

# THE JOURNAL OF MENTAL SCIENCE

[Published by Authority of the  
*Royal Medico-Psychological Association*]

No. 424

[NEW SERIES]  
[NO. 388.]

JULY, 1955

VOL. 101

## Original Articles

### THE TWENTY-NINTH MAUDSLEY LECTURE: THE ROLE OF THE TEMPORAL CORTEX IN CERTAIN PSYCHICAL PHENOMENA

By

**WILDER PENFIELD, O.M., C.M.G., M.D., B.Sc., F.R.C.S., F.R.S.**

*The Department of Neurology and Neurosurgery of McGill University and  
the Montreal Neurological Institute*

THE Founder of this lecture series was described with consummate skill by Professor Aubrey Lewis in the Twenty-fifth Maudsley Lecture, before this Association. Henry Maudsley was a clinician who turned again and again to the problem I shall approach today. He even wrote a monograph under the daring title of "The Physiology and Pathology of the Mind".

Always a severe critic of current opinion and dissatisfied with the contemporary care of psychiatric patients, Maudsley pledged his personal fortune to bring about a better order of things. The Maudsley Hospital is the realization of his dream. The splendid service that it gives to patients today and the great distinction of its staff bear eloquent witness to the wisdom of Maudsley's plan.

Psychical responses to electrical stimulation present many new problems of physiology. It was in 1934 that a patient, who was being operated upon under local anaesthesia, first told me that she seemed to be re-living a previous experience as the result of, or rather during, temporal lobe stimulation. She said she saw herself as she had been while giving birth to her baby. I recorded the event and waited.

Since that time there have been many other examples of psychical phenomena produced by electrical stimulation and I have realized that here was material of considerable interest to psychiatrists. But I postponed presenting the material to them, realizing that, although the facts were obvious, their meaning in terms of physiology was obscure. And so I have waited year after year for the accumulation of more evidence.

It was the invitation to give the Maudsley Lecture that finally impelled me to take the plunge. Time will tell whether I have produced useful hypotheses to explain the facts.

#### A. THE STREAM OF CONSCIOUSNESS

The first stage of this study was presented to the International Congress of Psychology last June.\* At that time I reported some of the evidence that has

\* Address to the Fourteenth Meeting of the International Congress of Psychology, 9 June, 1954, Montreal. This will appear shortly in *Acta Psychologica*.

to do with the permanent ganglionic record of life's experience. Long ago William James (1910) described the "stream of thought", or the "stream of consciousness", as a river forever flowing, forever changing, different in content in each succeeding unit of time.

The record of the stream of consciousness can be reactivated occasionally by electrical stimulation of the cortex of the temporal lobe, or by epileptic discharge restricted to the same area. When stimulation of the exposed cortex produces such a result in a conscious patient, it seems to him that he is re-living an earlier period of time in the greatest detail. Although he retains awareness of his actual surroundings, there is a re-experiencing of visual, auditory, and even somatic sensations; action goes forward and the interpretation and the understanding that belonged with that moment of time are reproduced.

This is a psychical response that may be described as *experiential*. There are other psychical responses also. We may call them *interpretive* since they consist in alterations of the interpretation of current experience.

Perhaps an objective description of experiential and interpretive responses may be of interest to psychiatrists as well as psychologists.

Psychical responses to stimulation are very different from the gross movements that may be produced by electrical stimulation of the motor cortex of mammal and man, very different from the elementary sensory responses reported by man when one of the various sensory areas of the cortex is stimulated. They constitute a new order of physiological phenomena, but one which Hughlings Jackson recognized years ago as occurring spontaneously in epileptic patients. He called them "dreamy states".

#### B. THE GANGLIONIC RECORD

The record of the stream of consciousness may be activated as though it were a strip of cinematographic film recording the sight and sound, the movement and meaning which belonged to each successive period of time. When a stimulating electrode sets off an experiential response, action may go forward as long as the stimulation continues.

Strange as it may seem there is no confusion of different experiences. During the time that the electrode is applied to the temporal cortex, delivering for example 60 impulses per second, one portion of the stream of consciousness, and one only, is caused to flow again through a man's mind, as though there were, in addition to the activation, an inhibitory effect on the other portions of the recording mechanism.

Since the electrode may activate thus a random sample of this strip from the distant past, and since the most unimportant and completely forgotten periods of time may appear in this sampling, it seems reasonable to suppose that the ganglionic record is complete and that it really does include all periods of each individual's waking, conscious life.

How is this record preserved, and how is it formed in the first place? One might surmise that there is a constant succession of impulses projected from the zone of central integration outward to the temporal regions, forming, among the millions of ganglion cells that cover the temporal lobes like a vast carpet,\* a continuous pathway. The pathway must undergo a physical change so that a simple electrical current can follow it years later. Thus, present experience

\* It may be that the pathway of facilitation is actually located in grey matter of some other area with which the temporal cortex is intimately connected, such as the hippocampal zone.

would be preserved for a life-time, preserved by means of successive facilitation through the cells and synapses which thus constitute the pathway.

Let us consider this hypothesis from another point of view. When present experience slips into past experience the ganglionic record becomes part of a continuous trail of facilitation that runs backward through 20 years of waking life and more! But it is a trail that can never be followed backward. It runs, like a one-way street, forward from any point at which stimulation makes an entrance into it.

As to the localization and the organization of the ganglionic mechanism of this record we have no certain information except the fact that it can be activated by an electrode on the temporal cortex, not elsewhere. As far as our experience goes it can only be activated in a temporal cortex that has been somehow conditioned by years of electrical discharges from a neighbouring epileptogenic focus.

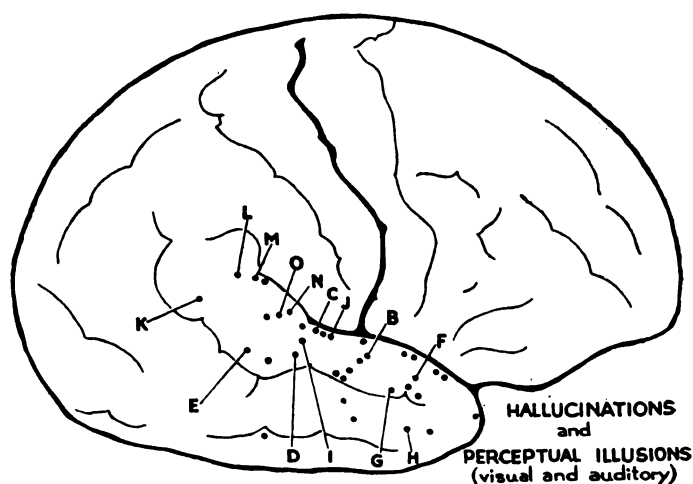


FIG. 1.—Summary chart of stimulation points (from unselected cases) producing psychical hallucinations (experiential responses) and illusions (interpretive responses). From Ferrier Lecture, Penfield, 1947.

Some years ago, in preparation for the Ferrier Lecture (Penfield, 1947), I reviewed 190 successive operations for focal epilepsy, all carried out under local anaesthesia. This included all the examples of such operations in unselected brain areas during a 9-year period. In 10 cases from that series stimulation produced "an experience that might be considered similar to Jackson's 'dreamy state.'"

These responses I called psychical and divided them into psychical hallucinations and perceptual illusions. The points of stimulation all fell on the temporal cortex as shown in Figure 1. No such responses were produced by stimulation elsewhere.

In the past eight years our understanding of temporal lobe seizures has advanced greatly, and there has been in the Montreal Neurological Institute a corresponding increase in the number of operations for this variety of epilepsy. Indeed the temporal lobe cases selected for surgical therapy now outnumber all others grouped together. With greater experience, we have learned to carry out deep stimulation with a coated electrode. By that method the superior and

mesial surfaces are now often explored electrically, as well as the lateral and inferior surfaces.

The present conclusion is that psychical responses result from stimulation principally of the lateral and superior surfaces of either temporal lobe (Fig. 2). The superior surface is that portion of the temporal lobe that is hidden within the Sylvian fissure and in the circular sulcus that surrounds the insula beneath it. The mesial surface is made up of uncus and hippocampal gyrus.

The actual recording mechanism may be in the cortical grey matter where the stimulating electrode seems to awaken it or it may well be elsewhere, in areas which give no response to direct stimulation, such as the hippocampus and hippocampal gyrus. But if it is in such a zone there must still be specialized connections between that zone and the areas of temporal cortex in which stimulation does produce psychical responses. Either way, it is not going beyond

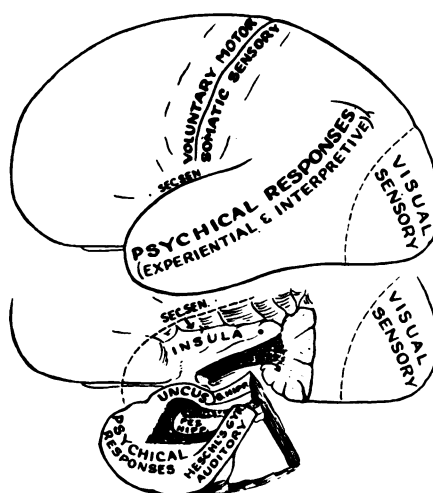


FIG. 2.—Chart of lateral surface of human brain and, below, a partial chart with the temporal lobe cut and turned down to expose the superior and mesial surfaces. Experiential and interpretive responses are most frequent on the superior and lateral surfaces. Furthermore, visual, auditory, somatic and second somatic sensation areas are indicated. “Temp. stem” indicates the white matter of the lobe which has been cut across.

the evidence to conclude that this area of cortex, which is marked “psychical responses” in Figure 2, must play an important role in the formation or preservation of the record of the stream of consciousness.

### C. PSYCHICAL RESPONSES

Psychical responses to stimulation may be divided into two groups (1) *Experiential* and (2) *Interpretive*, thus corresponding with the psychical hallucinations and illusions that appear in temporal lobe seizures.

#### 1. *Experiential Responses*

I will present certain examples of experiential response, without full clinical description, but using wherever possible the patient's own words as they were recorded at the time of operation.\*

\* For those who might be interested, further information in regard to many of the patients cited in this communication may be found in the books and papers which I have published in this general field with various associates. A Patient Index, by initials, will be found in each of the books.

D.F. heard an orchestra playing a certain song when a point on the superior surface of the right temporal lobe was stimulated after removal of the anterior half of the lobe. The hearing seemed to her so realistic that she thought a gramophone had been turned on. The point was restimulated many times and each time she heard the same orchestra which seemed to begin playing at the same place in the same piece. When she was warned falsely, and stimulation was withheld, she heard nothing; when stimulated, with or without warning, she heard it. When she hummed, accompanying thus the music in her mind, the tempo was about what might have been expected of an orchestra.

The continued repetition of the stimulation seemed to facilitate this particular response rather than other possible responses. It was not a song that she knew very well and she could not recall when it was that she had "heard it that way before".

M.G. said, when the first temporal convolution on the right side was stimulated, "I hear people coming in—I hear music now, a funny little piece." Stimulation was continued and she went on to explain that the music she was hearing was the theme song of a children's programme.

S. Be—when various points were stimulated on the right temporal convolution: 16—"something brings back a memory. I could see Seven-Up Bottling Company." Then, after a pause, "Harrison Bakery." Warning without stimulation—nothing. 19—"I am trying to find the name of the song. There was a piano there and someone was playing. I could hear the song you know." 19 repeated without warning—This time he said, "someone speaking to another, and he mentioned a name but I could not understand it. 21—"Someone speaking to me in my left ear (contralateral) Sylvère, Sylvère.\* It could have been my brother's voice." 25—"I seem to see someone—men and women—They seem to be sitting down and listening to someone but I do not see who that someone might be."

In general, the patient's awareness seems to be of an experience that is going forward but he is often not able to recall what had happened just before the incident nor what is about to happen following it.

L.G. saw a man fighting. When the point was re-stimulated he saw a man and a dog walking along a road.

A housewife G.F. heard her little son playing in the yard and was aware of the sound of automobiles passing.

J.T. exclaimed that he heard his cousins, who were actually in South Africa, talking. He was laughing, he said, at something with them and yet he knew at the same time that he was also in the operating room. Though he made the effort, he could not recall what they were laughing at.

A young woman exclaimed: "Oh, I had the same very, very familiar memory,—in an office somewhere. I could see the desks. I was there and someone was calling to me, a man leaning on a desk with a pencil in his hand."

#### D. RECORD AND MEMORY

These are all "strips" of experience. Sometimes the patient can recall the event. More often it has faded from recollective memory. But always it is familiar and he seems to be present and he acknowledges it as part of his own past. When music is heard, he may not be aware of its source or he may seem to

\* The hearing of his own name Sylvère repeated several times had been the aura that ushered in this man's seizures habitually, but for some years before operation the attacks had come without that hallucination and with no warning other than a sensation of nausea.

be present in the theatre or church or café. He may re-experience the sense of enjoyment that came to him in that moment.

Because such phenomena can occasionally be produced by stimulation of the cortex of the temporal lobe I have suggested that the electrical current follows a pathway of facilitation that was formed during the original experience while other pathways remain closed to it. This is an hypothesis. Many years of work by physiologists and psychologists will be required to prove, disprove or replace it.

I suspect that nerve impulses pass from temporal cortex into the closely connected subcortical nuclei, along connections that were utilized during the time of the original experience. Indeed, I suppose that a part of the ganglionic machinery, that was involved in the understanding and the recording of detail in the stream of consciousness, is set in motion once more, repeating similar sequences of nervous conduction. The action of that ganglionic machinery might seem to constitute the very substratum of consciousness,\* for the things that have been recorded are the things which once came within the spot-light of attention.

There is a very great difference between the stimulatory re-playing of a strip of record of the stream of consciousness and a voluntary act of recollection. It is obvious that, one minute after an experience, an ordinary individual can recall it voluntarily with a high degree of completeness. Unusual individuals can do so after longer intervals. Experiences which were surcharged with meaning or emotion may be recalled repeatedly and so remain available in considerable detail for a long time. But, in general, the record of routine experience passes quickly beyond our power of elective review. Most of it is lost to us forever, as far as voluntary recall is concerned.

Whether or not the methods of the psychoanalyst can re-activate the record with a completeness that rivals the electrode I have no means of knowing. I would suspect that the patient who is being analysed brings up a generalized memory, or one that has been modified by his subsequent thinking or subsequent experience. Electrical recall is quite different from this, since it often produces random samples of true experience, which may have no particular significance in the life of the patient.

Memory, as ordinarily defined, is something else. It includes so many generalizations and is so often progressively influenced by subsequent experience. Memory of a song or of a person may come in time to be a complete generalization assembled from a series of scattered experiences. The musician may call a song to mind or may play it or sing it from memory and yet be unable to recollect the circumstances of a single hearing of the song.

It is true that when a friend is seen by an individual after an interval of absence, or an old song is heard again, that one is apt to detect slight changes with astonishing accuracy and to make a judgment of familiarity or of alteration at once. It may well be therefore that each of the earlier experiential records of that person or song becomes available to the individual during the laying down of the new record. It is then that the new experience is interpreted and judgments of familiarity, strangeness, danger, distance, etc., are made.

#### E. TEMPORAL LOBE SEIZURES

Epileptic discharge, if localized and circumscribed, often produces a result which is similar to a stimulation response in the same area. Temporal lobe

\* Jackson called this nervous action the most special of all the special nervous processes, the series evolved out of all the other lower series—"co-ordinations"—"reco-ordinated".

seizures,\* produced by localized discharges, are often psychical in nature. They must be distinguished from the sensory seizures and motor seizures that are produced by discharge in other parts of the brain. But in order to interpret the phenomena encountered in temporal lobe seizures the clinician must realize that sensation and even movements may be produced by epileptic discharge which is not in the pre-central or post-central gyrus but deep within one Sylvian zone.

In the temporal lobe and in neighbouring structures deep within the fissure of Sylvius there are sensory areas. Thus discharge that originates in, or spreads to, these areas may give rise to sensations; for example, buzzing sound in Heschl's gyrus (Fig. 2), odours in the uncus, alimentary tract sensations in the insula, taste in the cortex just above the insula, somatic sensation from the "second sensory" area above the insula, and head sensations, and body sensations in the deep portion of the temporal tip. All of these phenomena may appear as auras or as integral parts of the unfolding pattern of a temporal lobe seizure.

When there is localized epileptic discharge in the areas of temporal cortex which, as already described, may give psychical responses to stimulation (Fig. 2) the result is a psychical seizure. Psychical seizures are of three kinds, (1) experiential, (2) interpretive and (3) amnesic as outlined in Table I. Perhaps it is more

TABLE I  
*Psychical Seizures or Dreamy States*

1. EXPERIENTIAL SEIZURE (psychical hallucination, "flash-back")
2. INTERPRETIVE SEIZURE (psychical illusion, déjà vu phenomenon, fear, etc.)
3. AMNESIC SEIZURE, AUTOMATISM (psychomotor confusion)

accurate to say that during psychical seizures there may be experiential, interpretive and amnesic phenomena since more than one of these three types of phenomena may appear in a single attack.

#### 1. *Experiential Seizures*

The *experiential attack* is an hallucination of past experience. The patient may call it a flash-back or a dream. It is the same as the experiential response to stimulation that was discussed at the beginning of this address.

#### 2. *Interpretive Seizures*

The *interpretive attack* is an illusion in regard to present experience; a false interpretation of the present situation.

During both types of attack the patient continues to be conscious and he is usually still capable of introspection. It is probably significant that these two forms of psychical seizure should come from the same general area. The first is a re-activation of the record of the stream of consciousness. The second is an altered interpretation of the recording that is being made at the moment.

Under normal conditions interpretations of present experience must depend

\* It is important to recognize that temporal lobe seizures are extremely common. The focus of origin is most often in the superior and mesial surface of the temporal lobe including uncus and hippocampus. These are the areas that are hidden away from the surface.

The commonest causal lesion is *incisural sclerosis*. This is a chronic atrophic abnormality produced at the time of birth by herniation of the temporal lobe through the incisura of the tentorium, producing thus temporary occlusion of the anterior choroidal artery and adjacent arteries that cross the edge of the tentorium.

Although the ischaemic injury is produced during birth, the attacks may begin at any time within the first 20 or 30 years of life. For a general discussion of temporal lobe seizures, see Penfield, 1954a.

upon a comparison of the present recording with similar past recordings. It is therefore not particularly surprising to discover that limited discharge in an area where past and present recordings seem to have some form of localization, disturbs the interpretation of the present experience.

An interpretive seizure is an illusion, perhaps better called "illusory feeling", as suggested to me by Dr. Kubie. The following are the commonest varieties; a sense of false familiarity. This illusion is often called the "déjà vu" phenomenon. But the sense of familiarity usually applies to the total present experience including the sounds and the meanings of the moment as well as the sights. The patient may have the feeling that is opposite to familiarity, and report an illusion of strangeness, or absurdity; things seen or heard may seem to come nearer or to recede to a greater distance; a patient may experience a feeling of remoteness or a change in his own relationship to his environment.

Closely related to the interpretive seizures are *ictal\* emotions*. It is as though these emotions were interpretations of the meaning of present experience. But all of these emotions may appear without his being afraid of, or lonely for, anything in particular. The patients have described these feelings with the words: fear, loneliness, sadness, scared feeling, terror.†

A few examples of interpretive seizures may be presented here.

#### Case V.F.

This man of 33 years suffered from attacks which were due to an atrophic discharging lesion deep in the right temporal region near the insula. He had been operated upon elsewhere and a small temporal excision carried out.

His attacks were as follows: (1) Dizziness. He felt as though he were whirling around. (2) Interpretive illusions of familiarity and of fear and also of seeing himself.

He said he was apt to have a strange feeling that all of this had happened before. It was, he said, as though he were in the "future listening to the past". It seemed that all this had happened before and he was then seized with a feeling of fear and was aware of a tight sensation in his stomach and rectum.

Attacks might be precipitated, when startled by a sudden sound, and especially by a heavy "cloying" perfume such as that at a perfume counter. On two occasions in the Hudson's Bay Company Store in Winnipeg, he had had an attack in the perfume department. He had learned also that it was perilous to ride on a bus where he might smell such perfumes on women passengers. Bad odours, such as that of gasoline or of a fish factory did not have such a precipitating effect!

These minor seizures might be followed by automatism and falling, with a brief interruption of consciousness, but major generalized convulsive seizures were rare. Following minor seizures there was a post-ictal right frontal headache.

At operation, under local anaesthesia, the right temporal lobe was exposed (Fig. 3). Deep electrical stimulation was carried out through point 10 (Fig. 4), using a unipolar electrode which was covered with an insulating coat except at the tip. Stimulation at a depth of 2 cm. along the superior surface of the temporal lobe, within the fissure of Sylvius, caused the patient to say suddenly, "That bitter-sweet taste on my tongue." He seemed confused and made tasting and swallowing movements.

The stimulating current was shut off and the electro-corticogram showed that a slow wave 4 per second generalized rhythm had been set up as an after-discharge. While this was continuing the patient exclaimed: "Oh God! I am leaving my body." Dr. Karagulla, who was observing him, said he looked terrified at the time of the exclamation and made gestures as though he sought help. When the electrocorticogram had returned to normal the patient seemed to be himself again. He was asked by the operator whether that had been like his habitual seizures. He replied, "A bit, Sir", then after a pause he added, "I had the fear feeling."

Stimulations in the temporal lobe deep to point 11 produced vestibular sensations. Once he said he was spinning around. Once he felt as though he were "standing up".

\* The word ictal is used to refer to the active phase of the attack, the period of discharge, without including the immediately succeeding period of ganglionic exhaustion.

† There may be an associated gripping sensation in the epigastrium or pupillary, pilomotor and pulse changes—phenomena which are controlled by mechanisms located at a distance. The patient's facial expression may suggest dread or terror, and his behaviour also. Other emotions, such as anger, joy, pleasure, sexual excitement, have never been reported by our patients as results of local cortical seizure or cortical stimulation. I have not encountered any evidence of specific relationship of the human cerebral cortex to these forms of emotion.



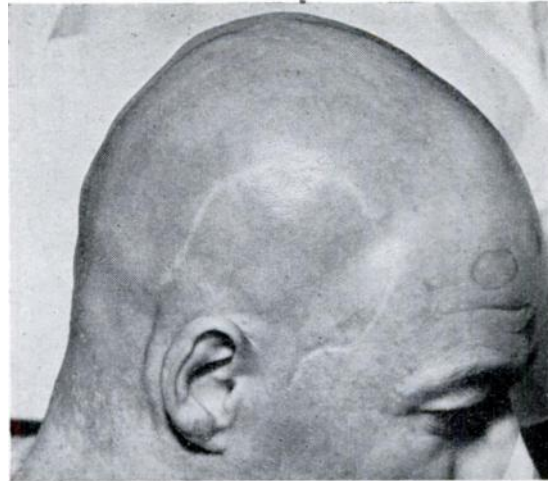


FIG. 3.—Case V.F. The patient is in position on the table ready for operation. Scar of former operation may be seen. See Fig. 4.

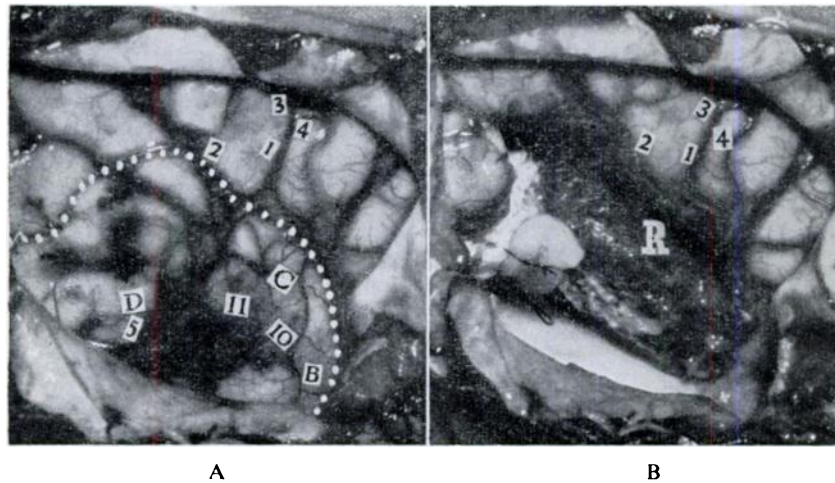


FIG. 4.—Case V.F. Craniotomy and exposure of right temporal lobe. Panel A shows the scar of a previous temporal excision which had been carried out elsewhere. Panel B shows the brain after the scarred anterior temporal lobe has been removed. R marks the exposed Island of Reil. The black thread over white gell-foam demonstrates the method of closing off the inferior horn of lateral ventricle.

Tickets B, C and D in panel A indicate the area in which the electrocorticograph demonstrated "sharp wave" and "spike" abnormalities of electrical potential characteristic of epileptogenic areas. Stimulation at points 1 and 2 produced—opening of jaw, 3—sensation left side of tongue, 4—"floating" sensation referred to chest and abdomen. At 10 and 11, deep stimulation was carried out—see Text. The dotted white line indicates fissures along which excision was carried out.

In summary, this patient had, during minor seizures, a sensation of dizziness probably produced by discharge in or near the transverse gyrus of Heschl deep in the Sylvian fissure. This was followed by complicated psychological illusions, interpretive illusions, during which he felt an unjustified fear, a sense of familiarity, and an altered relationship to his own person as though he were outside of his body. These illusions were probably due to discharge in the superior surface of the temporal lobe anterior to Heschl's gyrus.

The record, at the time of stimulation, fails to state whether he experienced the illusory feeling of false familiarity then, but stimulation did produce the illusion of fear and of leaving his own body.

Electrical stimulation produced a vestibular sensation of whirling which resembled his initial aura. But it also produced something that could be considered more complicated than a sensory response, i.e. the feeling that he was standing upright. This might be considered a somatic illusion in the same class with visual illusions of distance.\*

#### Case W.S.

A man of 30 years had had minor seizures for 5 years and major convulsive attacks for 3 years, evidently due to a traumatic injury of the left temporal lobe.

His minor attacks were as follows: (1) Thoracic sensation, (2) sounds seemed louder and faster, (3) thoughts or words came into his mind.

After the thoracic aura, if he was hearing a continuous sound, it would seem to become louder and if he was at work in the factory, the machinery seemed to be louder, the movement faster during such a seizure. Following that, "thoughts" came into his mind. But it was difficult to recall what the thoughts were. When he was asked if they were memories, he said, "No, they are more like words or combinations of words." He tried to explain by saying that it was like having a dictionary and having different words come to mind. At another time he said it was like thinking two things at once. At such times he would look around, he said, and know what was happening about him and yet the thoughts kept coming. This state was followed by confusion and automatism and after the automatism was over, some slight tendency to aphasia.

At operation there were dense subdural adhesions in the left Sylvian region due to an old subdural haematoma (Fig. 5). Stimulation at point 20 near the temporal tip caused him to have a small attack with thoracic sensation and "thoughts entering" his mind.

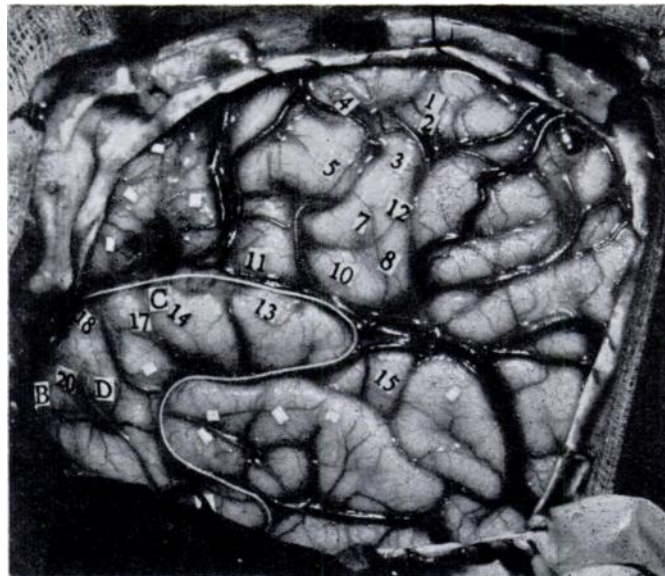


FIG. 5.—Case W.S. Left craniotomy carried out by my assistant Dr. John Hanbery. The white thread indicates the area of temporal lobe removed. B, C and D indicate electrographic abnormality. Stimulation produced responses: 4 and 5—movements of right mouth; 7 and 8—sensation in tongue; 10—swallowing; 11—sensation ("tiredness") in right leg and toe.—This is "second" sensory. It was repeated later, without warning the patient, with same result. 17 and 20—thoracic aura, perceptual illusion, hallucination of "thoughts".

\* Thus, it would seem that there may be interpretive illusions, regarding body position or body movement, which should be considered psychological rather than sensory. Other patients have made similar reports.

At 17, stimulation caused him to say, "I am going into a seizure." He was unable to speak and was automatic for a short time.

The change of interpretation of sounds which he described is a good example of an epileptic psychical illusion. It suggests that judgment of the intensity and the rate of sounds depends upon a neuronal mechanism that can be activated or disturbed by epileptic discharge or electrical stimulation. It is a change of interpretation. If there had been no sound he would not have been aware of the local discharge.

As a third phenomenon, thoughts or words came into his mind. This seemed to be a hallucination, always of the same type, but whether it was an experiential hallucination, which reproduced previous thinking, was never clear to the patient nor to us who studied his case.\*

It is clear that these phenomena were produced by discharge in the superior surface of the left temporal lobe and it seems likely that automatism followed as the discharge spread into the amygdaloid area.

These experiential and interpretive seizures were described by Hughlings Jackson under the heading of "dreamy states" and he included with them attacks of automatism.† This brings the discussion to the third group of psychical seizures.

### 3. *Automatisms, Amnesic Seizures*

There is one constant characteristic of automatism; for the duration of each attack there will be subsequent amnesia. While in the automatic state the patient does not seem to be unconscious. But he has an alteration in consciousness which may be severe or slight. Thus he may seem to be completely, or only slightly, confused. He may move about aimlessly or he may have some apparent purpose, a purpose not easily influenced by his companions.

The one constant defect lies in the fact that the patient has lost the capacity of making a permanent record of his stream of consciousness. He has not lost all memory of the past, for he may find his way back to his home passing through city traffic during such an attack. He may even carry on, and complete, a previously prepared speech which he had begun before the onset of an attack of automatism, or he may play a well-known piece on the piano.

If the basic defect is an inability to record present experience, this would explain why the patient cannot interpret his present experience normally. It seems likely that interpretation of present experience is made during the formation of the new record or just after it is formed since it must be compared with the past records. The confusion is due to an interference with experiential recording and experiential interpretation. Electrographic studies prove that automatism appears with the onset of epileptic discharge and continues during the period of ganglionic fatigue that follows after the active discharge is over.

We can now localize the area in which epileptic discharge may produce temporal automatism (Feindel and Penfield, 1954). My associate William Feindel‡ restudied a group of patients in whom automatism was produced by electrical stimulation during operation. He found a remarkable concentration of points in the vicinity of the amygdaloid nucleus (Fig. 6). This is about 4 cm. posterior to the tip of the temporal lobe and 4 cm. deep to the lateral surface.

Stimulations that produce automatism are usually, if not always, followed by after-discharge. That is to say, there is a brief continuation of confusion and amnesia after cessation of stimulation. We have assumed that the stimulation itself, or the local seizure discharge, fires inward along more centrally located tracts so as to interfere centrally with ganglionic nuclei which are involved in the process of experiential recording in both temporal lobes.

\* The thoughts that may force themselves into a patient's mind during this type of seizure are discussed elsewhere, Penfield, 1955.

† The dreamy states were subsequently called psychomotor seizures by Gibbs, Gibbs and Lennox (1937) who described the frequent association with them of 6 per second disturbances of electro-encephalographic rhythms.

‡ A study of automatism and the localization of the discharge and the electrical stimulation that produces it will be made shortly (Feindel and Penfield, 1954).

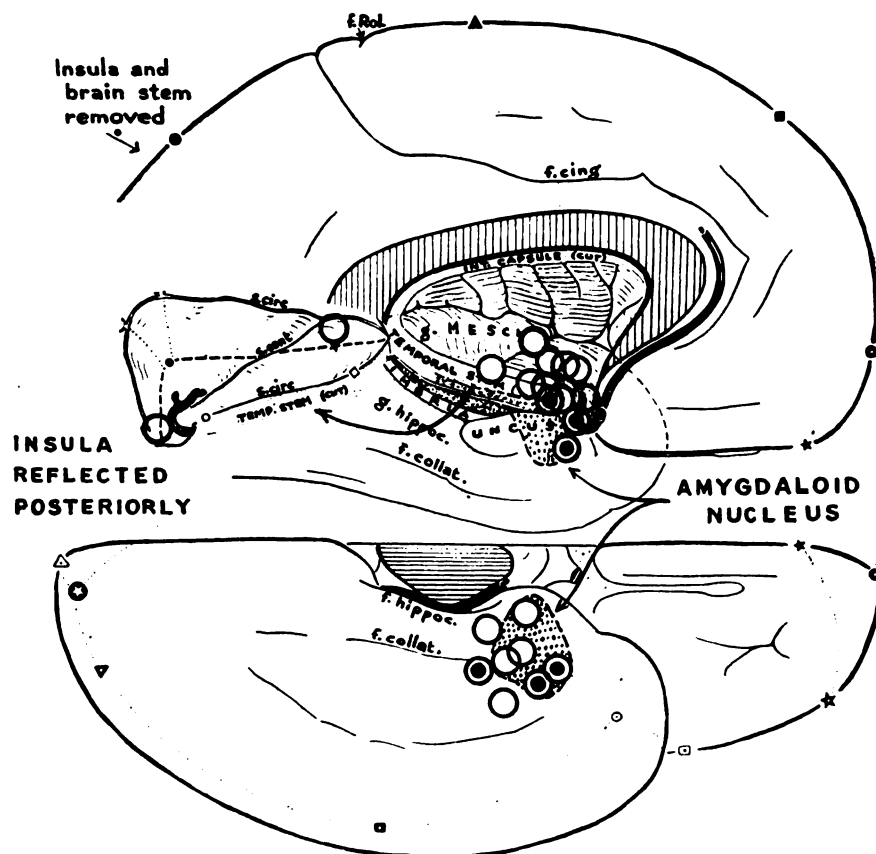


FIG. 6.—Stimulation points which produced primary automatism shown on the mesial and inferior surfaces of the brain. The projection of the amygdaloid nucleus to the surface is shown by the dotted area. The insula has been removed in the mesial view and is shown rotated posteriorly (after Feindel and Penfield, 1954).

#### F. DISCUSSION

Hughlings Jackson pointed out that clinicians must provide “facts bearing on the physiology of the mind” since they alone “witness the results of experiments of disease on the nervous system of man”. The facts which he reported 75 years ago are still facts. He also set for us a brilliant example of rationalization, spinning hypotheses from the threads of his observations made in the wards of the National Hospital at Queen Square. Some of those hypotheses stand today as established principles. Others have been discarded but all of them served useful purposes.

Before discussing the meaning of these phenomena it would be well to restate certain facts in summary.

(a) Stimulation of the temporal lobe of patients subject to focal epilepsy may produce re-enactments of previous experience in astonishingly complete detail.

(b) Similar stimulation may alter the patient’s interpretation of present experience (interpretive illusion).

(c) Stimulation, which causes after-discharge beneath the uncus and in the

peri-amygdaloid area, results in primary automatism during which there is complete interference with the recording of the patient's current experience.

All three of these results of stimulation may be produced also by spontaneous epileptic discharge if it is local.

The first two (*a* and *b*) are positive phenomena. That is to say, there is activation of a functional mechanism. In the first case the activation consists in the "re-playing" of a "strip" of experiential record. In the second case it consists in alteration of the interpretation of the new "strip" of record that is being formed during the time of the stimulation.

The third phenomenon, automatism, is not an activation in a functional sense. It is an interference with the normal process of experiential recording. When the electrode is withdrawn the interference continues for a little time. This suggests that local interference with the grey matter of the peri-amygdaloid area is not enough to produce the effect. There must be interference with the function of more centrally placed, but intimately connected, ganglionated areas.

Before discussing the experiential record further, let me repeat what was written in an earlier section of this paper:

"It seems reasonable to suppose that the ganglionic record is complete, and that it really does include all periods of each individual's waking, conscious life." This is a supposition that could never be proven. Some periods of time may be lost. But it is clear that the portions of the strip which are activated do represent to the individual those things of which he was aware during a certain period of time, and he feels that nothing is missing. Successive experiences are presented to him in proper sequence and at a rate which seems to be the same as that of the original experience.

Since a volley of electric pulses applied to a point on the temporal cortex produces this effect I would hypothecate that the electrical activation is following a ganglionic pathway, as already explained, and that that pathway was formed in the first place by a succession of impulses or a stream of neuronal activity that emerged from that zone in the brain in which final neuronal integration is possible. Call it for the moment the zone of central integration.

Where is this pathway that holds in its turnings the record of the past? It seems unlikely that any delicate or complicated function would be possible within the area of grey matter that is being stimulated, considering the relatively large zone that must be under the direct influence of the electrode. There must be blockage or inhibition of transmission from the area except along one line of neurone communication. This would allow passage of a single stream of impulses away from the stimulated zone and into some other ganglionic region where the single "strip" of the record can be activated, free from the confusing influence of the electrical state that surrounds the electrode.

This line of reasoning suggests the possibility that the recording pathway is located elsewhere in the temporal cortex or, as seems more likely, in a closely associated zone of grey matter such as the hippocampus.

The pathway is, it may be supposed, no more than a sequence of ganglionic connections. This sequence must be the same as that which was followed by the stream of neurone impulses which emerged from the zone of central integration at the time of the original experience. The pathway therefore is a trail of facilitation, permanent facilitation of each cell or dendrite or synapse, through which the original experiential stream of impulses passed.

There is evidence, that has been elaborated elsewhere (Penfield, 1938, 1952, 1954b), that the most important area of integration is not to be found in

association systems of the cerebral cortex, but in a more centrally placed area within the higher brain stem. It must be assumed that there is in this area a central or centrencephalic integrating system into which the afferent streams of the sensory pathways pass and from which the efferent stream of impulses emerges that results in voluntary action.

Hughlings Jackson assumed that such an area must exist. He called it the "highest level", the place where final re-representation occurred. But it would be stupid of us to assume that he believed in independent function at any level.

On the contrary, centrencephalic integration must be the outcome of synchronous central and cortical activity; activity in the brain stem and in those areas of cortex of either hemisphere whose function is suited to the changing requirements of the moment. It seems likely that the temporal lobes are used simultaneously, as though in duplicate, for the purposes of recording the stream of consciousness.

To return to the question of the formation of the record, it has been pointed out that it contains only those things of which the subject was aware in the interval of time during which the record was formed, those things to which he paid attention.

One may suppose that it is in this centrencephalic system that the selection of the content of consciousness is made. There, all those things of which an individual is aware may be formulated and expressed in a complex of neurone activity. That complex might be conceived of as a succession of nerve impulses that is projected outward in such a pattern that it forms the appropriate ganglionic sequence which creates the record of the stream of consciousness.

The pattern of the passage of that sequence through neurone connections, probably in some portion of the temporal lobes, is made permanent by facilitation. The conduction facilitation in that pattern is the record, the "strip", of the stream of consciousness. This is an hypothesis that would seem to fit the facts. It depends upon assumptions similar to those in the current conception of what happens in the central nervous system during the process of learning.

The final action of integration within the brain constitutes the neuronal mechanism of the mind. The original formation of the ganglionic record, in which the temporal lobes play such an important role, must constitute a part of this mechanism.

There may well be secondary employment of the record during voluntary recollection and in the process of recognition of familiar things. But, as has been pointed out above, memory comes to be a generalization while the record remains unaltered by subsequent experience.

In addition to that it is evident that the cortex of the temporal lobe plays an active role in the interpretation of present experience and the comparison of present with past experience. Stimulation or epileptic discharge in that same general area of temporal cortex (psychical responses, Fig. 2) may produce this second type of psychical phenomenon. It is as though some of the neuronal machinery that is normally employed in the interpretation of current experience is located here in the same general area in which the experiential record can be activated. One may assume that judgments are made normally while the original record is being formed and that the new record is thus compared with the past.

The sense of familiarity ("déjà vu") is an interpretation—it might be called a feeling or even an emotion—which accompanies new experiences. It is a reaction which is set off very easily in some patients and, it should be added, in some individuals who are not subject to overt seizures. The reaction may have the same character regardless of the nature of the experience.

The feeling of absurdity, or unfamiliarity, is a contrary interpretation but a reaction of the same order. Distortion of judgments of size, distance, and loudness are likewise of the same order. Similarly, such illusions may have to do with the relationship of the individual to his environment, described as being far away, out of this world, lonely. Feelings that are called emotions are similarly produced the most frequent being fear, nameless dread or specific menace which may or may not be associated with tears, panic, dilatation of pupils.

All of these things might be considered interpretations. They must be caused by more or less specific neuronal reactions or reflexes which serve a useful purpose under normal conditions but which may become habitual responses in states of chronic epileptic discharge located in temporal regions.

One might well question whether habitual misinterpretation of current experience may be related to disturbances of behaviour. It is our impression that disturbances of behaviour are more frequent among temporal lobe epileptics than in other groups. It is likewise our impression that successful removal of a discharging temporal focus sometimes results in behavioural improvement. However this is an aspect of temporal lobe activity regarding which no statistical conclusion has as yet been reached in our clinic.

#### BIBLIOGRAPHY

- FEINDEL, W., and PENFIELD, W., *Arch. Neurol. Psychiat.*, 1954, 72, 605-630.  
FRITSCH, G., and HITZIG, E., *Arch. Anat. Physiol.*, 1870, 37, 300-332.  
GIBBS, F., GIBBS, E., and LENNOX, W., *Brain*, 1937, 60, 377-388.  
JACKSON, J. HUGHLINGS, *Selected Writings of John Hughlings Jackson*, 1931. Hodder and Stoughton, London.  
JAMES, W., *The Principles of Psychology*, 1910.  
PENFIELD, W., *Arch. Neurol. Psychiat.*, 1938, 40, 417-442.  
*Idem*, *Proc. Roy. Soc.*, 1947, 13, 134.  
*Idem*, *Res. Publ. Ass. nerv. and ment. Dis.*, 1952, 30, 513-528.  
*Idem*, and JASPER, H., *Epilepsy and the Functional Anatomy of the Human Brain*, 1954. Little, Brown and Company, Boston.  
PENFIELD, W., *Brit. J. Surg.*, 1954a, 41, No. 168.  
*Idem*, *Brain*, 1954b, 77, 1-17.  
SHERRINGTON, C. S., *The Integrative Action of the Nervous System*, 1906.