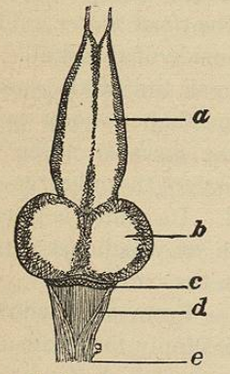
REVIEW TOPICS

1. Describe the sympathetic nervous system: its ganglia, nerves, plexus, and its connection with the spinal cord.
2. Describe the sensory impulses of the sympathetic nerves.
3. Describe its motor impulses and their relation to the arteries; to secretion of glands; to peristalsis; to the growth of cells, and to the heart.
4. Describe how the ganglia send out their impulses.
5. Describe how the spinal cord has influence over the ganglia, and how they work independently of the cord.
6. Describe how the brain can affect the ganglia.
7. Describe how the action of the ganglia may be seriously impaired by injuries.

CHAPTER XXXI

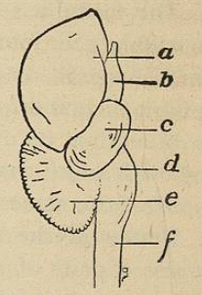
THE BRAIN

518. General structure. — The brain is the part of the central nervous system which can *originate* orders in distinction from the spinal cord, which acts only in response



Brain of a frog; top view (× 10).

a cerebrum.
b optic tubercles.
c cerebellum.
d medulla.
e upper end of spinal cord.



Brain of a hen; side view (× 2).

a cerebrum.
b optic nerve.
c optic tubercle.
d medulla.
e cerebellum.
f spinal cord.

to impulses brought to it. In reptiles, toads, and frogs, it is very simple in structure, but yet contains parts corresponding to all the parts of the brain of man. In them the spinal cord swells out to form a cone-shaped body called the *medulla oblongata.* Above it there is a small flat

swelling called the *cerebellum*, the next two smaller bodies called the *optic tubercles*, and at the top two larger bodies which together are called the *cerebrum*. They follow each other in a straight line. In man the parts are bent upon each other, while the cerebrum is so large that it covers all the other parts.

519. Coverings. — The brain of man is a very soft body weighing about fifty ounces. It is contained in the top of the skull. It is covered with a delicate network of fibers called the *pia mater*, which carries the numerous blood tubes of the brain. Outside of the pia mater is a thick, tough membrane called the *dura mater*. The dura mater is the periosteum of the inside of the skull.

520. The medulla. — The upper end of the spinal cord becomes enlarged into a wedge-shaped body called the *medulla oblongata*, or simply the *medulla*. The medulla is about one inch and a quarter in length and three quarters inch in breadth at its upper end. Its center is gray matter covered with white matter, both of which are direct continuations of the same matter in the cord.

521. Nerves of the medulla. — From the medulla there go out seven pairs of nerves to supply the head and face. They, together with five other pairs which the brain gives off, are called *cranial nerves*, in distinction from the spinal nerves. The cranial nerves which arise in the medulla are sensory and motor, and supply the head and face just as the spinal nerves do the rest of the body. They connect with cells in the medulla which act only in a reflex way. In this sense, the medulla is a part of the spinal cord, and not of the brain. One of these seven cranial nerves is partly a nerve of the special sense of taste. Impressions of hearing, sight, and smell are carried by three cranial nerves arising higher up in the brain.

522. The vagus nerve. — One of the pairs of cranial nerves is called the *vagus*, or *pneumogastric*, nerve. It supplies a small sensory branch to the ear, and motor branches to the larynx and pharynx; then it passes into the thorax and gives off branches to the heart, which restrain its action. It gives sensory branches to the esophagus and lungs, and finally reaches the stomach and liver. The main nerve supply of these organs is from the spinal cord, or from the sympathetic system, but the vagus nerve is an additional means for better regulating their action to suit the needs of the body.

523. Centers originating impulses. — In the medulla, a collection of nerve cells, called the *respiratory center*, sends out a regular succession of orders for respiratory movements. While the orders may be hastened or retarded by other nerve centers to suit the needs of the body, yet the medulla compels the respiratory muscles to act so as to keep the body supplied with sufficient oxygen. Thus it is a real part of the brain. When the respiratory center is destroyed, respiration and life cease instantly.

There is another part of the medulla, called the *vasomotor* center, which controls the contraction of arteries, and another which regulates the peristalsis of the esophagus in swallowing. While these are partly reflex acts, yet their perfect action requires original impulses to be sent from the medulla.

524. Effects of reflex influences. — The respiration, circulation of the blood, and taking of food are essential vital processes of life which the medulla controls without our being aware of it. Strong influences from the nerves of the body may act in a reflex way to modify the impulses of the medulla. Great fear may cause the vasomotor center to send out impulses for the contraction of the arteries so as to produce great paleness. Instances have occurred in which the disturbance of circulation from this cause has produced death.

525. Effects of injury. — An injury to the respiratory and vasomotor centers causes death at once. A broken neck, if high up, may

involve the medulla and cause instant death. But the medulla is so situated that only the greatest violence can harm it.

526. The cerebellum. — Just above and overhanging the medulla is a rounded mass called the *cerebellum*. It forms less than one fifth of the brain. It consists of an interior white mass of nerve threads, covered with a layer of gray matter about $\frac{1}{15}$ of an inch in thickness. On the surface are deep fissures into which the gray matter dips, so that its amount is greatly increased. In the gray matter are nerve cells which are connected with the rest of the nervous system through the nerves of its white matter. These nerve cells are the essential part of the cerebellum. They have no connection with any vital process of life, and do not take part in thought. A man with a diseased cerebellum can perform a single muscular act like raising his hand, but he cannot direct changing and complicated movements, such as are required in writing, walking, or balancing his body. Thus the cerebellum acts like a balance wheel, so that orders for complicated movements may be sent with regularity and precision.

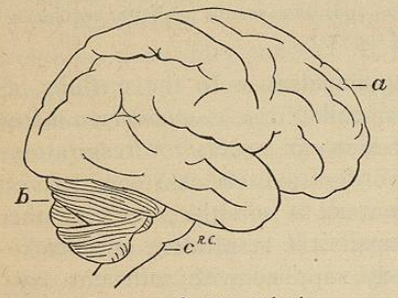
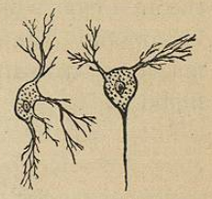


Diagram of a human brain.
a cerebrum. *b* cerebellum. *c* medulla.

527. The optic tubercles. — The optic tubercles are two small collections of gray matter situated upon the main nerve tracts which connect the cerebrum and medulla. They seem to be connected with the reflex movements of the eye. Other collections of gray matter near them seem also to be connected with the eye.

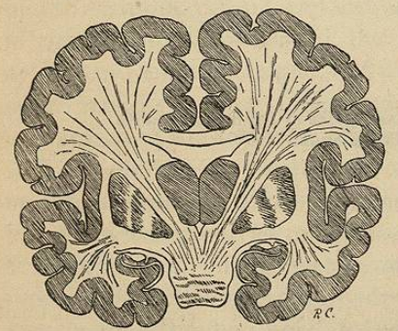
528. The cerebrum. — The main nerve tract, after passing through the spinal cord, medulla, and optic tubercles, spreads out to form a mass called the *cerebrum*. While in frogs and fishes it is no larger than the medulla or optic tubercles, in man it forms more than four fifths of the whole brain and overhangs all the other parts.



Cells from the gray matter of the cerebrum (× 300).

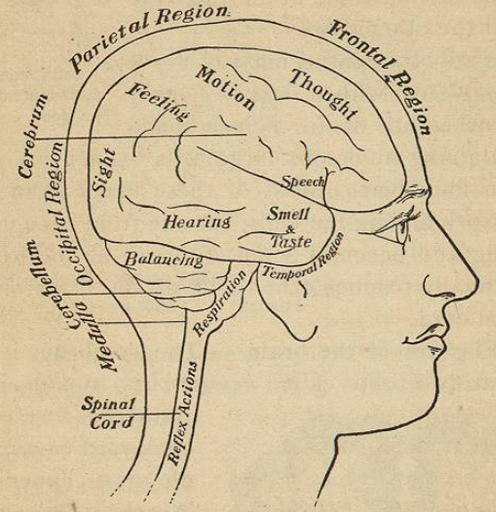
It consists of a central mass of nerve threads covered with a layer of gray matter one eighth of an inch in thickness, containing numerous large cells. Each cell gives off numerous fine fibers. Most of these fibers form an intricate network among the cells, but one from each cell takes a covering and becomes a nerve thread of the white matter, and finally reaches other cells of the brain or even of the spinal cord.

529. Fissures of the brain. — The cerebrum is divided nearly into two parts, called *hemispheres*, by a deep furrow running forward and backward upon the middle of its upper surface. Another furrow, called the *Sylvian fissure*, starts near the bottom of the fore part of the side of the cerebrum and runs backward and upward. Many other furrows and fissures from one quarter to one half inch in depth, run in waving lines between its main furrows, throwing its surface into folds called *convolutions*. The convo-



Human brain cut crosswise.

lutions increase the surface of the cerebrum, so that in all it measures about four square feet. This greatly increases the area over which the nerve cells in the gray matter may be spread. The interior of the cerebrum is a small irregular cavity, called the *ventricle*, which is filled with a clear liquid.



Regions of the head and action of the different parts of the brain.

530. Regions of the cerebrum. — The fissures and convolutions are nearly the same in all men, and mark out definite regions upon the surface of the brain. First, is the region just behind the forehead, called the *frontal region.* Second, is the region lying under the upper part of each side of the skull, and called the *parietal region.* Third, is the region about the ear, called the *temporal region.* It lies just above and in front of the ear. Fourth,

that part of the brain lying under the back of the skull is called the *occipital region.* Each region of the brain does a special work.

531. Action of the cerebrum. — The nerve centers may act reflexively in response to sensory impulses, as the spinal cord usually does; or automatically by originating their own impulses, like the respiratory center in the medulla and the nerve cells in the heart. The spinal cord, sympathetic system, medulla, and cerebellum all act in one or the other of these ways, and without our being conscious of their action. The cerebrum is the seat of the thinking mind. It acts in an automatic way, but we may be conscious of any of its actions. It acts first by feeling sensations; second by sending orders for voluntary muscular movements; third, by thought. It does each kind of work in a particular region of its surface.

532. Sensory regions. — Sensory impressions of which we are conscious are *sensations.* Sensations of hearing, smell, and taste are felt by the temporal region; of sight by the occipital region; and of touch by the parietal region. If either region is destroyed, the impressions going to that area are no longer received, and the person is devoid of the corresponding sense. Unless each impression reaches its own region of the surface of the brain, it produces no sensation, although it may still reach reflex centers in the optic tubercles, medulla, or cord, and give rise to reflex action.

533. Memory. — Impressions may be retained in the cells and be recalled. These constitute memories. Our memories are complex stores of impressions in widely separated parts of the brain. The sum of our different memories constitutes a great part of our *knowledge.*

Different regions of the brain are connected by nerve fibers. So when one region recalls a memory, another

region recalls another memory of the same object. Thus, when the temporal region recalls the memory of a sound of a bell, the occipital region recalls its appearance.

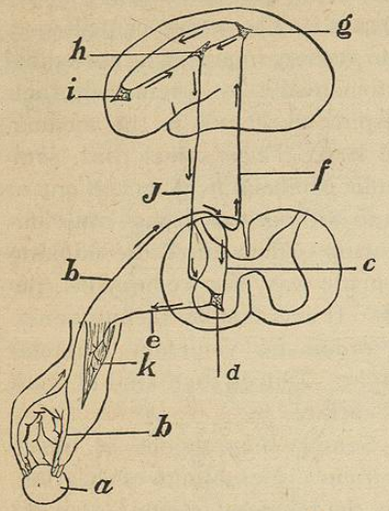


Diagram of the course of nerve influences in voluntary motions.

a object to be picked up.
b sensory nerve.
c the part of the influence which goes to the cells of the cord, and tends to produce reflex action.
d cell of spinal cord.
e motor nerve from spinal cord.
f continuation of the sensory nerve *b* up the cord to the brain.
g cell of the brain which perceives touch.
h motor cell.
i thought cell.
j motor nerve fiber running to the cells of the cord, and carrying an influence which continues along the motor nerve *e*.
k muscle which moves the hand.

534. Motor regions. — Orders for voluntary motion are sent by the cells lying just in front of a zone connecting the two ears. Each muscle of the body is controlled by a special set of nerve cells called its *motor center*.

A motor impulse passes down through the white matter of the cerebrum, medulla, and spinal cord to the spinal nerve cells, and then out along a motor nerve to a muscle. In an injury or disease in the top of the skull some of the cells of the motor region may be involved, giving paralysis of certain muscles. By the muscles affected one can often judge of the exact location of the trouble and remove it by an operation.

535. Relation of the sensory to the motor regions. — The motor and sensory regions are in close connection by nerve fibers in the white matter. The motor region regulates its impulses according to information brought to sensory regions by sensory nerves. A carpenter regulates the force with which he pushes his plane according to the feeling of muscular resistance.

536. Memory of movements. — Acts of motor cells are stored in memory and constitute a part of knowledge. All motions must be learned at first. When the brain centers have learned a movement thoroughly they teach the spinal centers so that finally their work is almost entirely relieved, and they can be occupied in other thoughts. Awkwardness is usually the result of the brain's attempting to send out orders for motion while it is occupied with other thoughts. Ease and grace of motion come when the spinal centers have learned to relieve the brain center.

537. Thought regions. — The cells of the frontal regions take note of memories stored in other regions, and by their comparison form new ideas. Thus, a pause between two sensations or mental acts gives rise to an idea of time; and the sight of two objects removed from each other gives the idea of space and of number. Neither time nor space nor number in itself can make an impression upon the senses, and yet they are realities in the mind. Comparison of memories and the formation of new ideas is *thinking*. Thoughts themselves are stored in memory and can be recalled and compared.

538. Speech. — Thought is expressed by speech. By means of speech new sensory and motor ideas and new thoughts are gained and stored in the memory without the cells of the different regions experiencing the particular sensations. Herein is the main difference between a man and an animal. An animal gains new ideas only by memory of its sensations and acts which it itself experiences, but a man can acquire them second hand by being told. Thus a man may be profited by the experience of

others. Knowledge gained only by long and patient research of wise men is imparted to children in a few moments, while an animal can impart knowledge only in a limited degree.

539. Speech in animals. — All animals have a variety of natural cries. Monkeys have a dozen separate cries which are similar in all species. A hen has at least five different cries to express as many different ideas. Parrots and crows have been taught to speak a few words, but they do it just as the mocking bird or brown thrush imitates any sound which it hears. Speech belongs to man alone.

540. Of what speech consists. — Speech is one of the highest and most complicated of mental processes. It is not a natural gift, but must always be learned at first. A child first hears a word spoken. He records it in the temporal regions of the brain, and learns to recall certain sensory and motor memories when he hears the word. By the time he is a year and a half old his motor region begins to form the word when he thinks of the memory. At the age of six or eight he begins to recognize the printed word with his sight region, and finally he learns to write the word with his motor region. Thus nearly every region in the brain takes part in some form of speech.

541. Center for spoken words. — The muscles of the mouth can be moved by the cells of the face center in the motor region, but their movements in speech are so precise and complicated that a center is especially provided to produce their movements in talking. It is situated just below and in front of the motor area, but is usually upon only one side. When this center is disturbed, a person cannot talk, although he understands spoken and written speech, and has control of his lips and tongue in doing other things.

542. Disturbance of the speech centers. — There are cases in which the word-seeing center is disturbed so that a person can speak and write correct answers to questions, but cannot read and understand what he has just written. Sometimes a person cannot speak his thoughts, but can read aloud what he has written. Careful observation of the speech is of great value in locating brain diseases, for the speech centers involve nearly every region of the brain.

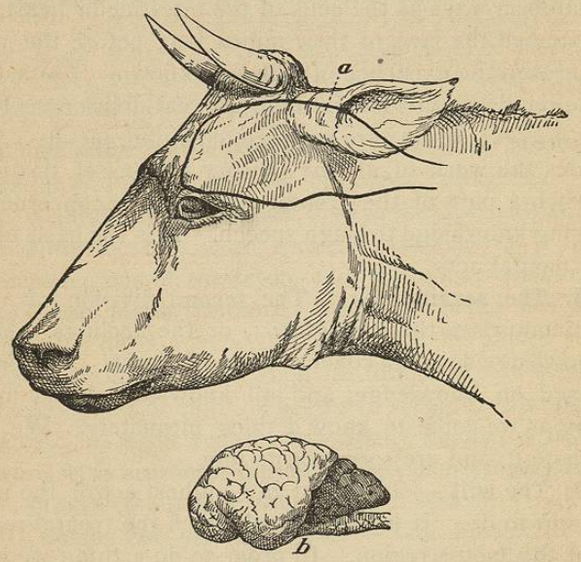
543. Mind study. — The cerebral cells act in as definite and uniform ways as the cells of the intestine or heart, and men studied the laws of their minds long before the structure or even the existence of cells was known. The actions of the mind are divided into three great divisions. First, is the *intellect*, or the pure knowledge-gaining faculty. This includes the work of all the sensory regions of the brain and such a part of the frontal regions as is concerned in receiving knowledge through speech. It is the basis of the other mental acts.

544. The sensibilities. — The second division of mind study comprises the *sensibilities*, or the feelings. Much of knowledge does not concern us in the least. All feeling is based on knowledge, and all knowledge leads up to feeling as we come to know a thing intimately. We love it or hate it, and are sorry for its loss.

545. The will. — The third and highest act of the mind is to *will* to do. It is the control which the frontal region has of the motor region. In order to do a thing we must first have knowledge, and, second, we must feel some degree of emotion or desire to do it. Only a small part of knowledge causes feeling or emotion, and only a small part of even our strong feelings are expressed in action.

Of all the actions of the mind the will is the most difficult to arouse and control. Since it depends upon feeling, this faculty must first be aroused. Men readily act their feelings of anger and fear. To form a new will, active and brave, which is capable of controlling the natural and acquired appetites and passions, is the highest and noblest work of man.

546. Brains of animals. — The medulla is much the same in all animals from the frog up to man. This is because breathing and the flow of blood are much the same in all. The cerebellum in a frog or snake or fish is very small, for they need but a small regulating and balancing part. A bird or a hen must make precise movements in balancing itself in flying or roosting, and so it has a large cerebellum.



Brain of an ox.

a outline of brain in the skull. *b* the brain removed from the skull.

The optic tubercles of frogs and birds are well developed, for their eyes are perfect. The cerebrum of frogs and snakes and fishes is very small. Its hinder parts are the largest, for in them the impressions of sight, hearing, and smell are located. Its fore parts are mere points, as would be expected from the low intelligence of the animals. A bird has a larger cerebrum, corresponding to a greater mind. An animal's cerebrum is much larger and is somewhat folded to give room for more nerve cells, but the frontal or thought region is small. An animal's

senses are as acute as a man's, and so the back parts of its brain are well developed.

547. Animal intelligence. — An animal is capable of storing sensory and motor impressions in memory, and of sending out motor impulses according to sensory impressions. In some respects he is capable of doing this to a far greater extent than man. For instance, a dog can find his master by the sense of smell alone. He can also use his frontal region in thought and judgment, but to an extent which corresponds to the small size of this region.

548. The essential difference between man and animals. — The possession of speech seems to be the key to man's progress and noble ambitions. By means of it the Creator has revealed to him a knowledge of things before the foundation of the world, and of things to come. Animals are incapable of receiving instruction except through the senses and so they make no progress. Man rises in thought above time and space itself.

549. The nervous system in lower animals. — All four-footed animals, birds, fish, and reptiles possess nerves, a spinal cord, and a brain. Their nerves, sympathetic system, spinal cord, and medulla are developed nearly as much as in man, for the creatures eat, feel, move, and breathe, often to a greater extent than man. The cerebrum is developed according to the intelligence of the animal, and the cerebellum according to the complication of its movements.

Insects and worms and shellfish have no brain or spinal cord, but a row of ganglia like those in the sympathetic system extends through the body. Each ganglion gives off nerves to the cells of the body. These creatures do little else than eat and digest food, and hence the highest nervous system is not needed.

In the lowest form of life there is no nervous system at all. When the animal consists of a few cells or of only a single cell, no nervous system is needed.

SUMMARY

1. The brain is the part of the central nervous system which originates impulses.
2. The brain is continuous with the spinal cord, and consists of the medulla, cerebellum, optic tubercles,

and cerebrum. Each consists of gray matter containing nerve cells, and of white matter made of nerve threads.

3. The medulla is like the spinal cord in that it gives off sensory and motor nerves.
4. The medulla also originates impulses controlling respiration and the contraction of arteries.
5. The cerebellum adjusts the voluntary motor impulses of the brain, so that movements like balancing of the body are done with precision.
6. The optic tubercles are reflex centers for the eyes.
7. The cerebrum forms four fifths of the brain, and consists of a puckered covering of gray matter over a central mass of white nerve fibers.
8. The cells of each part of the brain have a definite work to do. They receive sensory impressions, send motor impulses, and think.
9. The impressions of each cell remain as permanent memories which can be recalled at will.
10. By means of speech, thought, sensory and motor impressions are conveyed to other persons and there become memories as though they had actually been experienced.
11. In speech the centers for motion, sound, and sight all take part.
12. There is a special center for producing the movements of the mouth in speech.
13. The first stage of mind action is knowledge; the next, emotion; and the third, willing and acting.

DEMONSTRATIONS

126. Show as types the brains of a frog or fish; of a hen; and of a fourfooted animal. A frog's, fish's, or chicken's brain can easily be

removed by cutting away the skull. After opening the top of the skull, place it with the brain in Müller's fluid or formalin for a few days, when the brain will be hard and can be removed with little injury.

127. In the frog, note the medulla, then the thin cerebellum, looking like a disk of paper with its edge inserted just above the medulla. Note the swelling optic tubercles, and then the long, pointed halves of the cerebrum.

Next compare the same parts on a bird's brain. Note the similar medulla and optic tubercles. Note the large cerebellum forming a half moon above the optic tubercles, and marked with cross fissures upon its back part. Note the cerebrum in front, shaped like a chestnut and as large as the rest of the brain.

Next compare the same parts in a mammal's brain. Note the similar medulla, but the larger cerebellum. The optic tubercles are obscured by the cerebrum. Note the cerebrum, large enough to cover almost all the rest of the brain. Note the convolutions.

Now compare these brains with a model or a picture of the brain of man. Note the large frontal regions in man and the larger and more numerous fissures and convolutions, and that the cerebrum completely covers all the other parts of the brain.

128. When the skull of an animal is opened, note the lining of tough and thick *dura mater*, which may be peeled off with little difficulty. Note that it extends in between the two hemispheres of the brain and between the cerebrum and cerebellum. Underneath it, note the delicate meshes of the *pia mater*, containing numerous blood tubes. Note that it dips into all the fissures and contains a small amount of a thin, clear fluid.

129. Examine a specimen of the gray matter of the cerebrum or cerebellum with a microscope magnifying 400 diameters. Note its nerve cells with fine branches. The white matter will appear like a collection of ordinary nerve fibers. Sketch the specimen.

REVIEW TOPICS

1. Name the different parts of a frog's brain in order, and tell how they differ from the same parts in a man's brain.
2. Describe the two coverings of the brain.

3. Describe the medulla, its nerves and reflex action; its respiratory center; its vasomotor center; and the effects of its injury.
4. Describe the cerebellum and give its action.
5. Describe the optic tubercles and give their action.
6. Describe the cerebrum; its hemispheres, fissures, convolutions, gray and white matter, and regions.
7. Locate the region in which impressions of sight are received; of touch; of hearing; of smell; and of taste.
8. Describe the region from which motor impulses for voluntary motion are sent out.
9. Describe the memory, and show why recalling one thought brings to mind another thought of the same object.
10. Locate the thought region of the brain, and describe the process of thought.
11. Show that by speech man gains ideas which an animal can get only by actual experience.
12. Locate and describe the mode of action of the center for spoken words; for written speech; and of the speech-hearing and speech-seeing centers.
13. Describe the three main divisions of the acts of the mind.
14. Compare the corresponding parts of the brains of different animals with each other and with the same parts of the brain of man.
15. Describe the nervous system in insects, worms, shell-fish, and in the lowest forms of animals.

CHAPTER XXXII

INFLUENCES WHICH AFFECT THE MIND

550. Stimulation to action. — The thought cells of the brain are given power over voluntary actions of the body, with no higher power to cause them to act, except the will, which is the result of their own action. Were a child left entirely to itself, it would probably exercise its mind no more than an animal. But the sight of objects and ambitions not yet attained spurs the thought cells to action, just as sensations cause the spinal cord and motor region to act. Without constant stimulus of the senses and feelings the thought cells languish and almost cease to act. As the body is compelled to grow by the cells of the spinal cord, so must the mind be compelled to grow by an effort of the will. Few men possess a will strong enough to act without the stimulus of other minds, but association with trained minds arouses the will to exercise one's own mind.

551. Concentration of the mind. — In order to become educated, the mind must be exercised persistently and for hours at a time. The mind does not grow unless its whole energies are often directed towards a single object. It is not study to read a page and then to converse about sports for a moment and then to study another moment, for each impression sweeps away the preceding one. True study is to sit down in a quiet room, and to fix the mind upon the book continuously for an hour or more. Then the mind will be occupied so that it takes no note of time or outside