ber of persons, including Darwin, Haldane, Oparin, and Urey and demonstrated by Miller, Fox, and others (*21*). It is then possible reasonably to assume that the ability to synthesize such a compound biologically could arise through a series of separate single mutations, each adding successive enzymatically catalyzed steps in the synthetic sequence, starting with the one immediately responsible for the end product. In this way each mutational step could confer a selective advantage by making the organism dependent on one less exogenous precursor of a needed end product. Without some such mechanism, by which no more than a single gene mutation is required for the origin of a new enzyme, it is difficult to see how complex synthetic pathways could have evolved. I know of no alternative hypothesis that is equally simple and plausible.

Place of Genetics in Modern Biology

In a sense, genetics grew up as an orphan. In the bginning, botanists and zoologists were often indifferent and sometimes hostile toward it. "Genetics deals only with superficial characters," it was often said. Biochemists likewise paid it little heed in its early days. They —especially medical biochemists—knew of Garrod's "inborn errors of metabolism" and no doubt were aware of their significance in the biochemical sense and as diseases, but the biological world was inadequately prepared to appreciate fully the significance of Garrod's investigations and his thinking. Geneticists, it should be said, tended to be preoccupied mainly with the mechanisms by which genetic material is transmitted from one generation to the next.

Today, happily, the situation is much changed. Genetics has an established place in modern biology. Biochemists recognize the genetic material as an integral part of the systems with which they work. Our rapidly growing knowledge of the architecture of proteins and nucleic acids is making it possible—for the first time in the history of science—for geneticists, biochemists, and biophysicists to discuss basic problems of biology in the common language of molecular structure. To me, this is most encouraging and significant.

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CURRENT PROBLEMS IN RESEARCH

The Interpretive Cortex

The stream of consciousness in the human brain can be electrically reactivated.

Wilder Penfield

There is an area of the surface of the human brain where local electrical stimulation can call back a sequence of past experience. An epileptic irritation in this area may do the same. It is as though a wire recorder, or a strip of cinematographic film with sound track, had been set in motion within the brain. The sights and sounds, and the thoughts, of a former day pass through the man's mind again.

The purpose of this article is to describe, for readers from various disciplines of science, the area of the cerebral cortex from which this neuron record of the past can be activated and to suggest what normal contribution it may make to cerebral function.

The human brain is the master organ of the human race. It differs from the brains of other mammals particularly in the greater extent of its cerebral cortex. The gray matter, or cortex, that covers the two cerebral hemispheres of the brain of man is so vast in nerve cell population that it could never have been contained within the human skull if it were not folded upon itself, and refolded, so as to form a very large number of fissures and convolutions (Fig. 1). The fissures are so deep and so devious that by far the greater portion of this ganglionic carpet (about 65 percent) is hidden in them, below the surface (Fig. 2).

The portion that is labeled "interpretive" in Figs. 1 and 3 covers a part of both temporal lobes. It is from these two homologous areas, and from nowhere else, that electrical stimulation has occasionally produced physical responses which may be divided into (i) experiential responses and (ii) interpretive responses.

Experiential Responses

Occasionally during the course of a neurosurgical operation under local anesthesia, gentle electrical stimulation in this temporal area, right or left, has caused the conscious patient to be aware

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of some previous experience (*1*). The experience seems to be picked out at random from his own past. But it comes back to him in great detail. He is suddenly aware again of those things to which he paid attention in that distant interval of time. This recollection of an experiential sequence stops suddenly when the electrical current is switched off or when the electrode is removed from contact with the cortex. This phenomenon we have chosen to call an experiential response to stimulation.

Case examples (*2*). The patient S.Be. observed, when the electrode touched the temporal lobe (right superior temporal convolution), "There was a piano over there and someone playing. I could hear the song you know." When the cortex was stimulated again without warning, at approximately the same point, the patient had a different experience. He said: "Someone speaking to another, and he mentioned a name but I could not understand it . . . It was like a dream." Again the point was restimulated without his knowledge. He said quietly: "Yes, 'Oh Marie, Oh Marie'! Someone is singing it." When the point was stimulated a fourth time he heard the same song again and said it was the "theme song of a radio program."

The electrode was then applied to a point 4 centimeters farther forward on the first temporal convolution. While the electrode was still in place, S.Be. said: "Something brings back a memory. I can see Seven-Up Bottling Company—Harrison Bakery." He was evidently seeing two of Montreal's large illuminated advertisements.

The surgeon then warned him that he was about to apply the electrode again. Then, after a pause, the surgeon said "Now," but he did not stimulate. (The patient has no means of knowing when the electrode is applied, unless he is told, since the cortex itself is without sensation.) The patient replied promptly, "Nothing."

A woman (D.F.) (*3*) heard an orchestra playing an air while the electrode was held in place. The music stopped when the electrode was removed. It came again when the electrode was reapplied. On request, she hummed the tune, while the electrode was held in place, accompanying the orchestra. It was a popular song. Over and over again, restimulation at the same spot produced the same song. The music seemed always to begin at the same place and to progress at the normally expected tempo. All efforts to mislead her failed. She believed that a gramaphone was being turned on in the operating room on each occasion, and she asserted her belief stoutly in a conversation some days after the operation.

A boy (R.W.) heard his mother talking to someone on the telephone when an electrode was applied to his right temporal cortex. When the stimulus was repeated without warning, he heard his mother again in the same conversation. When the stimulus was repeated after a lapse of time, he said, "My mother is telling my brother he has got his coat on backwards. I can just hear them."

The surgeon then asked the boy whether he remembered this happening. "Oh yes," he said, "just before I came here." Asked again whether this seemed like a dream, he replied: "No, it is like I go into a daze."

J.T. cried out in astonishment when the electrode was applied to the temporal cortex; "Yes doctor, yes doctor. Now I hear people laughing—my friends in South Africa!"

When asked about this, he explained the reason for his surprise. He seemed to be laughing with his cousins, Bessie and Ann Wheliow, whom he had left behind him on a farm in South Africa, although he knew he was now on the operating table in Montreal.

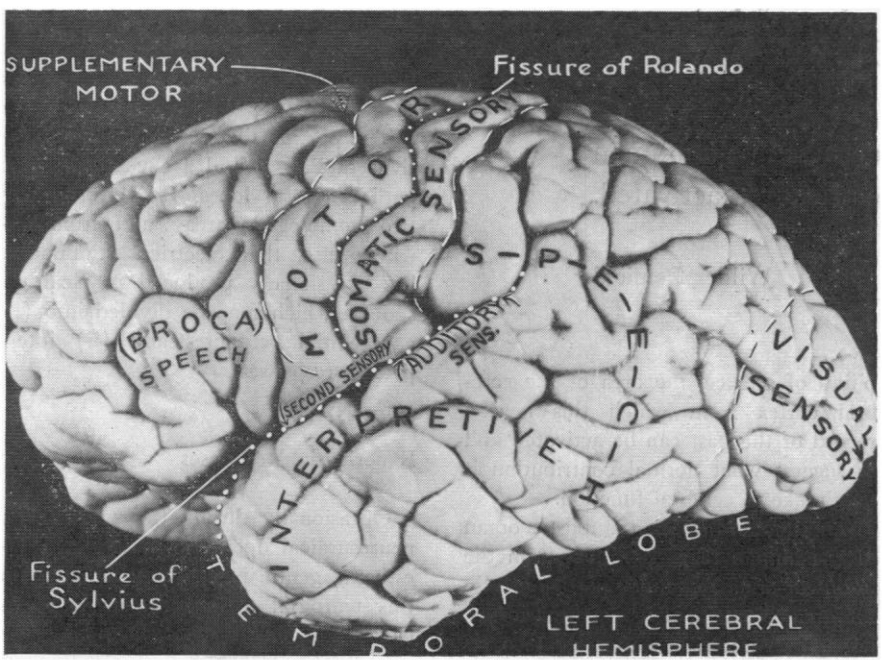


Fig. 1. Photograph of the left hemisphere of a human brain. The frontal lobe is on the left, the occipital lobe on the right. The major motor and sensory areas are indicated, as well as the speech areas and the interpretive area. [Penfield and Roberts (*18*)]

Interpretive Responses

On the other hand, similar stimulation in this same general area may produce quite a different response. The patient discovers, on stimulation, that he has somehow changed his own interpretation of what he is seeing at the moment, or hearing or thinking. For example, he may exclaim that his present experience seems familiar, as though he had seen it or heard it or thought it before. He realizes that this must be a false interpretation. Or, on the contrary, these things may seem suddenly strange, absurd. Sights or sounds may seem distant and small, or they may come unexpectedly close and seem loud or large. He may feel suddenly afraid, as though his environment were threatening him, and he is possessed by a nameless dread or panic. Another patient may say he feels lonely or aloof, or as though he were observing himself at a distance.

Under normal circumstances anyone may make such interpretations of the present, and these interpretations serve him as guides to action or reaction. If the interpretations are accurate guides, they must be based upon previous comparable experience. It is conceivable, therefore, that the recall mechanism which is activated by the electrode during an experiential response and the mechanism activated in an interpretive response may be parts of a common inclusive mechanism of reflex recognition or interpretation.

No special function had been previously assigned by neurologists to the area in each temporal lobe that is marked "interpretive" in Figs. 1 and 3, though some clinicians have suggested it might have to do with the recall of music. The term *interpretive cortex,* therefore, is no more than slang to be employed for the purposes of discussion. The terms *motor cortex, sensory cortex,* and *speech cortex* began as slang phrases and have served such a purpose. But such phrases must not be understood to signify independence of action of separated units in the case of any of these areas. Localization of function in the cerebral cortex means no more than specialization of function as compared with other cortical regions, not separation from the integrated action of the brain.

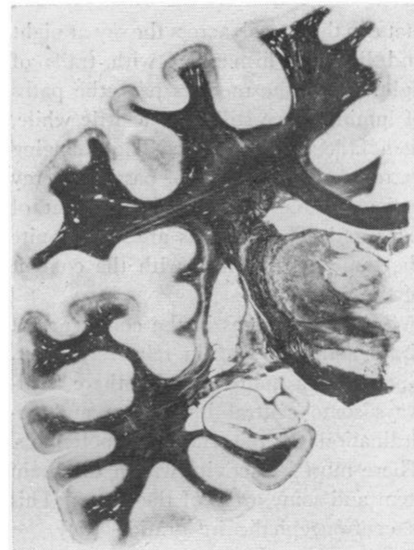
Before considering the interpretive cortex further, we may turn briefly to the motor and sensory areas and the speech areas of the cortex. After considering the effects of electrical stimulation there, we should be better able to understand the results of stimulation in the temporal lobes.

Specialization of Function in the Cortex

Evidence for some degree of localization within the brain was recognized early in the 19th century by Flourens. He concluded from experiment that functional subdivision of "the organ of the mind" was possible. The forebrain (*4*), he said [cerebral hemispheres and higher brain stem (Fig. 4)] had to do with thought and will power, while the cerebellum was involved in the coordination of movement.

In 1861, Paul Broca showed that a man with a relatively small area of destruction in a certain part of the left hemisphere alone might lose only the power of speech. It was soon realized that this was the speech area of man's dominant (left) hemisphere. In 1870, Fritsch and Hitzig applied an electric current to the exposed cortex of one hemisphere of a lightly anesthetized dog and caused the legs of the opposite side to move. Thus, an area of cortex called motor was discovered.

After that, localization of function became a research target for many clinicians and experimentalists. It was soon evident that in the case of man, the precentral gyrus (Fig. 5) in each hemisphere was related to voluntary control of the contralateral limbs and that there was an analogous area of motor cortex in the frontal lobes of animals. It appeared also that other separate areas of cortex (Figs. 1 and 5) in each hemisphere were dedicated to sensation (one for visual sensation, others for auditory, olfactory, and discriminative somatic sensation, respectively).



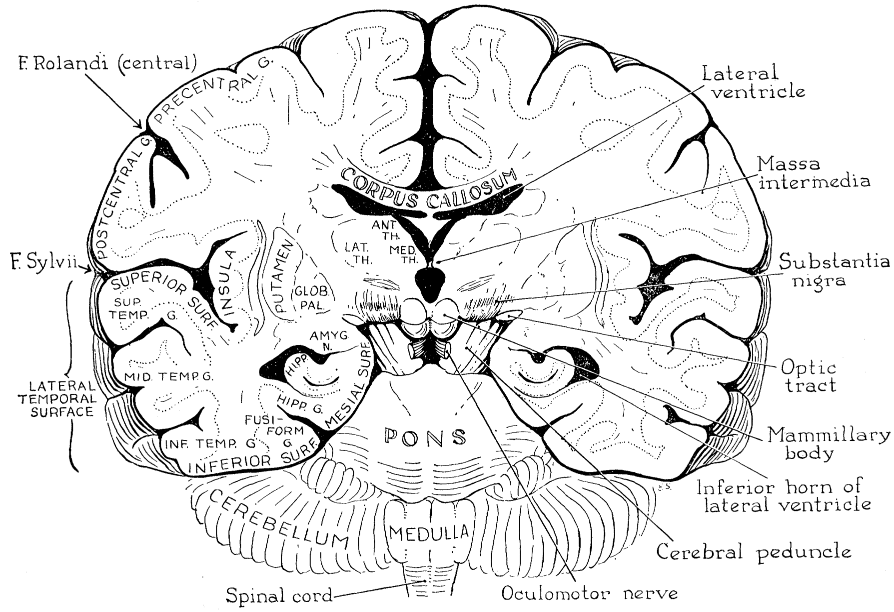


Fig. 2. (Right) Photograph of a cross section of the left cerebral hemisphere [Jelgersma (*19*)]. The white matter is stained black and the gray matter is unstained. The major convolutions of the cerebral cortex and the subcortical masses of gray matter can be identified by reference to the diagram below. (Bottom) Drawing of the cross section shown at right, above, with additions. The surfaces and convolutions of the temporal lobe are identified, and the relationship of one hemisphere to the other and the relationship of the hemispheres to the brain stem and cerebellum are shown.

It was demonstrated, too, that from the "motor cortex" there was an efferent bundle of nerve fibers (the pyramidal tract) that ran down through the lower brain stem and the spinal cord to be relayed on out to the muscles. Through this efferent pathway, voluntary control of these muscles was actually carried out. It was evident, too, that there were separate sensory tracts carrying nerve impulses in the other direction, from the principal organs of special sense (eye, ear, nose, and skin and muscle) into separate sensory areas of the cortex.

These areas, motor and sensory, have been called "projection areas." They play a role in the projection of nerve currents to the cortex from the periphery of the body, and from the cortex to the periphery. This makes possible (sensory) awareness of environment and provides the individual with a means of outward (motor) expression. The motor cortex has a specialized use during voluntary action, and each of the several sensory areas has a specialized use, when the individual is seeing, hearing, smelling, or feeling.

Traveling Potentials

The action of the living brain depends upon the movement, within it, of "transient electrical potentials traveling the fibers of the nervous system." This was Sherrington's phrase. Within the vast circuits of this master organ, potentials travel, here and there and yonder, like meteors that streak across the sky at night and line the firmament with trails of light. When the meteors pass, the paths of luminescence still glow a little while, then fade and are gone. The changing patterns of these paths of passing energy make possible the changing content of the mind. The patterns are never quite the same, and so it is with the content of the mind.

Specialized areas in the cortex are at times active and again relatively quiet. But, when a man is awake, there is always some central integration and coordination of the traveling potentials. There must be activity within the brain stem and some areas of the cortex. This is centrencephalic integration (*5*).

Sensory, Motor, and Psychical Responses to Cortical Stimulation

My purpose in writing this article is to discuss in simple words (free of technical terms) the meaning of the "psychical" responses which appear only on stimulation of the so-called interpretive cortex. But before considering these responses let us consider the motor and sensory activity of the cortex for a moment.

When the streams of electrical potentials that pass normally through the various areas of sensory cortex are examined electrically, they do not seem to differ from each other except in pattern and timing. The essential difference is to be found in the fact that the visual stream passes to the visual cortex and then to one subcortical target and the auditory stream passes through the auditory cortex and then on to another subcortical target.

When the surgeon stimulates the intact sensory cortex he must be sending a current along the next "piece of road" to a subcortical destination. This electrode (delivering, for example, 60 "waves" per second of 2-millisecond duration and 1-volt intensity) produces no more than elementary sight when applied to visual cortex. The patient reports colors, lights, and shadows that move and take on crude outlines. The same electrode, applied to auditory cortex, causes him to hear a ringing or hissing or thumping sound. When applied to postcentral gyrus it produces tingling or a false sense of movement.

Thus, sensation is produced by the passage inward of electrical potentials. And when the electrode is applied to the motor cortex, movement is produced by passage of potentials outward to the muscles. In each case positive response is produced by conduction in the direction of normal physiological flow—that is, by dromic conduction (*6*).

Responses to electrical stimulation that may be called "psychical," as distinguished from sensory or motor, have been elicited from certain areas of the human cortex (Fig. 6). But they have never been produced by stimulation in other areas. There are, of course, other large areas of cortex which are neither sensory nor motor in function. They seem to be employed in other neuron mechanisms that are also associated with psychical processes. But the function of these other areas cannot, it seems, be activated by so simple a stimulus as an electric current applied to the cortex.

Dreamy States of Epilepsy

"Epilebsy" may be defined, in Jackson's words, as "the name for occasional, sudden, excessive, rapid and local discharges of grey matter." Our aim in the operations under discussion was to remove the gray matter responsible for epileptic attacks if that gray matter could be spared. When the stimulating electrode reproduced the psychical phenomenon that initiated the fit, it provided the guidance sought (*7*).

During the 19th century clinicians had recognized these phenomena as epileptic. They applied the term *intellectual*

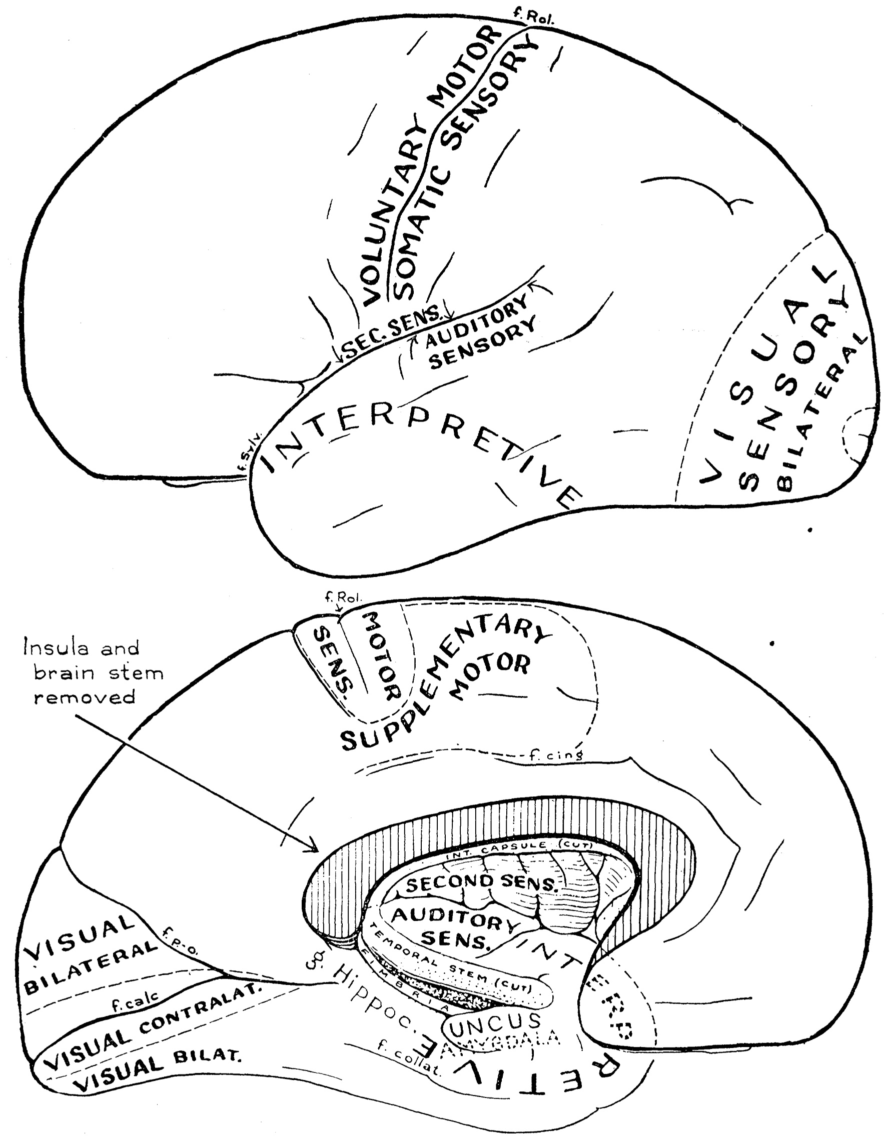


Fig. 3. The left cerebral hemisphere; the lateral surface is shown above and the mesial surface below. In the lower drawing the brain stem with the island of Reil has been removed to show the inner banks of the fissure of Sylvius and the superior surface of the temporal lobe. The interpretive cortex extends from the lateral to the superior surface of the temporal lobe. [Penfield and Roberts (*18*)]

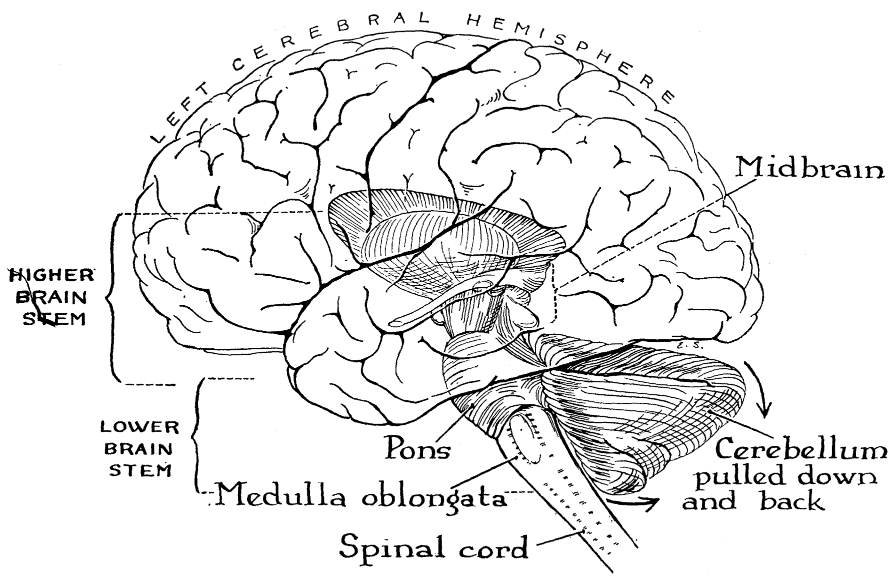


Fig. 4. Drawing of the left cerebral hemisphere, showing the higher brain stem, including the thalamus, within and the lower brain stem and spinal cord emerging below. The cerebellum is shown, attached to the lower brain stem. [Penfield and Roberts (*18*)]

aura to such attacks. Jackson substituted the expression *dreamy states* (see *8*). These were, he said, "psychical states during the onset of certain epileptic seizures, states which are much more elaborate than crude sensations." And again, he wrote, "These are all voluminous mental states and yet of different kinds; no doubt they ought to be classified, but for my present purpose they may be considered together."

"The state," he said, "is often like that occasionally experienced by healthy people as a feeling of 'reminiscence.'" Or the patient has "dreamy feelings," "dreams mixing up with present thoughts," "double consciousness," a "feeling of being somewhere else," a feeling "as if I went back to all that occurred in my childhood," "silly thoughts."

Jackson never did classify these states, but he did something more important. He localized the area of cortex from which epileptic discharge would produce dreamy states. His localization was in the anterior and deep portions of the temporal lobes, the same area that is labeled "interpretative" cortex in Fig. 3.

Case example. Brief reference may be made to a specific case. The patient had seizures, and stimulation produced responses which were first recognized as psychical.

In 1936, a girl of 16 (J.V.) was admitted to the Montreal Neurological Institute complaining of epileptic attacks, each of which was ushered in by the same hallucination. It was a little dream, she said, in which an experience from early childhood was reenacted, always the same train of events. She would then cry out with fear and run to her mother. Occasionally this was followed immediately by a major convulsive seizure.

At operation, under local anesthesia, we tried to set off the dream by a gentle electrical stimulus in the right temporal lobe. The attempt was successful. The dream was produced by the electrode. Stimulation at other points on the temporal cortex produced sudden fear without the dream. At still other points, stimulation caused her to say that she saw "someone coming toward me." At another point, stimulation caused her to say she heard the voices of her mother and her brothers (*9*).

This suggested a new order of cortical response to electrical stimulation. When the neighboring visual sensory area of the cortex is stimulated, any patient may report seeing stars of light or moving colors or black outlines but never "someone coming toward me." Stimulation of the auditory sensory cortex may cause any patient to report that he hears ringing, buzzing, blowing, or thumping sounds, perhaps, but never voices that speak. Stimulation in the areas of sensory cortex can call forth nothing more than the elements of visual or auditory or tactile sensation, never happenings that might have been previously experienced.

During the 23 years that have followed, although practically all areas of the cerebral cortex have been stimulated and studied in more than 1000 craniotomies, performed under local anesthesia, psychical responses of the experiential or interpretive variety have been produced only from the temporal cortex in the general areas that are marked "psychical responses" in Fig. 3 (*10, 11*).

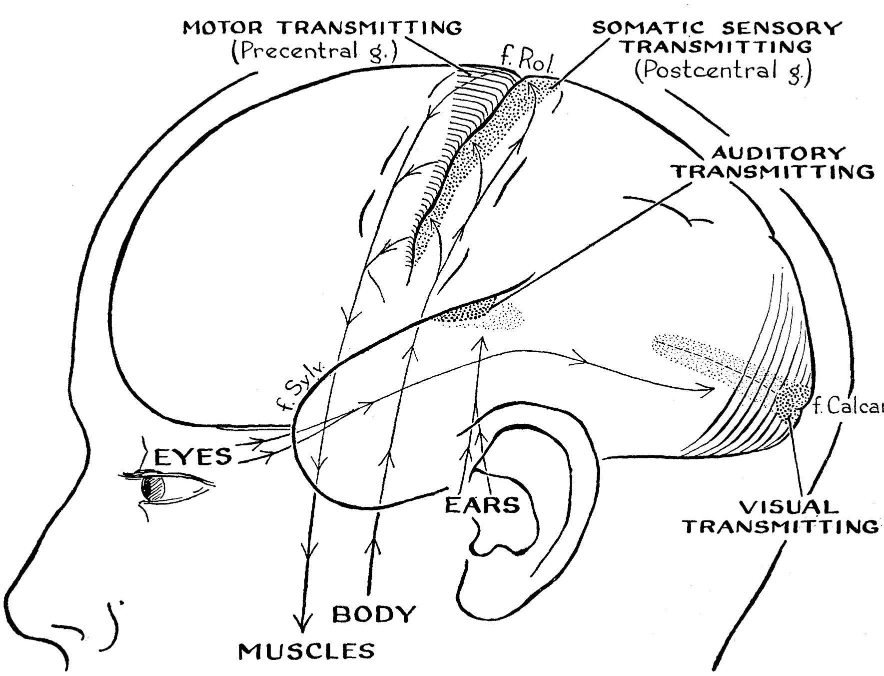


Fig. 5. Sensory and motor projection areas. The sensory areas are stippled, and the afferent pathways to them from eyes, ears, and body are indicated by entering arrows. The motor cortex is indicated by parallel lines, and the efferent corticospinal tract is indicated by emerging arrows. [Penfield and Roberts (*18*)]

Classification

It seems reasonable to subdivide psychical responses and psychical seizures (epileptic dreamy states) in the same way, classifying them as "interpretive" or "experiential." Interpretive psychical responses are those involving interpretations of the present experience, or emotions related to it; experiential psychical responses are reenactments of past experiences. Interpretive seizures are those accompanied by auras and illusions; experiential seizures are those accompanied by auras and hallucinations.

The interpretive responses and seizures may be divided into groups (*11*) of which the commonest are as follows: (i) recognition, the illusion that things seen and heard and thought are familiar (*déjà vu* phenomenon); (ii) visual illusion, the illusion that things seen are changing—for example, coming nearer, growing larger (macropsia); (iii) auditory illusion, the illusion that things heard are changing—for example, coming near, going away, changing tempo; (iv) illusional emotion, the emotion of fear or, less often, loneliness, sorrow, or disgust.

Experiential phenomena (hallucinations) are an awareness of experiences from the past that come into the mind without complete loss of awareness of the present.

Discussion

What, then, is the function of the interpretive cortex? This is a physiological question that follows the foregoing observations naturally.

An electrode, delivering, for example, 60 electrical pulses per second to the surface of the motor cortex, causes a man to make crude movements. When applied to the various sensory areas of the cortex, it causes him to have crude sensations of sight or sound or body feeling. This indicates only that these areas have something to do with the complicated mechanism of voluntary action or conscious sensation. It does not reveal what contribution the cortex may make, or in what way it may contribute to skill in making voluntary movement or qualify the incoming sensory streams.

In the case of the interpretive cortex, the observations are similar. We may say that the interpretive cortex has something to do with a mechanism that can reactivate the vivid record of the past. It has also something to do with a

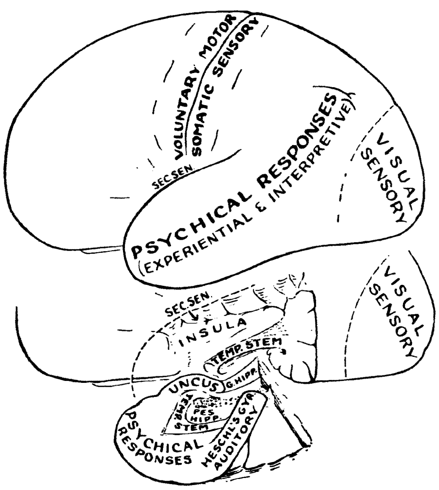


Fig. 6. The left cerebral hemisphere is shown with the temporal lobe cut across and turned down. The areas of cortex from which psychical responses have been elicited are indicated. [Penfield (*1*)]

mechanism that can present to consciousness a reflex interpretation of the present. To conclude that here is the mechanism of memory would be an unjustified assumption. It would be too simple.

What a man remembers when he makes a voluntary effort is apt to be a generalization. If this were not so, he might be hopelessly lost in detail. On the other hand, the experiential responses described above are detailed reenactments of a single experience. Such experiences soon slip beyond the range of voluntary recall. A man may summon to mind a song at will. He hears it then in his mind, not all at once but advancing phrase by phrase. He may sing it or play it too, and one would call this memory.

But if a patient hears music in response to the electrode, he hears it in one particular strip of time. That time runs forward again at the original tempo, and he hears the orchestration, or he sees the player at a piano "over there." These are details he would have thought forgotten.

A vast amount of work remains to be done before the mechanism of memory, and how and where the recording takes place, are understood. This record is not laid down in the interpretive cortex, but it is kept in a part of the brain that is intimately connected with it.

Removal of large areas of interpretive cortex, even when carried out on both sides, may result in mild complaints of memory defect, but it does not abolish the capacity to remember recent events. On the other hand, surgical removals that result in bilateral interference with the underlying hippocampal zone do make the recording of recent events impossible, while distant memory is still preserved (*12, 13*).

The importance of the hippocampal area for memory was pointed out long ago in a forgotten publication by the Russian neurologist Bechterew (*14*). The year before publication Bechterew had demonstrated the case before the St. Petersburg Clinic for Nervous and Mental Diseases. The man on whom Bechterew reported had "extraordinary weakness of memory, falsifications of memory and great apathy." These defects were shown at autopsy to be secondary to lesions of the mesial surface of the cortex of both temporal lobes. The English neurologists Glees and Griffith (*15*) reported similar defects, a half century later, in a patient who had symmetrical lesions of the hippocampus and of hippocampal and fusiform gyri on both sides.

The way in which the interpretive cortex seems to be used may be suggested by an example: After years of absence you meet, by chance, a man whose very existence you had forgotten. On seeing him, you may be struck by a sudden sense of familiarity, even before you have time to "think." A signal seems to flash up in consciousness to tell you that you've seen that man before. You watch him as he smiles and moves and speaks. The sense of familiarity grows stronger. Then you remember him. You may even recall that his name was Jones. The sight and the sound of the man has given you an instant access, through some reflex, to the records of the past in which this man has played some part. The opening of this forgotten file was subconscious. It was not a voluntary act. You would have known him even against your will. Although Jones was a forgotten man a moment before, now you can summon the record in such detail that you remark at once the slowness of his gait or a new line about the mouth.

If Jones had been a source of danger to you, you might have felt fear as well as familiarity before you had time to consider the man. Thus, the signal of fear as well as the signal of familiarity may come to one as the result of subconscious comparison of present with similar past experience.

One more example may be given from common experience. A sudden increase in the size of objects seen and in sounds heard may mean the rapid approach of something that calls for instant avoidance action. These are signals that, because of previous experience, we sometimes act upon with little consideration.

Summary

The interpretive cortex has in it a mechanism for instant reactivation of the detailed record of the past. It has a mechanism also for the production of interpretive signals. Such signals could only be significant if past records are scanned and relevant experiences are selected for comparison with present experience. This is a subconscious process. But it may well be that this scanning of past experience and selection from it also renders the relevant past available for conscious consideration as well. Thus, the individual may refer to the record as he employs other circuits of the brain.

Access to the record of the past seems to be as readily available from the temporal cortex of one side as from that of the other. Auditory illusions (or interpretations of the distance, loudness, or tempo of sounds) have been produced by stimulation of the temporal cortex of either side. The same is true of illusional emotions, such as fear and disgust.

But, on the contrary, visual illusions (interpretations of the distance, dimension, erectness, and tempo of things seen) are only produced by stimulation of the temporal cortex on the nondominant (normally, right) side of the brain. Illusions of recognition, such as familiarity or strangeness, were also elicited only from the nondominant side, except in one case.

Conclusion

"Consciousness," to quote William James (*16*), "is never quite the same in successive moments of time. It is a stream forever flowing, forever changing." The stream of changing states of mind that James described so well does flow through each man's waking hours until the time when he falls asleep to wake no more. But the stream, unlike a river, leaves a record in the living brain.

Transient electrical potentials move with it through the circuits of the nervous system, leaving a path that can be followed again. The pattern of this pathway, from neuron to neuron along each nerve-cell body and fiber and junction, is the recorded pattern of each man's past. That complicated record is held there in temporal sequence through the principle of durable facilitation of conduction and connection.

A steady stream of electrical pulses applied through an electrode to some point in the interpretive cortex causes a stream of excitation to flow from the cortex to the place where past experience is recorded. This stream of excitation acts as a key to the past. It can enter the pathway of recorded consciousness at any random point, from childhood on through adult life. But having entered, the experience moves forward without interference from other experiences. And when the electrode is withdrawn there is a likelihood, which lasts for seconds or minutes, that the stream of excitation will enter the pathway again at the same moment of past time, even if the electrode is reapplied at neighboring points (*17*).

Finally, an electric current applied to the surface of what may be called the interpretive cortex of a conscious man (i) may cause the stream of former consciousness to flow again or (ii) may give him an interpretation of the present that is unexpected and involuntary. Therefore, it is concluded that, under normal circumstances, this area of cortex must make some functional contribution to reflex comparison of the present with related past experience. It contributes to reflex interpretation or perception of the present.

The combination and comparison of present experience with similar past experience must call for remarkable scanning of the past and classification of similarities. What contribution this area of the temporal cortex may make to the whole process is not clear. The term *interpretive cortex* will serve for identification until students of human physiology can shed more light on these fascinating findings.

References and Notes

1. W. Penfield, *J. Mental Sci.* 101, 451 (1955).
2. These patients, designated by the same initials, have been described in previous publications in much greater detail. An index of patients (designated by initials) may be found in any of my books.
3. This case is reported in detail in W. Penfield and H. Jasper, *Epilepsy and the Functional Anatomy of the Human Brain* (Little, Brown, Boston, 1954) [published in abridged form in Russian (translation by N. P. Graschenkov and G. Smirnov) by the Soviet Academy of Sciences, 1958].
4. The forebrain, or prosencephalon, properly includes the diencephalon and the telencephalon, or higher brain stem, and hemispheres. Flourens probably had cerebral hemispheres in mind as distinguished from cerebellum.
5. "Within the brain, a central transactional core has been identified between the strictly sensory or motor systems of classical neurology. This central reticular mechanism has been found capable of grading the activity of most other parts of the brain"—H. Magoun, *The Waking Brain* (Thomas, Springfield, Ill., (1958).
6. W. Penfield, *The Excitable Cortex in Conscious Man* (Thomas, Springfield, Ill., 1958).
7. It did more than this; it produced illusions or hallucinations that had never been experienced by the patient during a seizure.
8. J. Taylor, Ed., *Selected Writings of John Hughlings Jackson* (Hodder and Stoughton, London, 1931), vol. 1, *On Epilepsy and Epileptiform Convulsions.*
9. Twenty-one years later this young woman, who is the daughter of a physician, was present at a meeting of the National Academy of Sciences in New York while her case was discussed. She could still recall the operation and the nature of the "dreams" that had preceded her seizu [W. Penfield, *Proc. Natl. Acad. Sci. U.S.* 44, 51 (1958)].
10. In a recent review of the series my associate, Dr. Phanor Perot, has found and summarized 35 out of 384 temporal lobe cases in which stimulation produced experiential responses. All such responses were elicited in the temporal cortex. In a study of 214 consecutive operations for temporal lobe epilepsy, my associate Sean Mullan found 70 cases in which interpretive illusion occurred in the minor seizures before operation, or in which an interpretive response was produced by stimulation during operation. In most cases it occurred both before and during operation.
11. S. Mullan and W. Penfield, *A.M.A. Arch. Neurol. Psychiat.* 81, 269 (1959).
12. This area is marked "Hipp" and "Hipp. G" in Fig. 2 (bottom) and "g. Hippoc." and "amygdala" in Fig. 3.
13. W. Penfield and B. Milner, *A.M.A. Arch. Neurol. Psychiat.* 79, 475 (1958).
14. W. V. Bechterew, "Demonstration eines Gehirns mit Zerstörung der vorderen und inneren Theile der Hirnrinde beider Schläfenlappen," *Neurol. Zentralbl. Leipzig* 19, 990 (1900). My attention was called to this case recently by Dr. Peter Gloor of Montreal.
15. P. Glees and H. B. Griffith, *Monatsschr. Psychiat. Neurol.* 123, 193 (1952).
16. W. James, *The Principles of Psychology* (Holt, New York, 1910).
17. Thus, it is apparent that the beam of excitation that emanates from the interpretive cortex and seems to scan the record of the past is subject to the principles of transient facilitation already demonstrated for the anthropoid motor cortex [A. S. F. Grünbaum and C. Sherrington, *Proc. Roy. Soc.* (*London*) 72B, 152 (1901); T. Graham Brown and C. S. Sherrington, *ibid.* 85B, 250 (1912)]. Similarly subject to the principles of facilitation are the motor and the sensory cortex of man [W. Penfield and K. Welch, *J. Physiol.* (*London*) 109, 358 (1949)]. The patient D.F. heard the same orchestra playing the same music in the operating room more than 20 times when the electrode was reapplied to the superior surface of the temporal lobe. Each time the music began in the verse of a popular song. It proceeded to the chorus, if the electrode was kept in place.
18. W. Penfield and L. Roberts, *Speech and Brain Mechanisms* (Princeton Univ. Press, Princeton, N.J., 1959).
19. G. Jelgersma, *Atlas anatomicum cerebri humani* (Scheltema and Holkema, Amsterdam).