CHAPTER XXVIII

NERVES

477. Uniformity of cell action. — Certain cells forming the *nervous system* are set apart for purpose of commanding the rest to work in the proper time and manner. The commanding cells, called *nerve cells*, form the essential part of the brain and spinal cord. From them as a center, fine threads called *nerves* run to the cells of the body. The outer end of each nerve thread touches a company of cells and carries to them the orders from the central nerve cells. Although each cell in the body lives and acts independently of the rest, yet the central nerve cells cause all to act in harmony.

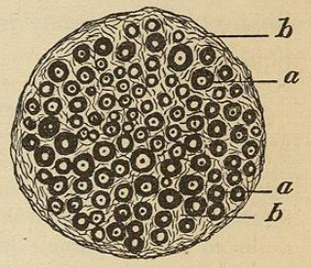
478. Nerves. — Each nerve thread is composed of a central fiber surrounded by a protective layer of a kind of fat. The whole thread is only about $\frac{1}{4000}$ inch in diameter. Those which go to each part of the body, as a hand or leg, run together in a bundle, which divides into its separate threads upon reaching its destined part. Each bundle of nerve threads is usually called a *nerve*. The main nerves of the arms are about the size of knitting needles, while the great sciatic nerve of the leg is as large as the end of the little finger.

A nerve thread (× 400).

a central conducting fiber. *b* covering of fat.

As a general rule, a large nerve accompanies an artery down the inside of each limb and across the center of joints upon the side toward which the limb is bent. Thus they are in protected positions. One nerve cord is situated on the inside of the back of the elbow joint and is called the *funny bone*. Owing to its unusual position, it is sometimes hit, producing a pain in its ending on the inside of the hand.

479. Nerve action. — When one of the main nerves of the arm is irritated, as by a pinch or prick, or shock of electricity, an impulse is started along the nerve in each direction. It goes to the brain and produces a *sensation* either of pain or pleasure. It also goes to the muscle cells of the arm, causing them to contract and move the arm. If a nerve is cut and the end nearest the brain is irritated, a sensation will be felt, but there will be no motion. If the other cut end is irritated, the muscles will move the arm, but no feeling whatever will be produced.



A thin slice from the end of a cut nerve (× 200).

a nerve thread.
b connective tissue binding the threads into a cord.

Whether the nerve be irritated at its outer endings at the cells or anywhere in its course, an influence will travel to the central nerve cells carrying the news, and also in the opposite direction to the cells of the body, causing them to act. The cells of the body can originate influences which travel up the nerve to the central nerve cells; and, on the other hand, the nerve cells can originate influences which travel to the cells of the body and cause them to act. *Transmitting impulses* is the essential duty of nerves. They may be compared to telephone wires which transmit any kind of electrical influences over

their whole length without affecting anything in their course.

480. Kinds of nerves. — Each thread of a nerve transmits influences in only one direction. Some threads carry influences only from the cells of the body to the central nerve cells. Because they often produce sensation they are called *sensory* nerves. Other threads carry orders for action from the nerve cells to the cells of the body and are called *motor* nerves. Most nerves are made up of both sensory and motor threads, but some are wholly sensory and others wholly motor. There is no difference in their appearance.

481. Distribution of sensory nerves. — Nearly every cell in the body, except in the epidermis and blood, is probably in connection with a sensory nerve, and, through it, is in touch with the central nerve cells. The endings of the nerves are so abundant in the skin just beneath the epithelium, that the point of a fine needle cannot be thrust in without producing pain. In the ends of the fingers they are more numerous than in any other part of the body. The muscles and internal organs have fewer sensory nerves than the skin, so that a cut may be continued into the deeper parts with but little pain.

482. Kinds of sensations. — The cells are continually sending impulses to the central nerve cells telling of their needs, as of food or rest. These impulses often give rise to feelings which may seem to pervade the whole body. Then they are called *common sensations*. Some are pleasant and some are disagreeable. The natural unreasoning inclinations to gratify desires aroused by the needs of the body are *instincts*.

When something outside the body is acting upon the nerves it produces a feeling or impression of which a person is usually aware. By means of these sensations the mind forms definite ideas of the surroundings of the body,

and so the feelings are called *special sensations*. Unlike common sensations, the meaning of the sensations must be learned.

483. Common sensations. — Hunger, thirst, and fatigue are the usual common sensations felt by the mind. Hunger seems to be located in the stomach. If a substance swallowed is not nutritious, hunger soon returns, even if the organ is filled full. On the other hand, if nutritious food is introduced into the body through the intestine, the feeling of hunger will pass away, even though the stomach remains empty. Some persons suffering from indigestion are always hungry, though they eat enormously. But the food is not digested, and does not reach the cells, and there is always a feeling of hunger.

Thirst seems to be located in the mouth. Moistening the mouth allays it but for a moment only, while if water is introduced into the intestine or veins, the thirst disappears, even though the mouth receives no water.

The amount of common sensations is small compared with similar impulses which we do not feel. Every cell is continually sending tiny messages of its needs, and the central nerve cells promptly respond.

484. Special sensations. — Knowledge of the outside world is gained by means of the touch, sight, hearing, smell, and taste. Of these, touch is located in all parts of the body, while special organs are needed to enable the nerves to catch the delicate impressions of sight, sound, smell, and taste.

485. Sensations of touch. — When an object touches the epithelium of the skin, it causes an impulse to travel to the central nerve cells as a sensation either of touch, temperature, pain, or weight. All these sensations are included under the general term of *touch*. Touch proper

is a slight sensation caused by contact of the skin with an object. By means of it such ideas as those of shape, smoothness, size, and dampness are gained.

Different parts of the body vary greatly in the ability of their nerves to detect slight differences between two sensations. Thus the ends of the fingers distinctly feel two points $\frac{1}{12}$ inch apart as separate points, while if two points are applied to the back, they seem as one point until they are separated two inches. So we naturally use the ends of the fingers to feel with.

486. Sensations of temperature. — In the skin special nerves seem to end in minute points which are situated from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch apart. When these are touched, a sensation of heat or cold is felt, while the skin between feels only a touch or pain. Some spots give a sensation of cold only, and others of heat only.

Sensations of extreme heat or of extreme cold cease to be feelings of temperature, but are felt only as pain. The skin is so sensitive that it can detect a difference of $\frac{1}{5}$ of a degree of temperature between two objects.

487. Painful sensations. — A sensation of touch or of temperature, if greatly increased or often repeated, becomes unpleasant and is called a *pain*. The same sensation may be felt at one time as a pleasant touch and at another as a pain. When an influence is becoming great enough to endanger the body, it arouses the nerves of pain and produces a strong and unpleasant feeling which overpowers the simple sensation of touch and compels us to withdraw from the danger. Pain is a protection for the body and not altogether an evil or a punishment. When the nerves of pain in an arm or leg are diseased, the limb may be burned beyond recovery without a person's knowledge. In many diseases pain is a prominent symptom, and the physician is besought to give it relief. Yet he

hesitates before giving morphine, knowing that to relieve the pain is to mask the danger signals so that he cannot judge of the real cause of the trouble.

Tickling is a sensation between touch and pain. It is produced in parts which are poorly supplied with nerves of touch, as on the back or the neck. At first, tickling is a pleasant sensation, but if continued, it becomes extreme suffering. Some persons and animals who are able to endure great pain are unable to control themselves when tickled

Itching is a sensation which is overcome by producing a greater sensation in the part, as by scratching. Although itching is usually only an annoyance, in a greater degree it is a torment even worse than pain, and may lead a person to injure the skin seriously by deep scratching.

488. The muscular sense. — Sensations of weight or of resistance are judged partly by the amount of muscular effort needed to move the body, and so depend in large part upon the motor nerves. But the feelings of pressure upon the body and of muscular effort aid in producing the sensation. An object lifted seems distinctly heavier if its weight is increased only $\frac{1}{17}$, while if it is placed upon the skin, its weight must be increased $\frac{1}{3}$ before it feels heavier.

489. Necessity of epithelium. — The covering of epithelium not only protects the nerves from injury, but also modifies an impulse which produces a sensation, so that it is spread over a larger area of nerves and is made a gentle instead of a painful sensation.

490. Motor nerves. — Besides touching a sensory nerve, each cell probably communicates with a motor nerve also. Motor nerves begin at the central nerve cells and end at the cells of the body. Over them the central nerve cells send orders based upon information brought by the sensory nerves. Many orders are sent by willful efforts of a person, but by far the most are sent without our knowledge.

Motor impulses are of three kinds, — for motion, for secretion, and for growth.

491. Impulses producing motion. — The action of every muscle cell depends upon an impulse brought from the central nerve cells by its motor nerve. When these influences are cut off, there is *paralysis* of the part, so that no amount of willful effort can cause the muscles to move the limb. The peristalsis of the intestine and the beating of the heart are caused by influences brought to their muscle cells by motor nerves. Orders for movements of which we know nothing are far greater in amount than those sent to voluntary muscles.

492. Impulses producing secretion. — Secretion is also dependent upon orders brought to the glands by motor nerves. For example, when food is taken into the mouth, the sensory nerves carry the news to the nerve cells, which at once send out an order along the motor nerves to the salivary glands to produce more saliva. If the nerves are cut, only a little saliva will be produced, while if the end in connection with the gland is irritated, the gland will respond with a greater quantity of saliva. In the same way the secretion of all glands is controlled.

493. Influences producing growth. — When the motor nerve to a part is cut, the cells will be inactive, and, as it were, too lazy even to eat. So, unless continually under the influence of motor nerves, the cells become weak and waste away. When the cells of a part are much used, impulses are sent causing them to take in more nourishment, so that they increase in size and strength. Thus a muscle becomes larger and stronger by use. During the action of a muscle its motor nerves also bring orders for the arteries to dilate and carry more blood to feed the working part.

494. Rate of transmission of nerve impulses. — Ordinary sensations travel about 100 feet per second. This is about the rate of the fastest express trains, but our arms are so short that pain seems to follow an injury instantly. In some diseases the rate is very much retarded, so that if the hand should happen to rest upon a hot stove it would be badly burned before the sensation would travel to the brain and give warning of the danger.

495. A sensation traveling over a nerve seems to come from its beginning. When the funny bone, or nerve that winds around the back of the elbow, is pinched, the little finger side of the hand, where the nerve ends, feels as if pricked by needles. When an arm or a leg is cut off, and the nerves in the stump are irritated, a pain is felt which seems to be in the lost limb. When a nerve is pressed upon, it may be partly paralyzed for a while. Then the part which it supplies becomes less sensitive and is moved with difficulty. At the same time an impulse caused by the irritation of the pressure produces a sensation which seems to the brain to come from the end of the nerve. Thus when sitting crosslegged the foot often seems asleep and full of needles, while it is itself insensitive when touched.

A cut nerve will become whole again, but it takes some weeks. In the meantime the parts supplied by the nerve cannot feel or move.

496. Diseases of the nerves. — Nerves may become inflamed, producing the disease called *neuritis*. Then there will be great pain and tenderness over the entire course of the nerve. In severe cases there will be paralysis and loss of feeling. The disease is very slow in its course.

Sciatica is a mild but painful form of inflammation in the main nerve of the leg. Inflammation of the nerves may be caused by rheumatism or malaria, but, above all, by alcohol.

497. Effect of alcohol upon nerves. — A little alcohol seems to hasten the rate of transmission of nervous impulses by increasing the circulation of the blood, but a few drinks retard their action. A great danger of using alcohol is that it may cause *neuritis* or inflammation of the nerves. Slow, steady drinking may produce it as well as occasional sprees. It comes without warning, but remains a long while, producing pain and paralysis. Alcohol produces the disease as often as all other causes combined.

SUMMARY

1. The cells of the body are made to act harmoniously by means of orders sent from a few cells in a *central nervous system.*
2. A nerve is a bundle of microscopic threads, each running from a central nerve cell to the cells of the body.
3. Nerves transmit impulses caused by irritation from outside the body, and also impulses originated in either the cells of the body or the central nerve cells.
4. Sensory nerves carry from the cells news concerning a substance which is touching the body, and they inform the central nerve cells when the cells are tired or are in need of food.
5. Motor nerves carry orders to the cells to move, to secrete, to eat, and to grow.
6. Impulses in nerves travel about 100 feet per second.
7. Nerves may become inflamed and produce pain and paralysis.
8. Alcohol often produces severe inflammation of the nerves.

DEMONSTRATIONS

116. Skin the leg of a small animal or frog, and push apart the muscles upon the inside of its upper part. White nerve cords will be seen to lie alongside the main artery and vein, and can be traced upward to the spinal cord and downward until they become lost in the skin or muscles. Notice that those which branch off to the skin are as large and numerous as those which supply all the rest of the leg. Notice how much force is needed to break one of the nerves. In ancient times it was supposed that tendons and nerves were the same. Compare a nerve with a tendon to see their points of resemblance.

117. To show the effect of irritating a nerve in its course, pinch a boy's funny bone. He will wonder how the sensation travels to the brain when he feels it go down to his little finger. Explain that it only seems to come from the finger, but does not go there.

118. With a power of at least 200 diameters, show specimens of a nerve mounted for the microscope. In a specimen of nerve cut lengthwise, notice the slender conducting fiber running down the middle of each thread and its thicker, clear covering of fat. In a specimen cut across the nerve, notice that the conducting fiber of each nerve thread appears as a central dot within a circle of the protecting fat. Notice the fine connective tissue between the threads. Sketch the specimen.

119. Show the difference in sensibility of different parts of the skin by touching it with the points of a pair of compasses Upon the balls of the fingers the points will seem separate even if near together, while upon the back they will seem one when separated two inches.

120. Show that some parts of the skin feel sensations of temperature more than the others by drawing the point of a lead pencil slowly across the cheek. At intervals there will be felt a cold sensation, showing that a special nerve of temperature has been touched.

121. Cut a nerve in a recently killed frog and separate it from the flesh for a short distance. After a moment, pinch the nerve, and the muscles will contract.

REVIEW TOPICS

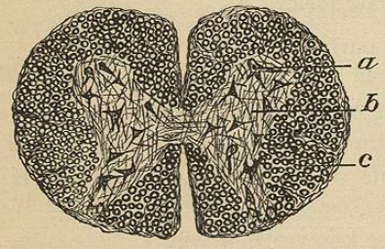
1. Describe the essential parts of the nervous system.
2. Describe a *nerve.*
3. Explain the two results of irritating a nerve.
4. Define and name the kinds of sensory impulses.
5. Describe the sensations of touch, pain, temperature, and weight.
6. Tell how the cells make known their wants.
7. Show how epithelium aids the sense of touch.
8. Name and describe the three kinds of motor impulses.
9. Give the rate of transmission of impulses along nerves.
10. Describe the effects of pressure upon a nerve; of cutting a nerve; and of disease of a nerve.
11. Tell how alcohol affects a nerve.

CHAPTER XXIX

THE SPINAL CORD

498. The first collection of central nerve cells is in the spinal cord. The spinal cord is a soft white cylinder of nervous tissue, about half an inch in diameter. It is securely hung in the upper two thirds of the tube formed by the bony rings of the backbone. It extends from the bottom of the skull to about the level of the lowest rib, a length of about eighteen inches. It is only about two thirds as large as its tube, and so is not likely to be injured by bending the backbone.

499. The gray matter. — When the cord is cut across, the central part of its end shows the grayish outline of a butterfly surrounded by a thick layer of a whiter substance. The gray matter is a collection of *nerve cells*, which give off numerous nerve fibers like the central fibers of ordinary nerve threads. The cells are about $\frac{1}{1000}$ of an inch in diameter. Some of the nerve fibers communicate with other cells of the cord, and some take coverings and become ordinary nerve threads. The whole is bound together by delicate connective tissue.



A thin slice from the spinal cord with the cells and nerves magnified 200 diameters.

a cells in the gray matter.
b fibers in the gray matter.
c nerve threads in the white matter.

The spinal cells receive a part of every impulse from the sensory nerves, and take part in sending out motor impulses to the various parts of the body.

500. The white matter. — The white matter is made up of nerve fibers which still retain their coverings. In fact, the white matter is simply a huge nerve. The nerve threads of the white matter adjoining the right and left sides of the gray matter are motor threads carrying impulses from the brain to the cells of the gray matter. The nerve threads outside of these and the threads behind the gray matter are prolongations of the sensory nerves of the body, some of which finally go to the brain, and others connect with the cells of the gray matter of the cord.

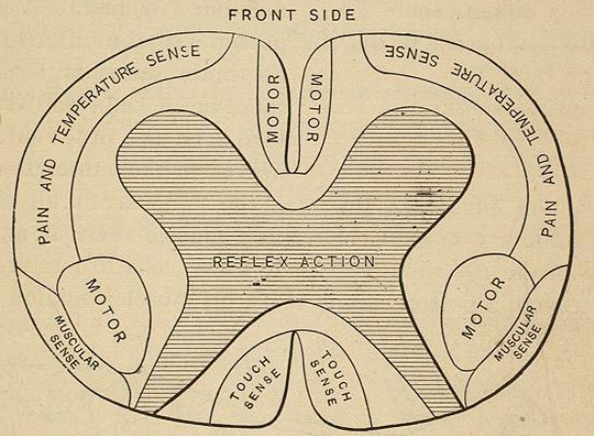


Diagram of the action of each part of the spinal cord.

501. Spinal nerves. — The spinal cord gives off thirty-one pairs of nerves through openings between the rings of the backbone. Each nerve is made of a sensory and of a motor part which soon unite into a single bundle in which the two kinds of nerves cannot be dis-

tinguished. These spinal nerves supply the whole body below the neck.

502. Action of nerve cells in voluntary motion. — The spinal cells do not originate impulses or act of their own accord, but they act only when ordered to do so by the brain or when the cells of the body express a need of protection, nutrition, or rest. When a person wishes to lift his hand, his brain sends an order to these nerve cells, and they in turn send the order over the nerves to the muscles which move the hand. In this way the mind sends all orders for voluntary motion. For each muscle there is a separate group of spinal cells. If these cells are injured or destroyed, a person cannot move his muscles voluntarily.

Diagram of the origin of nerves in the spinal cord.

a motor nerve root from the front part of the nerve.
b sensory nerve root from the back part of the cord.
c gray matter of the cord.
d white matter.

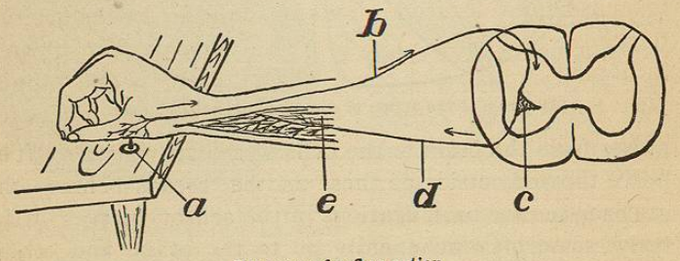


Diagram of reflex action.

a tack pricking the hand. *b* sensory nerve. *c* nerve cell in the spinal cord. *d* motor nerve. *e* muscle moving the hand.

503. Reflex action. — The spinal cells also send out orders in response to impulses brought by sensory nerves. Motor impulses sent in response to influences brought by

sensory nerves are *reflex acts*. Reflex action is designed to protect the body from injury and to supply its needs. Most acts of the cord are reflex. When the finger touches a hot object, the sensory nerves carry the sensation to the cells of the spinal cord and to the brain. Before the sensation reaches the brain, the spinal cord sends out an order for the muscles to move the finger away from the heat. The brain becomes conscious of the burn and of the movement of the finger at about the same time. In this way the spinal cord protects the body against all kinds of injuries.

504. Reflex action in relation to nutrition. — Digestion is mainly a reflex act. Motor impulses for glands to produce the digestive juices are sent out from the spinal cord when the sensory nerves bring word that food is present in the stomach or intestine. Peristalsis is also a reflex act dependent upon the presence of food. The sensory nerves also carry to the spinal cells news of the temperature of a part and of its need of more or of less blood, and, in response, the cells send out motor impulses for the arteries to change their size. The heart is also somewhat affected in a reflex way. The sensations of exertion and fatigue are carried to the spinal cells, which send out orders for more rapid heart beats. Fear, joy, anger, and sorrow all affect the heart in a reflex way.

The growth of each separate cell is controlled by the same set of spinal cells that produce motion in a part. Muscle cells, especially, need the constant stimulus of the spinal cells to keep them growing, for otherwise they slowly waste away and become weak. The spinal cord is continually overseeing the nutrition and growth of cells, and if it were to cease its oversight, their death would soon take place.

505. Reflex action in habitual movements. — The reflex action of the cord aids in performing simple movements of

the body. The peculiar sensations which tell a man that he is beginning to fall pass to the cells of the cord, and they in a reflex way send out the proper orders for the muscles to put the body in an upright position again.

506. Reflex action in education. — The reflex action of the spinal cord can be educated. Even a simple reflex action like standing must be learned. When a baby first tries to walk, his brain cells give the proper orders to the cells of the spinal cord, and they in turn give them to the muscles. Thus he slowly directs each detail of the movements with his brain. Soon the spinal cord learns to send the next order as soon as it feels the sensation of the previous movement, and finally all the movements needed become reflex, and the child runs about with but little effort on the part of his brain.

In learning to play a piano, the brain is occupied both in reading the notes and directing the movements of the fingers in playing. But, at last, the brain has only to read the notes to the cord and it instantly sends the proper orders that they be played.

Education and skill in any art consist in the ability of the cord to execute proper movements while the brain is wholly occupied with the design. In this ability to acquire new uses, the cells of the nervous system differ from all other cells of the body. When the hand is educated, it is really the spinal cells which are educated.

507. Excessive reflex action. — Reflex acts are sometimes not beneficial. A slight noise gives some people a fright, and in lockjaw the slightest sensation causes the spinal cells to send out orders for the muscles of the body to contract violently. Self-control is largely the power which the brain has of restraining the spinal cells from sending out orders even when strong and sudden sensations are received. Thus, when something tickles the throat, it is possible for the brain to restrain the spinal cells from sending the order to cough. In the same way men sometimes endure great pain without shrinking.

508. Broken back. — Injuries to the backbone may injure the spinal cord so that it cannot conduct nervous influences past the injured point. Then parts of the body below the point of injury can neither send nor receive messages from the brain, but are paralyzed both in sensation and motion. Yet the reflex action of the part may persist, for the part of the cord below the injury still retains its vitality.

509. Disease of the spinal cord. — There are diseases which may destroy the action of any single part of the cord or of the whole cord below the seat of the disease. Then there will be loss of sensation or of motion or impairment of nutrition, usually in the lower part of the body. The diseases are generally slow in their course and incurable.

510. The action of the cord is unconscious. — The cord always acts wholly without a person's knowledge. Like a faithful nurse, it stands guard over the cells of the body and controls them in their nutrition, growth, and work. The brain restrains its excessive action and directs it in ordering the voluntary movements, but leaves to it almost the entire care of individual cells.

SUMMARY

1. The spinal cord is made up of a central mass of gray matter surrounded by white matter.
2. The gray matter is made up of cells from which nerve fibers extend both to the brain and to the cells of the body.
3. The white matter is composed of nerve threads which connect the cells of the cord with the brain and with the nerves of the body.

4. Thirty-one pairs of nerves connect the cord with all parts of the body.
5. The use of the cells is to send orders over the motor nerves when told to do so by the brain, and also to send orders in response to information brought to them by sensory nerves.
6. Orders sent in response to sensations are reflex acts.
7. Reflex acts are for protection, nutrition, and to relieve the brain from the drudgery of sending orders for every detail of bodily movements.
8. The reflex action in an educated spinal cord enables a person to work with skill.
9. Restraint of excessive reflex acts constitutes self-control.

DEMONSTRATIONS

122. Procure a spinal cord at the butcher's. Notice the nerves going off from the cord. Notice how the cord is enveloped by a thick, fibrous sheath and is held in place by the nerves and fibrous bands. Remove the cord from the bone and slit open its sheath. Notice the soft consistency of the cord and its shape like two cords pressed together. On its clean-cut edge notice the grayish butterfly-shaped center and the pure white outer part.

123. Examine a thin cross section of the cord under the microscope with at least 200 diameters. In the outer parts of the specimen notice the round circles of cut nerve threads. Explain that this is the white matter of the cord.

Examine the central part, noticing the large nerve cells and nerve fibers which run in all directions. Notice the fine and wavy connective tissue fibers binding the whole together.

124. The pure reflex action of the cord can be shown with a decapitated frog. Place a small piece of blotting paper, wet with a strong acid, upon its back, and it at once kicks it off with its hind leg. Prick its back, and it makes one leap. Suspend it with its hind legs hanging down, and let a toe touch a dish of acid, and it at once draws up the leg. (See demonstration 35.)

Explain that the frog has no feeling or sense, but performs the movements in a reflex way to escape danger in the same way that a boy suddenly jumps when he touches a sharp pin.

125. To show reflex action, have a boy sit with one knee crossed over the other and hanging perfectly limp. Now strike the front of the knee just below the patella. The thigh muscles will contract and cause the leg to kick. This will succeed best if the boy is not looking when you strike.

REVIEW TOPICS

1. Describe the spinal cord; its appearance and situation; its gray matter, its white matter, and the origin of the nerves which arise from it.
2. Describe how the cells of the gray matter act in causing voluntary movements, and in causing reflex movements.
3. Explain how reflex action is a protection to the body; how it controls all processes of the growth and secretion of the cells; and how it enables a person to acquire skill in movements.
4. Explain how reflex acts may be harmful; how self-control may overcome the harm.
5. Describe the effects of injury to the spinal cord.
6. Describe the effect of diseases of the spinal cord.