PSYCHOLOGY

A STUDY OF MENTAL LIFE

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Cerebrum read Chap. 20 & 21.

CHAPTER III

REACTIONS OF DIFFERENT LEVELS

HOW SENSATIONS, PERCEPTIONS AND THOUGHTS MAY BE CONSIDERED AS FORMS OF INNER RESPONSE, AND HOW THESE HIGHER REACTIONS ARE RELATED IN THE NERVOUS SYSTEM TO THE SIMPLER RESPONSES OF THE REFLEX LEVEL.

Having defined a reaction as an act of the individual aroused by a stimulus, there is no reason why we should not include a great variety of mental processes under the general head of reactions. Any mental process is an activity of the organism, and it is aroused by some stimulus, external or internal; therefore, it is a reaction.

I hear a noise—now, while the noise, as a physical stimulus, comes to me, my hearing it is my own act, my sensory reaction to the stimulus. I recognize the noise as the whistle of a steamboat—this recognition is clearly my own doing, dependent on my own past experience, and may be called a perception or perceptive response. The boat's whistle reminds me of a vacation spent on an island—clearly a memory response. The memory arouses an agreeable feeling—an affective response, this may be called. In its turn, this may lead me to imagine how pleasant it would be to spend another vacation on that island, and to cast about for ways and means to accomplish this result—here we have imagination and reasoning, aroused by what preceded just as the sensation was aroused by the physical stimulus.

In speaking of any mental process as an act of the individual, we do not mean to imply that he is always *conscious* of his activity. Sometimes he feels active, sometimes passive. He feels active in hard muscular work or hard thinking, while he feels passive in reflex action, in sensation, and in simply " being reminded " of anything without any effort on his own part. But he is active in everything he does, and he does everything that depends on his being alive. Life is activity, and every manifestation of life, such as reflex action or sensation, is a form of vital activity. The only way to be inactive is to be dead.

But vital activity is not " self-activity " in any absolute sense, for it is *aroused* by some stimulus. It does not issue from the individual as an isolated unit, but is his *response* to a stimulus. That is the sense of calling any mental process a reaction; it is something the individual does in response to a stimulus.

To call a sensation a form of reaction means, then, that the sensation is not something done to the person, nor passively received by him from outside, but something that he himself does when aroused to this particular form of activity. What comes from outside and is received by the individual is the stimulus, and the sensation is what he does in response to the stimulus. It represents the discharge of internal stored energy in a direction determined by his own inner mechanism. The sensation depends on his own make-up as well as on the nature of the stimulus, as is especially obvious when the sensation is abnormal or peculiar. Take the case of color blindness. The same stimulus that arouses in most people the sensation of red arouses in the color-blind individual the sensation of brown. Now what the color-blind individual *receives*, the light stimulus, is the same as what others receive, but he responds differently, *i.e.*, with a different sensation, because his own sensory apparatus is peculiar.

The main point of this discussion is that all mental phenomena, whether movements, sensations, emotions, impulses or thoughts, are a person's acts, but that every act is a response to some present stimulus. This rather obvious truth has not always seemed obvious. Some theorists, in emphasizing the spontaneity and "self-activity" of the individual, have pushed the stimulus away into the background; while others, fixing their attention on the stimulus, have treated the individual as the passive recipient of sensation and "experience" generally. Experience, however, is not received; it is lived, and that means done; only, it is done in response to stimuli. The concept of reaction covers the ground.

While speaking of sensations and thoughts as belonging under the general head of reactions, it is well, however, to bear in mind that all mental action tends to arouse and terminate in muscular and glandular activity. A thought or a feeling tends to "express itself" in words or (other) deeds. The motor response may be delayed, or inhibited altogether, but the tendency is always in that direction.

Different Sorts of Stimuli

To call all mental processes reactions means that it is always in order to ask for the stimulus. Typically, the stimulus is an external force or motion, such as light or sound, striking on a sense organ. There are also the internal stimuli, consisting of changes occurring within the body and acting on the sensory nerves that are distributed to the muscles, bones, lungs, stomach and most of the organs. The sensations of muscular strain and fatigue, and of hunger and thirst, are aroused by internal stimuli, and many reflexes are aroused in the same way.

Such internal stimuli as these are like the better known external stimuli in that they act upon sense organs; but it seems necessary to recognize another sort of stimuli which act directly on the nerve centers in the brain. These may be called "central stimuli" and so contrasted with the "peripheral stimuli" that act on any sense organ, external or internal. To do this is to take considerable liberty with the plain meaning of "stimulus", and calls for justification. What is the excuse for thus expanding the notion of a stimulus?

The excuse is found in the frequent occurrence of mental processes that are not directly aroused by any peripheral stimulus, though they are plainly aroused by something else. Anything that arouses a thought or feeling can properly be called its stimulus. Now it often happens that a thought is aroused by another, just preceding thought; and it seems quite in order to call the first thought the stimulus and the second the response. A thought may arouse an emotion, as when the thought of my enemy, suddenly occurring to mind, makes me angry; the thought is then the stimulus arousing this emotional response.

If hearing you speak of Calcutta makes me think of India, your words are the stimulus and my thought the response. Well, then, if I *think* of Calcutta in the course of a train of thought, and next think of India, what else can we say than that the thought of Calcutta acts as a stimulus to arouse the thought of India as the response? In a long train of thought, where A reminds you of B and B of C and C of D, each of these items is, first, a response to the preceding, and, second, a stimulus to the one following.

There is no special difficulty with the notion of "central stimuli" from the physiological side. We have simply to think of one nerve center arousing another by means of the tract of axons connecting the two. Say the auditory center is aroused by hearing some one mention your friend's name and this promptly calls up a mental picture of your friend; here the auditory center has aroused the visual. What happens in a train of thought is that first one group of neurones is aroused to activity, and then this activity, spreading along the axons that extend from this group of neurones to another, arouses the second group to activity; and so on. The brain process may often be exceedingly complex, but this simple scheme gives the gist of it.

The way nerve currents must go shooting around the brain from one center or group of neurones to another, keeping it up for a long time without requiring any fresh peripheral stimulus, is remarkable. We have evidence of this sort of thing in a dream or fit of abstraction. Likely enough, the series of brain responses would peter out after awhile, in the absence of any fresh peripheral stimulus, and total inactivity ensue. But response of one brain center to nerve currents coming from another brain center, and not directly from any sense organ, must be the rule rather than the exception, since most of the brain neurones are not directly connected with any sense organ, but only with other parts of the brain itself. All the evidence we have would indicate that the brain is not "self-active", but only responsive; but, once thrown into activity at one point, it may successively become active at many other points, so that a long series of mental operations may follow upon a single sensory stimulus.

The Motor Centers, Lower and Higher

A "center" is a collection of nerve cells, located somewhere in the brain or cord, which gives off axons running to some other center or out to muscles or glands, while it also receives axons coming from other centers, or from sense organs. These incoming axons terminate in end-brushes and so form synapses with the dendrites of the local nerve cells. The axons entering any center and terminating there arouse that center to activity, and this activity, when aroused, is transmitted out along the axons issuing from that center, and produces results where those axons terminate in their turn.

The *lower* motor centers, called also reflex centers, are located in the cord or brain stem, and their nerve cells give

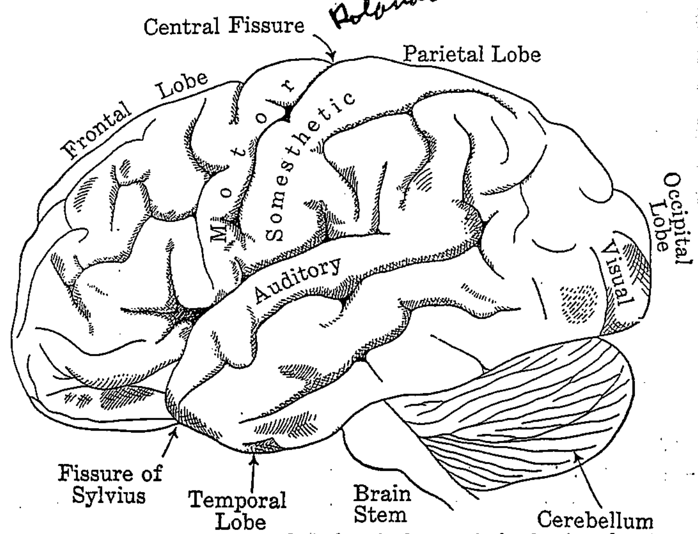
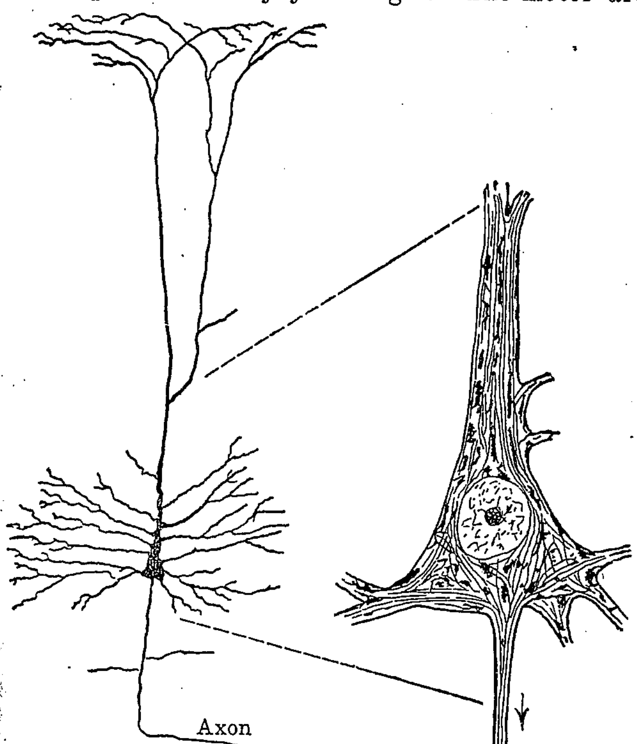


FIG. 12.—Side view of the left hemisphere of the brain, showing the motor and sensory areas (for the olfactory area, see Fig. 18). The visual area proper, or "visuo-sensory area," lies just around the corner from the spot marked "Visual," on the middle surface of the hemisphere, where it adjoins the other hemisphere.

rise to the axons that form the motor nerves and connect with the muscles and glands. A muscle is thrown into action by nerve currents from its lower motor center.

The principal *higher* motor center is the "motor area" of the brain, located in the cortex or external layer of gray matter, in the cerebrum. More precisely, the motor area is a long, narrow strip of cortex, lying just forward of what is called the "central fissure" or "fissure of Rolando", If you run your finger over the top of the head from one side to the other, about halfway back from the forehead, the motor areas of the two cerebral hemispheres will lie close under the path traced by your finger. The motor area in



Giant pyramid cell from the motor area of the cerebral cortex, magnified 35 diameters

Cell body of same further magnified

FIG. 13.—(After Cajal.) Type of the brain cells that most directly control muscular movement.

the right hemisphere is connected with the left half of the cord and so with the muscles of the left half of the body; the motor area of the left hemisphere similarly affects the right half of the body. Within the motor area are centers for the several limbs and other motor organs. Thus, at the top, near the middle line of the head (and just about where the phrenologists located their "bump of veneration"!), is the center for the legs; next below and to the side is the center for the trunk, next that for the arm, next

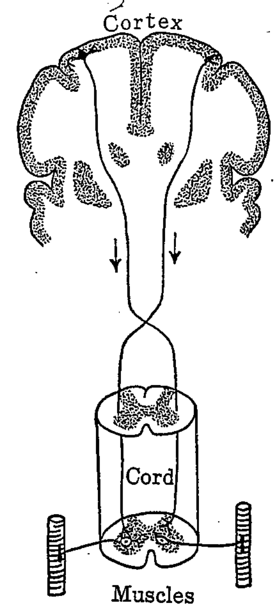


Fig. 14.—The nerve path by which the motor area of the cortex influences the muscles. The upper part of this path, consisting of axons issuing from the giant pyramids of the motor area and extending down into the spinal cord, is the pyramidal tract. The lower part of the path consists of axons issuing from the motor cells of the cord and extending out to the muscles. The top of the figure represents a vertical cross-section of the brain, such as is given, on a larger scale, in Fig. 18.

that for head movements, and at the bottom, not far from the ears, is the center for tongue and mouth.

The largest nerve cells of all are found in the motor area, and are called, from their shape, the "giant pyramids". They have large dendrites and very long axons, which latter, running in a thick bundle down from the cortex through the brain stem and cord, constitute the "pyramidal tract", the principal path of communication from the cerebrum to the lower centers. The motor area of the brain has no direct connection with any muscle, but acts through the pyramidal tract on the lower centers, which in turn act on the muscles.

How the Brain Produces Muscular Movements

The motor area is itself aroused to action by nerve currents entering it through axons coming from other parts of the cortex; and it is by way of the motor area that any other part of the cortex produces bodily movement. There are a few exceptions, as, for example, the movements of the eyes are produced generally by the "visual area" acting directly on the lower motor centers for the eye in the brain stem; but, in the main, any motor effect of brain action is exerted through the motor area. The motor area, as already mentioned, acts on the lower motor centers in the cord and brain stem, and these in turn on the muscles; but we must look into this matter a little more closely.

A lower motor center is a group of motor and central neurones, lying anywhere in the cord or brain stem, and capable of directly arousing a certain coördinated muscular movement. One such unit gives flexion of the leg, another gives extension of the leg, a third gives the rapid alternation of flexion and extension that we see in the scratching movement of the dog. Such a motor center can be aroused to activity by a sensory stimulus, and the resulting movement is then called a reflex.

The lower center can be aroused in quite another way, and that is by nerve currents coming from the brain, by way of the motor area and the pyramidal tract. Thus flexion of the leg can occur voluntarily as well as reflexly. The same muscles, and the same motor neurones, do the job in either case. In the reflex, the lower center is aroused by a sensory nerve, and in the voluntary movement by the pyramidal tract.

The story is told of a stranger who was once dangling his legs over the edge of the station platform at a small backwoods town, when a native called out to him "Hist!" (hoist), pointing to the ground under the stranger's feet. He "histed" obediently, which is to say that he voluntarily threw into play the spinal center for leg flexion; and then, looking down, saw a rattler coiled just beneath where his feet had been hanging. Now even if he had spied the rattler first, the resulting flexion, though impulsive and involuntary, would still have been aroused by way of the motor area and the pyramidal tract, since the movement would have been a response to *knowledge* of what that object was and signified, and knowledge means action by the cerebral cortex, which we have seen to affect movement through the medium of the motor area. But if the snake had made the first move, the same leg movement on the man's part, made now in response to the painful sensory stimulus, would have been the flexion reflex.

Facilitation and Inhibition

Not only can the motor area call out essentially the same movements that are also produced reflexly, but it can prevent or *inhibit* the execution of a reflex in spite of the sensory stimulus for the reflex being present, and it can reinforce or *facilitate* the action of the sensory stimulus so as to assist in the production of the reflex. We see excellent examples of cerebral facilitation and inhibition in the case of the knee jerk. This sharp forward kick of the foot and lower leg is aroused by a tap on the tendon running in front of the knee. Cross the knee to be stimulated over the other leg, and tap the tendon just below the knee cap, and the knee jerk appears. So purely reflex is this movement that it cannot be duplicated voluntarily; for, though the foot can of course be voluntarily kicked forward, this voluntary movement does not have the suddenness and quickness of the true reflex. For all that, the cerebrum can exert an influence on the knee jerk. Anxious attention to the knee jerk inhibits it; gritting the teeth or clenching the fist reinforces it. These are cerebral influences acting by way of the pyramidal tract upon the spinal center for the reflex.

Thus the cortex controls the reflexes. Other examples of such control are seen when you prevent for a time the natural regular winking of the eyes by voluntarily holding them wide open, or when, carrying a hot dish which you know you must not drop, you check the flexion reflex which would naturally pull the hand away from the painful stimulus. The young child learns to control the reflexes of evacuation, and gradually comes to have control over the breathing movements, so as to hold his breath or breathe rapidly or deeply at will, and to expire vigorously in order to blow out a match.

The coughing, sneezing and swallowing reflexes likewise come under voluntary control. In all such cases, the motor area facilitates or inhibits the action of the lower centers.

Super-motor Centers in the Cortex

Another important effect of the motor area upon the lower centers consists in combining their action so as to produce what we know as skilled movements. It will be remembered that the lower centers themselves give coördinated movements, such as flexion or extension of the whole limb; but still higher coördinations result from cerebral control.

When the two hands, though executing different movements, work together to produce a definite result, we have coördination controlled by the cortex. Examples of this are seen in handling an ax or bat, or in playing the piano or violin. A movement of a single hand, as in writing or buttoning a coat, may also represent a higher or cortical coördination.

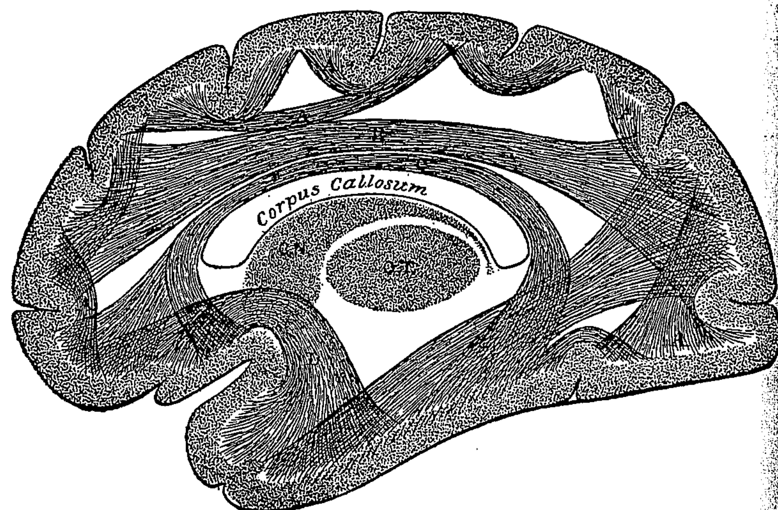


FIG. 15.—(From Starr.) Axons connecting one part of the cortex with another. The brain is seen from the side, as if in section. At "A" are shown bundles of comparatively short axons, connecting near-by portions of the cortex; while "B," "C," and "D" show bundles of longer axons, connecting distant parts of the cortex with one another. The "Corpus Callosum" is a great mass of axons extending across from each cerebral hemisphere to the other, and enabling both hemispheres to work together. "O. T." and "C. N." are interior masses of gray matter, which can be seen also in Fig. 18. "O. T." is the thalamus, about which more later.

Now it appears that the essential work in producing these higher coördinations of skilled movement is performed not by the motor area, but by neighboring parts of the cortex, which act on the motor area in much the same way as the motor area acts on the lower centers. Some of these skilled-movement centers, or super-motor centers, are located in the cortex just forward of the motor area, in the adjacent parts of the frontal lobe. Destruction of the cortex there, through injury or disease, deprives the individual of some of his skilled movements, though not really paralyzing him. He can still make simple movements, but not the complex movements of writing or handling an instrument.

It is a curious fact that the left hemisphere, which exerts control over the movements of the right hand and right side of the body generally, also plays the leading part in skilled movements of either hand. This is true, at least, of right-handed persons; probably in the left-handed the right hemisphere dominates.

Motor power may be lost through injury at various points in the nervous system. Injury to the spinal cord, destroying the lower motor center for the legs, brings complete paralysis. Injury to the motor area or to the pyramidal tract does not destroy reflex movement, but cuts off all voluntary movement and cerebral control. Injury to the "super-motor centers" causes loss of skilled movement, and produces the condition of "apraxia", in which the subject, though knowing what he wants to do, and though still able to move his limbs, simply cannot get the combination for the skilled act that he has in mind.

Speech Centers

Similar to apraxia is "aphasia" or loss of ability to speak. It bears the same relation to true paralysis of the speech organs that hand apraxia bears to paralysis of the hand. Through brain injury it sometimes happens that a person loses his ability to speak words, though he can still make vocal sounds. The cases differ in severity, some retaining the ability to speak only one or two words which from frequent use have become almost reflex (swear words, sometimes, or " yes " and " no "), while others are able to pronounce single words, but can no longer put them together fluently into the customary form of phrases and sen-

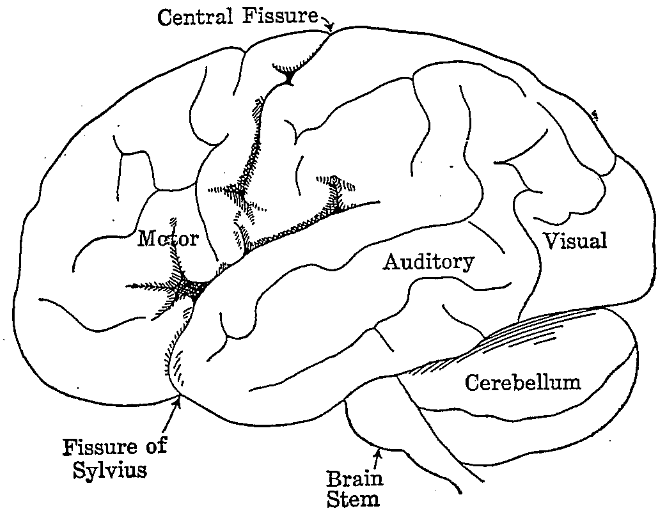


FIG. 16.—Side view of the left hemisphere, showing the location of the "speech centers." The region marked "Motor" is the motor speech center, that marked "Auditory" the auditory speech center, and that marked "Visual" the visual speech center.

tences, and still others can utter simple sentences, but not any connected speech.

In pure cases of *motor aphasia*, the subject knows the words he wishes to say, but cannot get them out. The brain injury here lies in the frontal lobe in the left hemisphere, in right-handed people, just forward of the motor area for the mouth, tongue and larynx. This " motor speech center " is the best-known instance of a super-motor center. It coördinates the elementary speech movements into the combinations called words; and perhaps there is no other motor performance so highly skilled as this of speaking. It is acquired so early in life, and practised so constantly, that we take it quite as a matter of course, and think of a word as a simple and single movement, while in fact even a short word, as spoken, is a complex movement requiring great motor skill.

There is some evidence that the motor speech center extends well forward into the frontal lobe, and that the front part of it is related to the part further back as this is to the motor area back of it. That is to say, the back of the speech center combines the motor units of the motor area into the skilled movements of speaking a word, while the more forward part of the speech center combines the word movements into the still more complex movement of speaking a sentence. It is even possible that the very front part of the speech center has to do with those still higher combinations of speech movements that give fluency and real excellence of speaking.

The Auditory Centers

Besides the motor aphasia, just mentioned, there is another type, called *sensory aphasia*, or, more precisely, auditory aphasia. In pure auditory aphasia there is no inability to pronounce words or even to speak fluently, but there is, first, an inability to "hear words", sometimes called word deafness, and there is often also an inability to find the right words to speak, so that the individual so afflicted, while speaking fluently enough and having sense in mind, misuses his words and utters a perfect jargon. One old gentleman mystified his friends one morning by declaring that he must go and "have his umbrella washed", till it was finally discovered that what he wanted was to have his hair cut.

The cortical area affected in this form of aphasia is located a little further back on the surface of the brain than the motor speech center, being close to the auditory area proper. The latter is a small cortical region in the temporal lobe, connected (through lower centers) with the ear, and is the only part of the cortex to receive nerve currents from the organ of hearing. The auditory area is, indeed, the organ of hearing, or an organ of hearing, for without it the individual is deaf. He may make a few reflex responses to loud noises, but, consciously, he does not hear at all; he has no auditory sensations.

In the immediate neighborhood of the auditory area proper (or of the "auditory-sensory area", as it may well be called), are portions of the cortex intimately connected by axons with it, and concerned in what may be called auditory perceptions, i.e., with recognizing and understanding sounds. Probably different portions of the cortex near the auditory-sensory center have to do with different sorts of auditory perception. At least, we sometimes find individuals who, as a result of injury or disease affecting this general region, are unable any longer to follow and appreciate music. They cannot "catch the tune" any longer, though they may have been fine musicians before this portion of their cortex was destroyed. In other cases, we find, instead of this music deafness, the word deafness mentioned just above.

The jargon talk that so often accompanies word deafness reminds us of the fact that speech is first of all auditory to the child. He understands what is said to him before he talks himself, and his vocabulary for purposes of understanding always remains ahead of his speaking vocabulary. It appears that this precedence of auditory speech over motor remains the fact throughout life, in most persons, and that the auditory speech center is the most fundamental of all the speech centers, of which there is one more not yet mentioned, used in reading.

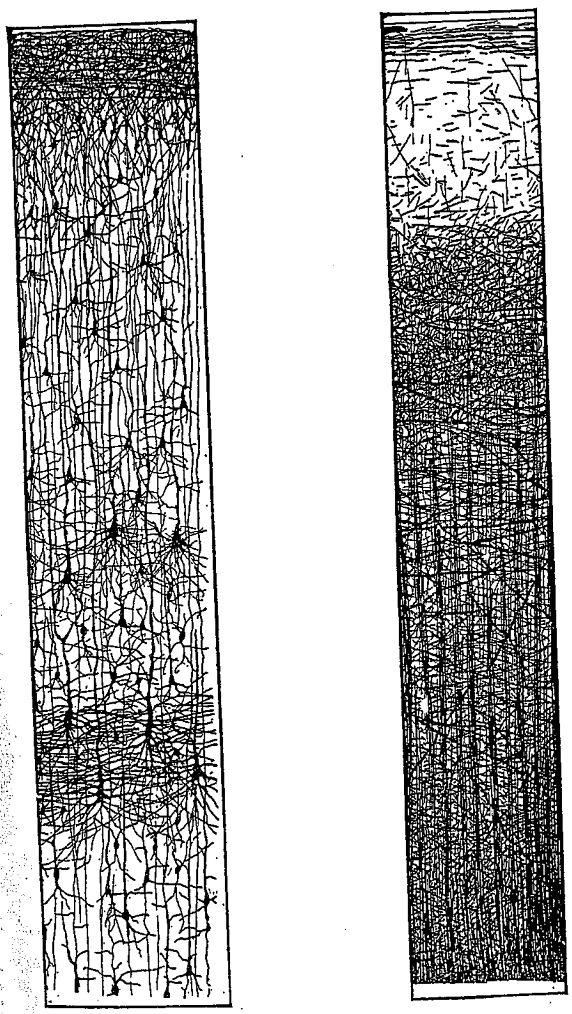


FIG. 17.—(From Cajal.) Magnified sections through the cortex, to show the complexity of its inner structure. One view shows nerve cells and their dendrites, with only a few axons, while the other shows axons, outgoing and incoming, and some of their fine branches. Imagine one view superimposed upon the other, and you get some idea of the intricate interweaving of axons and dendrites that occurs in the cortex.

THE VISUAL CENTERS

There is a visual-sensory area in the occipital lobe, at the back of the brain, that is connected with the eye in the same way as the auditory center is connected with the ear. With-

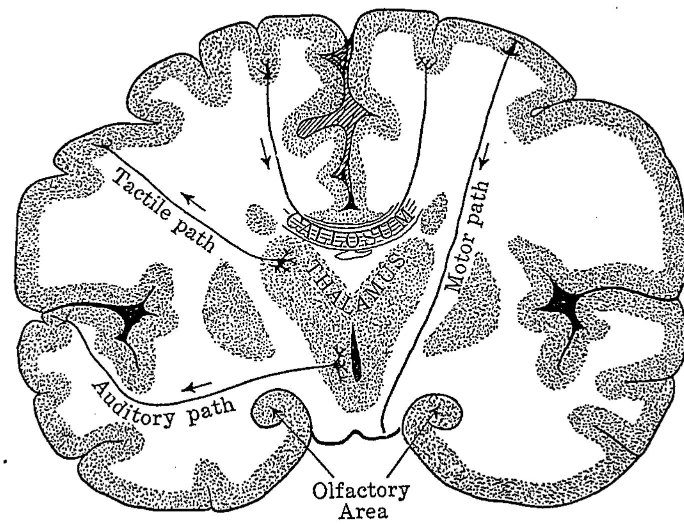


FIG. 18.—Vertical cross-section through the brain, showing the cortex on the outside, the thalamus and other interior masses of gray matter, some of the paths to and from the cortex, and the callosum or bridge of axons connecting the two cerebral hemispheres. The "Motor path" is the pyramidal tract, only the beginning of which is shown here, its further course being indicated in Fig. 14.

out it, the individual still shows the pupillary reflex to light, but has no sensations of sight. He is blind.

This visual-sensory area occupies only a small portion of the occipital lobe, and yet practically the whole lobe is concerned with vision. Some portions of the lobe are concerned in perceiving words in reading, and without them the individual is "word blind". Other portions are concerned in perceiving (recognizing, understanding) seen objects, and without them the individual is "object blind". Other portions are concerned in perceiving color relations, and still other portions in perceiving spatial relations through the sense of sight and so knowing where seen objects are and being able to guide one's movements by sight.

Cortical Centers for the Other Senses

There is an olfactory area in a rather secluded part of the cortex, and this is related to the sense of smell in the same general way. Probably there is a similar taste center, but it has not been definitely located. Then there is a large and important area called the "somesthetic", connected with the body senses generally, i.e., chiefly with the skin and muscle senses. This area is located in a narrow strip just back of the central fissure, extending parallel to the motor area which lies just in front of the fissure, and corresponding part for part with it, so that the sensory area for the legs lies just behind the motor area for the legs, and so on. Destruction of any part of this somesthetic area brings loss of the sensations from the corresponding part of the body.

Just behind this direct sensory center for the body, in the parietal lobe, are portions of the cortex concerned in perceiving facts by aid of the body senses. Perception of size and shape by the sense of touch, perception of weight by the muscle sense, perception of degrees of warmth and cold by the temperature sense, are dependent on the parietal lobe and disappear when the cortex of this region is destroyed. It appears that there is a sort of hierarchy of centers here, as in the motor region and probably also in the visual and auditory regions. Skill in handling objects is partly dependent on the "feel" of the objects and so is impaired by injuries to the parietal lobe, as well as by injury to the frontal lobe; and knowing how to manage a fairly complex situation, as in lighting a fire when you have the various materials assembled before you, seems also to depend largely on this part of the cortex.

LOWER SENSORY CENTERS

As already indicated, no portion of the cortex, not even the sensory areas, is directly connected with any sense organ. The sensory axons from the skin, for example, terminate in the spinal cord, in what may be called the lowest sensory

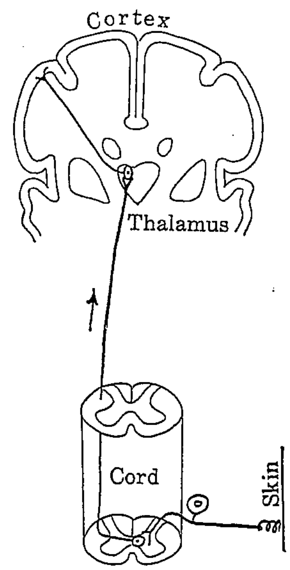


FIG. 19.—Sensory path from the skin of any portion of the trunk or limbs. The path consists of three neurones, the cell body of the first lying just outside the spinal cord, that of the second lying in the cord, and that of the third lying in the thalamus. The last part of this path is the "Tactile path," shown in Fig. 18.

centers. Here are nerve cells whose axons pass up through the cord and brain stem to the thalamus or interbrain, where they terminate in a second sensory center. And cells here send their axons up to the somesthetic area of the cortex.

The thalamus is remarkable as an intermediate center for all the senses, except smell; but exactly what is accomplished by this big intermediate sensory center remains rather a mystery, though it certainly appears that the thalamus has something to do with feeling and emotion.

The Cerebellum

Regarding the cerebellum, there is much knowledge at hand, but it is difficult to give the gist of it in a few words. On the one hand, the cerebellum receives a vast number of axons from the lower sensory centers; while, on the other hand, it certainly has nothing to do with conscious sensation or perception. Its use seems to be motor. It has much to do with maintaining the equilibrium of the body, and probably also with maintaining the steadiness and general efficiency of muscular contraction. Though it has no known sensory or intellectual functions, it is very closely connected with the cerebrum, receiving a tremendous bundle of axons from different parts of the cerebrum, by way of the brain stem. Possibly these are related to motor activity. The phrenologists taught that the cerebellum was the center for the sexual instinct, but there is no evidence in favor of this guess.

Different Levels of Reaction

Let a noise strike the ear and start nerve currents in along the auditory nerve, passing through the lowest and intermediate centers and reaching the auditory-sensory area of the cortex. When this last is aroused to activity, we have a sensation of sound, which is the first conscious reaction to the external stimulus. Axons running from the auditory-sensory to the near-by cortex give a perception of some fact indicated by the external stimulus, and this perception is a second and higher conscious reaction, which, to be sure, ordinarily occurs so quickly after the first that introspection cannot distinguish one as first and the other as second; but the facts of brain injury, already mentioned, enable us to draw the distinction. The perceived fact may call up a mental image, or a recognition of some further fact less directly signified by the noise; these would be reactions of still higher order. Much of the cortex is apparently not very directly connected with either the sensory or the motor areas, and probably is concerned somehow in the recognition of facts that are only very indirectly indicated by any single sensory stimulus, or with the planning of actions that only indirectly issue in muscular movement.

On the sensory and intellectual side, the higher reactions follow the lower: sensation arouses perception and perception thought. On the motor side, the lower reactions are aroused by the higher. Thus the speech center arouses the motor centers for the speech organs, combining the action of these into the speaking of a word; and in a similar way, it seems, the intention to speak a sentence expressing a certain meaning acts as a stimulus to call up in order the separate words that make the sentence. A general plan of action precedes and arouses the particular acts and muscular movements that execute the plan.

EXERCISES

1. Outline of the chapter. Fill in sub-topics under each of the following heads:
   - A. Mental processes of all kinds are reactions.
   - B. The stimulus that directly arouses a mental process is often "central".
   - C. Brain activities of all sorts influence the muscles by way of the motor area and the lower motor centers.
   - D. Brain action in skilled movement.
   - E. Brain action in speech.
   - F. Brain action in sensation.
   - G. Brain action in recognizing seen or heard objects.
   - H. Relations of reactions of different levels.
2. Define and illustrate these classes of stimuli:
   - A. Peripheral:
     - (1) External.
     - (2) Internal.
   - B. Central.
3. Show by a diagram how one cortical center arouses another. Compare the diagram in Fig. 9, p. 37.
4. Facilitation of the patellar reflex or "knee jerk". Let your subject sit with one leg hanging freely from the knee down. With the edge of your hand strike the patellar tendon just below the knee cap. (a) Compare the reflex movement so obtained with a voluntary imitation by the subject. Which is the quicker and briefer? (b) Apply a fairly strong auditory stimulus (a sudden noise) a fraction of a second before the tap on the tendon, and see whether the reflex response is reinforced. (c) Ask the subject to clench his fists or grit his teeth, and tap the tendon as he does so. Reinforcement? (d) Where is the reflex center for the patellar reflex, and whence comes the reinforcing influence?
5. Construct a diagram showing the different centers and connections involved in making the skilled movement of writing; and consider what loss of function would result from destruction of each of the centers.

REFERENCES

Herrick's *Introduction to Neurology*, 1918, Chapter XX, on the "Functions of the Cerebrum".

Stile's *Nervous System and Its Conservation*, Chapters X, XI and XII. XIII