BRAIN

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THE BRAIN'S RECORD OF AUDITORY AND VISUAL EXPERIENCE[1]

A FINAL SUMMARY AND DISCUSSION

BY

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[1] Given in part by the senior author as the Lister Oration, Royal College of Surgeons, London, April 27, 1961. Parts were included also in his Hughlings Jackson Lecture, Montreal Neurological Institute, Montreal, June 2, 1961. The work was done in that Institute and in the Department of Neurology and Neurosurgery of McGill University. W. P. holds a Guggenheim Fellowship and Ph. P. a Special Fellowship, United States Public Health Service.

(1) INTRODUCTION

> "He who is faithfully analysing many different cases of epilepsy is doing far more than studying epilepsy."
> (HUGHLINGS JACKSON.)

IT has long been known that visual or auditory hallucinations sometimes come to patients with seizures. In the latter part of the nineteenth century Jackson recognized that they had a special relationship to irritant lesions in the "temporo-sphenoidal" lobes and that they were actually manifestations of local epilepsy. He grouped them with the sudden illusions and confusions which such patients experience, and referred to them all as "dreamy states."

Similar "psychical" states are sometimes produced, during operation, by electrical stimulation of the cerebral cortex. Those that are in fact hallucinations of things previously seen or heard or experienced, we have called experiential responses. In this paper we propose to summarize all our cases in which these epileptic states and electrical responses occurred, in the hope of throwing further light on the nature of the record of experience within the brain. It is hoped also that by placing the details of these cases on record we may provide useful material on which others may build.

Twenty-five years ago, one of us reported electrical activation of such phenomena for the first time (Penfield, 1938). A past experience, which had occurred regularly as part of the patient's seizure pattern, was reproduced by electrical stimulation of the cortex of the temporal lobe. And also, more surprising still, a previous happening which was not related to previous attacks, was recalled by the surgeon's electrode. These stimulations were carried out during operation under local anæsthesia in an attempt to localize the origin of the patient's seizure.

At rather long intervals during subsequent years, stimulation produced such results again and again, but only in a certain portion of the temporal cortex (Penfield, 1947). We are now able to delimit this area. As the cases became a little more numerous we began to speak of an *experiential hallucination* when the phenomenon occurred during a spontaneous seizure, and of an *experiential response* when produced by electrical stimulation of the cortex during operation. Produced either way, the phenomenon is sometimes extensive and elaborate, sometimes fragmentary. It may include the sights and sounds and the accompanying emotions of a period of time, and the patient usually recognizes it spontaneously as coming from his past.

In some cases it could not be proved by witnesses that the experience was from the patient's past. But in most cases he was confident that it came from his previous experience. When the experience was fragmentary, his present awareness might be invaded by no more than a picture,

a spoken word, voices, music, or bits of experience that he might or might not be able to localize in time and place.

In the succeeding years, partial temporal lobectomy proved to be an effective method of treatment of patients whose dreamy states could not be controlled by medical management. With the co-operation of neurologists and radiologists and the introduction of electroencephalography, the diagnosis of temporal lobe epilepsy was made with increasing frequency. So our experience multiplied rapidly.

Jackson had recognized that, in their seizures, these patients sometimes had "dreamy states" which were really psychical phenomena more complex than sensory and motor phenomena. In the sense in which a Jacksonian march of movement, caused by epileptic discharge in the pre-Rolandic gyrus, may be called a motor seizure and an attack of sudden localized somatic sensation due to discharge in the post-Rolandic region may be called a somatic sensory seizure, and sudden lights and colours due to discharge in the occipital cortex may be called a visual sensory seizure—so a sudden re-experiencing of the past, or a sudden false interpretation of the present may be called a psychical seizure. Both the experience and the interpretation are produced by discharge in temporal cortex and not in other areas.

But irritation or stimulation in various areas of the temporal lobes may produce other phenomena, a sensation in the body which is most often in the chest and abdomen, and occasionally sensations of smell or taste with lesions deep in the middle fossa. Jackson said the psychical phenomena or dreamy states, being different from sensory or motor phenomena, should be classified. But he did not undertake it. Reproduction of these states by stimulation has made the classification a little easier in our hands.

Interpretive Response or Interpretive Illusion

In addition to the experiential states that we have described above, gentle electrical stimulation of temporal lobe cortex also produced sudden "feelings"—sometimes the feeling of familiarity that clinicians had been in the habit of calling *déjà vu*, sometimes an alteration in the apparent meaning of things seen or heard. Again it might be a sudden feeling of fear or loneliness. These are signals of altered interpretation of present experience. When they occur during a seizure they come as illusions of interpretation.

A third psychical phenomenon, that may be produced by electrical stimulation at times, is an attack of automatism (psychomotor attack of Gibbs, Gibbs and Lennox, 1937, uncinate fit). This is not produced by stimulation of the area of cortex in which the other two psychical responses are produced. The site of production is beneath the uncus and the stimulus must be strong enough to produce after-discharge.

Thus we would classify psychical seizures and psychical responses under the general heading of spontaneous and induced dreamy states as in Table I below.

TABLE I.—DREAMY STATES

Spontaneous and Induced

Seizure or response	*Site of activation*
1. Automatism (amnesia, confusion)	Amygdaloid region
2. Interpretive signal (illusion, *déjà vu*)	Interpretive cortex
3. Experiential hallucination (flash-back)	Interpretive cortex

All of these phenomena may present themselves as small epileptic seizures. They may also be produced during operations by gentle electrical stimulation.[1] Since this paper has to do with the third group, the experiential phenomena, further reference may be made to the other two before leaving them.

Automatism

These were known to Jackson as uncinate fits. The patient is suddenly confused to a greater or lesser extent. He behaves in an automatic manner. But he is obviously not to be called unconscious although he will have complete amnesia for the period of the confusion. The electrically produced interference, in the vicinity of the uncus and hippocampus and the deeper connected areas, seems to arrest memory-recording (Feindel and Penfield, 1954).

Interpretive Signals or Interpretive Illusions

These were studied and finally summarized by Mullan and Penfield (1959). These illusions were encountered either as a part of the seizure pattern or as a result of stimulation at operation in 70 patients out of a series of 214 cases of temporal lobe epilepsy in which craniotomy was carried out. Lateralization of the origin of these illusions was arrived at initially by preoperative study. Further localization was made possible by electrical recording and stimulation at the time of operation. It was concluded that these signals are illusions of interpretation of present experience. They were divided into the following four groups for study:

[1]The automatism is only produced when a coated electrode is introduced deeply into the amygdaloid area and the stimulus is strong enough to produce after-discharge and probable epileptic interference with deeper connected areas of grey matter. The interpretive signal (illusion) or the experiential (flash-back) hallucination is produced by gentle superficial stimulation of the cortex without after-discharge.

TABLE II.—INTERPRETIVE RESPONSES AND ILLUSIONS

1. *Auditory illusions:* Sounds heard seemed louder or clearer, fainter or more distinct, nearer or farther.
2. *Visual illusions:* Things seen seemed clearer or blurred; nearer or farther; larger or smaller; fatter or thinner.
3. *Illusions of recognition:* Present experience seemed familiar (*déjà vu*), strange, altered, or unreal.
4. *Illusional emotions:* Feelings of fear, loneliness, sorrow, or disgust.

It was concluded in that review that visual illusions and illusions of familiarity were predominantly associated with the non-dominant temporal lobe (minor for handedness and speech). Reference to fig. 1 and the accompanying legend will show the localization conclusions based on stimulation alone. It is to be noted that the area of temporal cortex devoted to speech is avoided. The illusional emotions, group 4, were not numerous enough for statistical conclusion except in regard to fear which was clearly elicited from either side, dominant or non-dominant.

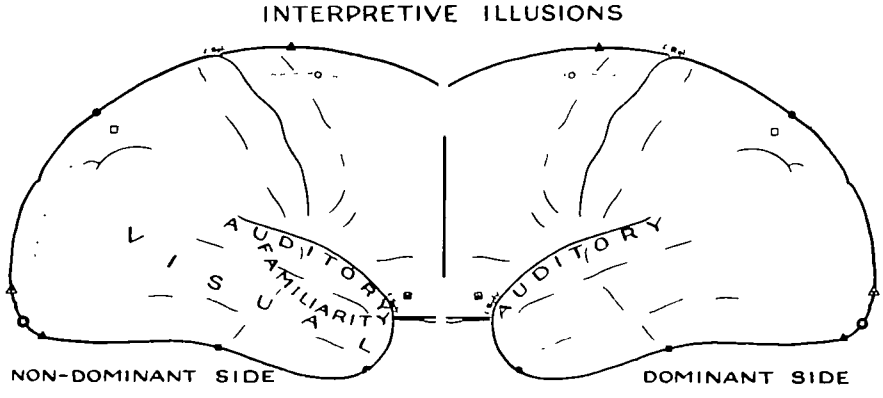


FIG. 1.—*Interpretive Illusions or Signals.* Illusions of familiarity, and visual illusions were produced by electrical stimulation predominantly in the minor, or non-dominant hemisphere. Auditory illusions were produced on both sides, chiefly in the first temporal convolutions. Feelings of fear, unreality, lonesomeness, or of being somewhere else, were produced by stimulation in either temporal region. (*After* Mullan and Penfield, 1959.)

Interpretive Cortex

Because of the association of the temporal cortex with these two classes of psychical phenomena (recall of past experience, and interpretation of present experience) the term *interpretive cortex* was used for descriptive purposes (Penfield, 1959). Motor cortex, sensory cortex and speech cortex are terms that serve similar purposes. None of these names suggests, of course, that there is independent action of the area of cortex in question. The localization of the experiential responses in the inter-

pretive cortex will be shown below, and the functional significance of these new findings will be discussed.

(2) Historical Note

Some medieval physicians knew that complex mental states, visual or auditory hallucinations, could occur in patients with seizures. The Arabian physician and surgeon, Abulquasim, who served as doctor to the Caliph at Cordova during the middle of the tenth century, recorded two examples of experiential hallucinations reported by epileptics. One was a man who saw a woman coming toward him at the onset of his attacks; the other case concerned a younger patient whose attack he described thus:

"And I also saw a boy, a patient of mine suffering from the same disease who told me that it seemed to him that a black woman came towards him having over herself a small leather garment and when she approached him he immediately fell down."[1]

Antonius Guainerius (Lennox, 1940) who lectured at the University of Pavia, 1412–1413 wrote, "I myself have seen a certain choleric youth who said that in his paroxysms he always saw wonderful things, which he most ardently desired to set down in writing."

In the latter part of the nineteenth century these mental states were analysed and recognized as integral parts of the epileptic seizure march by Hughlings Jackson as already mentioned.

"It is not very uncommon," he wrote (Collected Writings, 1931*a*), "for epileptics to have vague and yet exceedingly elaborate mental states at the onset of epileptic seizures. . . . The elaborate mental state, or so-called intellectual aura, is always the same, or essentially the same, in each case. 'Old scenes revert.' 'I feel in some strange place.' 'A dreamy state.' "

Jackson (1888) reported cases of epilepsy with "dreamy states" consisting of scenes or experiences remembered from the past. A 37-year-old man had attacks that began with an olfactory sensation; "He said that he 'began to think of things years gone by,'—'things from boyhood's days.' "

A second patient also had an initial olfactory sensation. "The next thing was his 'dreamy state.' He seemed to actually see large buildings which he had once seen; it might be that he seemed near a church, 'close to its wall.' In the last attack he 'saw' certain alms-houses, 'all in a moment saw that building and could actually see the clock.' The things he 'saw' seemed of a natural colour."

Gowers (1901) described several cases with elaborate visual and auditory "warnings" in their attacks. Among the examples he described was a patient who saw "beautiful places, large rooms, etc.," and heard at the same time "beautiful music."

[1]Albucasis (1519). Translated for us by the late Dr. W. W. Francis, Osler Library, McGill University, Faculty of Medicine.

(3) Source Material

For the purpose of this study one of us (Ph. P.) carried out a complete review of the records of patients who had been operated upon for the relief of focal epilepsy in the Montreal Neurological Institute since its founding in 1934. He was thus able to reconsider the series independently and to select for analysis all cases of seizures with an experiential hallucination in their pattern and all examples of experiential responses to electrical stimulation at operation. Such phenomena occurred in relation to the temporal lobes and not in relation to other areas of the brain. This constitutes the material for this final study.

Case records.—The records of 1,288 consecutive brain operations of this type were examined. In almost every case exploratory stimulation had been carried out under local anæsthesia.[1] These operations were performed on 1,132 patients most of whom suffered from seizures. It was found that gentle electrical stimulations produced experiential responses only when they were applied to the cortex of the temporal lobe. This region was exposed and explored with a stimulating electrode in 520 patients. Practically all of these 520 patients were suffering from temporal lobe seizures.

In the remaining 612 cases, other areas of the brain were exposed, and electrical stimulation was employed as a guide to therapy exactly as in the temporal cases. In none of these 612 cases were there any experiential responses. And it is fair to say that, over the years, every accessible part of the cortical mantle of the two hemispheres has been subjected to stimulation at one time or another.

Of these 520 patients whose temporal regions were explored 248 were operated upon in the right hemisphere and 272 in the left. Experiential responses occurred in 40 patients (7·7 per cent), and ictal experiential hallucinations had occurred spontaneously in 53 patients (10 per cent) in the temporal lobe group (*see* Table III).

The operative procedure under local anæsthesia has been described in detail elsewhere and will not be repeated here (Penfield and Baldwin, 1952; Penfield, 1954*a*). The surgeon and the patient are able to discuss the

[1]The majority of these operations were performed by one of us, W. P. In a considerable number of instances, however, the operation was carried out by one of our associates; but the record was preserved in the carefully standardized form used for the whole series. We express our gratitude to these neurosurgeons and especially to Theodore Rasmussen, William Feindel, Theodore Erickson, and Lamar Roberts. We have benefited too from the operative studies of Edwin Boldrey, Joseph Evans, Kristian Kristiansen, Herman Flanigin, Maitland Baldwin, Keasley Welch, Harry Steelman, Kenneth Paine and Sean Mullan.

The help of our colleagues in allied fields was of ever increasing importance, Francis McNaughton in Neurology, Herbert Jasper in EEG, Donald McRae in Neuroradiology and Brenda Milner in Clinical Psychology.

TABLE III

Temporal lobe cases		520
Experiential responses	40, 7%	
Spontaneous experiential hallucinations	53, 10%	
Other cases		612
Experiential responses	0, 0%	
Spontaneous experiential hallucinations	0, 0%	
Total cases with craniotomies, local anæsthesia and cortical stimulation		1,132

effect of each application of electrode to cortex, and the conclusion is then dictated by the surgeon to a secretary who sits behind the glass of the viewing stand. Since the patient is hidden under surgical drapes, and since he cannot feel it when the brain is touched, the surgeon can check the reliability of the responses with certainty. The patient, on his part, occasionally interrupts and corrects the surgeon's dictation!

The mode of stimulation (kind of stimulator, monopolar or bipolar electrode) and the stimulation parameters have changed from time to time over the years, but there is no relation discernible between any of these changes and the incidence of experiential responses. Most commonly, and during recent years, stimulation has been carried out with a monopolar silver ball electrode for surface exploration (area of contact approximately 1·5 square millimetres), and a multiple contact needle electrode for depth stimulation. The stimulus, usually employed, consists of square wave pulses of 2–5 msec. duration at a frequency of 40–100 cycles per second, 1 to 5 volts, provided by a square wave generator. The resistance of the surface electrode is about 10,000–20,000 ohms so that the stimulus current varies between 50 and 500 micro-amperes.

(4) ANATOMICAL OBSERVATIONS

In our previous publications on the subject of the temporal cortex, the diagrams showed only the lateral surface of the temporal lobe and sometimes the mesial and inferior surfaces. It is true that more stimulations were carried out on the easily accessible lateral surface than on the relatively hidden superior, inferior and medial areas, but in many cases the electrode explored these as well, often by deep stimulation using a coated electrode. In the present study we have attempted to show the position of cortical points that gave experiential responses on all surfaces of the temporal lobe as completely as possible.

To illustrate the positions of these points on the temporal cortex we have used our conventional schematic charts of the lateral and inferior surface of the temporal lobe as in previous publications, and have added a new chart of the superior surface as well. This superior-surface map was drawn as a composite of the convolutional patterns found in the gross dissection of eight human brains (fig. 2). When a block of tissue

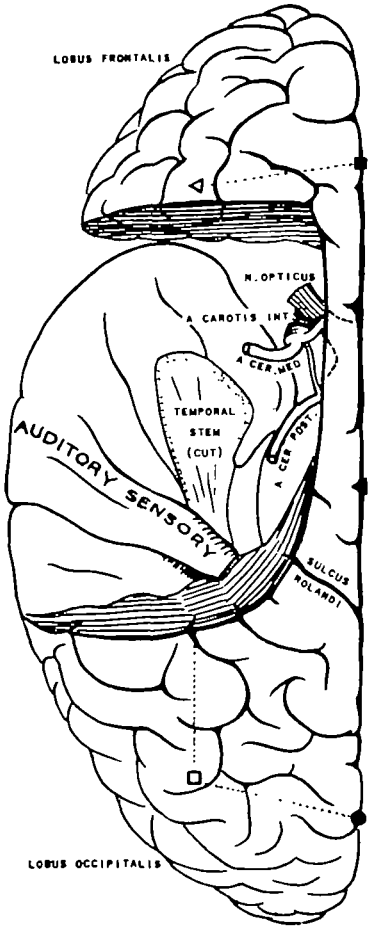


FIG. 2.—Map of superior surface of the temporal lobe shown after removal of parts of the frontal and parietal lobes as well as the insula. Our experience with stimulation indicates that the anterior gyrus (at least), of what are called the transverse gyri of Heschl, is to be identified as primary auditory sensory cortex.

is removed from the frontal, central and parietal opercular regions overlying the temporal lobe, the insula is exposed as it lies embedded within the medial part of the upper surface of the superior temporal gyrus (fig. 3). After removal of the insula and cutting across the temporal stem (which lies below as shown in fig. 5) the large superior cortical surface of the temporal lobe is exposed (fig. 2 and fig. 4). The temporal stem is the area of junction between the white matter of the temporal lobe and the hemisphere. In separating the temporal from the frontal lobe, below the insula, one has to make a horizontal section through this area of junction from the circular sulcus in a mesial and inferior direction to the upper surface of the uncus as indicated in figs. 4 and 5. Among other structures, the temporal stem contains portions of the uncinate fasciculus (connecting frontal and temporal lobes), claustrum, anterior

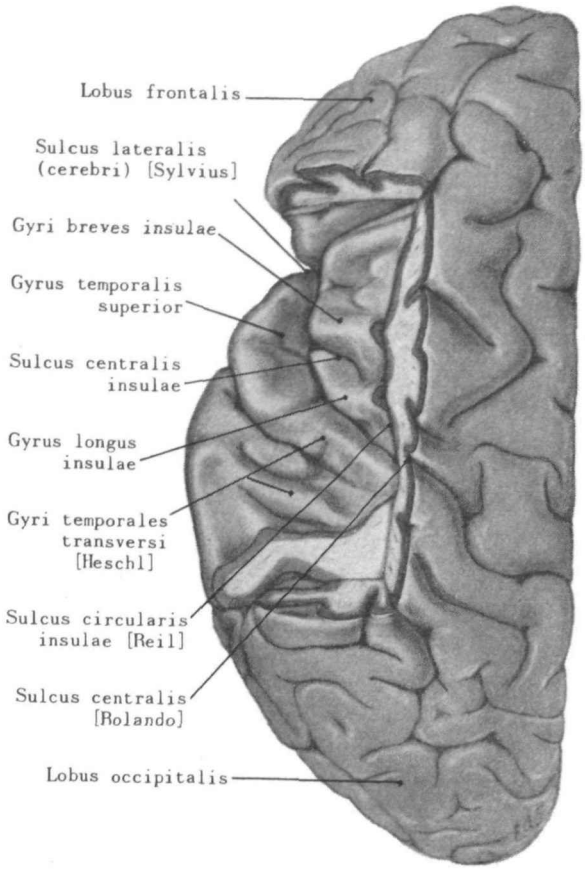


FIG. 3.—Drawing of the superior surface of the temporal lobe cortex after removal of parts of the frontal and parietal lobes to show the relations of the insula to the temporal lobe. The anterior transverse temporal gyrus of Heschl lies directly posterior to the insula. Stimulation here produces gross auditory sensation (not of the experiential type).

commissure, external capsule and peduncle of the lenticular nucleus. Anteriorly the superior temporal surface consists largely of the upper or Sylvian bank of the superior temporal gyrus except at the temporal pole where the superior temporal gyrus merges into the uncus. More posteriorly this surface is composed of the transverse temporal gyri (Heschl). These were described by Campbell (1905) as follows:

"On that portion of the superior temporal gyrus concealed within the Sylvian fissure, the surface of which looks upwards and inwards toward the insula, several parallel gyri—sometimes as many as five—may be distinguished, running from before and laterally backwards toward the middle line. They have been termed by Heschl the transverse temporal gyri. Of these the most constant and best developed is the anterior. It springs from the superior temporal gyrus at about the middle of the fissure of Sylvius, and the sulcus which divides it from the succeeding transverse gyrus behind is often of great depth, and of such extent that it appears on the lateral surface, where it may not only indent but even bisect the superior temporal gyrus. This arrangement is commoner in the left hemisphere than in the right, and in males than in females."

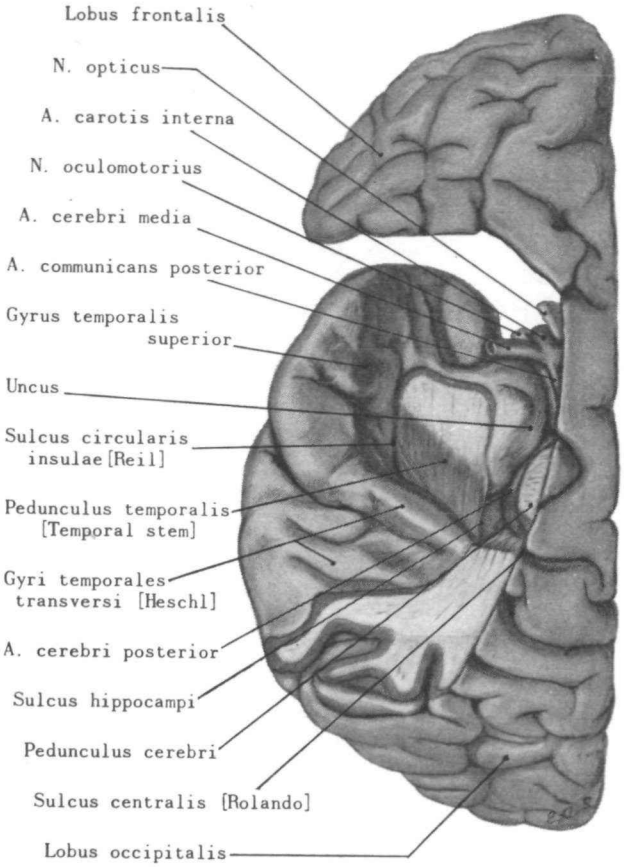
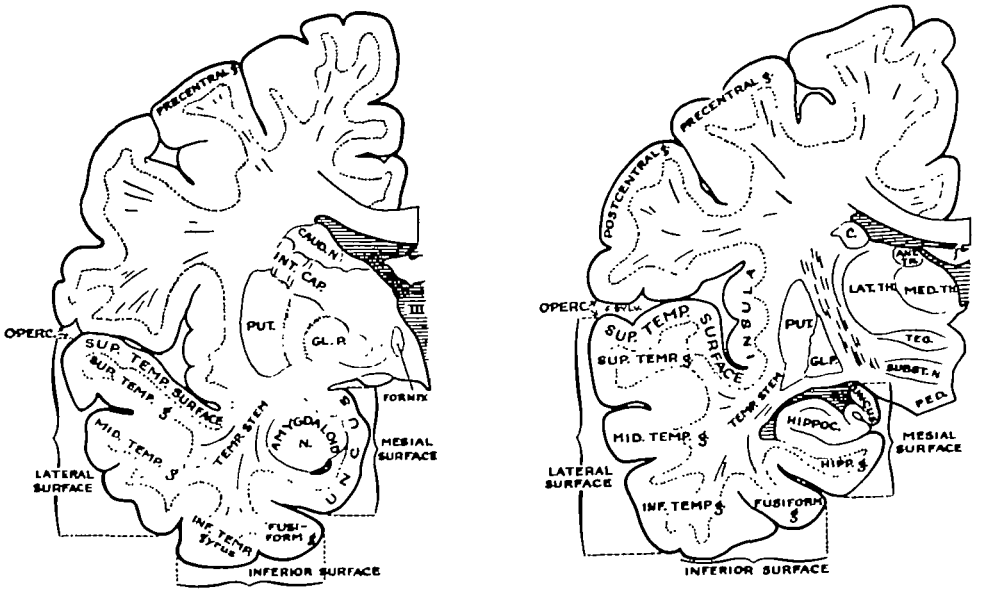


FIG. 4.—Drawing of the superior surface of the temporal lobe cortex. The insula has been removed and a section made across the temporal stem. This corresponds with the map shown in fig. 2.

Mettler (1948) notes that the transverse temporal gyri of the left temporal lobe, in right-handed individuals, display a greater complexity than those of the right side. More posteriorly, behind the transverse temporal gyri, the superior temporal surface may continue as a small smooth area until the caudal end of the Sylvian fissure is closed off. Von Economo (1929) describes this area as the posterior planum temporale.

The mesial surface of the temporal lobe is formed by the uncus, with underlying amygdaloid nucleus anteriorly, and the hippocampus and hippocampal gyrus more posteriorly (fig. 5). The mesial surface is separated from the superior surface by the temporal stem except anteriorly where they join at the temporal pole.

Laterally the temporal cortex presents the familiar horizontally arranged superior, middle and inferior temporal gyri. The inferior surface is composed of the inferior temporal gyrus, fusiform gyrus, uncus, and more posteriorly the hippocampal gyrus.



A B

FIG. 5.—A, Frontal transection of the left hemisphere in a plane that passes through the amygdaloid nucleus, and, B, posterior to it, through the hippocampus. The superior temporal surface (lower operculum) is continuous with the cortex of the insula. The medial surface is separated from the superior surface by the temporal stem, but the surfaces are joined just anterior to the stem. (*After* Jelgersma, G., Atlas Anatomicum Cerebri Humani.)

The posterior boundary of the temporal lobe is an arbitrary line which separates it from the occipital lobe. This vague line extends from the parieto-occipital fissure to the pre-occipital notch.

As von Bonin (1950) has pointed out, the classical subdivision of the brain into lobes is unsatisfactory from any functional point of view and it is well to remember that the term "temporal lobe" is only an anatomical convention. From a cytoarchitectonic standpoint it is true that most of the temporal cortex is of a composition that sets it apart from the surrounding areas of the brain. A further differentiation can be made within the anterior transverse temporal gyri so as to delimit a granulous, primary receptive type of cortex, *Koniocortex* (von Economo, 1929), similar to that found in the post-central and calcarine regions. It has been considered that this is devoted to auditory function.

The older anatomists further subdivided the temporal cortex into a bewildering number of areas on the basis of minor differences in lamination and cell type. It is tempting to use these maps for guidance in studies of functional localization, but in the present state of our know-

ledge of brain function the significance of minor differences in cellular structure is not at all clear.

Lashley and Clark (1946) state, regarding their studies of the temporal lobe of Macaca and Ateles (monkeys), except for the primary auditory area, ". . . we can find no areal differences in the temporal lobe which can be delimited with sufficient accuracy to have topographic value or which have characteristics of probable functional significance."[1]

Earlier studies, e.g. Walker on the chimpanzee (1938), indicated another distinctive feature of a large portion of the temporal cortex. It has no direct connexions with the nuclei of the thalamus except posteriorly where projections are received from nucleus lateralis posterior and pulvinar, and within the transverse temporal gyri which receive auditory afferent projections from the medial geniculate body. More recently, with the fibre dissection technique, Klingler and Gloor (1960) have demonstrated connexions between the anterior temporal cortex and the medial thalamus as well as the pulvinar by way of the extra-capsular thalamic peduncle and the temporopulvinar bundle of Arnold respectively. Connexions between the temporal cortex and thalamus can be quite readily demonstrated electrographically (Stoll, Ajmone-Marsan and Jasper, 1951). Anatomical studies by Votaw (1960) also indicate that the temporal cortex receives a large projection of fibres from the hippocampus.

Our evidence for localization of the auditory sensory cortex, derived from stimulation of the human brain, was recorded by Penfield and Rasmussen (1950) and amplified by Penfield and Jasper (1954). Subsequent experience with deep stimulation confirms this and indicates that the primary audito-sensory area lies on the anterior one of the transverse gyri of Heschl within the fissure of Sylvius. This lies just posterior to the insula (*see* figs. 2 and 3). Stimulation here results in a crude auditory sensation. In our earlier studies a change in the perception of sounds was not clearly distinguished from an auditory sensation which may have led us to indicate auditory sensory cortex as extending more widely than it should (*see* fig. 6).

Our present study bears out this conclusion. The buried anterior transverse temporal gyrus, which is applied to the posterior slope of the insula, often yields an auditory sensation upon stimulation, usually a tone, a buzzing or knocking sound. On the lip of the fissure of Sylvius the zone, where auditory sensation can be elicited, extends forward and back along the first temporal convolution. Some of this scattering may be

[1]They were able to find general characteristics only for the frontal granular, the precentral agranular, the post-central, the parieto-occipital, and temporal regions, the striate area, the agranular insula and possibly also a characteristic cortex on the transverse temporal gyri of Heschl, and they felt that previous subdivisions of the human cerebral cortex were based on no more reliable evidence than they had obtained in the monkeys.

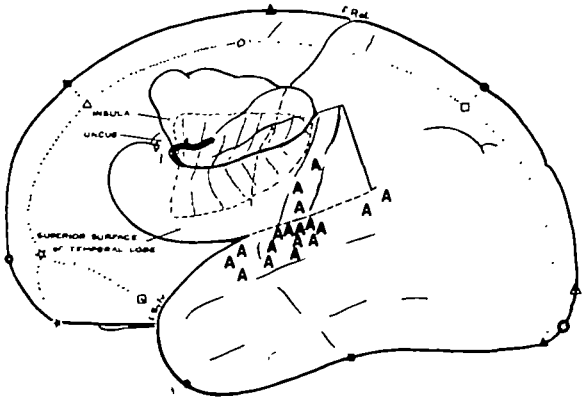


FIG. 6.—*Auditory responses* (crude auditory sensation) to electrical stimulation in 108 temporal explorations, right and left. The superior surface of the temporal lobe and the surface of the insula are turned upward. The letter A indicates the general position of one or more stimulation placements in each case. (*From* Penfield and Jasper, 1954.) (Fig. 2 shows better our present conclusion.)

produced by distant response due to facilitation. But it is now more likely that some of these points should have been considered alterations in interpretation of sounds being heard, rather than newly created auditory sensation. Such alterations would now be called interpretive illusions or responses.

The distribution of these points, giving crude auditory responses, corresponds fairly well to the area Campbell (1905) delimited and to which he assigned an auditory function. He termed the cortical zone surrounding the primary auditory cortex in Heschl's gyri the "audito-psychic" cortex and postulated that it had to do with the elaboration of auditory sensation.[1]

It will be seen later that it is within this region that auditory experiential responses and auditory interpretive responses occur.

It might be observed in passing that although the interpretive cortex covers the area that Campbell called audito-psychic, it does not seem to encroach on the area immediately surrounding the primary visual cortex in the occipital lobe which Campbell named visuo-psychic. He postulated that this visuo-psychic cortex was concerned with an elaborative function on the same kind of evidence presented for the audito-psychic cortex.

[1]Campbell made this assumption on the basis of suggestive experimental, clinical and histological evidence. He cited the "mind-deafness" in Munk's dogs with lesions, a "psychic disability" in auditory function seen in man with lesions in the first temporal gyrus, and especially his observations that this area had a special histological structure that set it apart from the primary auditory sensory area as well as the remainder of the temporal cortex.

In addition to auditory sensation, there is some evidence from operative exploration that a functional localization exists in the temporal cortex for vestibular sensation, probably adjacent to the auditory zone. There is only occasional evidence of olfactory sensation from stimulation in or near the cortex of the uncus (Penfield, 1958*a*).

(5) Experiential Responses to Stimulation

In this section we will review all cases (40 in all) in which gentle stimulation of the cortex of conscious patients produced experiential responses. All of these patients were subject to cerebral seizures and we hoped to cure them or improve the condition by operation.[1] The pre-operative conclusion (verified at operation) was that the discharge responsible for the attacks arose in the temporal area in each instance.

A. Material

Experiential responses were reported during 40 operations on 40 different patients out of the entire series of 1,132 patients. This represents an incidence of 7·7 per cent of those cases in which the temporal region was stimulated (520 patients). Among these 40 patients, 24 had, in addition to their experiential responses, an experiential hallucination in their habitual seizure pattern, and in 16 of these patients the same experience was reproduced at operation by stimulation. Twenty-nine other patients in the group of 520 with temporal lobe seizures were also found to have an experiential hallucination in their seizure pattern, making a total of 53 cases with ictal experiential hallucinations. These patients will be considered in detail in Section 6.

Expressing the data differently, there were 53 patients who were subject to seizures in which an experiential hallucination occurred. And there were 40 cases in which electrical stimulation produced experiential responses, a total of 93 examples of recall of previous experience by epileptic discharge or electrical stimulation. Of the 53 patients in whose seizures there were experiential hallucinations, experiential responses of some sort were produced in 24 or 45 per cent. In 16 of these 24 patients the ictal hallucination was successfully reproduced by stimulation as a response at operation, i.e. these responses were the same as the ictal hallucination in 67 per cent. In many of these cases experiential responses not directly related to the ictal hallucination were obtained as well.

[1]Clinical results have been reported in a series of publications (*see* Penfield and Jasper, 1954). No patients were taken for operation until the best neurological effort to control the attacks had been declared a failure. Approximately half of the patients would consider themselves cured by operation, some continuing with medication and some free of all medication. Still others were improved and not cured. There were bitter disappointments, but in general this is a most rewarding therapeutic field, though difficult.

In this group of 40 patients who had experiential responses there were 18 males and 22 females. The average age at onset of their seizures was 14 years and the average age at the time of operation was 25 years.

The relationship to cerebral dominance was as follows: 15 of these patients were operated upon on the left side and 25 on the right. There were 2 patients with speech dominance on the right, but as one patient had his epileptogenic focus and his craniotomy on the right, and the other on the left, the proportion was not changed, i.e., 25 to 15, or 62·5 per cent non-dominant to 37·5 per cent dominant.[1] This difference should be kept in mind when the data on lateralization are considered in detail.

EEG.—Electroencephalographic study was made of only 36 of these patients since 4 were operated upon before clinical electroencephalography had been introduced. In 21 of the 36 cases studied there was a well-lateralized area of electrographic abnormality in or near the temporal lobe responsible for the seizures. In the other 15 there was some bilateral temporal or fronto-temporal abnormality in the records, although it was maximum on the side of operation.

Pathology.—In these cases, as in all the others in the series, convolutions thought to be the irritant cause of the recurring fits for which the patient sought help, were removed. The tissue was studied microscopically and the information derived was added to the clinical evidence to establish the presumptive cause of the epileptogenic activity (*see* Table IV).

TABLE IV.—PATHOLOGICAL FINDINGS AT OPERATION IN 40 PATIENTS WITH EXPERIENTIAL RESPONSES

Incisural sclerosis	17
Cerebral cicatrix	8
Meningo-cerebral cicatrix ..	5
Neoplasm..	3
Arteriovenous angioma ..	1
Post-infectious atrophy	1
Cortical atrophy, cause unknown	1
Cause unknown	4

In 17 out of the 40 cases, there was clear evidence that the cause was birth ischæmia located in the inferior and mesial portion of the temporal lobe near the incisura of the tentorium. This we have called incisural sclerosis (Earle, Baldwin and Penfield, 1953; Penfield and Jasper, 1954). In 13 cases the pathologist called the atrophic process meningocerebral or cerebral cicatrix. In three cases there was a small neoplasm and in one an arteriovenous angioma.

[1]In one left-handed patient (R. B., Case 2) who had a left-sided operation, the left hemisphere was found to be non-dominant for speech. One right-handed patient (R. McA., Case 10) who had a right-sided operation was found to have the right hemisphere dominant for speech.

In general there was cortical atrophy and gliosis in the convolutions which, before removal, gave clear evidence of unbridled (spiking) electrographic discharge. Electrocorticography was carried out during operation with the help of Dr. Herbert Jasper.

Seizure pattern.—In 24 out of the 40 cases, the patient had reported experiential hallucinations at some point in the march of his habitual seizures. Nine patients reported it as the first phenomenon in the march and often the only phenomenon. When the initial ictal phenomenon was not experiential it was still of the type to be expected from epileptogenic discharge in temporal cortex or the amygdaloid-hippocampal zone, i.e. interpretive illusion, cephalic sensation, epigastric sensation, body sensation, thoracic sensation, etc.

It is of interest to note also that in these 40 cases, when the attack was "strong" enough to continue on from the initial phenomenon through the ictal march, the terminal phenomenon was usually automatism, i.e. in 24 cases (60 per cent). One may assume then that the discharge usually ended by spreading to the amygdaloid-hippocampal zone and into the central grey matter to which these structures are directly connected (Feindel and Penfield, 1954).

In 13 out of the above 40 cases there was occasionally a generalized convulsion instead of automatism as the terminal event. In only 9 cases the terminal event was regularly a generalized convulsion instead of automatism. In 4 the terminal event was usually simple loss of consciousness.

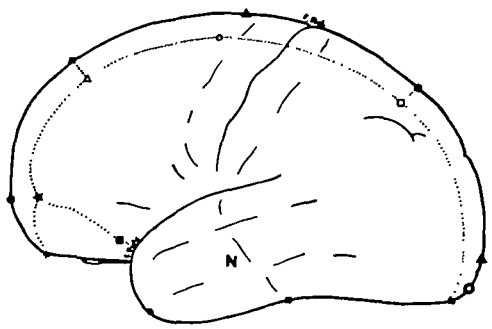
B. Case Reports

Brief case histories and the verbatim operative stimulation records of the 40 patients that yielded experiential responses will now be presented. Brain charts will be presented with each case history which will illustrate precisely where each response-producing stimulus took place. Each number that appears on a brain map indicates a different point on the cortex from which experiential responses were elicited. What the patient reported when the electrode was applied at this point is listed after the corresponding number in the stimulation record in each case.

It should be noted that in all of the positive stimulations the active electrode tip was probably in contact with cortical grey matter of the lateral, superior, medial or inferior surface of the temporal lobe. Stimulation of the superior or Sylvian surface of the temporal cortex was most often accomplished by inserting a coated electrode through the second temporal gyrus and directing it in an upward and medial direction for a measured depth. The positions of those points located on the superior temporal surface that gave experiential responses were carefully

re-checked with the stimulating electrode in gross dissections of the brain. It is not possible to state with absolute certainty, but it would seem that stimulation of the white matter has never produced an experiential response. Deep stimulation within the temporal lobe in the amygdaloid area or in the hippocampus has also failed to elicit experiential responses (Jasper and Rasmussen, 1958).

Case 1.—E. Wh. This 37-year-old housewife began to have seizures at age 20 consisting of the following pattern: (1) thoracic sensation and palpitation, (2) experiential hallucination, visual type, (3) occasional major seizure, mainly right-sided. At the beginning of an attack she would see scenes which she sometimes had difficulty recognizing or remembering, but they were often from her own past. Frequently the scene consisted of herself as she appeared in childbirth and also a picture of the child. Often as soon as she recognized the scene it would disappear. At operation the left temporal lobe was exposed and an area of gliosis found.



CASE 1.—E. Wh.

Stimulation at point N caused the patient to say that she suddenly saw herself in childbirth, and she felt as if she were re-living the experience.

Case 2.—R. B. This 21-year-old left-handed man had no history of a difficult birth or postnatal illness but he began to have seizures at age 9. At first these were brief attacks of staring with salivation; later there were in addition smacking movements of the lips. At the time of his investigation he felt that he had two types of warning for his attacks: (1) an epigastric sensation followed by a change in his thinking so that things became "unreal", (2) a sensation in the right side of his neck, a right auditory sensation and vertigo. Both of these were frequently followed by a period of automatic behaviour. Skull X-rays and air-contrast studies indicated selective smallness of the left cerebral hemisphere probably dating from birth or early life. The electroencephalographic abnormality was consistent with a well-lateralized extensive epileptogenic lesion of the left temporal lobe involving the lateral and inferior medial surface anteriorly.

Operation was carried out under local anæsthesia. Fig. A illustrates the patient prepared for operation and the skin incision for exposing the left temporal region is outlined above the ear. In fig. B, the upper panel is an operative photograph of the

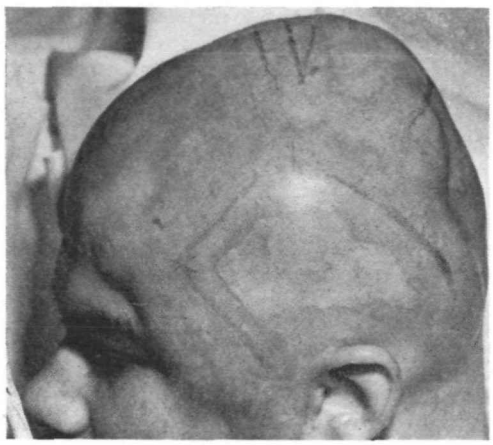


FIG. A.—*Case 2.*

brain surface after the scalp, bone and dura have been reflected. Stimulation was carried out and numbered tickets mark the sites of positive responses. The lower panel of fig. B indicates the area of temporal lobe removed at operation.

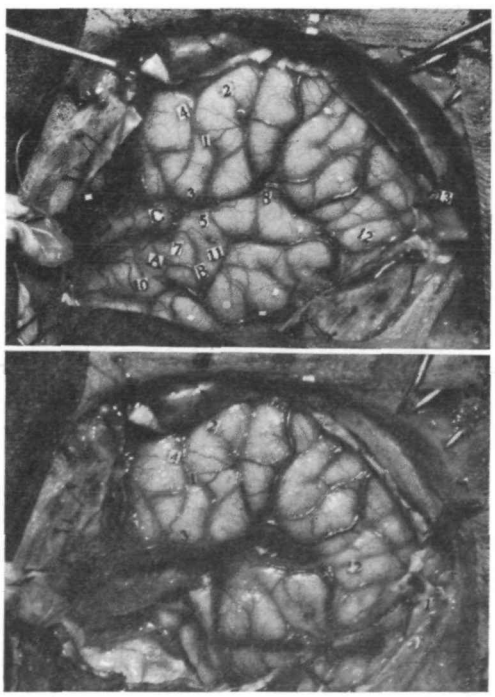
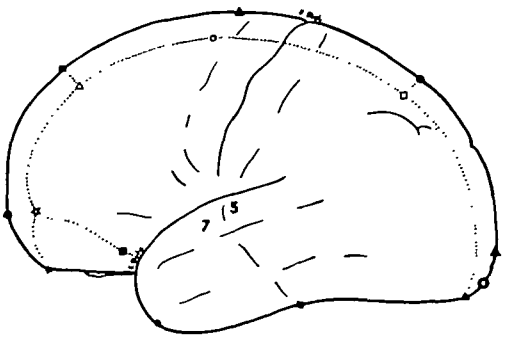


FIG. B.—*Case 2.*

The first temporal convolution was found to be narrow and leathery as it extended anteriorly to join the uncus which was also sclerotic. There were a few adhesions

under the temporal lobe on the floor of the middle cranial fossa. When the ventricle was opened, a brownish discoloration was seen on the surface of the hippocampus. This area was very tough and beneath it a small hæmorrhagic cyst was encountered within the substance of the hippocampus itself, fig. C.



CASE 2.—R. B.

Before the removal was carried out, stimulation at points 5 and 7 produced the following experiential responses.

5. Patient did not reply.
5. Repeated. "Something."
5. Patient did not reply.
5. Repeated. "Something."
5. Repeated again. "People's voices talking." When asked, he said he could not tell what they were saying. They seemed to be far away.
5. Stimulation without warning. He said, "Now I hear them." Then he added, "A little like in a dream."
7. "Like footsteps walking—on the radio."
7. Repeated. "Like company in the room."
7. Repeated. He explained "it was like being in a dance hall, like standing in the doorway—in a gymnasium—like at the Kenwood Highschool." He added, "If I wanted to go there it would be similar to what I heard just now."
7. Repeated. Patient said, "Yes, yes, yes." After withdrawal of the stimulus, he said it was "like a lady was talking to a child. It seemed like it was in a room, but it seemed as though it was by the ocean—at the seashore."
7. Repeated. "I tried to think." When asked whether he saw something or heard something, he said, "I saw and heard. It seemed familiar, as though I had been there."
5. Repeated (20 minutes after last stimulation at 5). "People's voices." When asked, he said, "Relatives, my mother." When asked if it was over, he said, "I do not know." When asked if he also realized he was in the operating room, he said "Yes." He explained it seemed like a dream.
5. Repeated. Patient said, "I am trying." After withdrawal of the electrode he said, "It seemed as if my niece and nephew were visiting at my home. It happened like that many times. They were getting ready to go home, putting their things on—their coats and hats." When asked where, he said, "In the dining room—the front room—they were moving about. There were three of them and my mother was talking to them. She was rushed—in a hurry. I could not see them clearly or hear them clearly."

7. Repeated. "Radio. I think it was Philadelphia; it was news." He said it was at his home.

Depth stimulation was carried out within the region of the anterior transverse temporal gyrus (Heschl) by inserting a coated electrode at points 11 and 14 (*see* fig. C).

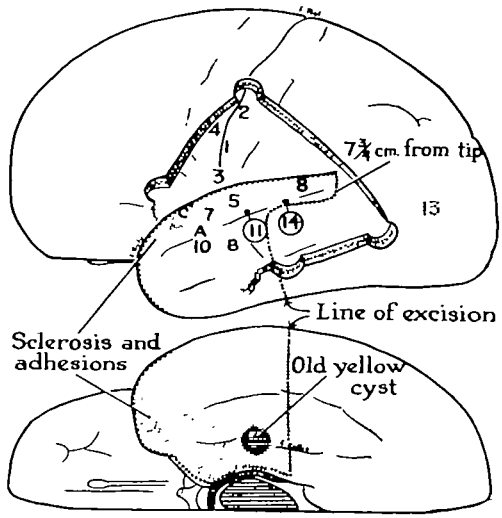


FIG. C.—*Case 2.*

Crude auditory sensations resulted. When point 13 was stimulated near the occipital lobe beneath the bone edge posteriorly (fig. C), the patient reported a crude visual sensation, "a sun or a moon."[1]

Case 3.—R. W. This 12-year-old boy had a difficult birth but his early development was normal. His seizures began at age 9. The pattern of his attacks was: (1) visual sensation (coloured triangles); (2) experiential hallucination—visual; (3) automatism with an occasional generalized seizure (mainly left-sided). After the visual sensation usually he would see a robber, or a man with a gun, moving toward him. The man was someone he had seen in the movies or the comic strips. The figures then moved to the left and the patient's head and eyes would turn to the left.

At operation the right temporo-occipital region was exposed. Fig. A indicates the outline of the operative incision. The local anæsthetic is being placed into the scalp. The exposed brain is shown in fig. B after stimulation has been carried out and positive responses marked with tickets. The proposed area of removal is outlined by white thread. A local cortical scar was found on the undersurface of the occipital lobe during the removal.[2]

[1]At operation, stimulation within the temporo-parietal speech zone did not interfere with speech, and there was no post-operative dysphasia. It was therefore considered that the left hemisphere was non-dominant for speech. He has had no seizures in the six years since the operation. Unfortunately he developed paranoid schizophrenia five years ago. He had shown some slight evidence of this before his operation although he was perfectly normal at the time of operation.

[2]It has now been eleven years since his operation and he has grown to be a fine young man. He has had no further seizures and has completely adjusted to his hemianopia.

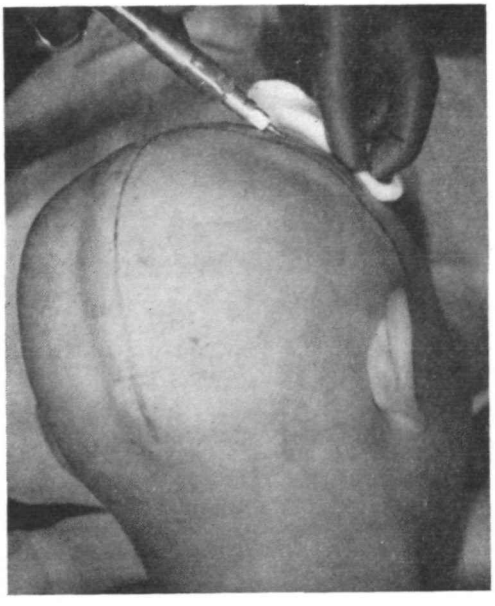
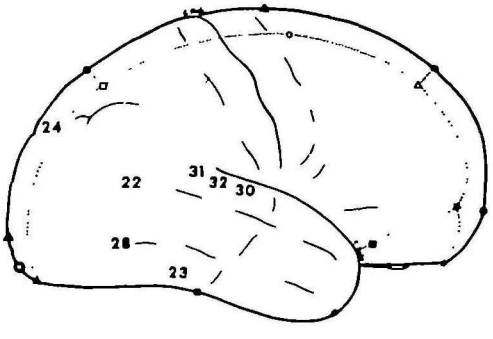


FIG. A.—*Case* 3.

FIG. B.—*Case* 3.

At the time of stimulation the following experiential responses were produced.



CASE 3.—R. W.

22. He said nothing for a little interval, and then he said, "Oh, gee, gosh, robbers are coming at me with guns!" He heard nothing, he just saw them coming at him. The robbers seemed to have been coming at an angle from the left. When asked if they came in front of him, he said no they were behind him.

This seems to be the reproduction not of a real event, but of a fantasy or a dream drawn from the reading of a comic book, a silent fantasy devoid of auditory components.

23. "Pain in my forehead, and there was a robber. He wasn't in front, he was off to the left side."

24. "Yes, the robbers, they are coming after me."

Following this stimulation there was after-discharge. Since there was current spread to contiguous areas this point has not been included in the summary maps in Section 7.

28. "Oh gosh! There they are, my brother is there. He is aiming an air rifle at me." His eyes moved slowly to the left. The figures seemed to disappear before the cessation of the stimulus. When asked, he said his brother was walking toward him, and the gun was loaded. When asked where he was, he said at his house, in the yard. His other little brother was there, that was all. When asked if he felt scared when he saw his brother, he said, "Yes." When asked if he always felt scared when he saw the robbers, he said, "Yes."

30. "I heard someone speaking, my mother telling one of my aunts to come up tonight."

31. "Would you do it again, please?"

31. Repeated. After a pause, he said, "The same as before. My mother was telling my aunt over the telephone to come up and visit us tonight." When asked how he knew she was talking over the telephone, he said he did not see her, but from the way his aunt's voice sounded when she answered he knew it was over the telephone.

32. "My mother is telling my brother he has got his coat on backwards. I can just hear them." When asked if he remembered it, he said, "Oh yes, just before I came here." When asked if he thought these things were like dreams, he said, "No." When asked what it was like, he said, "It is just like I go into a daze."

Case 4.—A. Bra. This 32-year-old woman began to have seizures at age 31. She had no childhood attacks, but at age 16 when her father died (he was a Dutch sculptor), she had a "nervous breakdown" and heard noises in the walls. Two months before her admission she was frequently disoriented, had frequent hallucinations and was depressed and silent. She had difficulty recognizing her friends and even her husband.

The pattern of her seizures was: (1) experiential hallucination—visual, or visual sensation; (2) nausea, (3) vomiting; (4) adversive turning to the left; (5) generalized convulsion. She described her attacks as follows:

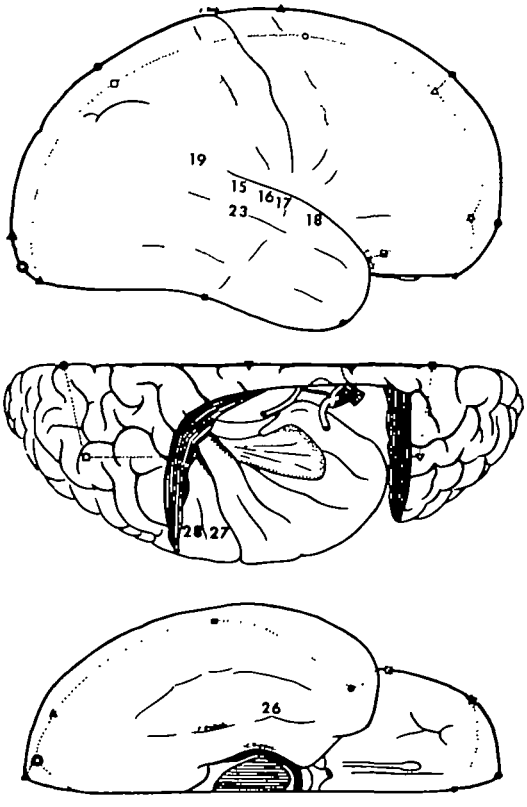
(*a*) *Experiential hallucinations* (ictal).—She saw different things that were familiar to her, things which came from the past. The most frequent was as follows: She would see a square with a circle in it. (She believed this to be the sign used for advertising purposes by a photographer in her home town of Hilversum.) With this she might be nauseated and vomit. Usually, however, the square and circle were followed in turn by the hallucination that she was in a kitchen. It seemed to be in the country and it had many windows. There were two boys in the room coming towards her. One was "nice," the other "sneering" and "nasty." She thought this must have been a real experience at some time but she could not remember where it had occurred.

At other times she saw faces, or people, coming toward her. She sometimes seemed to see pictures—more distinctly than she could recall them when she tried. For example, she saw Rembrandt's *Night Watch* on one occasion and his *Self-Portrait* on another. Art was a subject of common interest in her Dutch home. Once she had seen, as though in a picture, "Christ coming down from the sky." There was no movement but this frightened her, for it was her first hallucination. Later she realized the unreality of the hallucinations as they presented themselves.

(*b*) *Visual sensations* (ictal).—Sometimes she saw lights and little things that were always on the left side of her field of vision.

At operation the right hemisphere was exposed and an atrophic abnormality found in the occipital lobe and medial temporal lobe in the distribution of the posterior cerebral artery. This may have been produced by brain herniation through the incisura of the tentorium at the time of birth.

Stimulation produced these responses.



CASE 4.—A. Bra.

15. "I hear singing."
15. Repeated. "Yes, it is White Christmas." When asked if anyone was singing, she said, "Yes, a choir." When asked if she remembered it being sung with a choir, she said she thought so.
16. "That is different, a voice—talking—a man."
17. "Yes, I have heard it before. A man's voice—talking."
17. Repeated without warning. "Yes, about the same."
18. "There is the sound again—like a radio program—a man talking." She said it was like a play, the same voice as before.
19. "The play again!" Then she began to hum. When asked what she was humming, she said she did not know, it was what she heard.
19. Repeated. Patient began to hum. She continued at the ordinary pace of a song. "I know it but I don't know the name—I have heard it before. I hear it, it is an instrument—just one." She thought it was a violin.

15. Repeated (26 minutes after last stimulation at 15). "White Christmas," she said it was the orchestra playing.
17. Repeated (24 minutes after last stimulation at 17). "Yes, the play again."
18. Repeated (21 minutes after last stimulation at 18). "White Christmas."
23. "The play—they are talking." When asked who, she said, "The men are talking." When asked who they were, she said, "I don't know."
26. Patient said, "It hurts." Stimulation was stopped. She said, "I see a picture." She added, "It was a face which comes from a picture."
26. Repeated. "Nothing."
27. "The same thing. The play and they are banging on something like a drum."
28. "I see people walking." When asked where they are, she said, "I think they are here." She said they were strangers.
23. Stimulation next to point 23. Patient said, "A voice singing."

Case 5.—D. F. This 26-year-old woman worked as a secretary in an office. She began to have seizures at age 6, probably as the result of anoxic brain injury following an anæsthetic. At first she had only periodic thoracic sensations, but in her teens she developed this attack pattern: (1) substernal thoracic sensation; (2) automatism, (3) occasional generalized seizure. At operation the right temporal region was exposed and atrophy of the first temporal convolution was found which extended into the temporal cortex adjacent to the island of Reil as well as into the inferior surface of the temporal lobe and uncus.

After removal of the anterior end of the temporal lobe, stimulation was carried out on the cut surface of the cortex which was exposed in cross section. Point 23 was located on the cut surface of the superior and medial aspect of the first temporal convolution where that convolution lay against the insula. Fig. A is an operative diagram

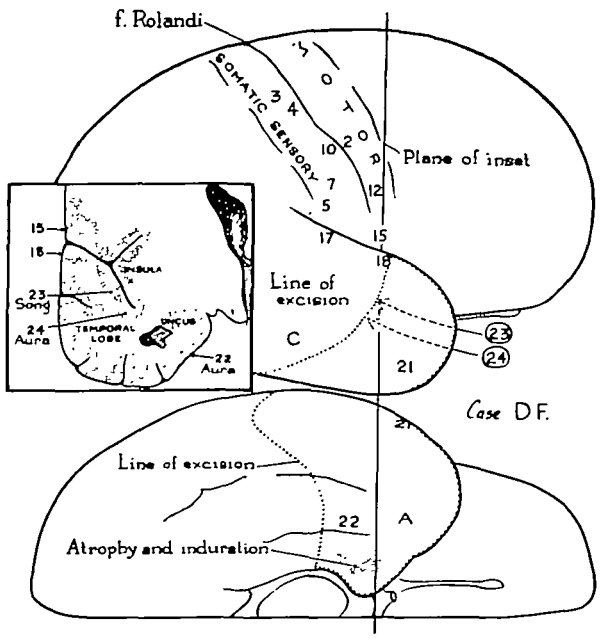


FIG A.—*Case 5*

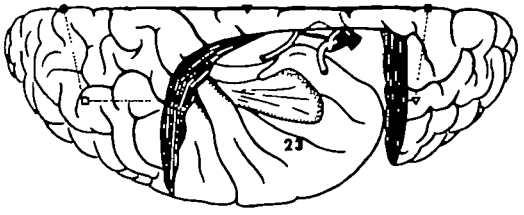
illustrating the location of point 23. The thoracic aura of her habitual attacks was reproduced when points 22 and 24 were stimulated.

23. Stimulation produced a slight substernal sensation.

23. Repeated. "I hear some music." Repeated without warning, "I hear music."

23. Repeated without warning. "I hear the music again. It is like the radio." When asked what tune, she said she did not know but that it was familiar.

23. Repeated again without warning. The patient said, "I hear it." The electrode was kept in place and she was asked to tell us about it. She then hummed the tune. When asked, she said she never noticed that before an attack.



CASE 5.—D. F.

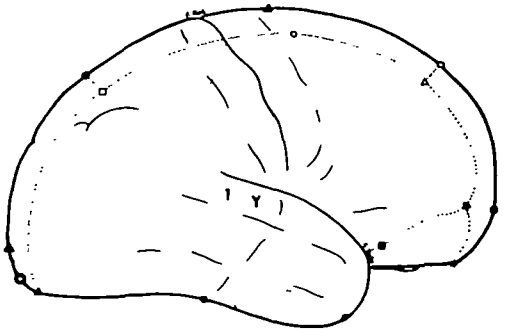
Stimulation of the first temporal convolution above, near the lip of the fissure produced no result, but at a depth of 1½ cm. where the first temporal convolution lies along the island of Reil, stimulation at three points in the vicinity of point 23 caused the patient to hear the same tune. She hummed it quite distinctly. Miss Stanley, the operating room nurse, recognized the tune as "Rolling Along Together." The patient agreed that this sounded like the words in the song. On enquiry, the patient said it was not a question of being made to think about it, but that she actually heard it. When she accompanied the music that she heard, the timing was just what one would have expected, no faster and no slower. This suggests that the bombardment of electrical pulses from the electrode can only cause the stream of experience to move forward smoothly in the original tempo.

Since the anterior portion of the temporal lobe was already removed and the anterior end of the hippocampus as well, it seems unlikely that the neuronal record that was being activated was within that temporal lobe or hippocampus. Conduction seems much more likely along some fibres of the temporal stem posterior to the point of stimulus to a pattern of neurone connexions at a distance, a pattern which received its lasting facilitation once when this orchestra was listened to.

During the past twelve years since this patient's operation she has been free of attacks although she continues to have occasional warning sensations. These have not prevented her from living a happy, normal life.

Case 6.—M. G. This 16-year-old girl had her first attack at age 14. The pattern was: (1) experiential hallucination—combined auditory and visual type; (2) generalized seizure. Before each of her attacks she would hear music which was always the same, a lullaby her mother had sung, "Hush-a-bye, my baby . . ." She seemed to be in church or in a convent when she heard the song. A neoplasm was suspected in the

right temporal region but none was found at operation. A subtemporal decompression only was carried out. Stimulation produced the following responses.



CASE 6.—M. G.

Y. After stimulation was over she said, "I had a dream—I wasn't here." She said its was not like the dreams she had had before.

Y. Repeated without warning. Patient said, "Dream." After stimulation was over she seemed to find it difficult to explain for a time. Finally, she said it was gone. She said, "I seemed to be here, but things sounded different." She also heard a lot of "funny sounds."

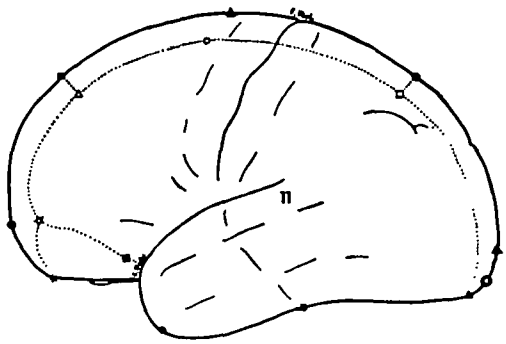
Y. Repeated. "I hear people coming in." Then, "I hear music now—a funny little piece." Stimulation was continued. Patient became more talkative than usual, explaining that the music was something she had heard on the radio—that it was the theme song of a children's program. When asked, she said it was a record.

Y. Repeated. "Another dream. People were coming in and out and I heard boom, boom, boom." She said, "I don't remember the rest."

1. "It's a dream. There are a lot of people—I don't remember the rest." When asked whether she heard or saw people, she said, "I don't seem to see them—I hear them. I don't hear them talking, I just hear their feet."

Case 7.—S. H. This 20-year-old college student had one convulsion at age 3 associated with a febrile illness. Recurring seizures began at age 12. The pattern of his attacks changed somewhat over the years. At first (age 12–14) they consisted of "warnings only." He would suddenly hear an unfamiliar male voice which usually told him that he was going to have an attack. This was followed by a scene which was always the same, "something involving a chariot," but he could not remember any more detail or where he had actually seen such a scene. After this hallucination he would become "rigid" for a few seconds without loss of consciousness. Between the ages of 14 and 18 years the attacks were similar, but he practically always lost consciousness and had a posturing type right-sided seizure. He remembered the voice and scene in less than 50 per cent of his attacks. In addition some attacks would begin with "music" instead of the voice and scene. He stated that he might be humming a tune to himself and then the tune would continue after he stopped humming, or sometimes the tune would simply "start by itself." He never thought that it was coming from somewhere outside himself. It was always a familiar tune, one that he knew

well, and it might be a folk song or an orchestra playing classical music. There was never any vocal accompaniment. At age 18 his seizure pattern changed again to: (1) a thought or an awareness that an attack was imminent; (2) experiential hallucination —auditory; (3) the attack might stop at this point or go on to a mainly right-sided tonic posturing seizure with loss of consciousness. He was unable to explain the thought or awareness, "It is a sudden clear, mental feeling which I know means an attack is coming." In about 10 per cent of his attacks this was followed by the voice as in earlier seizures. The hallucination of music occurred frequently and when present came after the thought or awareness and the voice would be absent. The visual hallucination no longer occurred in his attacks. Electrographic studies indicated a left anterior temporal epileptogenic focus and at operation a cerebral cicatrix with yellowing and gliosis was found in the anterior portion of the temporal lobe. Stimulation at point 11 produced the following responses:

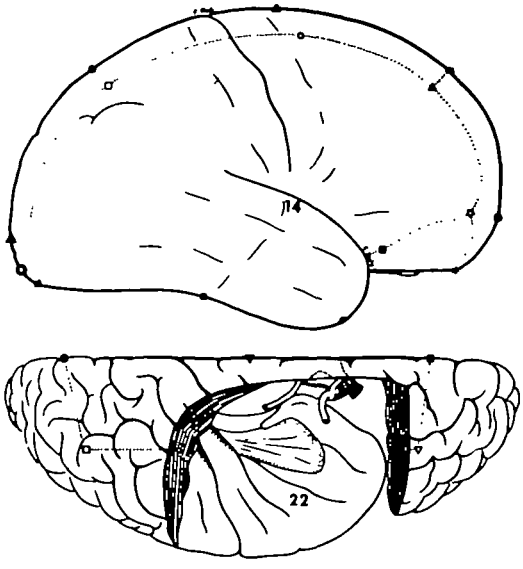


CASE 7.—S. H.

11. "Oh, I hear voices." Patient was warned and then not stimulated, he said, "Nothing."
11. Repeated. Patient said, "I hear a humming."
11. Repeated five minutes later. He exclaimed, "I hear voices." Stimulation was stopped and he explained, "They sounded like a bunch of women talking together, just a lot of women chattering."
11. Repeated five minutes later, but stimulus parameters were changed from 2 volts, 2 msec. square wave, 60/sec. as usually employed to 2·5 volts, 2 msec. square wave at 40/sec. He said, "Again I hear voices, I sort of lost touch with reality."
11. Repeated, frequency 20/sec. "Humming in my ears and a small feeling like a warning."
11. Repeated, frequency 20/sec. Patient said, "Voices, the same as before. I was just losing touch with reality again." When asked, he replied that he could not understand what the voices were saying, they sounded "hazy."
11. Repeated, frequency 100/sec. He said, "Humming in my ears."
11. Repeated, frequency 100/sec., patient counting. Counting was not interrupted. He heard nothing.
11. Repeated, frequency 20/sec., patient counting. There was no interference with speech and again he heard nothing.

Although this site of stimulation was near the posterior temporal and parietal speech zone, the lack of interference with counting during stimulation clearly indicates that it was anterior to speech cortex. Observations on changing the stimulus parameters will be discussed in Section 7, a summary of operative and clinical data.

Case 8.—R. L. This 26-year-old housewife began to have recurring seizures at age 24. At about age 18 months she had had two generalized convulsions at the time of an injection for pertussis. The pattern of her attacks was: (1) interpretive illusion—visual and auditory (objects seemed to come closer to her and things heard sounded louder and nearer); (2) turning of head to left; (3) momentary loss of consciousness; (4) occasional nocturnal generalized seizures. The right temporal region was exposed at operation and abnormality of the cortex found in its medial and inferior surfaces. Stimulation produced the following responses.



CASE 8.—R. L.

14. The electrode was applied and kept in position. Patient sighed. When asked what she noticed, she said there seemed to be a voice a way, way off. "It sounded like a voice saying words, but it was so faint I couldn't get it."

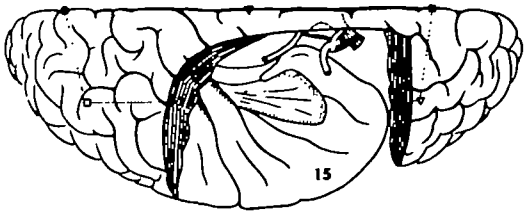
14. Repeated without warning and continued about 15 seconds. After withdrawal of the electrode, patient was asked whether she noticed anything and she said it sounded like a voice saying, "Jimmy, Jimmy, Jimmy." When asked, she said it was her husband's name and what she calls him.

Seven minutes after the first stimulation above, point 14 was restimulated four times with no result.

22. After the stimulation was over, she said she seemed to hear voices a way off.

Case 9.—E. Le. This 44-year-old woman began to have seizures at age 22 during a pregnancy. The attack pattern was: (1) flushing of face and neck; (2) automatism; (3) occasional generalized seizure. During an automatism she was apt to say, "I am alright." Then she would walk about her room and show marked affection toward anyone who happened to be present.

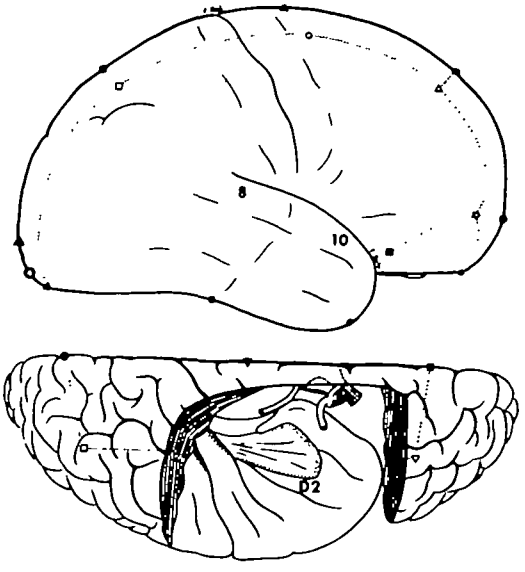
At operation the following response was obtained from the right temporal lobe in which incisural sclerosis was found.



CASE 9.—E. Le.

15. Stimulation at a depth of 1 cm. in the first temporal convolution. In a subdued voice she said, "Oh, a kind of sound in the distance like people singing." When asked what they were singing, she replied, "I don't know. It was like a bunch of old folks in the background, probably some hymns."

Case 10.—R. McA. This 18-year-old right-handed divinity student began to have seizures at age 13. The pattern of his attacks was: (1) epigastric sensation; (2) cephalic sensation; (3) experiential hallucination—auditory; (4) occasional major attacks beginning with initial unconsciousness. He stated that in most of his attacks he would "hear in my mind" the tune of some song that he had often heard when he was a child. He believed that it was a song from a children's program on the radio which he listened to often when 11 or 12 years old. It was orchestral music and there was no vocal accompaniment. A pneumoencephalogram showed generalized atrophy of the left cerebral hemisphere probably dating from birth or early life, and EEG studies revealed a right anterior temporal discharging focus. The right hemisphere was shown to be dominant for speech by the carotid amytal test. At operation the right temporal lobe was exposed and the following responses obtained.



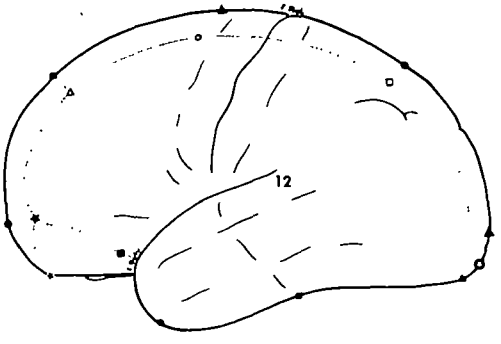
CASE 10.—R. McA.

8. Patient said, "Nothing."
10. He said, "I am not certain, but I seemed to hear the tune."
8. Repeated. The electrode was held in place for five or six seconds. There was a small after-discharge and he did not answer immediately. He then said that he seemed to hear the tune again.
10. Repeated. He very quickly said, "The song again, doctor!" When asked, he said that he could not sing the song. He explained that it was a very modern one and instrumental rather than vocal. It was a song that he had heard before, a popular one on the radio, but he did not know the name of it.

D2 Stimulation in the second temporal convolution at a depth of 1 cm. He exclaimed, "Here comes the song again." And then he added, "With a lot of old memories."

8. Repeated thirty minutes after last stimulation at this point. He stated that he heard the song as in a spell.
8. Repeated one hour later, after excision of the anterior end of the temporal lobe. The patient said, "Nothing."

Case 11.—M. N. A woman, aged 45, had seizures from age 9 months to 4 years; they subsided only to begin again as minor attacks at age 22 and major attacks at age 27. In her minor attacks she had an olfactory sensation and an experiential hallucination. She saw the faces of two women she recognized as former school teachers. They were apt to move towards her and crowd her backward, as though against a wall, and she would cry out in terror, Later, her seizure pattern changed to: (1) bilateral somatic sensation (pins and needles in the buttocks extending down the back of the knees); (2) interpretive illusion—auditory (sounds became much louder); (3) experiential hallucination—visual (she saw faces; a crowd of babies or people); (4) interpretive illusion-fear; (5) automatism. At operation, the left temporal lobe was exposed and the following responses were reported when a single point was stimulated.

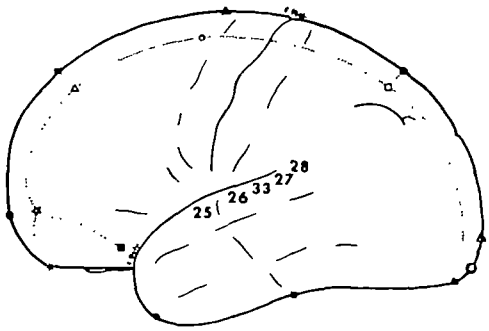


CASE 11.—M. N.

12. The patient said, "Oh yes, there is something." A little later she said, "It is like music in the background."
12. Warning without stimulation. "Nothing."
12. Warning with stimulation. She reported music that she thinks is like an orchestra. Stimulation along the first temporal convolution from before backwards produced nothing until point 12 was reached and then she said, "There, I hear the music." The electrode was kept in place and she was asked to let us know when the music stopped. Very shortly after withdrawing the electrode she said it had stopped. When asked, she said it was either an orchestra or an organ.

12. Re-stimulated 30 minutes after above stimulation. The patient said, "Oh, it is music." There was after-discharge.
12. Repeated 16 minutes after above stimulation. Patient said, "No, nothing." and then, "Oh, no, it is music but it is too far away."

Case 12.—Y. N. This 24-year-old woman began to have seizures at age 20. The pattern was: (1) sensation in her back; (2) experiential hallucination—combined auditory and visual; (3) interpretive illusion—fear; (4) turning to the right, generalized seizure. In describing her attacks, she said she heard "voices." She explained that it was just one man's voice and he was behind her. She usually could not understand the words, but once he said, "Bend down Y–, Bend down Y–," and on another occasion he said, "Alfred, Alfred, Alfred." This was the name of a young man who used to board with her mother but in whom she was apparently not interested. She was very much frightened when she heard this voice. On a few occasions she saw a little white cross moving in front of her. She also saw one eyeball moving across in front of her. The last time she saw this it was of three colours and, "Abnormal." At operation a large arteriovenous angioma was found in the left parietal region. Stimulation produced the following responses.

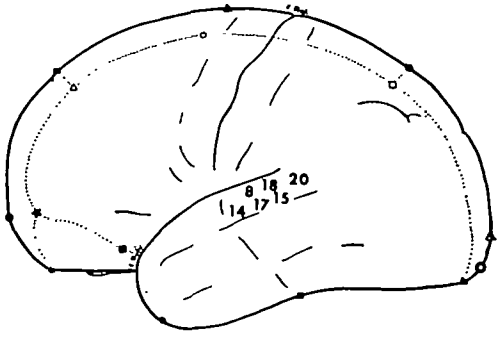


CASE 12.—Y. N.

26. "I could hear someone talking, murmuring or something."
25. "There was talking or murmuring, but I cannot understand it." Apparently this resembled the voices she heard before her attacks.
27. Silence, then a loud cry. "I heard the voices and then I screamed. I had a feeling all over."
28. "I hear something." She did not see anything. The electrode was kept in place. When asked what she heard, she said, "A buzzing-like." Then she added, "A man buzzing or murmuring." When asked where he was she said, "In the back."
27. Repeated thirteen minutes after last stimulation at this point. After a time the patient said that she was trying to hear what someone was saying, but she could not make it out. She said it was one man doing the talking.
33. She began to sob, "That man's voice again! The only thing I know is that my father frightens me a lot."

Case 13.—A. P. Male, age 19, with onset of seizures age 13. His birth was difficult. His seizure pattern was: (1) initial automatism or cephalic sensation and desire to stare; (2) automatism (sniffing, followed by lip smacking). On examination, there was

a right lower quadrantic homonymous visual field defect. At operation the left temporal region was exposed and the following responses obtained.



CASE 13.—A. P.

8. "Some crazy things ran through my mind; I was younger, at school. I was playing with a polo bat." When asked, he said he remembers doing this when going to school at about the age of 10.

14. Patient was asked to name some objects to test speech during the stimulation. He named several correctly. All of a sudden he said, "I hear someone talking." When asked, he said he did not know who it was. He said, "I think it was about a restaurant or something." When asked, he said it was a man or boy, but he did not know exactly what was said.

14. Repeated again, without warning after above. The surgeon said, "See if it comes again." Immediately upon application of the electrode, he said, "Yes, get out." It was a man's voice in a pool room, telling A. P. to get out. When asked, he said, "I have been in a pool room before; it might be that same one or it might not."

Six weeks after the operation, in the clinic, A. P. was asked about this. He said that he remembered the incident clearly; it had happened about three years previously. He got angry after missing a shot at the pool table and broke his cue. The manager attempted to throw him out and a fight ensued. This incident made quite an impression on him.

14. Repeated, without warning after above. "Now there are four voices. They are all jumbled up. I thought I got one word, but it has slipped."

8. Repeated nineteen minutes after previous stimulation at this point. "I hear voices again, but I cannot tell what they are saying."

8. Repeated without warning after above. Electrode kept in place. He said, "Tokyo." Electrode kept in place for some time. Patient said, "There are voices but I cannot get what they are saying—Tokike." He repeated the word, "Tokike." When asked how to spell it, he said, "I do not know—t-o-k-i or something like that."

15. Patient said, "It is coming again. They are saying something, but I cannot make it out."

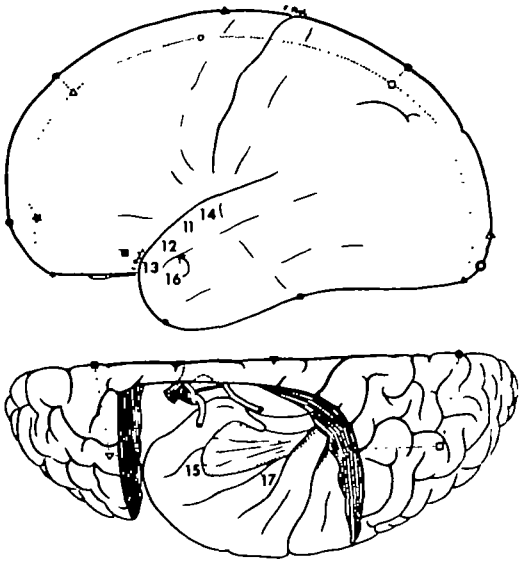
17. "Yes, it is coming again. It is water. It sounds like a toilet flushing or a dog barking." When asked where this was, he said he did not know. When asked, he said that "the toilet flushed first and then the dog started to bark."

18. "In my ears there seems to be music." When asked what tune, while the electrode was still on, he said, "I don't know, but your voice sounds as if it is in the distance."

18. Repeated after above. "Yes, music again." When asked if it was an orchestra or someone singing, he said, "It is a girl or a woman singing, but I am still unable to get the tune. It came from either a record player or a radio."

20. Patient said, "Shoulder, shoulder, is echoing." He seemed to have slight difficulty in speech. He then said, "Stay still. Someone is telling me to stay still." After withdrawal of the electrode, he said he had an electric sensation from the finger tips to the shoulder on the right. After this sensation someone was telling him to stay still. "My eyes started staring and then someone kept repeating 'stay still'." When asked, he said he did not know who it was, but it might have been a doctor.

Case 14.—R. Re. This 46-year-old man from South Africa began to have seizures one year before his operation. Nine years before this he had a severe bout of meningitis which lasted three months. His attack pattern was as follows: (1) at first there was some subtle change in his thinking or stream of thought; (2) he was then aware that he was making a mumbling sound and salivating; (3) he felt the corner of his mouth pull to the right; (4) he then lost consciousness and usually behaved in an automatic manner for some minutes. The following responses of an experiential nature were obtained during stimulation before left temporal lobectomy.



CASE 14.—R. R.

11. "Yes, something that someone has said." After a pause, "Not here, in Johannesburg."

11. Repeated without warning. "Yes," he spoke instantly when the electrode touched the cortex, "The same idea." He said it was a voice, but he could not remember; it was very hazy.

12. Patient heard a voice, again could not remember.

13. "Yes, something that was said, also something that was said in Johannesburg, and it was said by somebody that had been put out."

14. Stimulation just posterior to 11. "Yes, I was hearing at Johannesburg, it came and went very clearly."

14. Repeated without warning. "Yes, that same sort of sensation, somebody was speaking to me in Johannesburg." Patient said it is not the same voice each time.

11. Repeated. "Yes, very vaguely, what you said took me back to what somebody said in Johannesburg."

11. Repeated: "It is heard alright, but very faint."

15. Electrode inserted to a depth of 2 cm. "Yes, it reminds me of a song." Patient repeated the surgeon's words saying, "What do you hear?" He said afterwards that the song seemed to continue from the surgeon's words.

15. Repeated. Patient chuckled a little and said, "Yes, when did you notice that also goes into a song?" Warning without stimulation. "Nothing."

16. Electrode inserted to a depth of 1 cm. Patient said, "Yes." But then said "It was said and I know what was said, but I cannot put it into words."

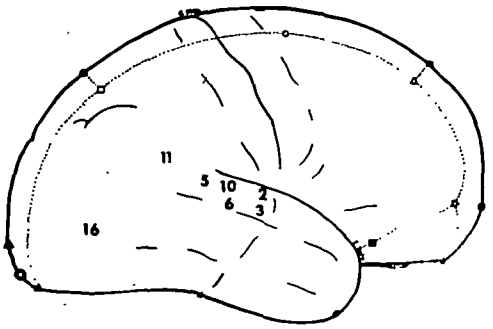
17. Stimulation at a depth of 4 cm. in the first temporal convolution. Patient said, "Yes." And referring to the anæsthetist, the patient said he seemed just like a woman and, "I almost spiritually spoke to that woman."

17. Repeated. "I recall looking up my doctor in Johannesburg and telling him of my sensations." When asked whether he seemed to be with him, he said, "Yes." And added, "Like I was telling the doctor the sensation I had when I got the disease from water." The patient explained that it was a memory going back to the time when he spoke to the doctor.

Case 15.—J. V. This 14-year-old girl began to have seizures at age 11. Before this, at age 7, she had had an experience that frightened her and caused her to have subsequent dreams about it. She was walking home from school through a field with her brothers shortly in front of her when a man carrying a sack approached her from behind and asked her how she would like to get into his bag with the snakes and be carried away. She was terribly afraid and screamed to her brothers who told her to run. They all ran home together.

The pattern of her attacks was as follows: (1) experiential hallucination—visual type; (2) interpretive illusion—fear; (3) automatism. The hallucination consisted of seeing herself as a little girl of 7 years walking through a field of grass. Suddenly she felt as though someone from behind was going to smother her or hit her on the head and she became terrified. The scene was almost always exactly the same in each attack.

At operation the right hemisphere was exposed and a meningo-cerebral cicatrix was found involving the temporal lobe. Stimulation produced the following responses.



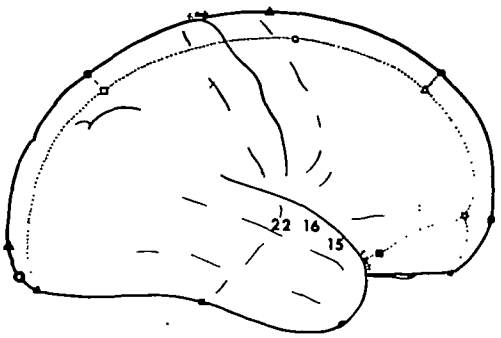
CASE 15.—J. V.

2. When the electrode was applied she said, "I imagine I hear a lot of people shouting at me." This was repeated, the stimulus being applied for two seconds, and she heard the voices for seven seconds. It was repeated a third time and she said, "I hear them again." The duration of voices with the third stimulation was 14 seconds.
3. "Oh, everybody is shouting at me again, make them stop!" The stimulus duration was two seconds; the voices lasted 11 seconds. She explained, "They are yelling at me for doing something wrong, everybody is yelling."
5. "Everybody is yelling at me again."
6. "Voices, yelling at me."
3. Repeated five minutes after above stimulation at this point. "Everybody is yelling again. It is mostly my family. I can hear my mother and brothers."
10. "Oh, there it goes, everybody is yelling. Something dreadful is going to happen."
10. Repeated. No result.
5. Repeated ten minutes after previous stimulation at this point. "There it goes, everyone yelling."
11. "There they go, yelling at me, stop them!" The voices lasted 21 seconds.
16. "I was holding on to a bar, and the bar seemed as though it was walking away from me. I saw someone coming toward me as though he were going to hit me." When stimulation was repeated at this point the patient reported only a visual sensation of "everything moving" and her eyes were noted to stare to the left. This may represent a visual interpretive illusion.

Stimulation of the first temporal convolution produced auditory experiential responses of people shouting over a wide area as the electrode was moved posteriorly. The content of the responses was almost the same in each case. When the experiential response at point 16 occurred, in a distant area near the visual cortex, the response was no longer auditory but visual. The content was also unrelated to the previous first temporal stimulations although the emotional tone was the same.

Case 16.—D. W. This 27-year-old man began to have seizures at age 25. The pattern of his attacks was: (1) epigastric sensation; (2) experiential hallucination—auditory; (3) olfactory sensation; (4) automatism, rare generalized seizure. After the sensation in his stomach he heard a phrase being repeated over and over again, and this

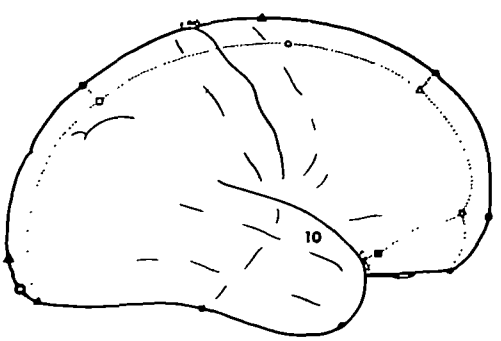
was usually composed of words he had heard recently, or it was the last thing someone had said to him just before the beginning of an attack. The words were different in each attack but repeated monotonously in the same tone and they seemed to get closer and closer and faster and faster. He never felt that some person was saying the words or that they were coming from a radio; they seemed to be within himself. He was not able to remember the words after an attack. A tumour was suspected in the right temporal lobe but was not found at operation. The following responses were produced by stimulation.



CASE 16.—D. W.

15. Patient exclaimed. He said he heard something—a voice.
15. Repeated without warning. The patient said he heard the operator's voice, but that the key was changing.
16. He exclaimed, and then said, "All that you said at the end seemed to be mixed up." The surgeon had not spoken during this stimulation.
22. He said, "Oh, your voice is changing." However, there was no talking during the stimulation. He explained that this resembled an attack.

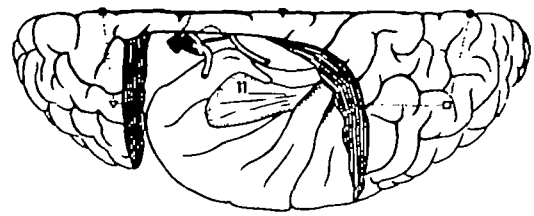
Case 17.—M. Wh. This 28-year-old woman began to have seizures at age 14. At age 6 months she had a transient left hemiparesis presumably due to a birth injury. The pattern of her attacks was: (1) body sensation (perineal); (2) epigastric sensation; (3) automatism. At operation the right temporal lobe was exposed and abnormality of the incisural sclerosis type found.



CASE 17.—M. Wh.

Stimulation at point 10 caused her to say, "I don't feel good." She then became unresponsive and there were swallowing movements and smacking of the lips which lasted about one minute. Upon regaining consciousness she volunteered that when the stimulation began she heard music, but she was unable to elaborate on this.

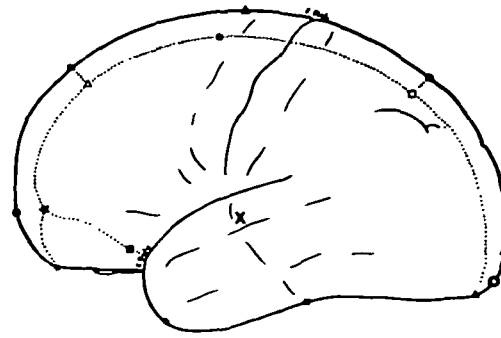
Case 18.—G. B. This 16-year-old girl had a difficult birth and onset of seizures at age 3. The seizure pattern was: (1) dizziness; (2) staring and confusion; (3) chewing movements, raising of right arm; (4) major generalized seizure with turning to right. At operation the following responses were obtained from the left temporal lobe.



CASE 18.—G. B.

11. Stimulation at a depth of 3 cm. "I am seeing a picture of a dog and cat." When asked what they were doing, she said, "The dog is chasing the cat." She said that they were running in the driveway at home and she remembered seeing them doing this before.
11. Repeated two minutes after above, without warning. She said, "Another picture, it is a fire in a forest." When asked by Dr. Millar if she had ever seen this before, she did not recall having seen it in the movies or elsewhere.

Case 19.—E. C. This 20-year-old Canadian army veteran had his first seizure at age 17. There was a *psychical precipitation* in his early attacks. Each of these attacks began after he had seen someone grab something from another person, and this would immediately produce a vivid recollection of an occasion when he was 13 years old. At this time he was playing with a dog, grabbing a stick from its mouth and throwing it; the dog chased the stick and brought it back. He would associate the two events, become confused, and have a seizure. Later his attacks consisted of: (1) an interpretive illusion—fear; (2) mental confusion; (3) automatism. At operation an epidermoid tumour was found just anterior to the left temporal lobe. Stimulation produced the following responses.



CASE 19.—E. C.

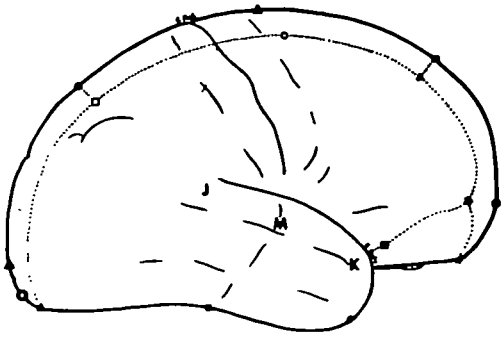
X. When stimulation was carried out, the patient was naming pictures of objects that were being presented to him in order to outline speech representation. He named one object after stimulation had been started at X., then he said suddenly, "There he is!" When questioned, he said, "It was like a spell. He was doing that thing; grabbing something from somebody. It was somebody else doing the grabbing." When asked what he was grabbing, he replied, "A stick, or something." When asked where he was, he said, "Up the street." Then he added, "That was like an attack, doing that thing."

X. Repeated ten minutes later, without warning. The patient spoke in an incoherent manner. He said, "There it is." The stimulating electrode was kept in place for a little time and this resulted in a major seizure.

Case 20.—C. Ft. This patient was an intelligent minister of the gospel, 27 years old, whose seizures began at age 26. The pattern of his attacks was: (1) experiential hallucination—unclassified; (2) generalized seizure.

The attacks were nocturnal, occurring about once in six weeks and associated with a series of dreams. On each occasion he had the same identical dream on each of four to six successive nights. This is to say, the dream was identical in each series but its nature might vary somewhat from series to series. For example, he gave the following description: he awakened one night during or after a dream in which he found himself in a room, perhaps in his own house. He went to the door. When he opened the door he felt that there was a familiarity about the dream, and he wanted to see more. He became aware then that this was the type of dream that was apt to lead to a seizure. It may be said that at this point he wakened to partial consciousness. He was not quite sure what he was doing in the dream. On the second night he had the same dream, and went a little further with it, perhaps saw more of the room. Following the dream on the second or third night he had a major seizure. On the third, fourth and fifth nights, he had the same dream without convulsion, and then found himself sitting up in bed at the close of the dream, "trying to throw it off." Several times when he walked into that room during the day it brought back a "little of the feeling of the dream."

The right temporal lobe was exposed at operation and an infiltrating glioma was found. The following responses were produced by stimulation.



CASE 20.—C. Ft.

J. The patient said, "A familiar sight danced into my mind and away again."

J. Repeated without warning. "Three or four things danced before my memory."

K. Twice he was told he was being stimulated, but no stimulus was applied. Each time he responded "No." The third time, and with the same warning, point K was stimulated. He said, "Yes, they went so fast I couldn't quite remember who they were. I saw three of them, but they were not before my eyes."

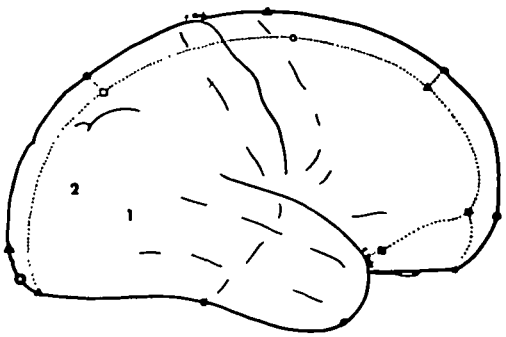
K. Repeated. He said, "The same sensation as before."

K. Repeated. He said he saw something again.

M. Patient said, "Very faint dream came back."

K. Repeated five minutes after last stimulation at this point He said, "No." Then "Yes, Yes, I think I saw the same scene before."

Case 21.—A. H. This 25-year-old man began to have seizures at age 16. At the age of four he had suffered a right parietal skull fracture. This had required operative decompression and some bone fragments were removed. The pattern of his attacks was: (1) mental confusion; (2) raising of extended right arm with turning of the body to the left; (3) a generalized seizure. At operation the right parieto-temporal region was exposed and a meningo-cerebral cicatrix found. Stimulation produced the following responses.



CASE 21.—A. H.

1. Patient said, "Just a minute. Like a figure, on the left side. Seems like a man or a woman. I think it was a woman. She seemed to have nothing on. She seemed to be pulling or running after a wagon."

1. Stimulation repeated without warning. Patient exclaimed, "Same damn thing! Same principal, but not so clear as last time."

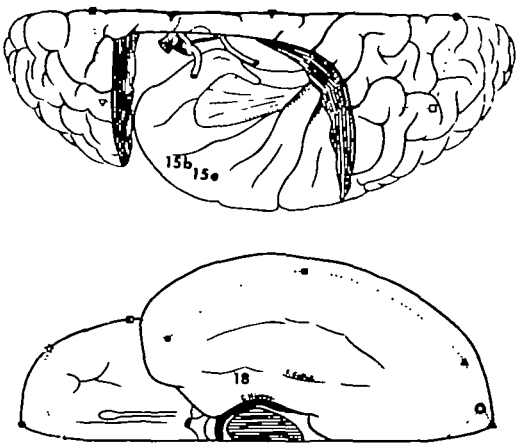
2. "I wish I could describe this. A section of steps with people trying to rise up."

2. Stimulated again without warning one minute later. "This is the funny feeling I get. I thought I saw a person. I think it was a man."

1. Repeated. Patient had a weak feeling but did not see anything.

Case 22.—G. Le. This 29-year-old woman began to have seizures at age 20. Her attack pattern was as follows: (1) experiential hallucination—an unreal sensation, usually a vivid and apparently very familiar dream that she is unable to remember

afterwards, primarily visual; (2) automatism. The left temporal lobe was exposed at operation and these responses elicited.



CASE 22.—G. L.

15b. Stimulation at a depth of 2 cm. She reported, "Something coming to me from somewhere. A dream." When asked whether it was like an attack, she said, "Yes."

15b. Repeated, four minutes later, without warning. Dr. Roberts, who was sitting beneath the protective drapes with the patient, spoke to her and made gestures with his hand during the stimulation and she did not reply. After cessation of stimulation, she was silent for a time (there was a small electrographic seizure). When asked if she noticed what Dr. Roberts did, she replied, "I don't know what he did, I was trying to see what they were doing. The scenery seemed to be different from the one just before. I think there were people there, but I could not swear to it. That is what I call an attack." When asked again about the gestures Dr. Roberts had made, she said, "Yes, I saw his hand. I see the people in this world and in that world too, at the same time."

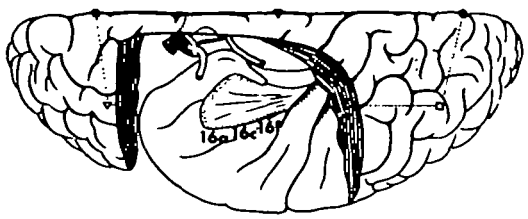
15e. Stimulation at a depth of 1½ cm. She said, "Wait a minute, something flashed over me, something I dreamt."

18. Stimulation just posterior to the uncus, after removal of the anterior part of the temporal lobe, in the vicinity of the cut uncus. She said, "I keep having dreams."

18. Repeated. "I keep seeing things—I keep dreaming of things."

Case 23.—R. M. This 31-year-old male stenographer had had seizures since the age of 6. The pattern was: (1) autonomic-visceral motor (scrotal movement); (2) experiential hallucination—unclassified; (3) automatism. The patient was unable to describe any specific experiential hallucination before operation, but during the operation hallucinations were produced which he said were like the beginning of an ordinary attack. Before operation he was only able to say that, "A thought comes into my

mind." Incisural sclerosis abnormality was found in the left temporal lobe at operation, and the following responses occurred with stimulation.



CASE 23.—R. M.

16c. Stimulation at a depth of 3 cm. The patient talked during stimulation. He said, "It was like a guy coming through the fence at the baseball game. I can see the whole thing." When asked if he had seen someone do that, he said, "Yes, I think so." When asked if he remembered the incident, he said, "I just happened to watch these two teams play when the fellow came through the fence. That would be like the beginning of an attack, anything might come up."

16a. He said, "I gather, I gather. I was so scared, if I can have that feeling again I could tell you what it was." When asked if that was the feeling of an atack, he said, "Yes." He explained, "It is in my thoughts."

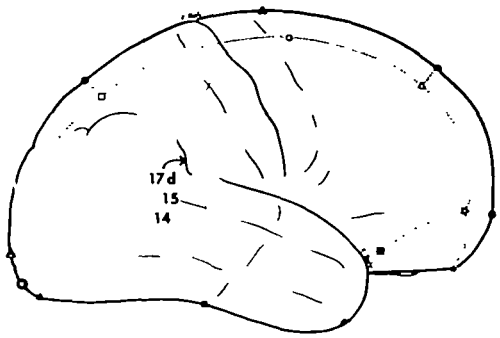
16a. Repeated thirteen minutes later. Patient was silent, then just before the cessation of the stimulus, he began to speak. He said, "That is just like the beginning of a spell." And, "I am going to die." Dr. Feindel, who was sitting where the patient could see him, asked him if he saw anything, and he said, "No, God said I am going to die." When asked, he said, "That is the beginning of a spell—that is why I do not remember it because they are so strange." He said, referring back to the first hallucination, that he was not in the habit of thinking about baseball much—"I do not go in for it."

16c. Repeated twenty-four minutes after previous stimulation at this point without warning. The patient observed spontaneously, "I feel the beginning of a spell." There was trembling of his legs so that the table shook a little. On questioning, he told Dr. Feindel, "I saw a man coming toward me." He could not remember who the man was and he was not sure what he was going to do, but he felt he was going to get scared, and then it faded.

16f. "Oh, it was like an attack, there was someone smoking tobacco, but I do not know who it was." When asked whether he heard or saw the man, he said he could not hear anything.

Case 24.—G. P. This 34-year-old French Canadian had his first seizure at age 30, two years after he had suffered a right parietal brain wound from a mortar fragment. The pattern of his attacks was as follows: (1) experiential hallucination—auditory type (2) dizziness; (3) visual sensation; (4) loss of consciousness with a generalized seizure. At the onset of an attack he would hear music that he referred to his left ear. There was a voice singing but he could not recognize any words or identify the tune. At

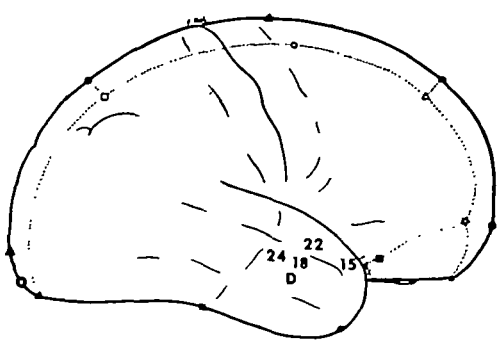
operation a cerebral cicatrix was found in the right parietal and posterior temporal regions. Stimulation produced the following responses:



CASE 24.—G. P.

14. When the electrode was applied, the patient said, "Wait a minute, I see someone." When asked, he said it was a man running.
15. He exclaimed, "Oui, là, là, là. It was he, he came, that fool."
17d. Patient said, "There, there, j'entend. It is just that somebody wanted to speak to me and he was going vite, vite, vite."

Case 25.—H. P. This 15-year-old girl had a severe bout of pneumonia with delirium at age 7. Her seizures began at age 11 and had this pattern: (1) experiential hallucination—visual; (2) head turning to left, generalized seizure. She described this experience as occurring in many of her attacks; she would seem to be in a park but she did not know where it was. Once or twice she had seen a boy, and once, when a little girl, she had become frightened and said, "There is that man again," as though she had had only the beginning of an attack. The circumstances in these experiences were always the same and they seemed familiar to her. At operation the right temporal region was explored and a cerebral cicatrix found involving its undersurface. Stimulation produced the following responses.

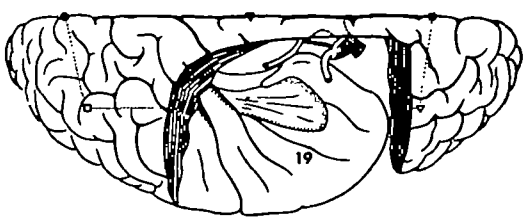


CASE 25.—H. P.

15. She said she felt as though she might have had an attack. When asked what she meant, she said, "I had that dream, but it passed over."
15. Repeated. No response.

18. Patient said, "I am getting dizzy." When asked if it was like an attack, she said, "I think it was."
18. Repeated. "I am seeing somebody." When asked if it was the same sort of thing she sees in the dream, she said, "Yes."
18. Repeated without warning. After a few seconds, she said, "It is coming again." When asked if she saw somebody, she said, "Sure, a boy." She did not know where he was.
22. Stimulation was continued for something less than a minute. Patient said she felt dizzy. "A dream is starting. There are a lot of people." When asked if they were speaking, she said she did not know. When asked where they were, she said, "In the living room. I think one of them is my mother."
24. She said, "I felt that feeling again. Someone is in the room."
D. "I feel dizzy. That thing is here again. I don't know what it is."

Case 26.—M. Ri. This 29-year-old housewife began to have seizures at age 7. One year before her first attack she was tossed by a cow and suffered a right temporal skull fracture. The pattern of her attacks was: (1) cephalic sensation; (2) interpretive illusion; (3) experiential hallucination—visual; (4) automatism. In her attacks she would see a "picture" before her eyes composed of scenes, frequently the same, but sometimes different, most of which she could recognize. Her husband was a butcher and they had come to Canada from Holland. Once she had received a photograph of her brother's tombstone in Holland and in a subsequent attack she saw, "Rows of gravestones in a field." In other attacks she saw, "Rows and rows of butchered sheep hanging," also "Fields of tulips and numerous houses being erected, all surrounded by strong wire fences." Again, "A large white rabbit," or "A sumptuous banquet table, all set," or "Many lines of miniature trains." At operation changes probably due to birth injury rather than trauma were found in the right temporal lobe. Stimulation at point 19 produced the following responses.

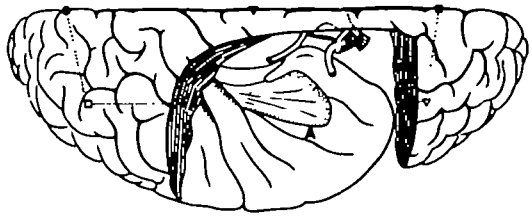


CASE 26.—M. Ri.

19. She said she saw something, but that it did not last long enough to describe.
19. Repeated five minutes later. She said, "I see a hospital bed with the covers off and turned down.
19. Stimulation without warning. She said, "It is coming." When asked if she felt something or saw something, she said, "I feel it and see it both." She then had one of her usual attacks during which she saw a fireplace. When asked, she said she did not recognize the scene.

Case 27.—R. S. This 21-year-old man began to have frequent major and minor seizures at age 12. Pattern: (1) cephalic sensation or visual sensation; (2) turning of

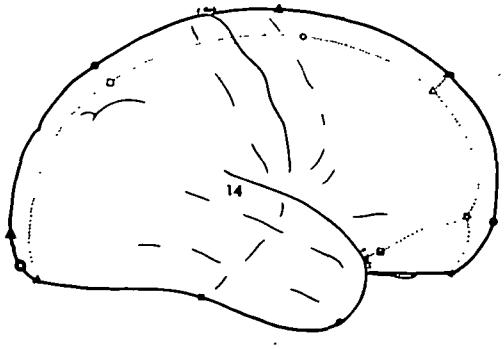
head and eyes ro the right; (3) brief automatism or generalized seizure. The following responses were obtained when the right temporal lobe was stimulated.



CASE 27.—R. S.

A. Patient said, "A peculiar feeling."
A. Repeated. He said, "Yes, like I was seeing somebody at home." He added that it was probably his mother.

Case 28.—E. B. This 12-year-old girl began to have recurring seizures at age five with this pattern: (1) interpretive illusion—feelings of fear and strangeness and objects would seem to move toward her; (2) loss of consciousness with occasional generalized seizure. The right temporal region was exposed at operation and no gross abnormality noted. Stimulation at point 14 on the first temporal convolution caused the patient to exclaim, "Somebody is speaking on the telephone."



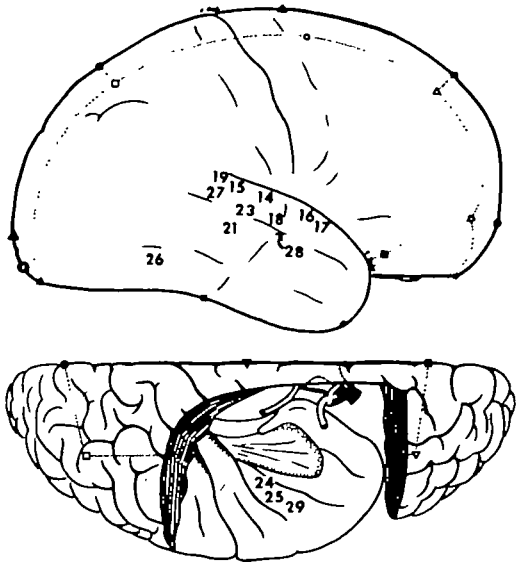
CASE 28.—E. B.

Case 29.—S. Be. This 25-year-old French Canadian began to have seizures at age 19. At first the pattern of his attacks was: (1) vertigo, (2) experiential hallucination—auditory. Later the attacks changed their character and consisted in: (1) thoracic sensation; (2) loss of consciousness and a generalized seizure. In his early attacks he would hear a voice calling, "Sylvère, Sylvère, Sylvère," which was his own first name.

Some of his attacks were apparently precipitated by a mental process. We have encountered this occasionally and called it *psychical precipitation* (cf. E. C., Case 19). He volunteered the information that an attack might be brought on when he sought to recall the name of a person, or to reflect whether or not he had seen a thing before.

At operation the right temporal lobe was exposed and an arteriovenous anastomosis was found in the fissure of Sylvius. Toughness and discoloration was present in the

superior-medial cortex covering the first temporal convolution, uncus and amygdala. The following responses were obtained upon stimulation.



CASE 29.—S. Be.

14. "Just like someone whispering, or something, in my left ear. It sounded something like a crowd." Warning was then given but no stimulation. He reported, "Nothing."
15. "Again someone trying to speak to me, a single person." When asked, he added, "Oh, a man's voice, I could not understand what he said."
16. While the electrode was held in place the patient said, "Something brings back a memory, I could see Seven-Up Bottling Company—Harrison Bakery." Warning was given again, but no stimulus applied. He was not fooled and replied, "Nothing."
17. While the electrode was held in place he replied, "Again something I have heard of but I cannot remember it." On questioning he added that it was a word but he could not remember what word.
18. Stimulus was applied without warning the patient. He said he was a little drowsy, then, "Someone was there in front of me right where the nurse is sitting."
19. During stimulation he said, "I am trying to find the name of a song." The electrode was removed. "There was a piano there and someone was playing. I could hear the song, you know. It is a song I have sung before but I cannot find out quite what the title of the song is. That was what I was trying to do when you finished stimulating!"
19. Repeated without warning. After withdrawal of the electrode, he said, "Someone was speaking to another and he mentioned a name but I could not understand it." When asked whether he saw the person, he replied, "It was just like a *dream*." When asked if the person was there he said, "Yes, sir, about where the nurse with the eyeglasses is sitting over there."

19. Repeated again without warning the patient, and without questioning him. "Yes, 'Oh Marie, Oh Marie'—someone is singing it." He was then asked who it was and he replied, "I don't know, Doctor, I cannot recognize the voice."

19. Repeated again without warning. He observed, while the electrode was being held in place, "Again, 'Oh Marie, Oh Marie.'" He explained that he had heard this before. "It is a theme song," he said, "on a radio program. The program is called the 'Life of Luigi,'" The patient then discussed the identity of the song with Dr. Sears and he ended by singing the well-known refrain, "Oh Marie, Oh Marie." All in the operating room recognized the song.

21. "Someone telling me in my left (contralateral) ear, 'Sylvère, Sylvère!' It could have been the voice of my brother."

21. Repeated without warning. When asked after the stimulation, he said, "I cannot make it out."

23. During stimulation he said, "It is a woman calling something, but I cannot make out the name."

19. Repeated eight minutes after first stimulation at this point. Patient said, "Nothing." This stimulation was preceded by stimulation just below this same point and he heard the singing.

24. Stimulation at a depth of 1·5 cm. "Somebody talking. I cannot make out who it was."

25. Stimulation at a depth of 1 cm. Patient said, "Buzzing sound." When asked if there was anything else, he said, "A man talking." (Auditory sensation and experiential response.)

26. Stimulation without warning. "There is someone near my left eye, but I cannot make it out."

26. Repeated without warning. "Oh, my left eye! I see someone." Then he explained that there were men and women. "They seemed to be sitting down and listening to someone. But I do not see who that someone might be."

27. During stimulation without warning he said, "Yes, there was something." He said he saw it; it was an object. The operator noted that each of these visual experiences seemed to disappear before the end of stimulation.

28. Stimulation at a depth of 1 cm. "A buzzing." Then the electrode was withdrawn slowly and he exclaimed, "Someone is calling." He could not understand the words. (Here the electrode was in the anterior transverse temporal gyrus of Heschl and upon withdrawal the adjacent first temporal gyrus was stimulated).

21. Repeated thirty minutes after last stimulation at this point. "Nothing."

29. "I don't know—I see someone in front of me."

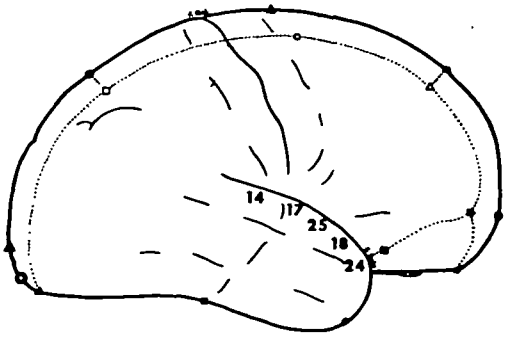
29. Repeated without warning. "I hear someone talking."

19. This point where the song had been produced earlier was restimulated several times near the end of the exploration but nothing was evoked.

Case 30.—A. Br. This 28-year-old woman had her first seizure at age 18. The pattern of her attacks was: (1) mental confusion or change in her thinking; (2) automat-

ism; (3) abdominal borborygmi at the end of the seizure. She had difficulty explaining the change in her thoughts at the onset of an attack. She felt that her thoughts were "going through a washing machine or wringer" or as if she were in another world. She also said she felt terrified.

At operation focal atrophy was found in the undersurface of the tip of the right temporal lobe. This was probably due to a febrile thrombophlebitis of cerebral veins at the time of a severe illness when one year of age. Stimulation produced the following responses.



CASE 30.—A. Br.

14. She said "Sounded like I was singing a song."

14. Repeated "Nothing."

17. "I seemed to hear a song, sort of familiar, like on the radio."

18. "Yes, I felt just terrified for an instant." Stimulation was continued. She was asked if she still felt terrified and she said, "No." She explained that it was the kind of terror she has with her attacks.

14. Repeated 23 minutes after last stimulation at this point, while the operator counted. Patient said it sounded like there was singing.

24. Patient said, "No." Then she said, "It reminded me of a song, but I do not know what song it was."

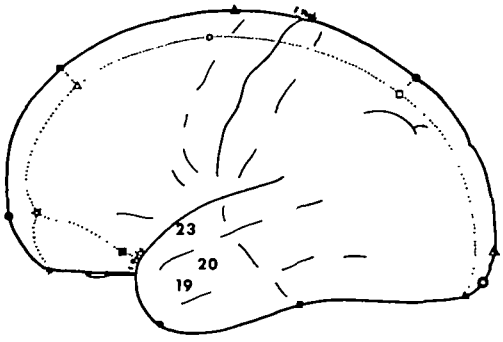
18. Repeated twenty minutes after the previous stimulation at this point. Patient said it made her try to imagine a familiar song. It was not that she heard the music.

24. Repeated two minutes after last stimulation at this point. Patient said immediately, "Right then." When asked what she meant, she said it reminded her of a song. She could not recall what the song was.

25. Reminded her of a song.

Case 31.—N. C. This 23-year-old woman had a series of convulsions at age 2 following an injection of anti-pertussis serum. Following this bout of seizures she developed a right hemiparesis which gradually cleared in a month. Recurring seizures began at age four with the following pattern: (1) abdominal sensation; (2) automatism; (3) tonic posturing of the right arm and leg. At operation focal atrophy

was found in the left first temporal convolution extending medially into the hippocampus. The following responses were obtained with stimulation.



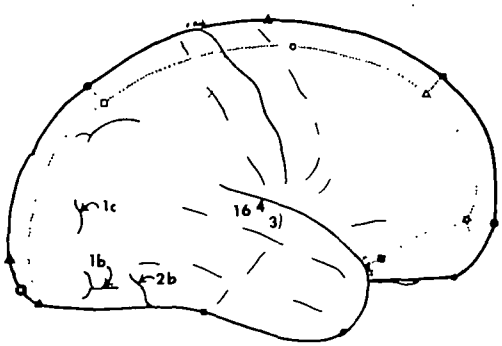
CASE 31.—N. C.

19. "I had a dream. I had a book under my arm and I was talking to a man. The man was trying to reassure me not to worry about the book." When asked, she said she did not know what the book was or who the man was.
20. Patient said, "I feel like I have a sick spell." Stimulus was withdrawn. She then added that, "Mother is talking to me."
20. Repeated ten minutes later. Patient laughed. When asked what had happened, while stimulation was still going on, she said, "Well, it is kind of a long story but I will tell you." Stimulus was withdrawn. She went on to explain a rather complicated situation, and then said she told her mother, "Don't forget the fabulous feeling." When asked if that was something she had said to her mother, she said her mother mocked her. When asked whether it was a dream or something she remembered, she exclaimed, "No." Then she said, "I took my arm and brought it down on the plate and broke the plate all to pieces." When asked where it was, she said in her home in Richland, Washington.
20. Repeated without warning. She said, "Yes, another experience, a different experience." Then she added, "A true experience. This man, Mr. Meerburger, he, oh well, he drinks. Twice his boy has run away. I went to the store once for an ice cream cone and I saw that he was back, and I said 'Hmm, he is back,' and the lady asked me 'What is the matter,' and I didn't know how to explain so I said, 'Well you know Mr. Meerburger drinks.' I thought that was the easiest way but later mother told me, no, and it made it a lot worse."
19. Repeated without warning, twenty minutes after the previous stimulation at this point. When asked afterward if she had noticed anything, she said, "I noticed I was having a dream, but I do not know what it was, it was crazy."
19. Stimulation near point 19. "Another dream, crazy."
20. Repeated seven minutes after previous stimulation at this point. "Nothing."
23. "It made me think of a baby song, I cannot think of the words."
23. Repeated. "I had a little pain in my head. I again thought of the song." When asked what song, she said, "That baby song—the War March of the Priests."
23. Repeated without warning. After withdrawal, the operator said, "You don't notice anything do you?" She replied, "Yes, I was trying to identify the song." When asked if she would like the stimulation repeated, she said, "Yes." Stimulus was applied and after a time she began to hum, and she hummed an air quite accurately. Then she said, "It is the War March of the Priests."

23. Repeated. Patient was asked if she heard the air and she said she heard another one which sounded very much like "War March of the Preiests." She added that it was not a baby song after all. She thought the first song she heard was a baby song.
23. As a final test the patient was asked to let the operator know when she heard the song. After some delay, point 23 was stimulated. As the electrode was applied, she said, "There." When asked what it was, she said all she could think of was the War March of the Priests. She said she had the Hallelujah Chorus on a record at home and that this was on the other side of it.

    When asked what it was she heard she said it was just an arrangement of the orchestra and no voice. She was only able to hum it part way, and she added that she did not know the words.

Case 32.—G. E. This 22-year-old woman began to have seizures two months following an occipital skull fracture at age 16 months. At age 13 a focal area of gliosis was removed from the right parieto-occipital region in another hospital and her seizures subsided for five years, but returned at age 17. Her seizures consisted of: (1) forced turning of head and eyes to left; (2) visual experiential hallucination—usually people seen; (3) staring and occasional generalized seizures. At operation the following responses were obtained from the right posterior temporal region.

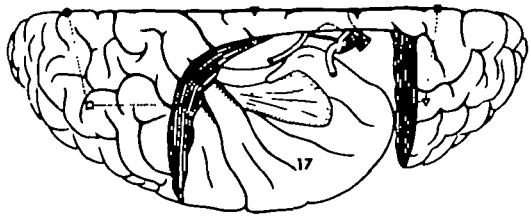


CASE 32.—G. E.

1b. Electrode at a depth of 2 cm. Patient said she heard a buzzing sound. Then she said she saw a friend of hers. When asked who it was, she said "Somebody I know who I met on the street." She said it was a man and that she sometimes sees people in her attacks.
1c. After a pause the patient said, "I see a machine, one that I have seen before." The machine seemed to disappear before the end of the stimulation.
2b. After stimulation was over she said, "I saw a few people. Some of the nurses on the floor (she meant her hospital ward). I cannot describe it now." When asked, she said that in her attacks she sees mostly people.
1c. Repeated eighteen minutes after last stimulation at this point "I see the nurse." When asked afterwards, she said, "It was a little dream." She saw the nurse just as she is now.
3. "Something new, I hear my mother singing." The electrode was replaced and she repeated, "I hear my mother singing."
3. Repeated without warning. After a little time, she said, "I hear my brother talking." When asked what he was saying, she said he was talking to one of his schoolmates.

3. Repeated again without warning. "I hear my mother and father talking and singing." And after a pause, "Christmas carols." When asked, she said, "I saw them for a second or two, then it faded." On further inquiry, she said they were talking and singing about Christmas. She was then asked if when she had heard her brother she also saw him and she replied, "Yes."
3. Repeated ten minutes after previous stimulation at this point. "Nothing."
3. Repeated. The electrode was moved slowly down over the convolution. Patient said, "I heard my mother again, singing."
4. She exclaimed "Was that my mother yelling?" When asked after withdrawal of the electrode, she said, "She was yelling at my little baby sister, Mary Jane." When asked if she saw them, she said she saw both distinctly. She said one was moving, but she could not remember which. "Mary Jane had done something bad, and mother was telling her not to do it."
4. Repeated five minutes after above stimulation at this point, the patient began to weep and said, "It is coming. A spell. A fainting one."
3. Repeated 11 minutes after last stimulation at this point. "I hear some kind of a machine. I saw it for a minute and heard it."
16. "I hear my mother calling." When asked afterwards what she was calling, she said, "Just yelling."
3. Repeated fifteen minutes after last stimulation at this point, "Nothing." When asked whether she ever heard people like her mother and father in any of her attacks, she said, "Sometimes."

Case 33.—G. F. This 45-year-old woman began to have seizures at age 37. Her attacks usually occurred in clusters at the height of a marked monthly gain of weight just before her menstrual periods. The pattern was: (1) interpretive illusion—characterized by fear, and things she looked at seemed far away, (2) automatism, (3) occasional generalized seizure. At operation incisural sclerosis was found in the right temporal lobe, and stimulation produced the following responses.



CASE 33.—G. F.

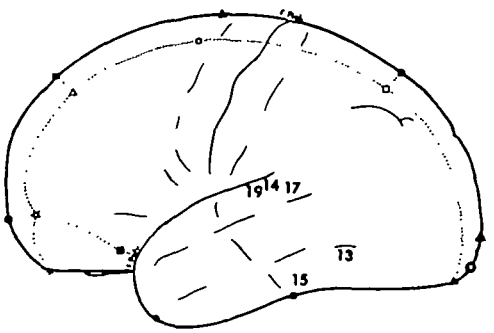
17. She said, "I just heard one of my children speaking." She added that it was the older one, Frank, and that she could hear the "neighbourhood noises" as well. She meant other children's voices and automobiles passing her house. When asked what Frank had said, she replied, "I could not get that."
17. Repeated without warning. She said she heard the "neighbourhood noises" again but not her boy's voice.

When questioned about this ten days later, she recalled that she had heard "Frankie and the neighbourhood noises." She was asked whether it seemed to her to be a memory and she replied, "Oh no, it seemed more real than that." She thought she was

looking into the yard and saw as well as heard the boy. She knew she was, in reality, still in the operating room, but she supposed that the surgeon had somehow brought it about! "Of course", she added, "I have heard Frankie like that many, many times, thousands of times."

She had never had a similar experience during any of her habitual seizures.

Case 34.—L. G. This 14-year-old French Canadian schoolboy began to have seizures at age 5. At age 3 he had fallen from his tricycle and was unconscious for a short time. The pattern of his attacks was: (1) general body "fullness"; (2) experiential hallucination, visual; (3) loss of consciousness with occasional generalized seizure. His father stated that he had episodes of seeing vivid scenes which had occurred in the past, usually at school. During some of these episodes he would talk to his father and describe what he was seeing. The patient also described seeing a room at the outset of an attack. He seemed to be in the room, but did not see himself. The room would then go far off, as though he were looking at it through the wrong end of field glasses. At operation the left temporal region was exposed and cortical abnormality found at the temporal tip and undersurface. Stimulation produced the following responses.



CASE 34.—L. G.

13. Patient stated that a thought entered his head which he seemed to have had before. He likened it to the beginning of an attack. It was something he had heard, felt and thought in the past.
14. Patient heard something that he had heard before. He was unable to describe it.
15. Patient said, "Something which has happened to me."
13. Repeated eight minutes after the previous stimulation at this point patient said, "Yes, something that sticks in front of my face." He explained that this was something that he had felt before. When asked if it was like before an attack, he said, "This is an attack."
17. Stimulation was continued a longer time than usual. Patient talked during the stimulation and said, "Un homme se battre" (a man fighting). When asked if it were someone he knew, he said, "No, a stranger." When asked with whom he was fighting, he said he could not distinguish very much.
17. Repeated ten minutes after the above stimulation, patient said, "Yes, a man." He then explained that he saw a man and a dog walking. When asked whether the man was in town or in the country, he said he could only see a man and a dog.
19. Patient was unable to respond but made a little sound. On renewal of the stimulation he said, "Chant, un chanson." He explained it was a song he had heard before. When asked whether it was someone singing or an orchestra, he only said he seemed to hear it.

19. Repeated eight minutes after stimulation. Patient was unable to answer and there was some after-discharge in the adjacent recording electrodes. When the after-discharge had ceased, he explained that a little boy was playing with another one, but he did not know what they were doing. When asked if he heard a song, he said, "Yes."
19. Repeated after above. Nothing heard.
14. Repeated thirty-eight minutes after the previous stimulation at this point. The patient was unable to talk and there was after-discharge. He then explained there were two men sitting in armchairs singing. He did not think that it was the same song he had heard before.
14. Repeated thirty minutes after the above stimulation. "Nothing."

Stimulation at points 19 and 14 produced interference with speech as well as an experiential response, however, the speech difficulty was almost certainly due to the after-discharge occurring with both stimulations which spread into the adjacent speech cortex.

Case 35.—C. M. This 21-year-old woman began to have seizures at age 11. Following her first attack she was unconscious for a few hours and a persisting right homonymous hemianopia developed. The pattern of her attacks was: (1) interpretive illusion—a feeling of familiarity, (2) automatism.

Pre-operative EEG studies disclosed epileptiform abnormality in the left temporal region. In fig. A the patient is shown prepared for operation, the local anæsthetic has

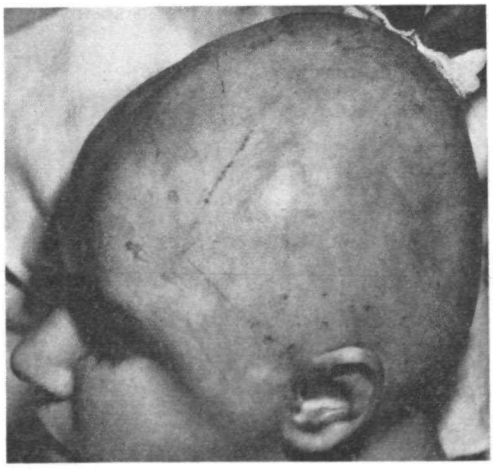


FIG. A.—*Case 35.*

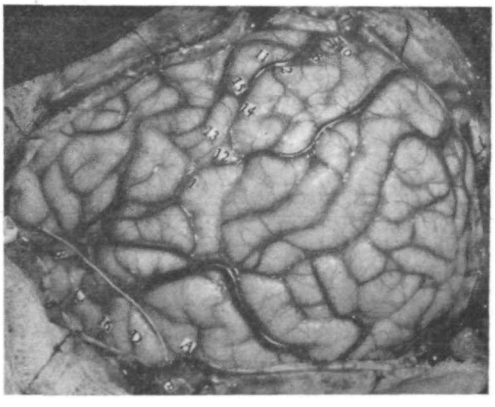
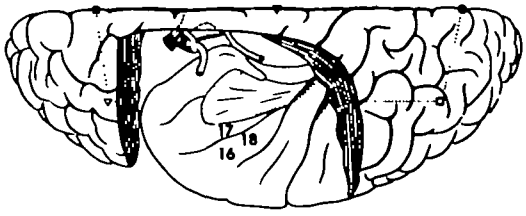


FIG. B.—*Case 35.*

been injected into the scalp and the proposed incision outlined by a scratch. The exposed brain is indicated in an operative photograph, fig. B, and tickets have been placed at the site of positive responses. The area of temporal lobe to be removed is outlined with a white thread. Stimulation produced the following experiential responses. (These stimulations were made with an electrode inserted through the

middle temporal gyrus and aimed at the cortex of the superior surface of the temporal lobe.)[1]



CASE 35.—C. M.

16. Stimulation at a depth of 2 cm. to reach the superior surface of temporal lobe. She said, "Like something that I have heard before."
17. She said, "I am having another one. I can't remember it. It seems like I was in my house." When asked where, she said, "In the hallway, going towards my bedroom."
17. Repeated. "I feel like this is the beginning of one. I was in the hospital and I was with the nurse's aide and she was telling me she had to go shopping." Which hospital was it? "The hospital we are in now." Where were you, on what floor? "I was on the fourth floor, in bed." Who else was there with you? "There were just us two." Could you see her? "Yes." Do you know her name? "The nurse's aide, the little Greek one."
17. Repeated. She said, "I see them and they are talking to me about a spell." Who is saying it? "Dr. Wilder Penfield."
18. "The people are walking down the trays."[2] She was asked if she saw them or heard them. "I saw them and I heard you." She was asked where this took place. She replied that it was at home in Detroit, "Maple Street, St. Claire Shores, Michigan." Where were you? "I was in the house." Were they in the house? "I can't remember what happened."

Case 36.—M. M. This 26-year-old woman had her first seizure at age 5. Her attacks at first consisted of a sensation in one arm and leg followed by weakness in the leg, but when she was in college the pattern changed. The pattern was: (1) interpretive illusion—a feeling of familiarity and fear; (2) experiential hallucination—combined visual and auditory; (3) automatism. She had sudden "flashes" which she described as experiencing something that she had experienced before. She gave as examples: being under the grape arbour at her grandparents' farm (she felt she was there herself); sitting in the railroad station of a small town which was either Garrison or Vanceburg, Kentucky—it was in the winter, the wind was blowing outside and she was waiting for a train.

Dr. Feindel recorded one of her spontaneous ictal hallucinations as she recounted it to him at the close of an attack while in hospital:

[1]During the three years that have elapsed since this operation she has had no further seizures. There was slight post-operative dysphasia which cleared completely. She continues to take small daily doses of phenobarbital.

[2]In reviewing this stimulation record it is not possible to be certain about what the patient meant by this statement so the response is given as recorded.

"She had the same flash-back several times. These had to do with her cousin's house or the trip there—a trip she has not made for ten to fifteen years but used to make often as a child. She is in a motor car which had stopped before a railway crossing. The details are vivid. She can see the swinging light at the crossing. The train is going by —it is pulled by a locomotive passing from the left to right and she sees coal smoke coming out of the engine and flowing back over the train. On her right there is a big chemical plant and she remembers smelling the odor of the chemical plant.

The windows of the automobile seem to be down and she seems to be sitting on the right side and in the back. She sees the chemical plant as a big building with a half-fence next to the road. There is a large flat parking space. The plant is a big rambling building—no definite shape to it. There are many windows."

Whether this is actually true or not she does not know but it looks like that in the flashes. She thinks she hears the rumble of the train. It is made up of black flat-top cars full of cinders—the kind they use for work on the road. In another flash-back she says she sees her cousin's home and she is in it. She smells coffee—'They always have coffee,' and 'It is part of the atmosphere of the house.'"

The foregoing experiential hallucination is of particular interest because of the complex olfactory component. It is the only example we have recorded of a specific and identifiable olfactory experience in a seizure pattern. Gowers (1901) mentioned a patient in whose attacks there invariably appeared before him an old woman in a brown-stuff dress, "who offered him something which had the smell of Tonquin beans," however, this may well have been a rather unspecific pleasant odour.

In our present series of cases the presence of an olfactory and/or gustatory *sensation* in the seizure pattern is highly suggestive of neoplasm. There were 6 cases with an olfactory-gustatory sensation. Four were proved to have a temporal lobe tumour, the fifth was a definite tumour suspect, and the sixth had incisural sclerosis (Cases 58, 42, 59, 47, 16 and 62).

At operation the right temporal region was explored and incisural sclerosis found. Fig. A is a photograph of the patient prepared for operation. Local anæsthetic has

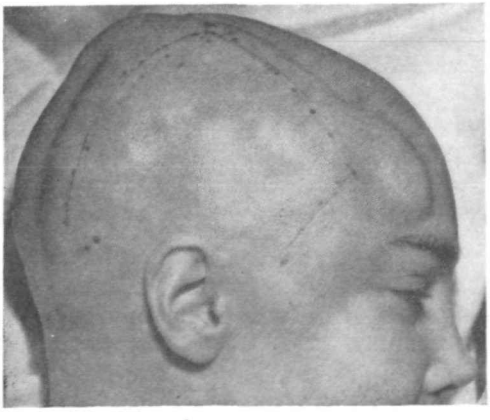


FIG. A.—*Case 36.*

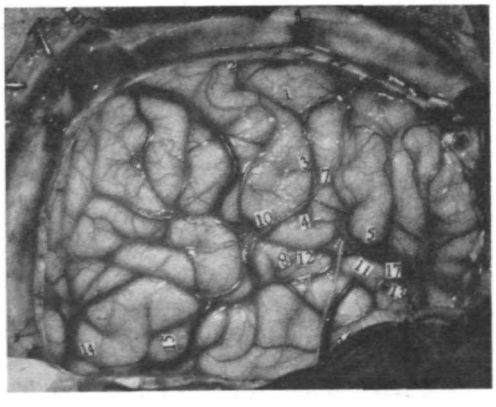
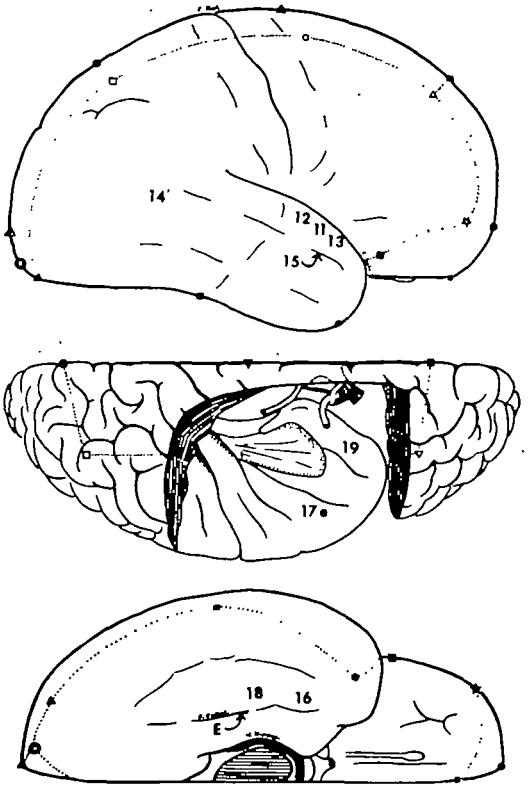


FIG. B.—*Case 36.*

been injected and the incision is outlined. In fig. B the scalp, bone and dura have been turned down and numbered tickets mark the sites of positive cortical stimulations. The white thread indicates the area of temporal lobe to be removed. The following experiential responses were produced with stimulation.[1]



CASE 36.—M. M.

11. She said, "I heard something familiar, I do not know what it was."
11. Repeated without warning. "Yes, sir, I think I heard a mother calling her little boy somewhere. It seemed to be something that happened years ago." When asked if she knew who it was, she said, "Somebody in the neighbourhood where I live." When asked, she said it seemed as though she was somewhere close enough to hear.
11. Repeated eighteen minutes later. "Yes, I hear the same familiar sounds, it seems to be a woman calling. The same lady. That was not in the neighbourhood. It seemed to be at the lumber yard." She added, "I have never been around any lumber yard."

It is now nine years since this operation. On continued medication the frequency of her major attacks gradually decreased. She is at work full time and had no attacks during the past year. An occasional warning of an attack still occurs.

13. "Yes, I heard voices down along the river somewhere—a man's voice and a woman's voice, calling." When asked how she could tell it was down along the river, she said, "I think I saw the river." When asked what river, she said, "I do not know, it seems to be one I was visiting when I was a child."

13. Repeated without warning. "Yes, I hear voices, it is late at night, around the carnival somewhere—some sort of a travelling circus. When asked what she saw, she said, "I just saw lots of big wagons that they use to haul animals in."

12. Stimulation without warning. She said, "I seemed to hear little voices then. The voices of people calling from building to building somewhere. I do not know where it is but it seems very familiar to me. I cannot see the buildings now, but they seemed to be run-down buildings."

14. "I heard voices. My whole body seemed to be moving back and forth, particularly my head."

14. Repeated. "I heard voices."

17e. Stimulation at a depth of 1½ cm. toward the superior surface of the temporal lobe. The patient said, "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."

11. Repeated forty minutes after the last stimulation at this point. "I had a flash of familiar memory, but I do not know what it was."

13. Repeated three times thirty minutes after the last stimulation at this point. "Nothing."

15. Stimulation of the inferior aspect of the first temporal convolution. "I had one of those very familiar memories."

16. Stimulation in the general vicinity of the uncus or just lateral to it. The patient said, "I had a little memory—a scene in a play. They were talking and I could see it. It was just seeing it in my memory."

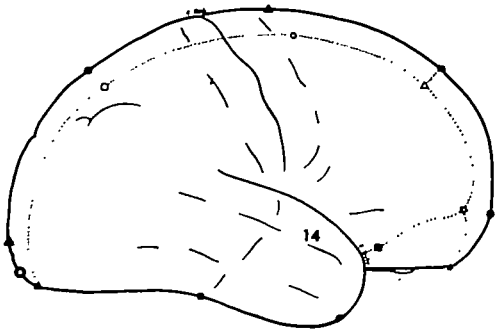
18. Stimulation more posteriorly on the undersurface of the temporal lobe. "A very familiar memory of a girl talking to me."

19. Stimulation of the superior surface of the first temporal convolution adjacent to the uncus. "I feel very close to an attack—I think I am going to have one —a familiar memory."

E. Stimulation without warning. She said, "Oh, it hurts, and that feeling of familiarity—a familiar memory—the place where I hang my coat up, where I go to work."

Case 37.—T. S. This 19-year-old boy began to have seizures at age 17. The pattern of his attacks was: (1) thoracic sensation; (2) sensation in right hand and arm; (3) experiential hallucination—visual; (4) automatism with occasional generalized seizure. Many of his attacks were precipitated by music, especially modern jazz. The hallucinatory component was usuallly some form of memory of himself reaching for something. Once at school he felt a seizure starting and put his right hand out to grasp something. Suddenly he experienced a "memory" of himself at the age of 6 performing exactly the same movement. He saw this as though he were "reviewing

a scene in a movie." He explained that it was more distinct than a memory. This happened often and always involved his right hand. At operation the right temporal region was exposed and the changes typical of incisural sclerosis found. Experiential responses were produced by stimulation but only at and about one point.



CASE 37.—T. S.

14. He said, "I feel as though I am going into an attack." He then explained that he had a sensation through his chest and even into his head.

14. Repeated. "I feel as though I am going into an attack." He then explained that he had a sensation in his right arm.

14. Repeated one minute later. Patient said, "Nothing." The electrode was held in place. Patient said, "I feel now as though I am going to have an attack—a feeling in my right arm."

14. Repeated just anterior to point 14 without warning the patient. After about ten seconds he said, "I feel as though I was in the bathroom at school." When asked about it, he said, "It was just a sort of a flash-back."

14. Stimulation in the vicinity of point 14 repeated two minutes later. Patient said, "Nothing." Then he added, "A slight blurring on the street corner." When asked where, he said, "South Bend, Indiana, Jacob and Washington." When asked about it, he said he seemed to be looking at himself at a younger age.

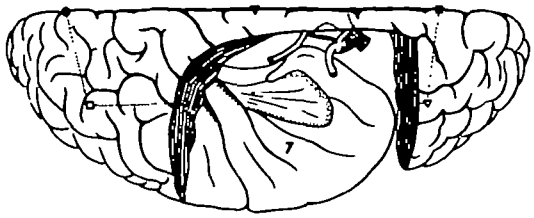
14. Stimulation in the vicinity of point 14 repeated. "Nothing."

14. Repeated. He said, "I feel as though I am going into an attack." When asked why, he said, "That music, from the stage hit 'Guys and Dolls'." When asked which song in this play, he said he did not remember. When asked whether he remembered it, he replied that it was more like it was when, "I was listening to it." It was an orchestration. When asked whether he seemed to be there or was remembering it, he said, "I seemed to be there."

14. Repeated without warning "Nothing."

Case 38.—J. T. This 22-year-old man from South Africa had had recurring seizures since age 3. The pattern of his attacks was: (1) cephalic sensation; (2) auto-

matism. At operation a glioma, type unclassified, was found in the right temporal lobe. Stimulation produced this response.



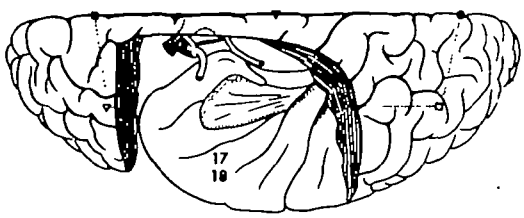
CASE 38.—J. T.

7. The electrode was applied to the cortex of the superior surface of the first temporal convolution, just anterior to the transverse gyrus of Heschl. As soon as the current was turned on, the patient exclaimed in great surprise, "Yes, Doctor, yes, Doctor! Now I hear people laughing—my friends in South Africa." He was asked if he could recognize who these people were, and he replied, "Yes, they are two cousins, Bessie and Ann Wheliaw." He said that he did not know why they were laughing, but that they must have been joking.

Some days after the operation this experience was discussed with the patient. He said that it seemed to him that he was with his cousins and that they were all laughing together at something.

This was a real experience and he was very surprised that he seemed to be with his friends back in South Africa which he had left about a month previously.

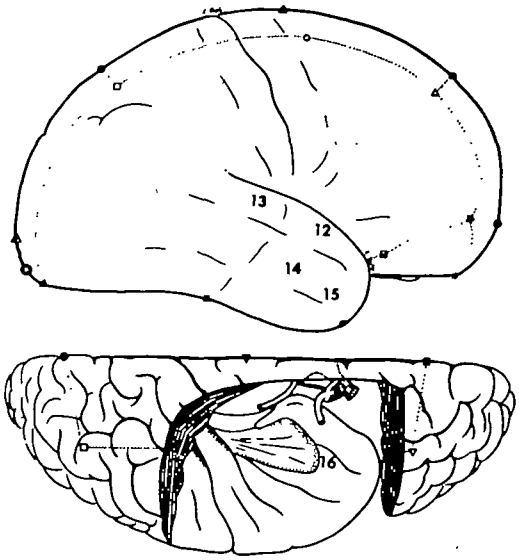
Case 39.—H. N. This 19-year-old boy had a head injury at age 11 and seizures began at age 12 with this pattern: (1) auditory sensation; (2) experiential hallucination —unclassified type; (3) generalized seizure. He explained that he heard a humming noise, sounds would fade out—"Then I start dreaming." He said, "The dream is usually something that I have been doing in a very fancy way, as dreams are." They were not always the same. At operation the left temporal region was exposed and no obvious abnormality found. Stimulation produced these responses.



CASE 39.—H. N.

17. The first temporal convolution was excised and stimulation carried out 1·5 cm. within the fissure of Sylvius on the cut surface of the first temporal convolution. The patient said, "I had a dream." When he was asked if it was like an attack, he replied, "Not the way they used to be."
18. Stimulation on cut first temporal surface, 1 cm. within the fissure of Sylvius. The patient said suddenly, "I am starting to get this dream! I can't hear."

Case 40.—S. S. This 20-year-old girl began to have seizures at age two. The seizure pattern consisted of: (1) an epigastric sensation; (2) experiential hallucination—unclassified type; (3) brief loss of awareness or infrequently a generalized seizure. She described her hallucination as one of remembering, and said, "I may see something before me at the time, not as a visual impression perceived externally, but something as seen within my mind. This thing reminds me of something else, which reminds me of something else, and there is a chain of association which follows." This was apparently never stereotyped and she could not remember any specific examples. At operation there was incisural sclerosis of the right temporal lobe, and the following responses were obtained.



CASE 40.—S. S.

12. There was a short electrographic after-discharge. The patient thought that she had a minor attack at this time. This she said was one of her "flash-backs."
12. Repeated, "Oh that was like a warning."
13. "Yes, like a flash-back."
14. "Like a warning." When asked, she said it reminded her of a football game.
13. "It made me think of something." But she could not remember what it was.
14. Repeated five minutes after last stimulation at this point. "Like a little flash-back."
14. Repeated. "Same thing, but not as much."
15. Again like a flash-back.
12. Repeated twelve minutes after last stimulation at this point. "Flash-back." She said she was thinking of when her mother went to the hospital.
16. Stimulation at a depth of 3 cm. in the region of the amygdaloid nucleus. She said, "Yes, a flash-back." She said she was thinking about her dog.

(6) Experiential Hallucinations—Ictal

Activation of this type of dreamy state by spontaneous seizure is familiar to clinicians. As pointed out above, there were 53 examples which we have restudied in this review of 1,132 cases of focal epilepsy. All 53 were found in the 520 examples of temporal lobe epilepsy. Of these 53 patients, all of whom were operated upon under local anæsthesia, some form of experiential response was produced by electrical stimulation in 24 cases. In 16 of these 24 cases, at least once an electrically activated mental state was said by the patient to be the same in character as the pre-operative ictal experiential hallucination.

Reference to the habitual ictal hallucinations of the above 24 cases may be found scattered through the foregoing case notes of the 40 patients who had experiential responses at operation. We have summarized the seizure patterns of the other 29 patients below to make the material available, and have added a review of the relative clinical literature.

A. Clinical Literature

This review of significant papers in the literature was made with particular reference to the side of temporal lobe involvement.

Anderson (1886) reported the case of a schoolmaster with a pituitary tumour involving the left temporal lobe. In his attacks he saw "childish scenes" and heard the voices of women and children in an event that he was able to recall from his past.

Jackson and Beevor (1889) reported the case of a cook with visual hallucinations and a tumour in the right temporal lobe. Jackson believed that the dreamy states in general were most often observed in patients whose seizures were due to abnormal discharge in the right hemisphere (Jackson, 1880).

A patient with right sided Jacksonian attacks and visual hallucinations was described by Harris (1897). There was presumably a left fronto-temporal lesion.

Buzzard (1906) reported two patients with seizures that were due to temporal lobe lesions. One had complex visual hallucinations in her seizure pattern and a right temporal lobe neoplasm.

Foster Kennedy (1932) described two cases with visual hallucinations and right temporal lesions. "One of my patients with a verified right temporo-sphenoidal tumour would often see men and women in eighteenth century court dress strolling across her New York apartment! A woman in Bellevue Hospital would be terrified by the repeated vision of a beckoning woman dressed in blue standing to her left side." It is most likely that the lesion in the last patient was on the right side. Earlier Kennedy (1911) had described another patient with a right temporal

tumour who heard a bell and saw "a strange bad woman" clad in rags in the beginning of her attacks.

Horrax (1923) reviewed Cushing's series of 72 tumours of the temporal lobe and reported 12 cases with seizures presenting "definite hallucinations of figures" (mostly people and some animals). The details of only 8 cases were given and of these patients 6 had lesions in the right temporal lobe and 2 in the left.

Robinson and Watt (1947) reported two patients with post-traumatic epilepsy from temporo-occipital injuries, each of whom had visual hallucinations of scenes that occurred at the time of the injury. The lesion was on the right in one patient and the left in the other.

Mulder and Daly (1952) studied 100 patients with temporal lobe lesions and reported the case of one patient who heard music during attacks caused by a left temporal tumour and two cases with complex visual hallucinations during attacks caused by right temporal lesions. They stated: "The hallucinatory phenomena were unusually vivid and complete, and, although these attacks might have been precipitated by tension, the content of the hallucination did not seem related to the present emotional problems of the patient. Frequently, the patient described the sensation of viewing vivid past experience while retaining awareness of the present."

Russell and Whitty (1955) studied 60 patients with wounds in the temporo-parieto-occipital regions who had seizures with a visual aura. 10 patients had visual hallucinations of an experiential nature (excluding the 2 cases from the same clinic previously reported by Robinson and Watt). In 4 patients the lesion was on the left side and in 6 it was on the right.

Rodin *et al.* (1955) reported 4 patients with seizures and complex visual hallucinations of people or scenes. 3 of these patients had right temporal lesions; the fourth was not completely studied.

The seizure patterns of 40 patients with temporal lobe seizures were analysed by Stevens (1957). Complex visual hallucinations occurred in two patients with a left temporal focus and in five with a right temporal focus.

Bingley (1958) studied 90 cases of temporal lobe seizures. Considering the "dreamy state" as an entity (not distinguishing the interpretive illusions from experiential hallucinations) he found that it occurred in 24 per cent of the patients with a lesion in the dominant temporal lobe and in 58 per cent of those with a lesion in the non-dominant temporal lobe. This was a statistically significant difference. He further noted that "auditory illusions and hallucinations" tended to occur more frequently in right sided lesions, but that "visual illusions and hallucinations" showed no significant association with the laterality of the lesion. The meaning of these two facts is not clear, however, since he did not

define what is meant by "hallucination" and it is uncertain whether this refers to crude auditory or visual sensations or complex experiential phenomena. There is no evidence in our data that crude auditory or visual sensations occur more often as the result of discharge in the right or left side either as an ictal phenomenon due to a lesion or with stimulation at operation.

In a study of paroxysmal disorders of the body image in temporal lobe epilepsy, Ionăşescu (1960) described a patient with a right temporal focus who in his attacks "relives long-past schoolboy scenes and meets his former colleagues." A second patient with a left temporal focus saw her late father at the end of an alley in a green garden with each of her attacks.

Schneider *et al.* (1961) have recently pointed out that rarely a lesion in the orbital frontal region may cause visual and auditory hallucinations. They suggest that this effect is possible through known anatomical connexions between the frontal and temporal lobes, i.e. the uncinate fasciculus (fronto-temporal association bundle) or the inferior fronto-occipital fasciculus.

Thus, in the 41 cases of temporal lobe seizures reported with complex visual hallucinations as part of their seizure pattern, 29 had right temporal lesions and 12 had left temporal lesions.

B. Case Reports[1]

For purposes of classification and further analysis, it has proved useful to divide the experiential hallucinations into groups according to the sensory system chiefly involved, i.e. auditory or visual. Therefore the cases are presented in four groups depending on the character of their hallucinatory experience as follows:

1. *Auditory*—experience with sound and no visual component.
2. *Visual*—scenes, persons or objects.
3. *Combined visual and auditory* experiences.
4. *Unclassified* experiences—for example, a "dream," a "flash-back," or a "memory" without further description.

(1) Experiential Hallucinations—Auditory Type

From reports in the literature it would appear that auditory experiential hallucinations are quite rare. Gibbs *et al.* (1948) studied 300 patients with temporal lobe epilepsy and found only eight with an auditory aura, and they did not state whether any of these were of a complex experiential nature. In a series of 750 patients with seizures of all types, Lennox and

[1]This section deals with the 29 cases with preoperative ictal experiential hallucinations in which stimulation at the time of operation did not succeed in producing experiential responses. The others are described in the preceding section.

Cobb (1933) mentioned six patients with pictorial visual hallucinations (0·8 per cent), and two with complex auditory hallucinations (0·3 per cent). The examples of this type in our series are summarized below:

Case 41.—J. Be. This patient was a 38-year-old man who began to have seizures when he was ten years old. His attacks consisted of: (1) experiential hallucination—auditory type; (2) generalized seizure with head turning to the right. In the beginning of an attack he would hear a male voice saying, "Someone call a doctor, someone call a doctor." He also stated that at the end of his attacks he heard the same male voice saying, "It's all over, forget the doctor." He did not recall whether this had actually ever happened or not. There was bilaterally synchronous fronto-temporal EEG abnormality with a predominance on the left side. At operation no obvious abnormality was found in the left temporal lobe.

Case 42.—L. Bu. This 31-year-old woman began to have seizures at age 29. The pattern of her attacks was as follows: (1) rising epigastric sensation; (2) a sensation of "taste and smell" at the back of the throat; (3) interpretive illusion (feeling of familiarity and increased visual distinctness); (4) experiential hallucinations—auditory type. In an attack she would often hear the voice of someone she knew. For example, shortly before leaving home to come to the hospital, while sitting at breakfast with her husband, she experienced the onset of an attack during which she heard her husband's sister speaking behind her, but she could not remember what she said. In addition she would occasionally have a sensation of unreality in an attack, "It would be as though I were two persons, one watching and the other having this happen to them." When asked which of these two persons she felt she was, she stated, "The one watching."[1]

There was an electrographic slow wave abnormality in the right temporal region and at operation a right temporal astrocytoma was found.

Case 43.—R. Bl. This 26-year-old man began to have seizures at age 21. The pattern was: (1) a prodrome of nervous tension; (2) experiential hallucination—auditory type; (3) major generalized seizure. Just before an attack he frequently heard a voice saying strange words which he could not understand. He also had a sensation of "strangeness of words" as if he had never seen or heard them before. In addition to these phenomena he described another sensation; in his own words, "An experience envelops my mind. There is a hypnosis which permits certain objects that are familiar, but which I can't remember, to float up from my subconsciousness. If I try and capture the object and look at it objectively, it disappears." This patient was studied before the routine use of the EEG so that there were no electrographic data. At operation a large meningo-cerebral cicatrix was found in the left temporal lobe.

Case 44.—V. B. The patient was a 14-year-old girl who began having seizures at age seven after a minor head injury. The pattern of her attacks was: (1) epigastric sensation; (2) vertigo; (3) experiential hallucination—auditory type; (4) turning to the right and posturing of right arm; (5) post-ictal automatism and aphasia. She had abortive attacks during which she occasionally heard people calling her name, and the voice was familiar, such as that of her mother, father or siblings. EEG studies disclosed a left temporal abnormality, and encephalomalacia was found in the left temporal lobe at operation.

[1]These autoscopic hallucinations (seeing one's self) are occasionally encountered in patients with temporal lobe seizures, *see* Ionăşescu (1960). This is also illustrated in Cases 1, 15, 37, 51.

Case 45.—C. C. This 46-year-old French Canadian housewife began to have seizures at age 42. These consisted of a cephalic sensation followed by an inability to speak, and a generalized seizure. At age 43 a meningeal fibroblastoma was removed from the lesser wing of the left sphenoid bone. This tumour lay within the left middle fossa where it pushed the temporal lobe backward. The anterior pole of the temporal lobe had lost its pial covering where it had been pressed upon by the neoplasm and was somewhat softened.

Two years after this operation she began to have seizures again but they were of a new and curious type. The pattern was: (1) epigastric sensation; (2) experiential hallucination—auditory type. In these attacks, she heard voices which seemed to be coming from her right side. They were not the voices of her children. Indeed she said she could not hear her children speak to her during an attack. Once, on getting up at night to go to the bathroom, she heard *music*. She thought it came from the radio in the living room. It was a song she had heard frequently on the radio. She could not hear the words. In a later attack she thought the room had filled with people, all talking at once, although she could not tell what they were saying.

In these attacks she retained the ability to move about. She was able to see but she could hear nothing except the rather complicated auditory hallucination, the content of which was either a musical memory or voices.

One such attack, which occurred in hospital, was described by Nurse Margaret Goldie as follows: After the attack was over, the patient said she had a peculiar sensation in the chest which "felt as though it came from the stomach." Then the voices started on the right side of her. Then she said, "I felt as if there were a crowd of people around me all talking to me. It made me very excited and nervous. Now I feel very tired and have a headache." In other attacks she heard music, and several times at night she went to see if someone had left the radio on. She sometimes heard people sing but could not remember what the song was. The voices or music were completely realistic and convincing, and the duration about one minute. The direction of sound seemed to be sometimes to the opposite side (right), and sometimes she referred them toward the supposed source, e.g. the radio.

This patient was investigated before electrographic studies were routinely employed. A second operation was performed and scarring was found at the tip of the left temporal lobe.

Case 46.—J. Jo. This 32-year-old man began to have attacks at age 26 with this pattern: (1) experiential hallucination—auditory; (2) sensation in right hand and then right side of body; (3) automatism. He heard and recognized clearly some music which heralded the onset of his attacks. It was an orchestra without vocal accompaniment playing either "I'll get by" or "You'll never know." These were songs that he often heard on the radio or at dances. At operation an oligodendroglioma was found in the left temporal lobe.

Case 47.—C. K. This 28-year-old man had had recurring seizures for two years. The pattern of his attacks was as follows: (1) olfactory sensation; (2) palpitation; (3) experiential hallucination—auditory type; (4) automatism. He stated that "thoughts and dreams come into my head" during an attack. This usually consisted of words set to music similar to a radio commercial, or a jingle. He could not remember any specific examples. EEG studies revealed continuous slow waves in the left temporal region, and at operation an oligodendroglioma was found.

(2) Experiential Hallucinations—Visual Type

Case 48.—N. Ba. This 18-year-old girl had had seizures since age 11. The seizure pattern was: (1) visual sensation—colours; (2) experiential hallucination—visual type (3) interpretive illusion; (4) head and body turning to left followed by a generalized seizure. At the onset of an attack she would see colours in her left visual field, and following this she would see people or scenes some of which recalled incidents in her past and often frightened her. Just before losing consciousness these scenes would suddenly seem to move toward her from her left visual field. EEG studies disclosed abnormality in the right posterior temporal region. At operation a meningo-cerebral cicatrix was found beneath the right temporo-occipital region.

Case 49.—J. C. The patient was a 26-year-old school teacher who began to have seizures at age 23. At the age of five she had had a transient papillœdema following bilateral otitis media. The pattern of her attacks was the following: (1) forced stereotyped thinking; (2) interpretive illusion—a feeling of familiarity; (3) epigastric rising sensation; (4) thirst; (5) experiential hallucination—visual type. The following is her description of an attack.

"A complete sequence of recollective thoughts, such as the following: Morning shall pass, then noon, then we shall have evening; or, for instance, this house was built, it shall be destroyed, and another shall be built and it will be destroyed. Haven't these thoughts occurred before? As a matter of fact, hasn't this all happened before? Then a deep breath, followed by a rising sensation from the region of the stomach and thorax, all the above occurring very rapidly, possibly less than a quarter of a second. Simultaneously a mental darkness, i.e. a dark figure being elevated, crouched in a threatening or menacing position. The figure seems gesturing with a long sharp implement, possibly an umbrella. Accompanying this is the persistent and beseeching desire for water. The above seems to be accompanied by a tenseness. Then a haze follows, as though fleecy clouds were floating by one after another. Then a complete loss of consciousness."

At operation a chronic right subdural effusion and meningo-cerebral adhesions were found. When seen one year later, her attacks had returned in an altered form after a seizure-free interval of six months following the operation. The initial phenomenon was now an experiential hallucination of the visual type. In this she would see herself riding in an automobile with her father. They seemed to be riding around Fordham Square in New York City (her home). It is of interest to note that she had once had a seizure while riding around Fordham Square with her father. The hallucinatory scene in her attack was exactly the same as the original event as she remembered it.

Case 50.—C. E. This 39-year-old man had had meningitis as an infant and his first seizure occurred at age 12. His seizure pattern changed slightly over the years but consisted primarily of: (1) a lower abdominal sensation—a "cold sensation" which rapidly became generalized and he sometimes referred to this as a sexual feeling; (2) experiential hallucination—visual type; (3) automatism. His hallucination varied but often involved going to catch a bus. Once, while eating supper at home, he had an attack and got up from the table to go and catch a bus, thinking he was in the bus terminal. On another occasion he had an attack on coming into his home. He saw two people sitting in the hallway. They semed to leave the house and he followed them. A short while later he found himself outside in the snow and he then realized that he had had a seizure. EEG studies indicated a right temporal focus, and at operation a cerebral cicatrix was found in the right temporal lobe.

Case 51.—M. De. This 32-year-old left-handed woman had had recurring seizures since she was 6 years old. Her attacks followed this pattern: (1) throat sensation

(salivation); (2) abdominal sensation; (3) experiential hallucination—visual type; (4) automatism. Her seizures often began with the recollection of a previous attack. For example, she described one attack in which she could distinctly see herself having a seizure in her automobile and stopping by the roadside. In another she saw herself having an attack in a restaurant and she could see the faces of her family around her. She described these scenes as though the action were progressing in a normal sequence and timing. There was left deep Sylvian electrographic abnormality, and at operation incisural sclerosis changes were noted in the left temporal lobe. The right hemisphere was presumably dominant for speech since there was no interference with naming during stimulation of the left hemisphere at operation and there was no post-operative speech difficulty.

Case 52.—R. D. This 10-year-old boy began to have attacks at age five which consisted of: (1) epigastric sensation; (2) experiential hallucination—visual; (3) automatism. In his attacks, after the epigastric sensation, he would see animals that he called dinosaurs, snakes, lions and elephants. He said he had read about them and that he had seen the dinosaurs in his encyclopædia of animals. The animals were described as moving and jumping about in their normal surroundings in the jungle. When asked, he said that he was not afraid of the animals because he remembered his mother telling him they were not real. Abnormality of the incisural sclerosis type was found in the right temporal lobe at operation.

Case 53.—L. Gr. This 34-year-old veteran began to have seizures at age 25 following a head injury. The pattern of his attacks was: (1) cephalic sensation; (2) aphasia, (3) experiential hallucination—visual type; (4) major generalized seizure. His hallucinations were varied but were usually a visual re-enactment of a previous event in his life. They were most often of some incident during or after army life and never involved events before his induction into service. When asked for examples of things he might see he gave the following: "Brass hats when we marched by them; the march from the prison camp; one of my buddies who was shot; pages of a comic book with characters like Fearless Fosdick; having a fight with a rival over a girl friend; having intercourse with a fiancee." There was left temporal EEG abnormality, and at operation gliosis was found in the left temporal lobe.

Case 54.—K. Mi. This 44-year-old man had his first seizure during the first few weeks of his life. In later years the pattern of his attacks was: (1) precordial sensation; (2) experiential hallucination—visual type; (3) turning to the right; (4) automatism. He said that when an attack started he had "a kind of hallucination." This was a distinct scene, usually a room which he recognized as familiar at the time. He knew that this was unreal and formed part of his attack, but was unable to give details of the scene. There was continuous electrographic slow wave abnormality in the left temporal region, and at operation an oligodendroglioma was found.

Case 55.—P. Ri. This 19-year-old ambidextrous French Canadian boy began to have seizures at age 17 following a head injury. His attack pattern was: (1) experiential hallucination—visual type; (2) body sensation; (3) automatism with occasional generalized seizure. At the onset of an attack he would see a man or several men standing around him. He felt that they were saying evil things about him. He expressed it thus: "Je vois un homme, ou des hommes qui me menacent." The men in his hallucination were not people he knew, but were characters he had seen in detective stories usually. They were not always the same characters. He explained that if he read a story and then had an attack afterwards, he would probably see the characters in the story in his hallucination. EEG studies indicated abnormality in the left temporal region and at operation a meningo-cerebral cicatrix was found.

Case 56.—H. S. This 27-year-old man had had recurring seizures for one year. The pattern of his attacks was: (1) cephalic sensation; (2) body sensation; (3) rising epigastric sensation; (4) experiential hallucination—visual type; (5) automatism. He gave several examples of hallucinations that had occurred in his attacks. On one occasion he saw a girl who was employed at the factory where he worked. Another time while walking along St. Catherine Street he saw the same or a similar girl walking. The street and the buildings seemed to disappear. He continued to walk and when he reached where she should have been, there was no one there, and the hallucination had disappeared. On another occasion he saw a familiar television star coming down some steps just as in her TV program. At the bottom of the steps was a man on his knees with an old fashioned camera and flash powder stand. He took her picture as she came to the bottom of the steps. He remembered having seen this on television. On another occasion he saw eight Germans in uniform and helmets shooting at him. The bullets were three inches long and they stopped about four inches from him.[1] There was right temporal electrographic abnormality, and at operation an astrocytoma was found in the right temporal lobe.

Case 57.—V. V. This 28-year-old man began to have seizures at age 6. The pattern of his attacks was the following: (1) epigastric rising sensation; (2) palpitation; (3) visual sensation, experiential hallucination—visual type; (4) automatism. He described his hallucination with difficulty. There would often be lights or streaks of light in front of him, and following this he might see a scene. For example, he remembered an attack in which he suddenly saw a large stadium filled with people and brilliantly illuminated. When asked if he seemed to be in a seat in the stadium, he replied, "I was on the other side of the stadium looking at them." On another occasion he described feeling as though he were in the centre of lines of lights which were like a cobweb, and he was struggling to get out of this web. There was a right temporal EEG focus, but at operation no gross abnormality was noted.

(3) Experiential Hallucinations—Combined Auditory and Visual Type

Case 58.—J. Ar. This 39-year-old man had his first seizure at age 37. The pattern of his attacks was: (1) a feeling of happiness and well-being; (2) experiential hallucination—combined type; (3) rising epigastric sensation; (4) an indescribable smell or taste; (5) generalized major seizure; (6) questionable automatism. His hallucination consisted of seeing a person or several people and hearing them talking. He was never able to "make any sense out of what they are saying." Sometimes the people he saw were recognizable friends, but at other times they were strangers. EEG abnormality was noted in the right temporal region, and at operation a hæmangioma was found in the right temporal lobe.

Case 59.—G. C. The patient was a 22-year-old woman who began to have seizures at age 11. The pattern of her attacks was: (1) epigastric sensation; (2) taste and smell; (3) experiential hallucination—combined auditory and visual; (4) turning of body to right; (5) automatism. In her attacks she would see small men standing about her and saying, "You shouldn't have." EEG studies revealed a slow wave abnormality in the left temporal region and at operation an astrocytoma was found.

Case 60.—P. C. This 43-year-old man had his first attack at age 40. The pattern was: (1) occasionally paresthesiæ in his right hand, or right and left hands, or occasionally "nausea" and general body warmth; (2) experiential hallucination—combined auditory and visual; (3) automatism. His hallucination consisted of peculiarly vivid

[1]It is quite likely that some patients allow imagination to assist memory at times!

recollections of past experience which he recognized clearly. In one attack he suddenly recalled an evening ten years before when he was dancing with his first wife (who later died) in a dance hall where the orchestra was playing "My happiness." He could hear the music very clearly. In another attack he was working in a railroad yard when he suddenly began to feel as if it were twenty years earlier when he was working in a mine. He felt he was underground learning how to do a certain job. He saw the place and persons surrounding him in the mine very vividly. Again, in another attack he had a vivid recollection of this series of events: It was twenty-five years earlier, he was painting a wall at a paper mill, it began to rain and he went into a room where he accidentally had his right index finger amputated by the belt of a machine. There was a well-localized left temporal electrographic abnormality, and at operation scarring (gliosis) was found in the left temporal lobe.

Case 61.—R. C. This 19-year-old boy had his first seizure at age 11. His attack pattern was: (1) an abdominal sensation; (2) loss of consciousness, throat noises, head movements; (3) experiential hallucination—combined auditory and visual type. He stated that upon regaining consciousness he occasionally had the definite feeling that he had been in the company of a certain cousin and had been carrying on a conversation with him. He would usually look around and be surprised not to find him present. The situation always involved the same cousin, but he could not recall any of the conversation. There was electrographic abnormality in the left temporal region, but at operation no definite abnormality was discovered in the left temporal lobe.

Case 62.—J. McR. This 37-year-old man had his first attack at age 19. Pattern: (1) vertigo; (2) olfactory sensation; (3) experiential hallucination—combined auditory and visual type; (4) automatism. The sensation of vertigo was followed by an odour like burning paint and then he had vivid memories during which he saw and heard things that had happened in the past. He worked in the parts department of an automobile company. In one attack he saw men that he knew and could name standing around him. They asked him for the number of a certain screw which he correctly said was No. 168593. At another time he recalled an attack in which a friend asked him for a screw which is used in the windshield which he correctly said was No. 44317. Before he began working for the automobile company his vivid recollections in his attacks had to do with other events in his past. EEG studies revealed bitemporal abnormality which was maximum on the left side. At operation incisural sclerosis was found in the left temporal lobe.

Case 63.—R. O. This 30-year-old man had been having recurring seizures since age 20. The pattern of his attacks was: (1) staring, slight movement of right hand; (2) experiential hallucination—combined visual and auditory type; (3) occasional automatism followed by generalized seizure. In his attacks he often saw distinct visual scenes that he could never describe in any detail afterwards. In some attacks he heard very familiar music. He felt that the attacks in which he saw scenes or heard music were almost always precipitated by music or some repetitive sound. EEG studies indicated bilateral temporal abnormality, maximum on the left. At operation typical incisural sclerosis was found in the left temporal lobe.

Case 64.—M. P. This 45-year-old man had had seizures since infancy. The pattern of his attacks in adult life was the following: (1) experiential hallucination—combined visual and auditory; (2) abdominal sensation; (3) confusion with amnesia. He explained that in the beginning of an attack he might suddenly see members of his family who were not really present. He might also hear strange noises or voices. As an example he said, "The noise might be that of a street car, or the room light whistling." The voices would belong either to a man or a woman whom he did not recognize, and who would tell him to do something. He stated, "I always do the

opposite for instance, if the voice says, 'Go out of the door,' I will stay inside." There was left temporal electrographic abnormality, and at operation the changes of incisural sclerosis were noted.

Case 65.—S. Sh. This 20-year-old girl had her first seizure at age 6. Her attacks followed this pattern: (1) experiential hallucination—combined auditory and visual type; (2) automatism; (3) occasional generalized seizure. At the onset of an attack she would see and hear people talking in front of her. She was unable to recognize them, but they were mostly women. She described their conversation: "The sentences that they say are never finished so that everything is mixed up." She did not appear to speak to the figures herself. On one occasion the scene before her was composed of soldiers marching toward or away from her. Rarely, she saw a pen or some familiar object in front of her. There was left temporal EEG abnormality, and incisural sclerosis was found at operation.

(4) Experiential Hallucinations—Unclassified

Case 66.—J. Bl. This patient was a 22-year-old man who had had seizures since the age of 2 years. His attack pattern was: (1) abdominal sensation; (2) automatism; (3) experiential hallucination—unclassified type. He stated that, at the end of his attack, he frequently had a "dream" which was always the same. He would find himself in a pool of blood and would be unable to get out of it. He referred to this as a "true dream." There was a well-lateralized left temporal EEG abnormality, and changes in the temporal lobe compatible with birth injury were found at operation.

It is not clear whether the experiential hallucination in this patient was in reality composed of a dream from his past, although this does occasionally happen (*see* Cases 20, 61, and 69). A vivid dream can often be recalled or remembered easily for long periods and as such it may be considered part of an individual's past experience.

It is most unusual for an experiential hallucination to occur at the end of a seizure or as the patient is regaining consciousness (*see also* Case 41). In these patients it is quite possible that the hallucination actually occurred at the onset of the attack before the clouding of awareness and that either the whole event or parts of it are recalled only when the seizure is over. Thus the patient may feel that the hallucination occurred at the end of his seizure.

Case 67.—R. H. This 28-year-old man began to have recurring seizures at age 21. His attacks followed this pattern: (1) a sensation in back of the neck; (2) experiential hallucination—unclassified type; (3) automatism; (4) occasional generalized seizure. He had what he called "a dream" in each attack. These were very varied but usually involved his being in some other place than where he really was, and he would be doing complex things that he could not recall afterwards. He felt that in about half of his attacks he had the "dream" and could remember nothing about it. There was a well localized left temporal EEG disturbance, but no obvious abnormality was found in the left temporal lobe at operation.

Case 68.—B. J. This 29-year-old woman began to have attacks at age 18 with the following pattern: (1) epigastric and cephalic sensations; (2) interpretive illusion; (3) sensation in left hand and body; (4) experiential hallucination—unclassified; (5) automatism. During her attacks, she said, "I think of something in the past," and she referred to these episodes as "flashes." These might consist of a person, an idea or a "memory" which usually ran through her mind "too fast to be recognized or remembered." When asked for specific examples, she remembered a house that she had once visited and on another occasion a little dog tied up in front of a trailer. She recalled his name as "Ginger Boy." When asked if she saw these things, she said that she did not. There was a right Sylvian electrographic abnormality, and incisural sclerosis was found in the right temporal lobe at operation.

Case 69.—B. Su. This 35-year-old woman had her first seizure at age 7. There was a head injury at age 4 to 5 months. The pattern of her attacks was: (1) interpretive illusion—fear; (2) experiential hallucination—unclassified type; (3) automatism; (4) rare generalized seizure. She referred to the hallucinations as "dreams," and said that they sometimes were the same as those she remembered from her childhood. When asked for details, she said that the dreams were "uninteresting," but that most of her recent ones had to do with food or getting food, and seemed to take place in her living room or garden. There was a well localized left temporal EEG disturbance, but at operation no gross abnormality was noted in that region.

(7) Summary of Operative and Clinical Data

In this section we will summarize the foregoing data and follow that with a preliminary discussion under the heading of Generalities.

A. Experiential Responses—Summary

In the maps shown in fig. 7, all the points in the brain which, upon stimulation, resulted in an experiential response, are summarized. It will be immediately evident that the responses fall within the anatomical boundaries of the temporal lobes and that there is a greater number of responses from the right temporal lobe.

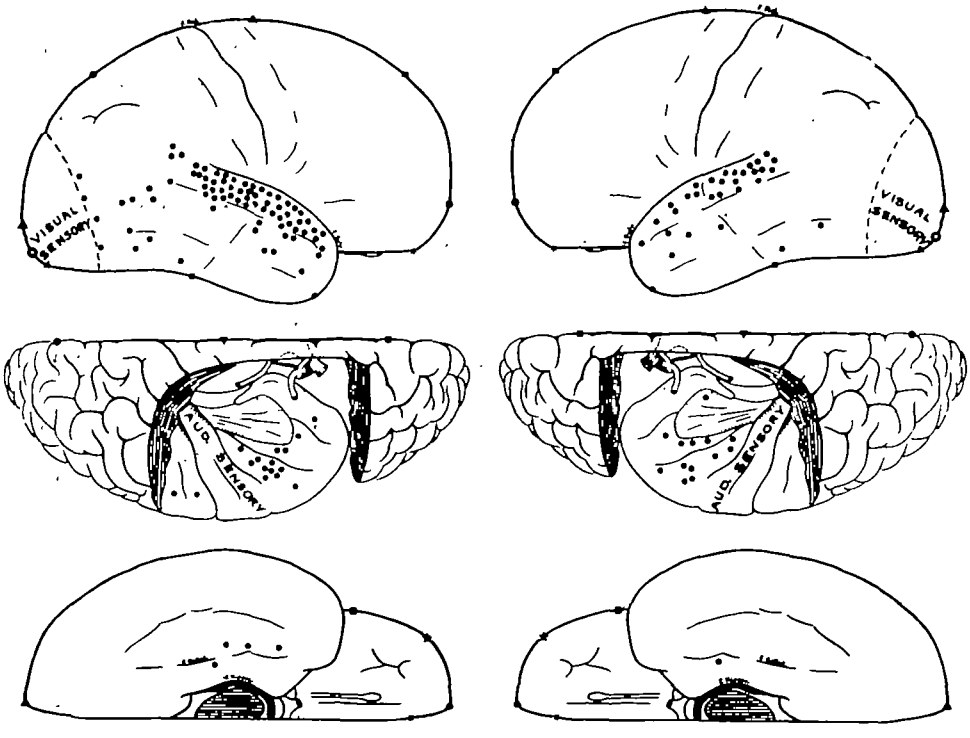


FIG. 7.—Summary maps to indicate where, in the two cerebral hemispheres, *experiential responses* of all types were produced by electrical stimulation.

Most of the responses are located on the lateral and superior surfaces of the first temporal convolution. None were obtained from the anterior transverse temporal gyrus (Heschl) but two occurred within the more posterior transverse temporal gyri of the posterior planum temporale. The few responses noted from the inferior temporal surface are located near its medial border in the cortex of the fusiform and hippocampal gyri. This under-surface was stimulated much less often than the lateral surface and this may account for the lack of responses here, in part. From the evidence we have, at least the medial part of this inferior surface cortex must also be included as part of the interpretive cortex.

Our evidence from stimulation suggests that the anterior transverse temporal gyrus of Heschl is devoted to auditory sensation and the whole of the lateral surface of the occipital lobe (as well as the medial surface) is devoted to visual sensory function in man. The experiential response points are located between these two areas of visual and auditory sensation without encroachment. This sharp change of response on stimulation was born out in Case 2, R. W. Occipital cortex stimulation produced coloured flashes of light and, immediately anterior to this, stimulation produced the figures of robbers with guns.

We have seen the same sudden change in response characteristics from a crude sensation to an experiential response when the stimulating electrode is moved from the primary auditory cortex within the fissure of Sylvius to the adjacent interpretive cortex of the first temporal gyrus. In Case 29, S. Be., an electrode was inserted into the anterior transverse temporal gyrus and the patient reported, "a buzzing." As the electrode was withdrawn, so that it came into the cortex of the first temporal gyrus, he exclaimed, "Someone is calling."

An equally striking delimitation is evident between the temporal speech area and the interpretive area. Fig. 8 shows the posterior speech area as outlined by the procedure of *brain mapping*.[1] Using this method, we have stimulated the speech areas hundreds of times, at least as often as any other portions of the temporal lobe and yet our present summary shows that we have not produced an experiential response that is clearly within the speech area of the left or dominant hemisphere.

[1]This procedure is explained as follows: an electric current applied to the cortex of the speech area has no positive result, since words are not produced. But the current interferes with the use of the area in speaking and so if the patient is being called upon to speak while the electrode is in place he discovers to his great surprise that he has lost the ability to name things. He is aphasic. But words come with a rush when the electrode is lifted. We have used this method as a guide so as to avoid producing aphasia by excision of epileptogenic cortex.

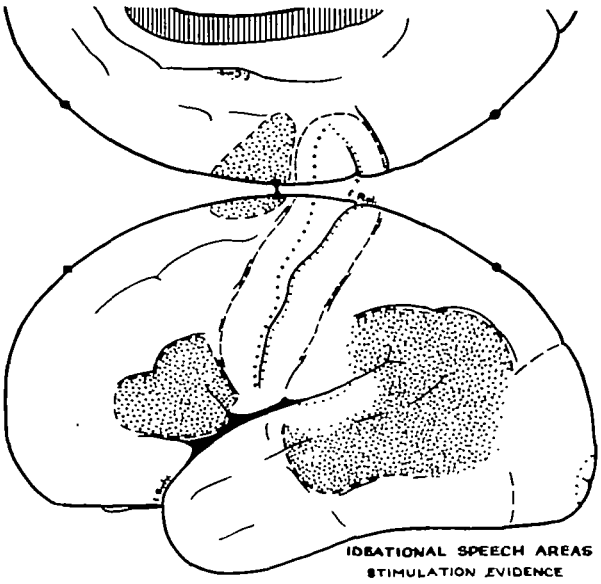


FIG. 8.—Summarizing map of the areas in the dominant hemisphere that are devoted to the ideational elaboration of *speech*. Evidence derived from electrical speech mapping in conscious patients. (*From* Penfield and Roberts, 1959.)

For the purpose of further analysis we have divided the experiential responses into four groups in the same way that the experiential hallucinations were classified in section 6. They are as follows:[1]

(*a*) *Auditory*—experiences with sound but no visual component.

(*b*) *Visual*—scenes, persons or objects.

(*c*) *Combined visual and auditory* experiences.

(*d*) *Unclassified* experiences—for example, a "dream," a "flash-back," or a "memory" without further description.

These separations are not completely accurate. In some cases when the patient said he heard music the surgeon may not have asked whether he could see the source and if he saw people. When he reported seeing something, occasionally no enquiry may have been made as to whether anything was heard. Nevertheless there is a surprisingly consistent

[1]As will be described in the later discussion, somatosensory awareness is a sensation often present, but rarely described. It might have been added to these auditory and visual experiences, also smell, though very rarely.

difference in localization of the activating stimulation points based on these groupings. These summary maps (figs. 9–13) that show the cortical distribution of each of the four types of responses may be explained in advance.

In the legend that accompanies each map, will be found a list of the responses obtained, numbered to correspond to the numbers on the map. The case number of the patient in whom they occurred is given after each group of responses. The number indicated in parentheses after each described response indicates the number of the actual stimulation point used in the case history and as indicated on each individual case stimulation map in Section 5. The response is designated as "familiar," e.g. a familiar voice, when the experience was actually identified, recognized or remembered by the patient either voluntarily or on direct questioning. If the response was not commented upon by the patient, or if he was not questioned about whether he recognized it or not, the word "familiar" is omitted.

This use of "familiar" is not to be confused with the term illusion of familiarity. In many instances, due to the exigencies of the operation, careful inquiry regarding recognition of the response by the patient was not possible. A few of the points numbered on the maps were stimulated only once, but most were re-stimulated several times. Those points which were stimulated more than once and which consistently gave auditory, visual, or combined responses are marked with only one number on the appropriate map. In five instances repeated stimulation at the same point gave an auditory response on one occasion and a visual response on another; these were numbered as points from which combined responses were obtained (*see* legend for fig. 11, responses 1, 3, 4, 18 and 20).

In the discussion of lateralization, a hemisphere is described as dominant when the convolutions devoted to ideational speech are located within it. Speech dominance was determined by electrical interference with speech at operation, or by the post-operative presence or absence of transient aphasic speech difficulty. In more recent years speech dominance was sometimes determined by the intracarotid amytal test (Wada and Rasmussen, 1960).

(*a*) *Auditory Experiential Responses*

A voice, voices, music or a meaningful sound was elicited from 66 different stimulation points in 24 patients. These points are indicated in fig. 9. This was the most frequently encountered type of experiential response.

It will be seen that the cortical points from which auditory responses were obtained are strikingly limited to the lateral and superior surface of

the first temporal convolutions. In the right hemisphere they extend more posteriorly along the lateral aspect of this gyrus than in the left hemisphere. None occurred within the most anterior of the transverse

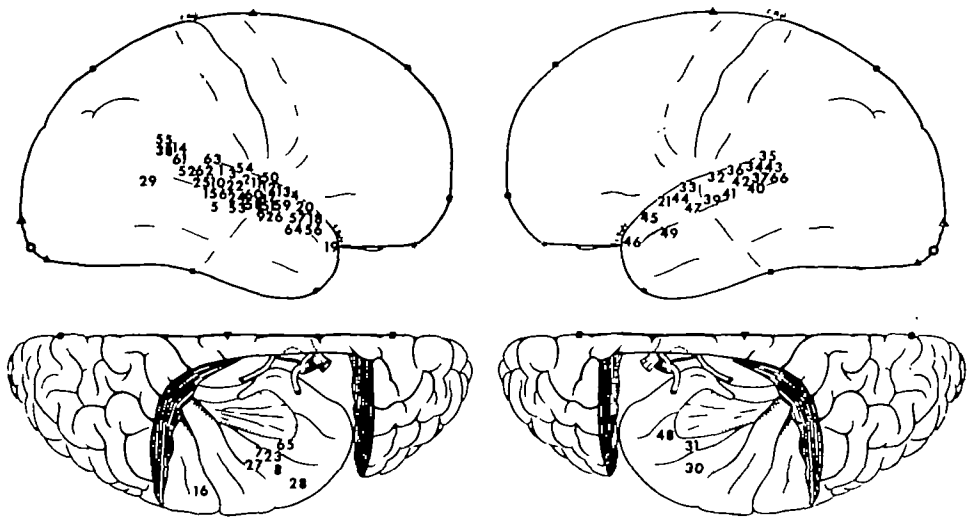


FIG. 9.—AUDITORY EXPERIENTIAL RESPONSES TO STIMULATION. 1. a voice (14); Case 28. 2. voices (14), 3. a voice (15), 4. a familiar voice (17), 5. a familiar voice (21), 6. a voice (23), 7. a voice (24), 8. a voice (25), 9. a voice (28); Case 29. 10. familiar music (15), 11. a voice (16), 12. a familiar voice (17), 13. a familiar voice (18), 14. familiar music (19), 15. voices (23), 16. voices (27); Case 4. 17. familiar music (14), 18. familiar music (17), 19. familiar music (24), 20. familiar music (25); Case 30. 21. familiar music (23); Case 31. 22. familiar voice (16); Case 32. 23. familiar music (23); Case 5. 24. familiar music (Y), 25. sound of feet walking (1); Case 6. 26. familiar voice (14), 27. voices (22); Case 8. 28. music (15); Case 9. 29. voices (14); Case 36. 30. familiar sound (16); Case 35. 31. a voice (16*a*); Case 23. 32. a voice (26), 33. voices (25), 34. voices (27), 35. a voice (28), 36. a voice (33); Case 12. 37. music (12); Case 11. 38. a voice (17*d*); Case 24. 39. familiar voice (14), 40. familiar voices (15), 41. dog barking (17), 42. music (18), 43. a voice (20); Case 13. 44. familiar voice (11), 45. a voice (12), 46. familiar voice (13), 47. familiar voice (14), 48. familiar music (15), 49. a voice (16); Case 14. 50. voices (2), 51. voices (3), 52. voices (5), 53. voices (6), 54 voices (10), 55. voices (11); Case 15. 56. familiar voice (15), 57. familiar voice (16) 58. familiar voice (22); Case 16. 59. music (10); Case 17. 60. familiar voice (30), 61. familiar voice (31), 62. familiar voice (32); Case 3. 63. familiar music (8), 64. familiar music (10), 65. familiar music (D2); Case 10. 66. voices (11); Case 7.

temporal gyri (primary auditory, Heschl) and only one response was obtained posterior to this in the posterior planum temporale.[1]

Forty-two of the responses were produced in the non-dominant hemisphere in 15 patients and 24 in the dominant hemisphere in nine patients (*see* Table V.)

TABLE V.—LATERALIZATION OF EXPERIENTIAL RESPONSES

	Non-dominant	*Dominant*	*Total*
Auditory* (*Audito-experiential*)	42 in 15 pts.	24 in 9 pts.	66 in 24 pts.
Visual* (*Visuo-experiential*)	28 in 12 pts.	10 in 7 pts.	38 in 19 pts.
Combined	13 in 7 pts.	9 in 5 pts.	22 in 12 pts.
Unclassified	8 in 3 pts.	4 in 2 pts.	12 in 5 pts.
Total	91	47	138

*We are not referring to auditory sensory or visual sensory hallucinations. These would be phenomena of a very different order, e.g. a buzzing, humming or hissing sound—flashing moving lights or colours. We refer to auditory experiential and visual experiential hallucinations. It might be preferable to use the terms audito-experiential and visuo-experiential to make this clear.

Experiential responses, in general, tend to occur more often with stimulation of the non-dominant temporal lobe than with stimulation of the dominant temporal lobe. This same trend is apparent in the auditory and visual groups of responses. However, it should be noted that this is only a trend since the difference in the incidence of responses in the two hemispheres is not large enough to be statistically significant.

Among the auditory experiences a voice or voices was the most common response and this was produced from 46 cortical points; music was the next most frequent and was elicited from 17 points; an otherwise meaningful sound was produced at 3 points. There was no topographical distinction among points giving voice, music or sound responses, nor was there any lateralization of voices as opposed to the other auditory experiences. Thirty-one out of the 46, or roughly two-thirds, were definitely recognized by the patient and can be thus considered as a part of his past experience. The remainder were either not commented upon, or unfamiliar to the patient, or no attempt was made to determine whether the patient recognized them or not.

[1]Thus it can be said that auditory experiential responses result from stimulation within what has been referred to as the secondary auditory areas in man. Elementary auditory sensations may sometimes be produced on stimulation here, as well as in the primary auditory sensory area (*see* Penfield and Rasmussen, 1950, pp. 149–154).

(b) Visual Experiential Responses

A person or group of people, a scene or a recognizable object was seen upon stimulation at 38 different points in 19 patients. These points are mapped in fig. 10. Twenty-eight of the responses were produced in the non-dominant hemisphere in 12 patients and 10 in the dominant hemisphere in 7 patients (Table V).

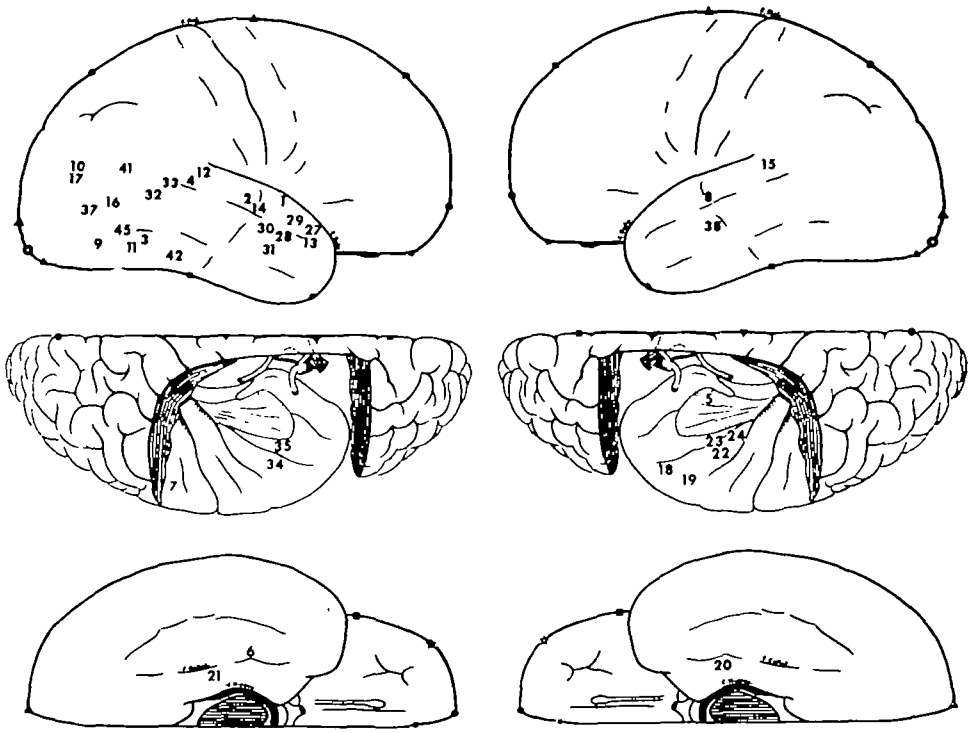


FIG. 10.—VISUAL EXPERIENTIAL RESPONSES TO STIMULATION. 1. familiar street scene (16), 2. a person (18), 3. a person (26), 4. an object (27); Case 29. 5. familiar scene (11); Case 18. 6. a face in a picture (26), 7. people (28); Case 4. 8. familiar man grabbing a stick (X); Case 19. 9. a friend (1*b*), 10. familiar machine (1*c*), 11. familiar nurses (2*b*); Case 32. 12. familiar scene (J), 13. people (K), 14. a scene (M); Case 20. 15. a man fighting (17); Case 34. 16. a woman (1), 17. steps with people on them (2); Case 21. 18. scene with people (15*b*), 19. a scene (15*e*), 20. a scene (18); Case 22. 21. familiar room (E); Case 36. 22. people (18); Case 35. 23. a man (16*c*), 24. a man smoking (16*f*); Case 23. 27. a scene (15), 28. a person (18), 29. people and her mother in the living room (22), 30. a person (24), 31. an object (D); Case 25. 32. a man (14), 33. familiar man (15); Case 24. 34. an object (19); Case 26. 35. his mother at home (A); Case 27. 37. familiar menacing man (16); Case 15. 38. herself in childbirth (N); Case 1. 41. robbers with guns (22), 42. robbers (23), 45. his brother at home in their yard (28); Case 3.

Like the auditory responses and experiential responses in general, they are more commonly seen from stimulation in the non-dominant hemisphere, but the difference is not so striking when one compares the numbers of patients involved on each side.

In the right hemisphere the points are scattered throughout the temporal lobe and into its most posterior extent covering the area that is devoted to speech on the dominant side. On the left side there are only three responses on the lateral surface in the first and second temporal convolutions. The remainder are situated on the superior surface of the first temporal convolution. Comparing figs. 9 and 10, it is obvious that there is considerable overlap between the zones of auditory and visual responses on both sides. In the right hemisphere there is a considerable collection of points in the posterior temporal region and a few of them lie quite close to the zone of transition between the temporal and the secondary visual cortex (Brodmann's area 19) that is probably concerned with visual sensory elaboration (Penfield and Rasmussen, 1950).

Action, which the patient seemed to see, constituted the second most frequently encountered type of experiential response. A person or people doing something were most often seen, 23 instances; scenes were reported ten times and objects five times. There was no topographical correlation between the sites of stimulation for these three kinds of visual response and specific regions of the cortex. Fourteen of the responses were recognized by the patient as being part of his past experience.

(*c*) *Combined Visual and Auditory Experiential Responses*

Scenes with appropriate sounds or a person or people talking or singing were reproduced from 22 different points in 12 patients. These points are mapped in fig. 11. 13 of the responses were produced in the non-dominant hemisphere in 7 patients and 9 in the dominant hemisphere in 5 patients (Table V). Unlike the experiential responses in general, these responses occurred with about equal frequency on the two sides in these 40 patients. These stimulation points were confined almost exclusively to the first temporal convolutions; thus like the auditory experiential responses they are associated with the so-called secondary auditory cortical areas. Combined responses were third in order of frequency among the four subgroups. In this kind of response most of the experiences were concerned with seeing a person or people and hearing what they were saying. Eighteen of these 22 responses consisted of an experience which the patient could easily recognize and identify as having been part of a previous experience.

(*d*) *Unclassified Experiential Responses*

These were experiences that were described vaguely or in such terms that classification was not possible. Patients refer to this kind of experience as "a thought," "a memory," "flash-back," or they may say, "that

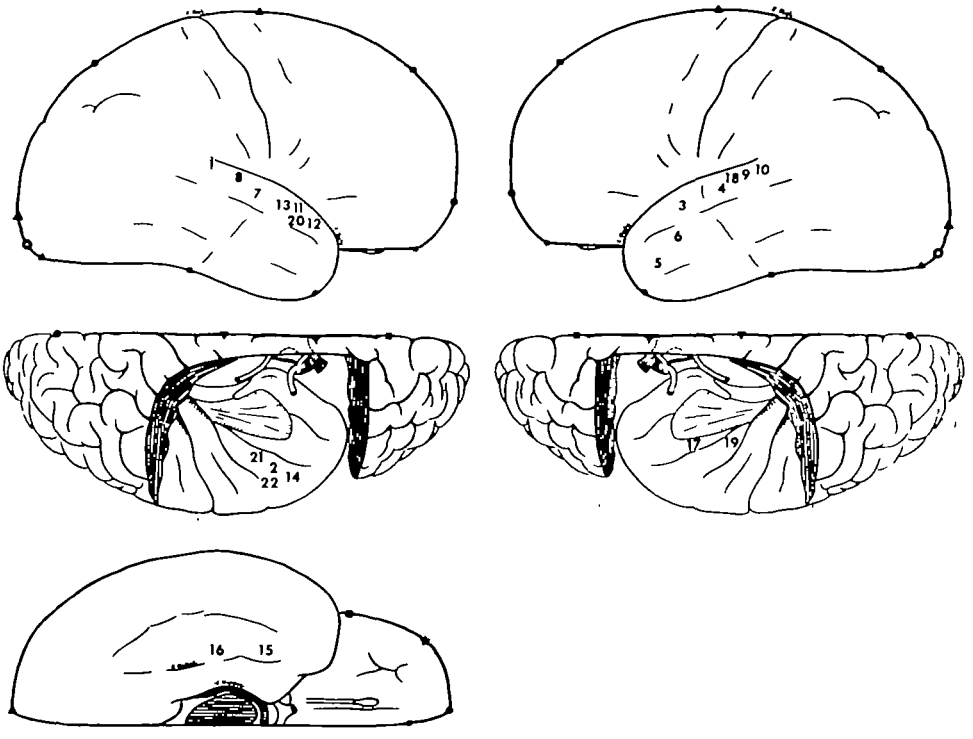


FIG. 11.—COMBINED AUDITORY AND VISUAL EXPERIENTIAL RESPONSES TO STIMULATION. 1. several responses—someone playing a piano, a voice, a familiar song (19), 2. a person talking (29); Case 29. 3. a familiar gymnasium with sounds, voices (7), 4. familiar voices, scene at home (5); Case 2. 5. a man talking (19), 6. her mother talking, familiar scene with mother talking (20); Case 31. 7. mother and father singing, brother talking (3), 8. mother talking (4); Case 32. 9. two boys and a song (19), 10. men singing (14); Case 34. 11. familiar woman calling (11), 12. voices along a familiar river (13), 13. voices from familiar buildings (12), 14. man talking in familiar office (17*e*), 15. familiar scene in a play, people talking (16), 16. a familiar girl talking (18); Case 36. 17. a familiar nurse talking (17); Case 35. 18. familiar scene, voices (8); Case 13. 19. familiar doctor talking (17); Case 14. 20. familiar scene, familiar scene, familiar song (14); Case 37. 21. patient's cousins laughing (7); Case 38. 22. her son speaking (17); Case 33.

reminded me of something." They are indicated in fig. 12. 12 responses were elicited in 5 patients. 8 were from the non-dominant hemisphere in 3 patients and 4 from the dominant hemisphere in 2 patients (Table V). The points giving these responses were distributed in the first and second temporal convolutions. There is no significant lateralization.

Music.—We were surprised at the number of times electrical stimulation has caused the patient to hear music. It was produced from 17 different points in 11 cases (*see* fig. 13). Sometimes it was an orchestra, at other

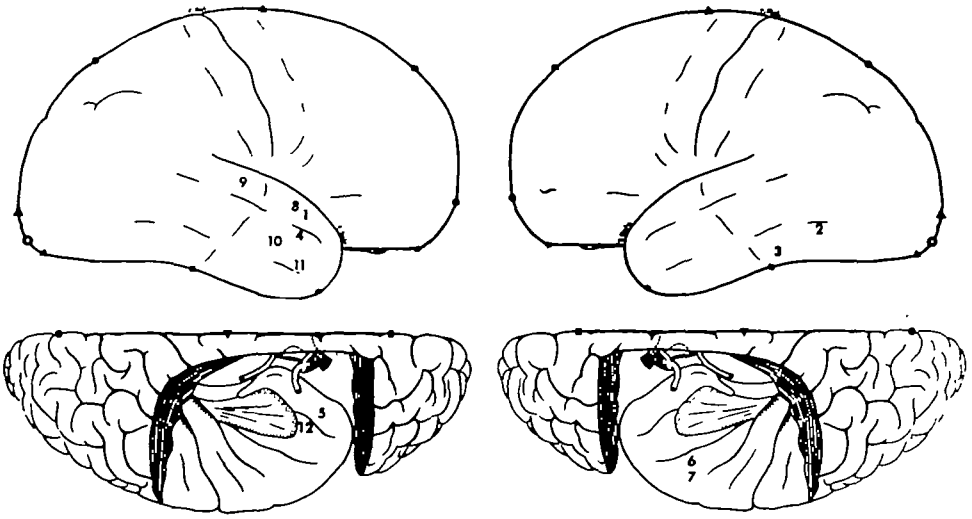


FIG. 12.—UNCLASSIFIED RESPONSES TO STIMULATION. 1. thought of a song (18); Case 30. 2. a thought from the past (13), 3. a familiar thought (15); Case 34. 4. a familiar memory (15), 5. a familiar memory (19); Case 36. 6. a dream (17), 7. a dream (18); Case 39. 8. a flashback (12), 9. a flashback (13), 10. memory of a football game (14), 11. a flashback (15), 12. a flashback (16); Case 40.

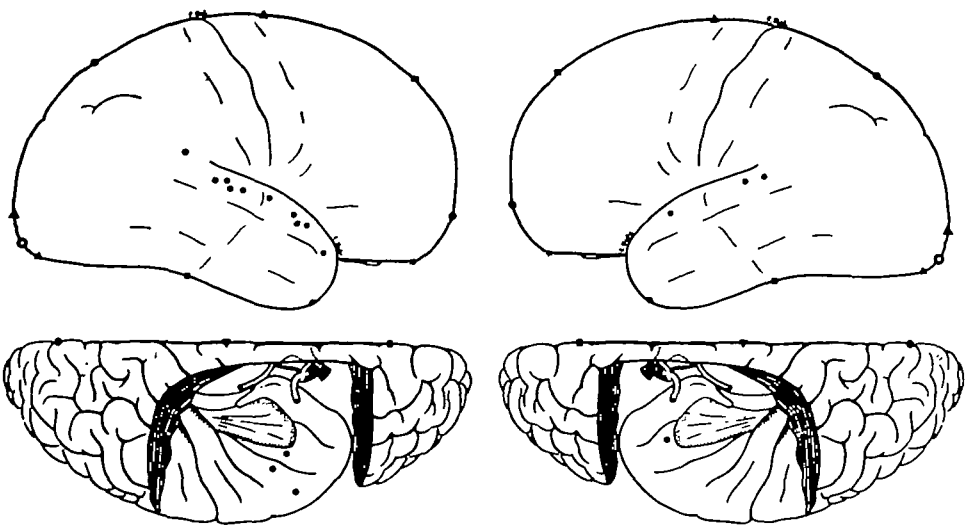


FIG. 13.—Summary maps to indicate those points which, upon stimulation, caused the patient to hear *music*.

times voices singing, or a piano playing or a choir. Several times it was said to be a radio theme song. The localization for production of music is in the superior temporal convolution either the lateral or the superior surface. This is not so far from the localization in the tip of the temporal lobe suggested by some reported clinical cases of what has been called *musicogenic epilepsy.*

B. Ictal Experiential Hallucinations—Summary

Experiential hallucinations occurred as part of the patient's epileptic attack in 53 of our series of 520 patients with temporal lobe seizures (10 per cent). The case histories of 1,132 patients suffering from focal epilepsy, and who came to operation, were reviewed. But no example of an experiential hallucination was found in a patient whose focus of epileptic discharge was outside the temporal regions.

A diagnosis of temporal lobe epilepsy was made in each of the 53 patients who had such experiential attacks. The localization was confirmed by electroencephalography in all but 6 who were studied before the introduction of this diagnostic technique. In 34 there was a well-lateralized electrographic focus in one or other temporal fossa. In 13 cases bilateral abnormality, maximum on one side, was reported. This is a somewhat higher percentage of bilateral abnormality than was present in a control series of temporal lobe cases without experiential hallucinations in their seizures.

When the attack patterns of these patients are reviewed, it is seen that the initial phenomenon was an experiential hallucination in 16, epigastric sensation in 14, body sensation in 6, interpretive illusion in 3, thoracic sensation in 3, cephalic sensation in 3 and so on. In other words the seizures began with a manifestation of temporal lobe discharge in all cases.

The following features may be noted: It is not rare for these patients to have an abortive attack that may consist of the experiential hallucination alone. The discharging focus was located in the non-dominant hemisphere in 24 cases and in the dominant hemisphere in 29 cases. Considered together these experiential hallucinations have no lateralizing value in a seizure pattern, but when they are subdivided into four groups, as were the experiential responses, it is seen that the visual hallucinations occur more than twice as often in patients with a focus in the non-dominant temporal lobe[1] (*see* Table VI).

[1]This can only be considered a trend since the number of cases is too small for the difference to be statistically significant.

TABLE VI.—LATERALIZATION OF SEIZURE FOCUS IN 53 PATIENTS WITH EXPERIENTIAL HALLUCINATIONS IN THEIR SEIZURE PATTERN

	Non-dominant	*Dominant*	*Total*
1. Auditory (*Audito-experiential*)	4	8	12
2. Visual (*Visuo-experiential*)	15	6	21
3. Combined	3	8	11
4. Unclassified	2	7	9
Total	24	29	53

Our impression that visual experiential hallucinations are more often associated with abnormality in the non-dominant temporal lobe is supported by the findings in the literature reviewed in section 6. It will be recalled that we found 41 cases of temporal lobe seizures with complex visual hallucinations; 29 had right temporal lesions and 12 had left temporal lesions.

Auditory hallucinations were encountered somewhat more often with an epileptogenic focus in the dominant hemisphere but the number of cases is too small for this to be significant. Data in the literature on complex auditory hallucinations and temporal lobe lesions are too scanty to be of any lateralizing value.

If the data on lateralization of the visual hallucinations are really indicative of a trend for their preferential occurrence with lesions in the non-dominant temporal lobe, (and a similar relationship is also suggested from the data on experiential responses in Section 7) what does this mean? An explanation can be found when one considers the interpretive cortex as outlined by stimulation (*see* fig. 14). In the left hemisphere the

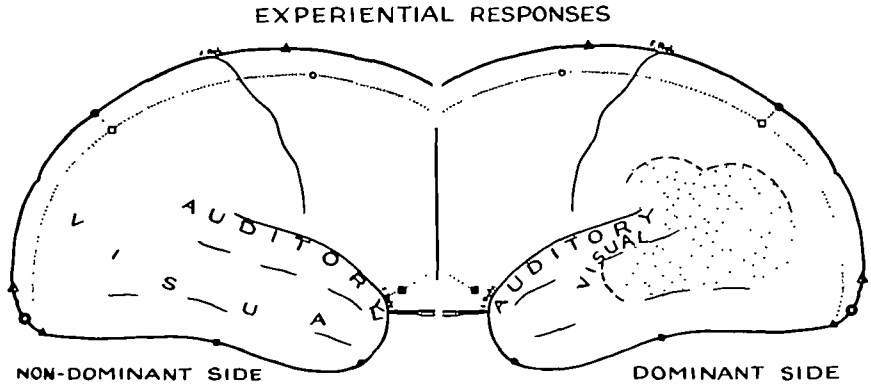


FIG. 14.—Experiential responses to stimulation, auditory and visual, shown for the lateral surfaces of both hemispheres. The temporal speech area (*see* fig. 8) is stippled on the left hemisphere. The number of experiential responses which are visual in character is much greater on the non-dominant side and nearer the occpital cortex. No experiential responses followed stimulation of the speech area.

use of the cortex for speech seems to have left only a smaller area for visual experiential representation on the lateral surface at least, whereas in the right hemisphere visual experiential representation is quite extensive.

At operation, 24, or 45 per cent of this group of 53 cases with experiential hallucinations, gave experiential responses to stimulation. Their case histories were included with the presentation of the 40 patients already discussed. In 16 of the 24 patients the content of their experiential hallucinations and their experiential responses (some of them) at operation was in general identical, 67 per cent. In the other 8 patients there was no obvious relation between the two (Table VII).

TABLE VII.—INCIDENCE OF EXPERIENTIAL RESPONSES IN 53 PATIENTS WITH EXPERIENTIAL HALLUCINATIONS AND THEIR SIMILARITY

	Experiential hallucinations	*Experiential responses*	*Same content*
1. Auditory	12	5	4
2. Visual	21	11	6
3. Combined	11	3	1
4. Unclassified	9	5	5
Total	53	24	16

Rodin *et al.* (1955) believe that the experiential hallucinations in seizure patterns are closely connected with the patient's wishes, anxieties or neurotic conflicts, even when the patient had a temporal lobe neoplasm. In four or five of our patients there has been an obvious association between their hallucinations and neurotic conflicts or anxieties, but in the remainder of the cases this has not been apparent. It would be very difficult to imagine that some of the trivial incidents recalled during stimulation or epileptic discharge could have any possible emotional significance to the patient even if one is acutely aware of this possibility.

Rodin *et al.* (1955) mention several possible explanations for the observation that the same experience will occur again and again as part of a seizure pattern:

"It may be a haphazard occurrence because this particular engram happens to be stored in the particular spot where the focus of seizure activity is."

The fact that it is still possible to remember events activated by the electrode from a certain cortical site even after excision of that particular area of cortex is a strong argument against this possibility.

They also point out that Pötzl suggested that at the onset of a seizure the cortex is hypersensitive and visual or auditory experiences at that time may leave a deeper imprint and thus be repeated in future seizures as hallucinatory phenomena.

Understandably, there is not much information available concerning this point, but there are a few cases reported in the literature that indicate that this may happen, at least in some patients. The seizure pattern of Case 49 may be recalled as an example. In these patients the experience that forms part of the habitual seizure pattern consists of an event intimately associated with the onset of their first or some subsequent attack.

Indeed, Jackson (1931*b*, Selected Writings) stated that Falret and Trousseau believed that the hallucination or "remembrance" was often composed of an event that had either caused or accompanied an early attack. He quoted Falret: "These ideas, these remembrances, these false sensations which differ singularly in different patients, are generally reproduced with remarkable uniformity in the same patient at each new attack. It is curious to add that very often this remembrance, this idea, this image is the reproduction of the idea or sensation which provoked in the patient the first epileptic attack."

However, this relationship would appear to be exceptional, and in several patients in our series the events recalled as an ictal experiential hallucination clearly occurred many years before their first epileptic attack. Case 60, P. C., illustrates this. His ictal hallucinations were composed of events derived from his past experience many years before his first seizure.

C. Generalities

It is obvious that the epileptic discharge in a minor seizure may actually activate the same physiological mechanism, by its irritation of temporal cortex, as is activated by an electrical stimulus. The reason we have consistently tried to reproduce electrically the minor seizure of every case is, of course, that such reproduction serves as a guide to the place of origin of the attack, and a guide to discriminating excision and cure.

The description of seizure-activated mental states is apt to be less reliable than the states produced in the operating room since, in the latter case, it is possible to control the reports critically. The phenomena can be repeated and questions asked. Also, and this is important, the operator can warn the patient of stimulation and ask for immediate report. He can, and does at some time in every case, warn when he does not stimulate. He can also stimulate at long intervals with no warning, thus verifying previous positives or questionable results. Because of these controls, and because the result of every positive response is dictated at once in each succeeding case by the same observer, the surgeon, these observations may be accepted as reasonably accurate.

The reader may have wondered why, in most of the 40 operative cases reported, the number of positive responses began at 10, 12 or somewhere in the teens. This is explained by the fact that the surgeon always

explores the sensory and motor areas in the cortex above the fissure of Sylvius before stimulating the temporal lobe. The first positive response, for example a sensation in the thumb, is marked quickly by a small paper ticket bearing the number 1, and the response is dictated. The second positive response is marked 2, and so on until the position of the central fissure of Rolando is clearly located and the minimum threshold of stimulus has been determined. The strength of stimulus must be below a certain threshold value to avoid the danger of producing a seizure.

Thus the number 10 or 12 has usually been reached by the time exploration of the temporal cortex begins. There are many time-consuming operative tasks to be carried out. But the surgeon can return to the stimulation exploration with the guidance of the little numbered tickets whenever opportunity presents. With each dictation of a positive result the secretary who sits in the observation stand behind a glass wall makes a note of the time. Thus time intervals are easily enough determined.

Record of experience.—The conclusion is inescapable that some, if not all, of these evoked responses represent activation of a neural mechanism that keeps the record of current experience. There is activation too of the emotional tone or feeling that belonged to the original experience. The responses have that basic element of reference to the past that one associates with memory. But their vividness or wealth of detail and the sense of immediacy that goes with them serves to set them apart from the ordinary process of recollection which rarely displays such qualities. Thus with stimulation at point 11, J. V., Case 15, said, "There they go, yelling at me, stop them!"

D. F., Case 5, upon stimulation at point 23 said, "I hear some music," and she hummed a tune. She said it was not a question of being made to think about it, but that she could actually hear it, and hear it so clearly that she could accompany the orchestra with her humming. With stimulation at point 14, T. S., Case 37, said, "I feel as though I am going into an attack." When asked "why," he said, "That music from the stage hit, Guys and Dolls." He was asked which song it was, and he replied that he did not remember. When asked if he had just thought of the music, he said it was more like it was when "I was listening to it." He said it was an orchestration. When he was asked if he seemed to be there or was remembering it, he said, "I seemed to be there."

Although there is a strong sense of immediacy in these experiences, none of the patients has ever confused the hallucination with reality except perhaps for a moment. All have retained awareness of the operating room and the events occurring in it, even during the time of an experiential response. For example, G. L., Case 22, at point 15b said, "I see the people in this world and in that world too at the same time." R. B., Case 2, at point 5 said, "People's voices," and when asked,

"Relatives, my mother." He was asked if he also realized that he was in the operating room, he said, "Yes," and tried to explain by saying that it was like a dream.

In general it can be said that in those patients in whom responses were elicited from a number of separate points in one area that there is a definite similarity in content or relationship among the successive experiences obtained, and this is apt to be preserved until one stimulates a point that is in a distant cortical area. For example, R. R.'s first response, Case 14, concerned a conversation in Johannesburg. The next three responses occurred from the same general area in the left first temporal convolution and were related to the same conversation. However, when stimulation was then carried out at a depth of 2 cm. in a fissure of the second temporal convolution, point 15, the experience abruptly changed to that of hearing a song. Later when stimulation was again performed at a depth of 4 cm. in the area of the first responses in the first temporal convolution, point 17, the experience once more concerned a conversation in Johannesburg.

As another example, when points 22 through 28 were stimulated in patient R. W., Case 3, he saw robbers with guns and his brother aiming an air rifle at him. The menacing robbers were like those he had seen in picture books. This must be repetition of a fantasy or an earlier dream. He saw them regularly in his ictal hallucinations. The brother aiming the air rifle was probably a real event, as both patient and mother testified. These were purely visual responses of related content and all resulting from activation of cortex just in front of the temporo-occipital transition area. Then, when the electrode was moved the long distance across the cortex to the first temporal convolution, and points 30, 31 and 32 were stimulated, purely auditory responses resulted. Each of these responses consisted of hearing his mother talking on the telephone—to his aunt at 30, and the same conversation at 31, and to his brother at 32.

Speed of re-enactment.—At times it has been possible to establish that if stimulation is maintained for a time, the action or the normal course of events in an experience progresses at a normal rate and ceases upon withdrawal of the stimulus. In patient N. C., Case 31, stimulation at point 23 on the left first temporal convolution produced music each time the stimulus was applied and the orchestra continued playing as long as stimulation was continued. Then to verify the patient's responses, the operator applied the electrode for a few seconds and as he withdrew it he said: "You didn't notice anything did you?" She replied, "Yes, I was trying to identify the song." When asked if she would like to have the stimulus tried again, she said, "Yes." The stimulus was applied and kept in place. After a time she began to hum and she hummed an air quite accurately, and then she said, "It is the War March of the Priests."

She said she had the "Hallelujah Chorus" on a gramophone disc at home and that this music was on the other side of it.

She had hummed the air at what seemed to us a normal tempo. The electrode was clearly activating a neuronal record which she could not activate herself by any voluntary effort. She was able to recognize it, however.

In the case of patient M. N., Case 11, stimulation at point 12 produced music which continued until the electrode was removed. Occasionally it has been noted that an experience outlasts the period of stimulation.[1] In patient J. V., Case 15, stimulation at point 2 caused her to say, "I hear a lot of people shouting at me." This was repeated three times, each stimulation not lasting more than 2 seconds, but the voices lasted 8 seconds, 7 seconds and 14 seconds beyond the three stimulations.

On the other hand, it is sometimes evident that the experience stops during stimulation, although this is rare. Patient S. Be., Case 29, saw a person, and an object when the electrode was applied at points 26 and 27 respectively. On each occasion the operator noted that the evoked visual scene seemed to disappear before the end of the stimulation.

Parameters of stimulation.—There is very little information available concerning the effect of changing the stimulus parameters on the evocation of experiential responses. Bickford *et al.* (1958) studied the parameters of stimulation in one patient who had experiential responses on stimulation (*see* discussion in Section 8). They found that the voltage necessary for the response was very constant over a three-day period of observation and that the threshold increased with increasing stimulus frequencies. In their patient the response could not be produced at frequencies below 10 per second and about 20 per second appeared optimal. Frequencies of 100 per second or more were not effective in eliciting the response. With increasing pulse duration lower voltages were required.

It is usually the case that little time can be spared for such analyses during an operation, when the occasion does present itself. In Case 7, S. H., some observations were made with variations in the frequency of stimulation. The response studied (voices, a group of women talking) was not a very good example but, in this patient, frequencies of 40–60 per second seemed optimum for the response, and as in Bickford's patient it was not obtained with a stimulus frequency of 100 per second.

Cortical facilitation and inhibition.—This subject was studied earlier for the sensory and motor cortex of man (Penfield and Welch, 1949). The conditioning of the human cortex (by previous stimulation and previous activity) for subsequent stimulations seems to follow the same principles

[1]In such cases the stimulus is doubtless followed by after-discharge, a fact that is easily demonstrated when recording electrodes are in place for an electrocorticogram.

that Sherrington and Graham Brown demonstrated in the motor cortex of anthropoids and monkeys. This is probably most important in the case of the interpretive cortex.

Ordinarily, repeating the stimulus at a cortical point that has given an experiential response results in repetition of the same response each time, provided the interval between stimulations is not too short and not too long. However, under certain conditions of stimulation it is possible to observe an instability of the experiential response. Thus examples of changes in experiential responses with different conditions of stimulation will be given in the following paragraphs.

The sequence of stimulations at point 5 in patient R. B., Case 2, is a good example of what may be considered *primary facilitation.* Only after six stimulations, repeated at the same point one after the other, did the experience develop sufficiently so that he was able to hear the voices clearly. Patient R. L., Case 8, when stimulation was carried out at point 14 said, "It sounded like a voice saying words, but it was so faint I couldn't get it." Point 14 was again stimulated just after the first stimulation. She said, "It sounded like a voice saying, 'Jimmy, Jimmy, Jimmy.' " When asked, she said it was her husband's name, and that was what she called him.

Extinction, which may be the result of a second stimulation occurring too soon after the first, may be illustrated by the responses to two successive stimulations at point 17 in patient G. F., Case 33. With the first stimulus she said, "I just heard one of my children speaking." She also heard the noises in her neighbourhood at the same time. The stimulus was repeated without any warning and she said she could hear the neighbourhood noises but not her child's voice. This second stimulus might also have activated a different strip of time, although this is not usually the case. Extinction may be said to have occurred also in the case of patient S. Be., Case 29. With stimulation at point 19 he heard the same song on several occasions. Stimulation just beside point 19 also produced the song, but when this was followed at once by stimulation again at point 19 there was no response at all.

Repeated stimulation at a cortical site may, exceptionally, give rise to several apparently unrelated experiential responses. The sequence of responses from point 7 in patient R. B., Case 2, will illustrate this. Footsteps, company in the room, like being in a gymnasium, a lady talking to a child at the seashore—these are the successive responses, and there would seem to be no connexion between them. Patient A. P., Case 13, had a memory of himself at age 10 at school upon stimulation of point 8. When this same site was re-stimulated nineteen minutes later, he heard voices but was not able to understand them. This is quite different from the usual sequence of responses as seen in patient M. N.,

Case 11, where 5 successive stimulations of point 12 over a period of about forty-five minutes produced music each time. It is not perfectly clear whether this was the same music or not.

From these bits of evidence it is apparent that the experiential responses have many neuronal properties in common with better understood sensorimotor mechanisms.

It is often evident that each stimulation leaves behind a facilitating influence so that the same response follows each stimulation and this facilitation may cause the same response to follow stimulation at one to three centimetres distance. This is illustrated by Case 5, D. F. She heard the same song played by an orchestra and beginning at the same place in the music when a certain point was stimulated more than ten times. Fifteen minutes elapsed between the first stimulation and the second which was carried out without warning her. There were no other experiential responses in this case. But the same music was produced at three points quite near the original spot 23. *See also* Case 15, J. V.

(8) Discussion and Conclusions

It is clear that the recall of past experience by local epileptic discharge and by electrical stimulation depends on one and the same brain mechanism. Excitation of grey matter, in the area which we may call interpretive cortex, activates the mechanism. Excitation elsewhere in the cerebral cortex does not produce this result.

All of these patients were subject to temporal lobe epilepsy which did, no doubt, make response from the cortex easier to elicit. This is to be expected since localized epileptic discharge renders the motor cortex of man more easily stimulable, and sensory cortex as well. This increase in stimulability (decrease in threshold) does not mean that the epileptic process is responsible for the nature of the response. It is clear enough that we are activating a normal mechanism of the brain, and after this revision of our material, we should try to understand how the mechanism is employed in normal living. How can we convert these clinical findings into physiological evidence?

There is some evidence of what might be called a *classification* of related experiences, and evidence that one experiential response may *condition* the cortex so that the nature of subsequent responses is influenced by it. Or it may be that all the responses are conditioned by a pre-existing influence. Stimulation in the interpretive areas of cortex, like that in motor and sensory areas, is subject to facilitation, and probably to extinction or alteration by preceding stimulation at that point, and by stimulation at more distant points. This was discussed at the close of the preceding section and in greater detail in the Sherrington Lecture (Penfield, 1958*b*).

That an experiential response at point B is modified by the response which had been obtained previously at point A nearby is an assumption derived also from the fact that when successive responses are not identical, there is still apt to be a remarkable similarity, as though they had been somehow made available through a selective influence. For example, the patient M. M., Case 35, heard someone calling in the different successive experiences which were elicited from the same and also from scattered points.

Evidence that the recording of present experience activates previous similar experiences in what seems to be a process of *classification* is suggested by the case of E. C., Case 19. In this case each attack began with recall of a boyhood experience, that of "grabbing" a stick from the mouth of a dog and throwing it. These experiential attacks, which occasionally ended in a generalized seizure, were precipitated by a number of varied experiences that were alike in one thing; snatching was a prominent feature—for example, on one occasion, it was someone snatching a rifle away from a cadet on parade, on another a man snatching his hat from the hat-check girl.

Perhaps we should point out that precipitation of seizures by means of a specific evoking afferent stimulus is well known to experienced clinicians. For example, attacks which begin with hand tingling may be, in some cases, precipitated by touching that hand, and visual attacks may be precipitated by lights. This is sensory precipitation. Thus, it is assumed that the arrival of a burst of electrical potentials at the corresponding area of cortex serves in some cases to precipitate the local discharge, and because of this an attack follows immediately. There is also clinical evidence of what might be called *psychical precipitation.*

Precipitation in the case of E. C. suggests that each new experience of "grabbing" caused electrical potentials to pass to the ganglionic record of a previous similar experience. The new experience was being recorded in a classified file for "grabbing." One may assume then that the electrical potentials were coming into relation with the records of previous similar experiences. In this case, the accompanying circumstances of the rifle-grabbing and hat-snatching were entirely different. But the abstract consideration of snatching provided an abiding link, a cross index in the catalogue, that must have been forming and which was directly connected with the superior temporal convolution. How such neuronal classification is carried out we may not even surmise. But the findings suggest that it is carried out.

When, in the case of E. C., stimulation of the surface of the superior convolution of the left temporal lobe was carried out at operation, an experience was evidently reactivated that was similar to that of his habitual attack, for the patient called out to the surgeon suddenly, "There he is!" Then he continued in great agitation, "It was like a spell. He

was doing that thing, grabbing something from somebody. It was somebody else doing the grabbing . . . that was like an attack, doing that thing."

When the stimulation was repeated at the same point, for verification ten minutes later and without warning him, he exclaimed, "There it is." Unfortunately the electrode was held in place a little too long, and he went suddenly into a major convulsive seizure.

Local epileptic irritation seems to create permanence of a particular facilitation (lower threshold) so that in time any increase of local discharge or the application of an electrode sets off the same experiential response time after time.

An example of this and an important confirmation of the reproduction of past experience by electrical stimulation of the temporal lobe has been published recently by Bickford *et al.* (1958) at the Mayo Foundation. Electrodes were implanted into the left temporal lobe of an 11-year-old boy with seizures, and upon stimulation of a point on the superior surface of the first temporal convolution, the patient reported, "I can hear voices hollering," also, "I can hear many voices hollering for me across the street. They want me to come and play. It is somewhere near home. I think there are five or six people. I can hear them but can't see anything." This same experience was reproduced by electrical stimulation on 62 occasions!

It is clear that there must be in the cortex a most important mechanism of *inhibition* associated with and protecting the activation and facilitation. The electrode applied to the cortex must bring electric current into contact with many possibly responsive neurone circuits. But the result is only the activation of one previous strip of experience, not two or three or more which would result in confusion. Subsequent stimulation at approximately the same point may produce a different scene in a different time but again only one, not two.

The points from which stimulation produced experiences which were chiefly auditory have a clear tendency to appear in the neighbourhood of the auditory sensory cortex but never in it. That is, they appear on the superior temporal convolution of one side or the other. To our surprise, they are almost exclusively there, but they never seem to fall on the anterior transverse temporal gyrus of Heschl (figs. 7 and 9). Stimulation there produces an auditory sensory response such as buzzing, whistling, etc. Withdrawal of the electrode tip from it into the neighbouring cortex has given a sudden change to a phenomenon of a different order such as someone speaking.

The points associated with experiences that are largely visual tend to be located in the posterior temporal cortex near the visual sensory area of

the occipital lobe, at least on the right side (fig. 10). It is evident, and most significant, that stimulation, within the large speech area of the temporal lobe on the dominant side, never produced visual experiential responses, although such responses are most numerous in that area on the non-dominant side (figs. 10 and 8).

It seems to follow then that large areas of the temporal cortex, exclusive of the auditory sensory area, must be functionally undeclared at birth. It is well known that the posterior portion of one temporal cortex comes to be devoted to the function of speech at the time that the child starts to learn to talk. This is usually in the left hemisphere, but occasionally it is in the right. And, of course, injury in the early years of childhood may cause it to shift and be formed anew on the other side.

On the opposite side (non-dominant) where there is no speech cortex, the area that could have been devoted to speech is devoted instead to the purposes of the interpretive cortex, and stimulation in that area is apt to produce recall of visual experiences particularly (fig. 14). Stimulation here on the non-dominant side also produces visual interpretive illusions, i.e. changes in the appearance of things—as though coming nearer or going farther away, and changes in apparent speed of moving things. Illusions of familiarity and of strangeness are also almost always produced by discharge or stimulation on the non-dominant side (Mullan and Penfield, 1959).

Thus the map of the area of temporal cortex that produces interpretive signals also shows that the temporal speech cortex is not utilized for the purpose of present interpretation (fig. 1). It may be pointed out that the anterior two-thirds of the superior temporal convolution does not form a portion of the speech cortex on the dominant side. (The anterior two-thirds includes the anterior transverse temporal gyrus of Heschl and all of the convolution in front of that.) The cortex posterior to Heschl's area extending backward and upward into the supramarginal gyrus may perhaps form part of the area devoted to the ideational aspects of speech (figs. 7 and 8).

Let us now reconsider these findings. The psychical phenomena that are produced by activations within the areas of interpretive cortex are of two types: (*a*) altered interpretation of the present; and (*b*) a state of mind. You may call the latter an experiential hallucination if you like. The true nature of such hallucinations becomes quite clear when the records of the stimulation responses are studied. They are reproductions of past experience. In the seizures this is not always evident, since the hallucination may be brief and the patient, following the fit, in no condition to discuss the matter. The remembrance of the original experience and its record may have been modified by dreams and by re-experiencing

in the attacks. But at operation it is usually quite clear that the evoked experiential response is a random reproduction of whatever composed the stream of consciousness during some interval of the patient's past waking life.

It may have been a time of listening to music, a time of looking in at the door of a dance hall, a time of imagining the action of robbers from a comic strip, a time of waking from a vivid dream, a time of laughing conversation with friends, a time of listening to a little son to make sure he was safe, a time of watching illuminated signs, a time of lying in the delivery room at childbirth, a time of being frightened by a menacing man, a time of watching people enter the room with snow on their clothes.

It may have been a time of hearing someone call your husband's name, a time of listening to your mother scold your brother, a time of watching a guy crawl through a hole in the fence at a baseball game, a time of standing on the corner of "Jacob and Washington, South Bend, Indiana," a time of telling the doctor the sensation you had when you got "the disease from water," a time of grabbing a stick out of a dog's mouth, a time of listening to (and watching) your mother speed the parting guests, a time of listening to the broadcast from Philadelphia, a time of seeing the nurses of the hospital as you lay in bed and hearing what they say, a time of hearing your father and mother singing Christmas carols.

It may have been a time of watching a man fighting, a time of standing in the bathroom at school, a time of watching circus wagons one night years ago in childhood, a time in an office where a man was leaning on a desk with a pencil in his hand while someone was calling your name, a familiar memory—"the place where I hang my coat up, where I go to work."

We are placing on record now the exact detail of every experiential response in the 40 operations in which the temporal cortex yielded them, and also the seizure patterns of the 53 cases in which experiential fits were habitually present. If we are to surmise the uses of the interpretive cortex, we must ask first whether all types of experience have been thus recalled. The answer is "No." That answer came to us as a surprise during this analysis.

The times that are summoned most frequently are briefly these: The times of watching or hearing the action and speech of others, and times of hearing music. Certain sorts of experience seem to be absent. For example, the times of making up one's mind to do this or that do not appear in the record. Times of carrying out skilled acts, times of speaking or saying this and that, or of writing messages and adding figures—these things are not recorded. Times of eating and tasting food, times of sexual excitement or experience—these things have been absent as well as periods of painful suffering or weeping. Modesty does not explain these silences.

Perhaps these times do not call for interpretation, and the activity is not really within the focus of attention in quite the same way as things heard and seen. During periods of constructive thought, one is conscious only of the subject matter. The same is true, in a way, of playing chess or tennis, or of writing messages and computing, eating and drinking, or arguing. But, we would not push this difference too far. J. T., Case 38, was suddenly conscious of laughing with his cousins but was not aware of why they laughed. If the reactivation had begun a little earlier in that strip of record, perhaps he would have known. Or it may be that he was aware of his situation with his cousins at that moment and had his attention focused on something else before that.

It is true that the record activated by the electrode, has to do chiefly with experiences in which hearing or seeing are most important, and for which, therefore, the auditory and visual cortex, and sometimes the speech cortex, must have been used in the original perception. But other sensations were appreciated, too, though less prominently. The individual was often aware of his position or movement. These things depend on somatic sensation. Take as examples, standing in a doorway, or walking along a road, or sitting at a baseball game, or standing on a street corner or in a bathroom. Many were aware of attendant pleasure or fear. One man seemed to be dancing with his wife years ago, before she died.

Stimulation of the visual cortex does not produce experiential responses nor interpretive illusions. In the speech area, it does not produce words or experiential responses either, nor interpretive illusions. But the electric current does interfere with the mechanism of ideational speech. The patient is not aware of any change when a current is applied to the speech area until he is called upon to speak. Then he discovers, to his astonishment, that he is aphasic or dumb.

The first temporal convolution (exclusive of the primary auditory sensory area), when stimulated, gives rise to recall of auditory experience with about the same frequency on the two sides. This does not result from stimulation elsewhere. But the experiential responses here are not made up exclusively of auditory material. Sometimes they are mixed, auditory and visual. Occasionally, too, stimulation there may give a purely visual recollection.

How are we to rationalize these facts? What application make to cerebral function?—It may be assumed that the cerebral cortex (on the two sides) which is adjacent to the auditory sensory area and adjacent to the visual sensory area is not functional at the time of birth. In early childhood a certain portion of this cortex (on the left or occasionally right) is taken over for the ideational uses of speech. It must, of course, function together with the subcortical grey matter of which it is an outward projection.

On the other (non-dominant) side, the same area of temporal cortex, together with the more anterior portions of the temporal lobe of both sides, takes on another function together with the centres in the posterior thalamus of which these areas are the outward cortical projections. What is this added function?

We have argued before, that since excision of these areas does not abolish memory, they do not contain the actual record of the past. They are, however, functionally connected with that neuronal record (Penfield, 1958*b*). Since stimulation produces at times detailed recall of past experience in these areas and nowhere else, and since, at other times, it produces a sudden alteration in the patient's present interpretation of things heard or seen, it seems likely that these areas play in adult life some role in the subconscious recall of past experience making it available for present interpretation. This recall makes possible that sudden flash of awareness that things have been seen or heard or experienced before, or that they are dangerous, coming near, or changing pace.

We have argued before, also, that past experience, when it is recalled electrically, seems to be complete including all the things of which an individual was aware at the time; also that, since the events were often unimportant, it seemed likely that the whole stream of consciousness must be so recorded somewhere, quite beyond the reach of voluntary summons (Penfield, 1954*b*).

If that is so, then what must we think about the kinds of experience that are not present in this, our last, exhaustive summary? The things that are missing are those that an intelligent dog might be aware of, such as eating food, body sensations, sexual experiences, running, playing; but also executive performances that no dog could carry out—skills of the hands, playing the piano, writing, speaking. These things that are absent from our experiential recall may all be recorded somewhere and may be made available by other means.

Our conclusion (summarized in the Liverpool Sherrington Lecture) from an earlier analysis of electrical stimulation in all areas of the human cerebral cortex (Penfield, 1958*b*), was that positive responses could be produced only when the electrode was applied to an area from which dromic axonal conduction would normally activate neurones in distant collections of grey matter, e.g. precentral convolution to anterior horn cells of spinal cord, or postcentral gyrus to grey matter of thalamus. We now suggest that the interpretive cortex has its activating connexions with that part of the record of the stream of consciousness in which hearing and seeing are the prominent components. We may assume then that during normal brain activity, the corticofugal impulses pass to the neurone record of experience. Our evidence indicates that this

neuronal record is not in the temporal cortex itself. It lies in other neurone circuits at a distance.[1]

The area of cortex which we have outlined plays a role in the subconscious interpretation of what is seen or heard in the present, and renders the record of the past available for that purpose. It enables man to make efficient use of the auditory and visual experience which the auditory and visual sensory cortex helps to bring to his understanding.

It is interesting to recall now Campbell's (1905) speculation on cytological grounds that there were "audito-psychic" and "visuo-psychic" cortical areas adjacent to the primary auditory and visual receptive centres. Ferrier made surmises (1876) that pointed in the same direction.

There is a sharp functional frontier between the sensory and the interpretive areas.[2] In the visual cortex (for example *see* Case 3, R. W.) the electrode may elicit lights, stars, or coloured flashes moving about. In the auditory cortex a ringing, humming or rumbling may result.

But then, if the electrode is moved only a few millimetres away into the neighbouring cortex around these sensory areas, a response of a totally different order of neuronal organization may result. There is no longer a sound but a voice, no longer a rumbling but music. Visual flashes of coloured lights give way to a scene, or the sudden appearance of a familiar person.

It is assumed by neuroanatomists that these sensory areas of the cerebral cortex (visual and auditory) are used to make possible man's complicated sense perceptions, although it is still not clear just what functional contribution these areas make to seeing and hearing.

In summary—the adjacent interpretive cortex makes possible:
(*a*) the recall of previous perceptions (chiefly auditory and visual) from the past, (*b*) the comparison of past experience with similar present

[1]An electrical current produces local interference with a complicated function in the immediately adjacent grey matter. Complete bilateral removal of temporal cortex has never been carried out. Our evidence would not therefore finally disprove the existence of duplicate records within the cortex of both temporal lobes, but this seems to us unlikely.

The hippocampus which is included in the temporal lobe, of course, must be excluded from this discussion of the temporal cortex and from the areas that yield interpretive responses. Bilateral loss of the hippocampus (Penfield and Milner, 1958 and Scoville and Milner, 1957) produce loss of ability to record current experience and a loss of recent memory. Futhermore, epileptic discharge in the adjacent amygdaloid nucleus produces not interpretive or experiential responses but automatism and amnesia (Feindel and Penfield, 1954).

[2]The visual sensory area, as determined by electrode exploration, occupies the occipital lobe running forward to its usual delimitation (areas 17, 18, 19 Brodmann). The auditory sensory cortex, as determined by our stimulations, is found mainly on the anterior transverse temporal gyrus of Heschl. Auditory sensory cortex has a sharp frontier, but we cannot yet delimit its borders in all directions.

experiences, and (*c*) the subconscious elaboration of signals that interpret present experience for an individual by means of such comparison. So much we may conclude. (*d*) We may surmise that interpretive cortex also assists in the process of adding to, or altering a previously recorded concept, e.g. of a place, a person, a voice, or a piece of music.

The grey matter of the interpretive cortex certainly has a direct functional connexion with a record of precious experience. We have no certain evidence as to whether or not the record is complete for all kinds of experience.

During infancy, the area of temporal cortex that is to be used for speech is interchangeable with that to be used as interpretive cortex. But as time passes the speech cortex develops functional communications which are quite different from those of the interpretive cortex. Stimulation of the adult human speech cortex produces only aphasia, while stimulation of interpretive cortex adjacent to it in the same hemisphere, or in a homologous position on the other side, summons a past experience or a sudden signal of interpretation of the present. These areas, which were once interchangeable, have developed separate and exclusive functional relationships.[1] This is quite different from the motor and sensory systems of the brain which do not seem to change with use and experience.

It is not surprising to discover this difference between the inborn (sensory and motor) systems of the brain and those systems (acquired, psychical) which form their conduction patterns and hold them in relation to the individual's stream of consciousness. The sensory and motor systems are used to make possible sensations and actions which are forever new and changing. They probably retain, in themselves, little or nothing from the past.

On the other hand, the temporal speech area[2] is used somehow in the process of holding and recording word experience, and making words and phrases available when called for in speech. The interpretive areas are used in the process of rendering moments of past experience (especially visual and auditory experience) available for comparison with, and interpretation of, the current stream of consciousness that is coming to the individual. Other areas, we have not discussed, are used in the acquisition of skills.

[1]This is consistent with the clinical evidence that, in childhood, if the speech area is destroyed, normal speech returns after a year or more of aphasia, and a speech area is formed in the previously non-dominant hemisphere. An adult after the same injury may never speak normally again.

[2]The temporal speech area in the dominant hemisphere is indispensable for normal speech. Broca's cortical speech area in the third frontal convolution is probably dispensable after a period of aphasia, and the cortical speech area in the supplementary area within the longitudinal fissure is certainly dispensable after a short period of aphasia (*see* Penfield and Roberts, 1959).

By the time a language has been learned, the cortical speech area must have acquired a vast number of functional neuronal connexions which become ever more firmly established with the passage of the years. The same may be said of the interpretive cortex by the time the experience of some years has been stored and classified. The temporal speech area is then no longer to be displaced easily, if at all, from the left to the right side. This may be due to the fact that the functional connexions that have been established for the area on the right side would now prevent its use for the purpose of a new speech unit.

It is obvious that present anatomical methods of study could not be expected to demonstrate the difference in the acquired connexions of the speech area and those of the interpretive areas of the human cerebral cortex. Only a physiological method can serve us. The local discharges of epilepsy, and the gentle stimuli of the electrode in conscious patients, constitute available methods of physiological analysis of such partially separable systems.

In *conclusion*: "He who is faithfully analysing many different cases of epilepsy is doing far more than studying epilepsy." We have placed on record a considerable body of evidence that is not available to physiologists in their laboratories. We have proposed such hypotheses as seem to be supported by the facts and hope that they may serve the purposes of those who seek to discover the physiological basis of thought.

There is within the adult human brain a remarkable record of the stream of each individual's awareness or consciousness. Stimulation of certain areas of cortex, lying on the temporal lobe between the auditory sensory and the visual sensory areas, causes previous experience to return to the mind of a conscious patient. There is no real overlap between this interpretive cortex and the areas devoted to visual and auditory sensation, no overlap with the zone of cortex devoted to the ideational processes of speech.

In such repetitions of previous experience perceptions are largely auditory, or visual, or both. Time seems to unroll at its normal tempo. The return of the content of consciousness thus evoked, is quite at random, except that there is some evidence of cortical conditioning. The evolving detail is far greater than in memories which can be summoned voluntarily.

This demonstrates the existence of a functional system devoted to subconscious recall of past experience and to the interpretation of present experience. Like the motor and sensory cerebral systems, this functional unit is partially separable from the overall activity of the brain. Like speech, it depends on an acquired system of functional neuronal connexions.

The challenge that lies before clinician and physiologist, electronics expert and psychologist, is this: How are these partially separable functional systems integrated into normal brain activity, and how is this total integration related to the mind? Final understanding of man's own brain and mind may seem very far away, but that is the ultimate goal of investigation. It may well prove to be man's most difficult achievement, to understand himself and the means by which this understanding is achieved.

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CASE INDEX

The patients' initials are listed seriatim as they appear in the text. Further information about some of these patients may be found in previous publications from the Montreal Neurological Institute where the same initials have been used. Books that have appeared contain a similar case index at the back.

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