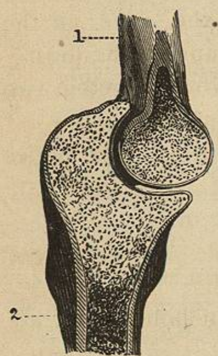
CHAPTER XXXVIII

JOINTS

651. Kinds of joints. — The union of two bones is called a *joint*. Some bones grow together and form a single rigid bone, while others are joined together only by loose fibrous tissue which permits the joints to bend freely. Between these two extremes, joints possess all gradations of movement.

652. Inflexible joints. — Some bones of the skull are joined together by cartilage during childhood. Later in life, when growth ceases, the cartilage becomes bone and unites the two bones into a single one.



Hinge joint of the elbow.
1 humerus. 2 ulna.

Other bones of the skull are dovetailed with each other, so that while they can move slightly, they cannot be separated. The thick bones of the top of the skull are united in this way.

Between the separate bones of the pelvis and between the vertebræ there are large pads of fibrous tissue, almost like cartilage. These pads permit slight movements between the bones and so prevent jarring during violent movements of the body. They are usually stronger than bone itself, so that, by pulling or bending, the bones will be torn apart rather than the pads.

Between the ends of the ribs and the sternum there are cartilages of the shape of the ribs. In old age they often take up lime and become real bone.

653. Flexible joints. — The joints of the head and trunk of the body are mostly inflexible, while those in the limbs permit very free movements of the bones. In flexible joints the bones are held together by a strong fibrous membrane called a *ligament*. The ends of the bone are smooth and rounded so as to move freely upon each other.

In some joints the movements are simply forward and backward like a hinge. The fingers, toes, elbows, knees, and ankles are hinge joints.

In some joints the movements can be made forward and backward and sideways like a ball in a socket. The thumbs, great toes, shoulders, and hips have this kind of a joint. In each the end of one bone is spherical and fits into a hollow socket in the other.

In other joints one bone can only rotate about another as a pivot. In its union with the spine, the skull turns about a fingerlike projection upon the top of the second vertebra. At the elbow, the upper end of the radius turns in a socket upon the side of the ulna through half a circle of revolution.

654. Structure of joints. — In all flexible joints the ligaments pass from bone to bone, like a collar upon the outside of the bone, enveloping a cavity which is lined with a thin and smooth membrane, called *synovial membrane.* The synovial membrane secretes a fluid like the white of an egg, called the *synovial fluid.* The fluid moistens and lubricates the joint so that it turns smoothly and easily. If it is absent the joint creaks when moved.

655. Loose joints. — The two bone surfaces of each joint fit together accurately. There is a considerable difference in the depths of the joint sockets and in the lengths of the ligaments in different persons. In some persons the sockets are shallow and the ligaments long, so that the joints can be bent to a far greater degree than usual. These persons are able to twist and contort themselves into strange positions and shapes, and thus they make good circus actors.

656. Action of muscles as ligaments. — Nearly every joint is crossed by muscles. By their pressure the muscles aid in keeping the bones in place. In addition, when one muscle acts, those upon the opposite side of the joint also contract enough to prevent the head of the bone from being drawn out of its socket.

If all the muscles and cords about a joint are cut, the ligaments stretch and the joint becomes loose and flabby. If the ligaments are cut while the muscles and cords are left, the joint remains snug and firm.

657. Effects of pressure. — After being kept in an unnatural position for some time, joints tend to retain the deformity. In wearing tight shoes, the great toes are bent outward, while the little toes are bent inward. If the joints are kept in this position day after day for years, they remain permanently fixed in the deformed position. The great toe joint may be tender, forming a *bunion*.

658. Curvature of the spine. — The spine is naturally straight from side to side. Strong muscles aid in keeping the head erect and the shoulders thrown well back. By weakness of the muscles or by carelessness the shoulders fall forward, increasing the natural curve of the spine so that a person becomes *round shouldered*.

If a child habitually sits sidewise at the desk, leaning continually upon one arm, the growing bones and the ligaments of the spine will gradually become fixed in the deformed position, which persists all through life. Any person who, in his occupation, always assumes the same attitude, may finally be unable to remove the curvature from his spine. On the other hand, if one acquires a habit of sitting and walking and working in an erect position, the spine will grow in a natural curve.

659. Sprains. — When a joint is bent to a greater extent than is natural, the ligaments and muscles are stretched and often torn. Then there will be great swelling and pain. When this accident happens, the joint should at once be put in water as hot as can be borne, while more hot water is added from time to time to keep up the temperature of the water. The joint should have rest for some time after the injury. Recovery is apt to be slow.

660. Dislocations. — When the bones of a joint are forced apart, the joint is *dislocated*, or *out of joint*.

In a dislocation, the ligaments are always torn. Then bleeding will take place, and there will be great pain and swelling, while only slight movements of the limb will be possible.

In a dislocation, the muscles around the joint are irritated, and so contract and hold the bone away from its socket. Often it is necessary to make a person insensible with ether before the muscles will relax enough to get the joint in place.

When a joint is dislocated, the limb should be kept as quiet as possible by binding a splint above and below the joint, as in a broken bone.

661. Inflammation of joints. — Sometimes the synovial membrane becomes inflamed and pours out a quantity of thin fluid which distends the joint and produces great pain. In rheumatism this often occurs. Sometimes a blow or a wrench may cause it.

Sometimes waste matter of the body is deposited in the synovial membrane and cartilage. This produces great pain and tenderness and constitutes an attack of *gout*. The great toe joint is especially liable to this disease.

Sometimes the cartilage and ends of the bone become distorted and rough, or form hard swellings. Then the limbs cannot be bent without producing pain and a creaking sensation. This change naturally occurs in old persons, and is due partly to deposits of lime in the cartilage and partly to a dry state of the synovial membrane.

Sometimes a joint slowly swells and discharges yellow matter for a long time, while the sufferer gradually loses flesh and strength. The disease is commonly known as a *white swelling*, but is really *tuberculosis*, or *consumption* of the joint. When it affects the hip joint, it is called *hip joint disease*. A form of the disease without the discharge of matter may affect the spine and produce the deformity called a *hunchback*.

SUMMARY

1. The union of two bones is called a *joint*.
2. In joints in which the bones do not move, the bones are united either by bone or strong pads of fibrous tissue, or by cartilage, or by being dovetailed into each other.
3. In flexible joints, bones are joined together by a collar of fibrous tissue and by the action of muscles.
4. Flexible joints are lined with synovial membrane, which secretes a fluid like the white of an egg to lubricate the joint.
5. By assuming one position day after day the joints become fixed in that position.
6. In sprains and dislocations the ligaments are stretched or torn, and require long rest in recovery.
7. The synovial membrane may become inflamed and swollen.
8. A joint may become affected with tuberculosis, forming a *white swelling* or *hip joint disease*. In it the joint forms an abscess and often discharges matter.

DEMONSTRATIONS

162. A fowl dressed for the table will illustrate the different kinds of joints. Notice that in some places the muscles unite with the ligament and in others simply cross it, usually as a white cord or tendon. Cut

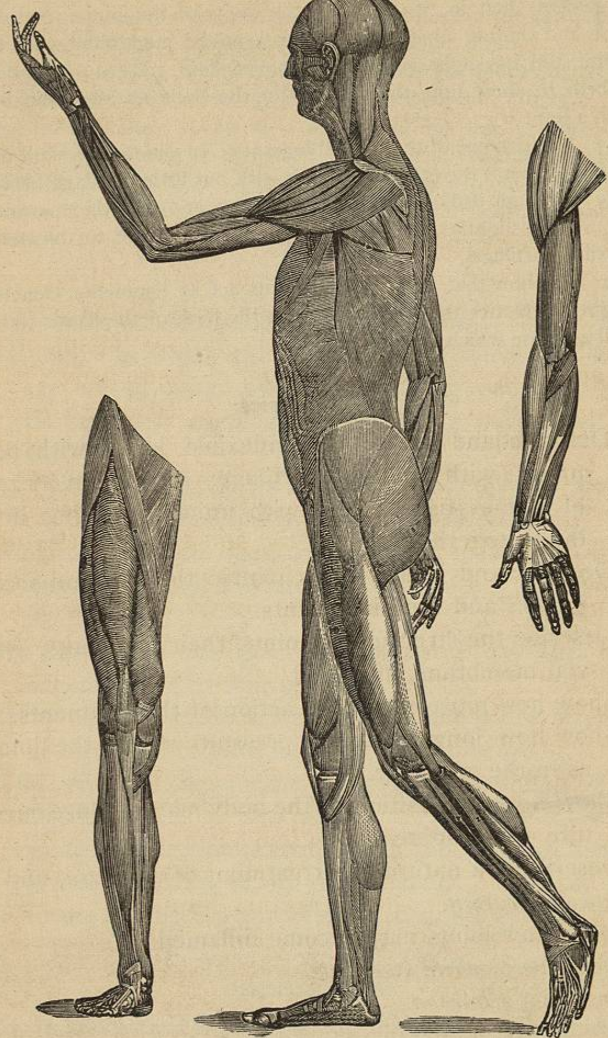
the ligaments half in two to show the cavity of the joint. Notice the smooth and shining appearance of the synovial membrane which lines the joint and its slight amount of synovial fluid. Bend the joint back and forth to show how the surfaces of the bone fit into each other. Sketch a joint.

163. Notice some of the inflexible joints. In an animal's skull notice that the joints are dovetailed together with but little cartilage between. Notice the tough pads between the vertebræ, and how they permit the spine to bend slightly. Notice that the ribs are united to the sternum by flexible cartilage.

164. To show that muscles and cords act as ligaments, clench the fist tightly. Notice that the cords upon the back of the hands tighten, as well as those which shut the hand.

REVIEW TOPICS

1. Describe and locate the inflexible joints with bony union; with union by cartilage; with union by pads of fibrous tissue; and with union by being dovetailed together.
2. Describe and locate hinge joints; the ball and socket joints; and the pivot joints.
3. Describe the structure of joints, their ligaments, synovial membrane, and fluid.
4. Show how muscles aid the action of the ligaments.
5. Show how long-continued pressure affects the joints, as in the great toe.
6. Show how the position of the body may produce curvature of the spine.
7. Describe the nature and treatment of a *sprain*, and of a *dislocation*.
8. Show how joints may become inflamed.
9. Describe a *white swelling*.
10. Describe a *bunion*.



The muscular system.

CHAPTER XXXIX

MUSCLES

662. Movements within the body. — Every action of the body has motion for its basis, and every cell possesses motion of some form. But certain cells of the body are set apart to produce motion in the various liquids of the body and to move different parts of the body itself. Cells whose work is to produce motion are called *muscle cells.*

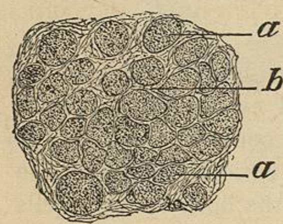
663. Involuntary muscles. — Some movements of the body go on wholly without our knowledge and are not affected by the will. Such are the movements of the blood, and of the peristalsis of the intestine. These involuntary movements are produced by muscle cells which are governed by the sympathetic nervous system. Each muscle cell resembles a string with pointed ends. They are wrapped around the arteries, intestine, bronchi, and other hollow organs. They are interwoven with the other tissues of the organ and cannot be recognized without a microscope.

A muscle cell (× 400).

664. Voluntary muscles. — The muscles which enable the body to move are under control of the will. They are situated mostly upon the outside of the bones, and altogether form over one half of the weight of the body. They round out the figure and impart to it strength and beauty. The other organs of the body of man exist in order that the brain and muscles may subsist and work out the plans of man's higher nature.

The lean part of meat is muscle. Each muscle can be split lengthwise into bundles again and again until each muscle cell is separated from the rest. Connective tissue binds the whole together.

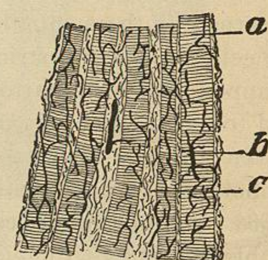
A muscle cell is a cordlike body about $\frac{1}{500}$ of an inch in thickness. Extending crosswise upon its surface are alternate dark and light bands which serve to distinguish a muscle cell from all other cells of the body. Each cell is surrounded but not penetrated by a network of capillaries and is held in place by delicate fibers of connective tissue, which are always small in quantity compared with the cells.



Muscle cells cut across (× 200).

a muscle cell.
b connective tissue binding the cells together.

665. Attachment of muscles. — One end of a muscular bundle is usually attached to the periosteum of a bone, while the other end is joined to a string of connective tissue called a *tendon.* A tendon is a white pliable cord and is exceedingly strong. It runs in a groove lined with synovial membrane, and its end is usually attached to a bone. A muscle usually forms a rounded projection above a joint to be moved, while its tendons extend across the joint and are attached to the periosteum of the next lower bone. This arrangement keeps the weight of the limbs near their upper extremities.

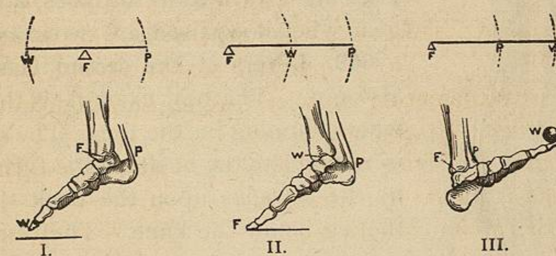


A thin slice of a voluntary muscle cut lengthwise (× 100).

a muscle cell.
b capillaries surrounding the cells.
c connective tissue binding the cells together.

666. Contraction of muscles. — When a muscle cell is cut or pinched or irritated in any way, it becomes shorter and thicker. This is called a *contraction,* and is the essential peculiarity of muscles. An end of a motor nerve thread touches every muscle cell and conveys to it orders from the cells of the spinal cord and brain. Each order causes a contraction.

A muscle cell requires about $\frac{1}{20}$ of a second to contract and another $\frac{1}{20}$ of a second to become relaxed. So it is impossible to move a limb more than ten times a second. The brain sends about ten orders per second. Thus before the muscle relaxes it receives another order and so remains in a tremulous state of contraction which becomes apparent during excitement or when a great effort is being made. Each contraction is a change in the shape and not in the size of the muscle.



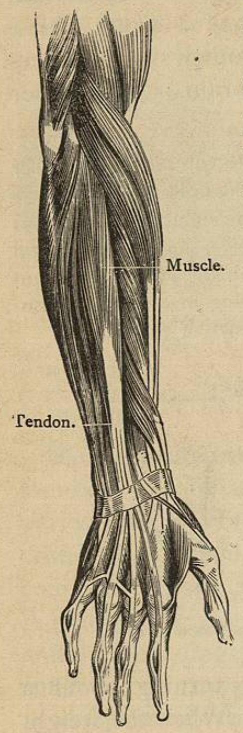
The three classes of levers, and also the foot as a lever.

667. Bones as levers. — A rigid bar turning about a fixed point or fulcrum is called a *lever.* When the weight is at one end of the bar and the power at the other end while the fulcrum is between the two, the bar is called a lever of the *first* class.

When the weight is between the power and the fulcrum, the bar is called a lever of the *second* class.

When the weight is at one end, the fulcrum at the other, and the power between, the bar is called a lever of the *third* class.

If the power is farther away from the fulcrum than the weight, it will move a weight greater than itself, but if it is a less distance away, it can move only a weight less than itself.



Right forearm.

A bone is a rigid bar. The joint is the fulcrum upon which it turns. The power is the contraction of the muscles which are attached to it. The weight is the weight of the body or limb together with anything which may be grasped.

668. **Levers of the first class** are not numerous in the body. The foot when pressing down with the toes, and the head when it is raised, are two examples.

669. **Levers of the second class** are also few. The best example is the foot when standing on the toes. The power is attached to the heels and is furnished by the muscles upon the back side of the leg below the knee. They end in a very strong tendon called the *tendon of Achilles*, which can be felt under the skin above the heel. It is the largest tendon in the body.

670. **Levers of the third class** are the most numerous. The foot in raising a weight upon the toes is an example. In nearly all joints of the arms and legs the power is furnished by the muscle attached to a bone near the fulcrum or joint, while the weight is farther away or near the outer extremity of the bone. Most of these muscles are so attached to their bones that they must exert a force

greater than the weight which they move. But the outer end of a lever moves over a greater distance in a given time than the part near the fulcrum. So if a muscle loses power by its attachment to a bone, it gains in rapidity of motion. The muscles of the body are strong enough to combine strength with quickness of motion.

The joints of the arms and legs are mostly so arranged that the limb can form a straight line, but can be bent in only one direction. The muscles which bend a limb are called the *flexors*, while those which straighten it are called *extensors*. Flexor and extensor muscles are usually arranged in opposing pairs, with the flexors upon the front and the extensors upon the back side of the limb. The flexor of the elbow reaches from the elbow to the shoulder upon the front of the arm and is called the *biceps*. The extensor of the elbow extends in the same way upon the back of the arm and is called the *triceps*. Both the flexors and extensors of the wrist and fingers are situated between the elbow and the wrist. Only a few small ones are in the hand.

The muscles which flex the knee end in strong tendons which can be felt as the hamstrings upon the back of the joint. The muscles which extend the knee end in a single large tendon inside of which is the patella. The patella acts as a pulley to protect the joint from the action of the tendon.

The muscles of the ankles and toes are arranged much like those of the wrist and fingers. By practice while young, it is possible to learn to use the toes in the same way as the fingers.

671. **Back muscles.** — The backbone is held upright and bent backward by large muscles which form ridges upon each side of the spine. They stretch the whole length of the spine so that the weight and power are at the same place while the fulcrum is the point of bending. Thus the spine is equivalent to a lever of the second or third class which uses most of the power of the muscle. So the back possesses great power with slow motion.

672. **Standing** is done by the contraction of the opposing flexor and extensor muscles of the lower part of the body, so that the

spine and legs are held rigid. If one set overacts, it pulls the body to one side and tends to upset it. Then the opposing set contracts and rights the body. In standing, the two sets continually act in this way.

Walking is due to a regular action of the flexor and extensor muscles of the leg, in such a way that there is always one foot upon the ground. In running, the whole body is completely removed from the ground at every step.

673. Face muscles. — The expression of the face is due to flat muscles which are attached to the skin. A circular muscle surrounds the mouth and each eye, while other muscles radiate from their edges. The contractions of

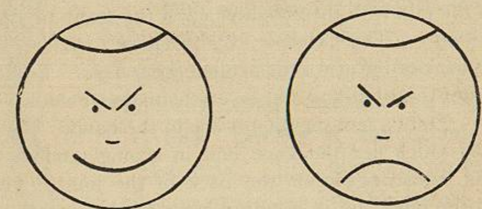


Illustration of the change of expression produced by the muscles of the mouth.

these muscles cause the mouth and eyes to assume a great variety of positions. Even the nose may be moved by muscles, and in rare cases the ears also. The different shapes of the mouth and eyes which these muscles produce are reliable indications of the feelings of the mind.

674. Muscular power. — The power which the muscles use is derived from the oxidation both of food and of their own substance. In their work they use about one fourth of the total heat produced in the body.

A horse can drag about two thirds of its own weight, while an ant can drag 40 times its own weight, and a grasshopper can leap 300 times its own length. In proportion to their size, all insects seem to be far stronger than man. The strength of a muscle depends upon its thick-

ness and not upon its length, yet in animals the muscle must be made many times longer than in insects as well as thicker. Thus the muscles of animals have more weight to lift and do a greater amount of work in proportion to their size. A man's muscle fiber is really the strongest known. An insect made as large as a man would probably be unable to move a limb.

675. Precision of movement. — By means of the muscular sense it is possible to regulate the action of a muscle with great precision. But as the effort put forth is greater, the ability to regulate it is less. So while slow and delicate movements can be made with precision, rapid and powerful motions are less under control. After a muscle has exerted itself to its full capacity, it is unable to perform delicate movements with precision for some time.

676. Alcohol and muscle. — Strong drink in any form diminishes both the strength and the endurance of muscles. Soldiers and athletes are not allowed to use it during periods of great exertion. It also interferes with the precision of movements. Drinkers are not allowed to work at railroading, where quickness and precision of movements are always required. Tobacco also weakens the muscles and lessens their precision of movement.

677. Physical effects of exercise. — When used, most cells of the body take in more nourishment, and increase in size and strength. Muscles, especially, grow larger and stronger by use. Then the digestion, circulation, and respiration all show increased vigor to supply them with extra energy. Thus the whole body grows stronger.

Round shoulders are most often due, not to weakness of the spine, but to weakness and inaction of the muscles of the back. The remedy is not to apply braces, for that only permits the muscles to rest and become weaker, but to make constant efforts to throw the shoulders back and so to increase the strength of the muscles. Military drill makes soldiers erect for this reason.

678. Overwork. — If the muscles turn too much heat of the body to motion and work, there is too little left to carry on the actions of the internal organs. Then there will be less food prepared for the repair of the cells, and to replenish the fuel for oxidation. So the whole body, including the brain, will remain fatigued. Besides the energy expended by the muscles, the brain also does a large amount of work in sending orders for their work. Probably the nervous system always becomes fatigued before the muscles.

679. Kinds of exercise. — It is a problem for students and clerks to determine how much exercise will rest and stimulate the brain to the greatest degree, and yet take no energy from it. The kind which a person enjoys best is the best exercise for that person. If possible, the exercise should be of a form which will turn one's thoughts completely from the day's work and from the exercise itself. So a useful occupation or some absorbing game is especially valuable as exercise. Dumb bells, chest weights, and all kinds of gymnastic exercises are excellent for developing the muscles. Their only disadvantage is that their use becomes monotonous, and a person must force himself to use them. They have the advantage that they can be exactly regulated to develop any defective part of the body. When done in classes and under an instructor they are especially valuable.

680. Amount of exercise. — A few moments of brisk running or romping will set the blood flowing faster and produce a clearer brain than an hour of slow walking. A person's own feelings should warn him when to stop. Boys and girls need plenty of exercise toward the end of their time of growth. A body well developed by exercise carries its strength through life.

In a school, a position upon either the baseball or football or athletic team often uses the surplus energy which in former years was expended in midnight hazings, and also develops the traits of bravery, manliness, and self-reliance. There is a special danger of overexertion in competitive sports, but with intelligent oversight of the teachers they are a great benefit to all.

SUMMARY

1. Cells whose use is to produce motion are called *muscle cells.*
2. In the arteries and in most of the organs of the chest and abdomen are spindle-shaped muscle cells, which are not affected by the will, but are controlled by the sympathetic system.
3. Muscles covering the bones and moving the body under the control of the will form one half of the body.
4. Voluntary muscles are made of ribbonlike cells which are marked crosswise.
5. Impulses from motor nerves cause a muscle to become thicker and shorter, so that it moves anything attached to its end.
6. A muscle ends in a stringlike tendon which crosses a joint, and is attached to the lower of the two bones which form the joint.
7. Muscles are arranged in pairs. Those upon the back side of a limb usually straighten the joint, while those upon the front side bend it.
8. Owing to the manner of their attachment, most muscles must put forth far greater force than the weight which they can lift.
9. A piece of a man's muscle is stronger than any other muscle of the same size.
10. The power for contraction of a muscle is derived from the heat of oxidation within the body. About one fourth of the heat is thus used.

11. By exercise of the muscles, the nutrition of the whole body is improved.
12. Too much exercise uses the power which should go to the brain and other organs and so harms the body.
13. That form of exercise is usually best which most interests a person.

DEMONSTRATIONS

165. Skin a chicken's leg and separate each muscle. Show their broad upper attachments and the small tendons into which the lower ends taper. Cut off the skin from the lower parts of the legs and toes and show how the tendons are attached to the toes. Notice that bending the leg tightens the tendons and flexes the toes. Explain how this compels the toes to grasp the perch while the fowl is roosting. Pick a muscle apart to show the separate fibers. Sketch a muscle.

166. Point out the main groups of muscles upon a boy. Have him perform such motions as raising his arm and clenching his fist, and feel what muscles are in action. Notice that when one set of muscles is in action the opposing set also acts so as to steady the limb. Point out the tendons, especially in the wrist and knee.

167. With two needles tear apart a small shred of muscle from a piece of cooked meat and examine it under the microscope with a power of at least 200 diameters. Sketch the ribbonlike muscle cells and their fine cross markings. Notice the small amount of wavy connective tissue between the cells. Examine a prepared specimen to show the cells cut across and the capillaries surrounding the cells.

168. Show involuntary muscle cells by preparing a shred from a fowl's gizzard, as in demonstration 167. Sketch the specimen.

169. Hold a pencil firmly with the elbow flexed. Contract all the muscles of the arm strongly. Notice that the whole arm trembles. Now let the pencil tap the table by means of this trembling motion, and notice that the taps are about ten a second. Explain that the taps are due to successive motor impulses from the brain. Now tap the table rapidly with the ordinary motion of the hand. Notice that it can be done only about five or six times a second. Explain that in this case the mind must cause two separate sets of muscles to contract alternately.

REVIEW TOPICS

1. Show that motion is essential to the process of life.
2. Describe involuntary muscles and tell their use.
3. Describe how voluntary muscles appear to the naked eye and under the microscope.
4. Describe tendons; how they cross the joints; and their attachment to bones.
5. Describe the contraction of a muscle.
6. Describe the three kinds of levers; show how bones and muscles form levers; and give examples of each kind.
7. Describe the arrangement of muscles in opposing sets.
8. Describe the action of muscles at the elbow; at the wrist; at the fingers; at the hip; at the knee; at the ankle; at the toes; in the back; over the abdomen; and upon the face.
9. Show how standing is performed; how walking; and how running.
10. Give the source and amount of muscular power.
11. Show that great exertion impairs the precision of movements.
12. Show that muscle training is really mind training.
13. Show that physical exercise benefits the whole body; and that overwork fatigues the brain.
14. Show what kind of exercise is the best.
15. Show how to regulate the amount of exercise.
16. Give an estimate of the value of competitive sports in schools.