THE FUNCTIONS OF THE TRIGEMINAL NERVE.[1]

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INTRODUCTION.

THE material on which this paper is founded is partly clinical and partly experimental. The clinical material is of two kinds: (1) The results of personal examination of thirty cases in which the Gasserian ganglion had been removed. The examination of some of the patients was repeated several times and at various periods from nine days up to seven years after the operation; in some cases the interval between the first and final observations was more than one year, and in one case it was over a year and a half. (2) The use of notes and the results of correspondence with patients in twenty further cases in which the Hartley-Krause operation had been performed.

In three cases the roots of the Gasserian ganglion were stimulated during the course of the operation for trigeminal neuralgia. This was suggested by Sir Victor Horsley, and was carried out as a means of ensuring complete removal of the ganglion.

The experimental evidence is based on certain experiments made on animals by Sir Victor Horsley.

I have been able to make use of fifty cases; forty-eight of these were operated on by Sir Victor Horsley and two by Mr. Bucknall. I take this opportunity of expressing my gratitude to these gentlemen for permission to use the material, and to the former for constant encouragement and advice throughout the course of this investigation.

[1] The greater part of this paper formed the thesis presented for the degree of M.D. (Cantab.).

The subject matter of the paper has been collected under the following headings :—

(1) Distribution of the fifth nerve to the skin of the face : (*a*) Anæsthesia determined with the camel's-hair brush. (*b*) Pressure-touch anæsthesia ; analgesia ; thermal anæsthesia. (*c*) Paræsthesiæ.

(2) Distribution to the external auditory meatus and the membrana tympani.

(3) Distribution to the mucous membranes.

(4) Distribution to the deep structures : (*a*) to the dura mater ; (*b*) to the subcutaneous parts of the face ; (*c*) muscle sense.

(5) Distribution to the organs of special sense : (*a*) taste ; (*b*) smell ; (*c*) hearing ; (*d*) vision.

(6) Motor distribution : (*a*) muscles of mastication ; (*b*) vaso-motor and secreto-motor.

At the end will be found a table giving a summary of the observations made on the thirty cases personally examined.

(1) Distribution of the Fifth Nerve to the Skin of the Face.

(*a*) *Anæsthesia determined with camel's-hair brush.*

Method.—In investigating the distribution of true tactile anæsthesia it is, of course, clear that no method is admissible in the use of which any pressure, however slight, is made upon the surface. To prevent this error the stimulation may be made either with a fine camel-hair brush, with a hair æsthesiometer, or with a small wisp of cotton wool. In this series of investigations the camel-hair brush has been used in every case ; and whenever the word anæsthesia is mentioned in this paper, it will imply, unless otherwise stated, loss of sensation to the light contact of a camel-hair brush.

Area of anæsthesia as determined by other observers.—Previous investigators, who have studied the distribution of the trigeminal nerve by means of the anæsthesia and motor changes following upon resection of the Gasserian ganglion, have devoted their attention mostly to examining the patients

at short intervals after the operation. The result of their researches is such as to indicate that the area of facial anæsthesia is fairly constant in all cases with slight individual variations, and that practically no change takes place at later periods. In fig. 1 the continuous line illustrates the average outline of loss of sensation to the hair æsthesiometer as observed by Harvey Cushing [12] ; the broken line being a very slightly simplified representation of the same. From this figure it is seen that the anterior boundary is the midline of the front of the head, of the forehead, nose, mouth and chin. The posterior margin may be described with a close approach to accuracy as consisting of three straight

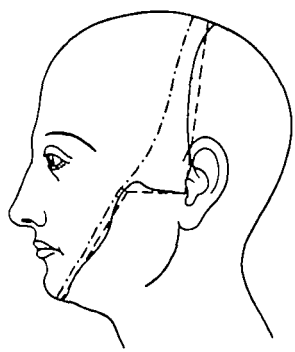


FIG. 1.

Continuous line.—Typical outline of anæsthesia, as given by Cushing.
Broken line.—The same, slightly simplified.
Dash and dot line.—Outline of analgesia.

lines (broken line in fig. 1) ; the upper line is almost vertical and extends from a point in the sagittal plane of the scalp, varying slightly about the mid-point between nasion and inion to the free margin of the tragus at the junction of its middle and lower thirds; thence the second line passes horizontally forwards to a point mid-way between the external auditory meatus and the outer canthus of the eye; here the third line begins, and runs obliquely downwards to a point on the lower border of the chin vertically beneath the angle of the mouth. The exact unsimplified boundary is shown by the continuous line in the diagram.

Its upper part has a slight anterior convexity most marked at the commencement; when it reaches the anterior attachment of the helix it follows this to the concha and then curves round the posterior aspect of the tragus, includes the external auditory meatus and membrana tympani to a greater or less extent and reappears at the junction of the middle and lower thirds of the tragus. The end of the horizontal part usually shows a sharp upward curve before it turns down into the third line, which it follows closely with slight undulations.

The posterior border of analgesia and anæsthesia to pressure-touch and heat and cold runs a much straighter course in front of the line above described.[1]

In three out of his twenty-six cases, Cushing [12] noted a uniform deviation; the posterior border of the anæsthesia including the upper half of the pinna, the antihelix and crura, part of the concha and a considerably greater area of the cheek; whilst the limits of pressure-touch anæsthesia corresponded with the normal outline of the lighter anæsthesia. He also observed one case in which the field was the same as that given by Frohse [30] as the average result of the dissection method.

Krause [50] in his monograph says that in R. Zander's researches there is an anatomical basis for the opinion that the anæsthetic area may diminish considerably, and of Case 3 of his series, Krause has given two diagrams showing the alteration in the extent and intensity of the anæsthesia between four weeks and two and a half years after the removal of the ganglion. The diminution is chiefly noticeable over the forehead and head, in front of the ear and in the neighbourhood of the jaw. But in a later article on trigeminal neuralgia [55] his diagrams show practically no shrinkage in the region of the ear.

Cushing, who has noticed some return of sensibility in the area of the ophthalmic division in two or three of his cases, attributes any change other than "an insignificant shrinkage of the border areas of the entire field" [13][2] to

[1] Fig. 1, dash and dot line. P. 219.

incomplete removal of the ganglion.[1] In his detailed description of twenty cases [13], however, he reproduces three photographs (without comment) which show an alteration of the field. The case on the tenth day had exhibited that most posterior limit of anæsthesia in which half the pinna was included; two years later the zone conformed with Cushing's normal type.

Personal Observations.—I have observed that if patients in whom the ganglion has been extirpated be examined within the months following the operation, the whole area of anæsthesia undergoes general shrinkage along the posterior margin, and that this shrinkage is more marked above than below. In some cases the shrinkage is inconspicuous or absent. The change is not a uniform recession of the posterior margin, but in some cases results in a detached area of anæsthesia remaining in the neighbourhood of the tragus. After a certain period (about six months) no further diminution occurs, and therefore in cases examined at periods longer than this after the operation, the area of anæsthesia will be found to have one of four characteristic and permanent forms: 1 and 2, the forms in which little or no reduction has occurred (figs. 2 and 5). Of these two outlines which closely resemble one another, one is very common (fig. 2) and the other rare (fig. 5); the latter will be described after the remaining forms have been dealt with; 3, the form in which pronounced reduction has taken place (fig. 4); 4, intermediate between these, the form in which the reduction has left a detached islet of anæsthesia over the tragus (fig. 3). These areas I propose to call respectively "A," "D," "C,"

[1] Pruschinin [70] records a case in which the Gasserian ganglion and its second and third divisions were removed and the sensory root ablated. Gradual return of sensation was observed. At the end of nine months tactile sensation with wool was present over the affected half of the face, and there was marked improvement in the recognition of painful stimuli. No recurrence of pain accompanied this return of sensation. Sapejko [77] also reports a case of complete trigeminal neurectomy, which, immediately after the operation, showed complete anæsthesia in the region of the fifth nerve. A year later the anæsthetic area was found to have diminished considerably.

Numerous other cases have been described (viz., by Pruschinin [70], Garré [31], and Perthes [67]) in which return of sensation has been associated with return of pain and regeneration of the peripheral nerves, after a partial extirpation of the ganglion.

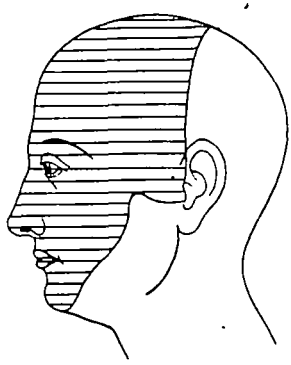


FIG. 2.
Type "A."

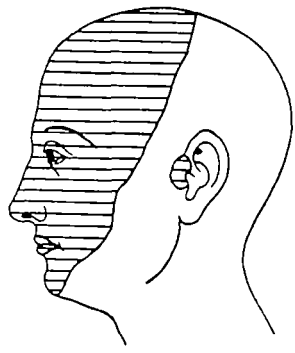


FIG. 3.
Type "B."

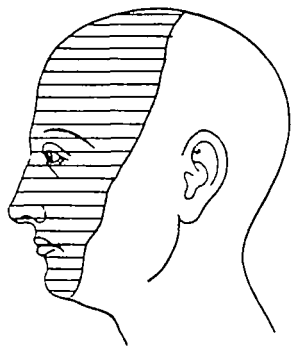


FIG. 4.
Type "C."

and "B."[1] The rest of this section will be devoted to establishing their permanence and attempting to infer their relative frequency.

If figs. 2, 3, and 4 be studied, the difference of the "A," "B," and "C" varieties are at once apparent. Type "A" (fig. 2) is practically identical with that shown in fig. 1 (continuous line), and considered by Cushing as the normal area of anæsthesia, resulting from removal of the ganglion.[2] Type "C" (fig. 4) corresponds very approximately with the area of pressure-touch anæsthesia and analgesia as

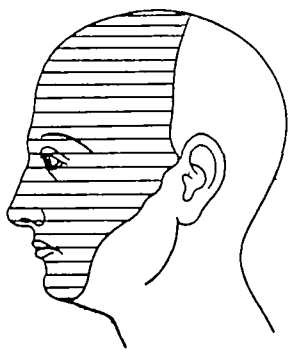


FIG. 5.
Type "D."

depicted in fig. 1 (dash and dot line). This, the type "B," also closely resembles, but shows in addition an isolated patch of anæsthesia over the tragus; this patch is of special interest in that it never shows pressure-touch anæsthesia or analgesia. In other words "A" passes into "C" by the disappearance of an area of right-angled triangular shape,

[1] Kruger (57) describes a case in which, seventy-one days after the operation, in addition to some return of sensation in the area of distribution of the first division, in the middle of the anæsthetic cheek a bridge had formed which was again sensitive.

[2] It is possible that some of the anterior branches of the small occipital nerve are divided by the posterior limb of the scalp incision, and that the anæsthesia of the skin immediately in front of this is then due to the loss of these fibres.

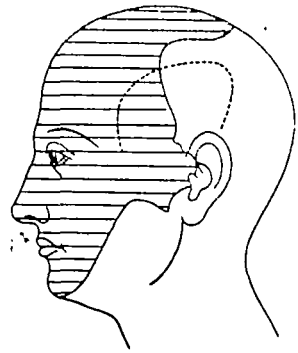


FIG. 6.
Case 23. Ninth day after operation.

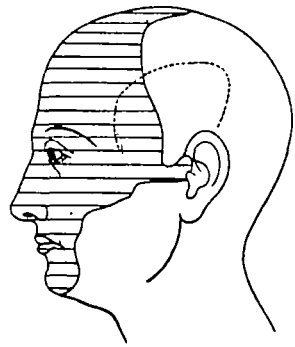


FIG. 7.
Case 23.—Forty-sixth day after operation.

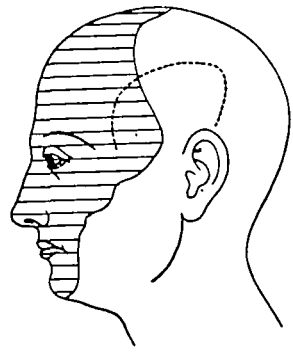


FIG. 8.
Case 23.—Sixty-seventh day after operation.

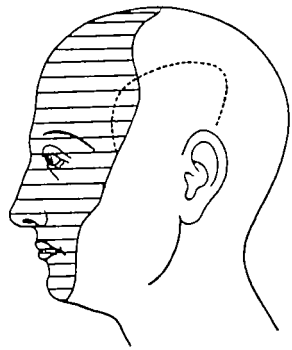


FIG. 9.
Case 23.—Hundred and ninetieth day after operation.

the right angle being at the external auditory meatus and the sides containing the angle being vertical and horizontal; "A" passes into "B" by the disappearance of this area except the part at the right angle.

Except for a modification of "A" already referred to as "D" no intermediate varieties ever occur as permanent types; they can only be observed during the transition. In "D" (fig. 5) the posterior border of the anæsthesia extends back to the helix, but curves forwards again without actually encroaching thereon; the horizontal and inferior oblique lines of the simplified outline (fig. 1) are replaced by

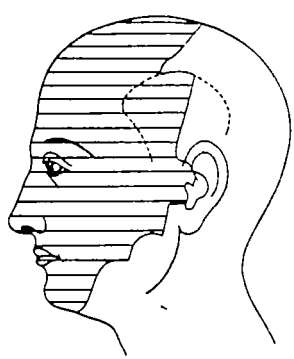


FIG. 10.
Case 27.—Twelfth day after operation.

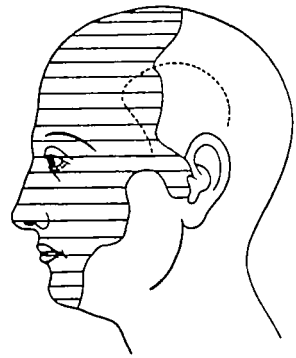


FIG. 11.
Case 27.—Seventeenth day after operation.

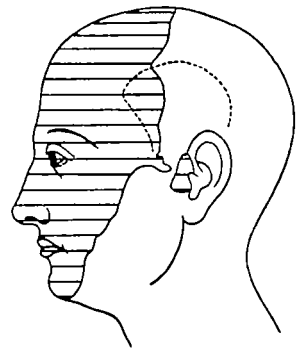


FIG. 12.
Case 27.—Twenty-second day after operation.

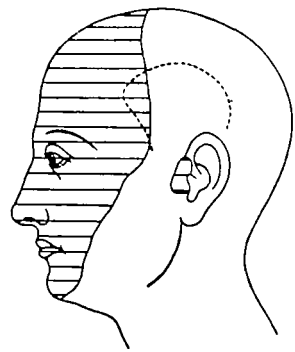


FIG. 13.
Case 27.—Fifty-fifth day after operation.

a single undulating oblique line which joins the superior vertical at the attachment of the helix.

The evidence of the permanence of these four forms of anæsthesia is as follows: Head [39 and 40] has shown that after nerve section, recovery of function, when it takes place, is frequently complete at the end of two years. It seems probable then that all changes in the anæsthetic zone after extirpation of the ganglion would be at an end by this time. Twelve[1] of the thirty cases examined in this series were seen at periods of two years or more after the operation; five[2] of these were furthermore examined more than once after the two years, and showed no alteration in the field of anæsthesia. To these may be added the three cases[3] examined more than once between one and two years subsequent to the operation, none of which showed any changes, and those three cases[4] in which the shrinkage of the field was traced from the commencement until it ceased; in the one case[5] the permanent form had been obtained by the hundred and forty-first day, in the other[6] by the fifty-fifth; the subsequent observations made three hundred and one, two hundred and sixty, and seventy-three days later respectively revealing no further alteration. In no case have I observed a continuance of the shrinkage after six months, the change when it did occur being completed generally within the first two months. In seven cases[7] this transformation was watched. The diagrams (figs. 6, 7, 8, 9) illustrate the process of shrinkage from "A" to "C" as observed on the ninth, forty-sixth, sixty-seventh, and the hundred and ninetieth days in Case 23. Again the alterations from "A" to "B" as observed on the twelfth, seventeenth, twenty-second, and fifty-fifth days in Case 27 are indicated in figs. 10, 11, 12, 13.

These four permanent forms must be taken as showing that the fifth nerve has at least four types of distribution,

[1] Cases 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 16 (see list of cases at end).
[2] Cases 6, 8, 9, 12, 13.
[3] Cases 14, 16, 17.
[4] Cases 26, 27, 30.
[5] Case 26.
[6] Case 27.
[7] Cases 21, 22, 23, 25, 26, 27, 30.

and it is therefore of great interest to attempt to estimate their relative frequency.[1]

There are nineteen cases[2] which we know to show permanent types because they were observed six months or more after the operation. These show type "A" four; "B" nine; "C" four; and "D" one. Three other cases[3] were watched through a period of change until one or other of the permanent types was reached; they may therefore be accepted with practical certainty for addition in attempting to estimate the relative frequency of types.

Of the remaining eight cases[4] two[5] are not available because the anæsthesia was not investigated with the camel-hair brush: of the six cases which are left, one[6] is type "B." There is good reason to suppose that type "B" is always permanent, and therefore this is available for the present purpose. Another[7] is of type "D," and all the evidence we have of this form is that it is permanent. This evidence, which is not very satisfactory, consists of two elements: (1) "D" has been observed at the end of twelve months; (2) "D" is certainly not an intermediate form which is passed through by "A" when undergoing transition to "B" or "C." So far then we have twenty-four cases on which the estimate of the frequency of the four types may be based. These give the frequency as follows:—

Type	"A"	"B"	"C"	"D"	Total.
Number of cases ...	4 ...	12 ...	6 ...	2 ...	24

These figures of course are very small, but we may take them as approximating in some way the probable proportion

[1] Before discussing the relative frequency of the permanent types of anæsthesia a word must be said of the varieties found existing as initial forms. Twelve cases were investigated for the first time at an interval after the removal of the ganglion varying between nine and twenty-four days; of these, ten showed the "A" form of anæsthesia; one anæsthesia of type "B" and one the "D" variety. These cases are: Case 2, 15 days "A"; Case 20, 16 days "D"; Case 21, 14 days "A"; Cases 22 and 23, 9 days "A"; Case 24, 9 days "B"; Case 25, 10 days "A": Case 26, 24 days "A"; Case 27, 12 days "A"; Case 28, 15 days "A"; Case 29, 12 days "A"; Case 30, 12 days "A."

[2] Cases 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 23, 25, 26, 27.

[3] Cases 21, 22, 30. Of these, Case 30 showed no change between the seventieth and the hundred and forty-third day.

[4] Cases 2, 5, 18, 19, 20, 24, 28, 29.

[5] Cases 5, 19.

[6] Case 24.

[7] Case 20.

of the areas to which the fifth nerve supplies the sensation to light touch.

It may be added that the four[1] cases which have not been included because they were only examined once, and not at a period when the anæsthesia might be considered of permanent form, were all of type "A" as was to be expected,[2] and would probably have become permanent as: one, type "A"; two, type "B"; one, type "C."

Two[3] of these cases showed a diminution of the area

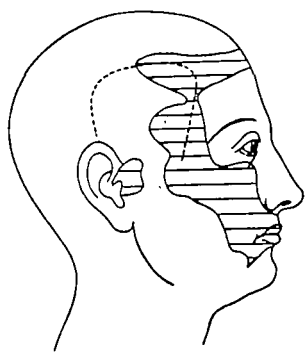


FIG. 14.
CASE 1.—Seven years after operation.

of anæsthesia, which was such as to suggest that the sensory root of the ophthalmic division of the ganglion had not been completely divided. The anæsthesia, however, which was present was sufficiently extensive to allow the cases to be classified. In one of these (Case 1), which I examined seven years after the operation, this condition had been noted on the fifth day.

Apart from these two cases, there has been no instance in this series in which any diminution of the anæsthesia along the middle line of the face has been noticed.

[1] Cases 2, 18, 28, 29. [2] See footnote [1] page 230.
[3] Case 1 (fig. 14), and Case 18.

(*b*) *Pressure-touch Anæsthesia. Analgesia. Anæsthesia to Heat and Cold.*

Method.—The limits of pressure-touch anæsthesia have been ascertained by the gentle application of the head of a large pin. The analgesia has been investigated by the use of a very sharp pin applied obliquely, so as not to penetrate the deeper layers of the cutis. In the determination of the heat and cold anæsthesia, narrow test tubes containing ice or water at different temperatures have been employed.

These forms of sensation will be considered together, as

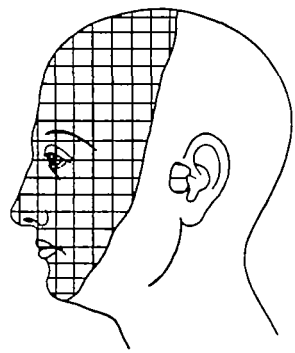


FIG. 15.

Type "X."—Vertical shading showing the relation to Type "B."—Horizontal shading.

in almost all cases they have been found to correspond; but those cases which show any divergence will be dealt with separately. Whenever analgesia only is mentioned, it will be understood that the distribution of this form of loss of sensation corresponded to that of the thermo-anæsthesia and loss of sensibility to pressure, unless otherwise stated.

Analgesia will be considered first in relation to anæsthesia, in those twenty-four cases[1] which have settled down to their permanent forms. The same proofs which were used to establish a permanency of type after a certain period for the anæsthesia, apply equally well to the analgesia, and so need not be repeated.

[1] Cases 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26, 27, 30.

In discussing the anæsthesia, it was shown that there were four different forms which had to be considered as permanent. Associated with these there are three forms of analgesia which must now be discussed.

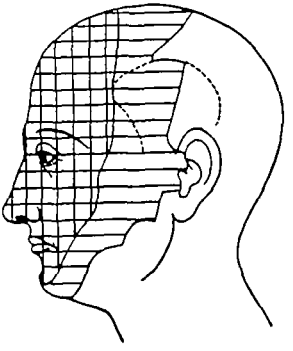


FIG. 16.

Case 27.—Twelfth day after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.

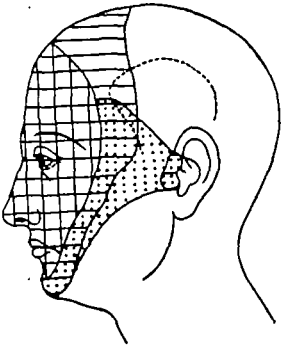


FIG. 17.

Case 27.—Three hundred and fifteenth day after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.
Dotted area.—Temperatures from 0° C. to 12° C. described as warm; temperature from 18° C. to 50° C. described as cold; temperatures between 12° C. and 18° C. not recognised as hot or cold; temperatures above 50° C. called hot.

In all these cases exhibiting either the "B" or "C" form of anæsthesia,[1] a constant distribution of the analgesic field

[1] Cases 1, 3, 8, 9, 10, 11, 12, 14, 16, 17, 21, 22 23, 24, 25, 26, 27, 30.

has been found. This area corresponds with that of the anæsthesia of type "C," so also with that of "B," except that the isolated area over the tragus is not analgesic (fig. 15), and it constitutes the most common permanent analgesic area. It will be referred to as type "X," and is found in fifteen cases.[1]

There are three exceptions to this. In Case 27 the analgesic area is considerably less than the anæsthetic; this marked diminution of the field was noted even on the twelfth day after the operation (fig. 16), and was still more marked on the three hundred and fifteenth (fig. 17). Case 9

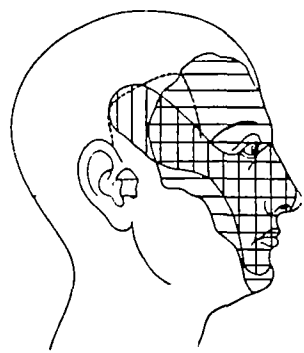


FIG. 18.

Case 3.—Five years after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.

shows a very slightly narrower area of the pressure-touch and analgesic field opposite the lobule and tragus, and over part of the area of the operation flap, the heat and cold anæsthesia are replaced by heat and cold paræsthesiæ (fig. 25). Finally, Case 3 exhibits a relationship of the analgesic and anæsthetic areas totally different from all others (fig. 18). It is necessary to state, however, that the man was extremely unsatisfactory to examine, and that the figure here given embodies the most constant answers which could be obtained.

Those patients who exhibit the "A" type of anæsthesia

[1] Cases 1, 8, 10, 11, 12, 14, 16, 17, 21, 22, 23, 24, 25, 26, 30.

show that form of analgesia which will be called "Y" (fig. 19).[1] Its limits cannot be defined with great accuracy, as the posterior margin varies slightly with each individual

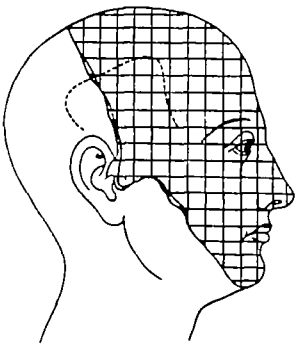


FIG. 19.

Case 13.—Twenty-one months after operation.
Type "Y."—Vertical shading showing the relation to Type "A."—Horizontal shading.

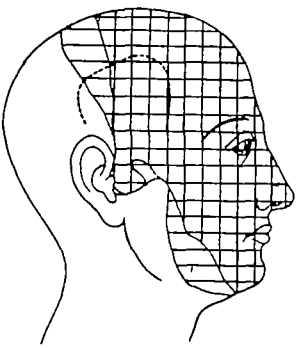


FIG. 20.

Case 6.—Four years, four and a half months after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.

case; but it may be said that the analgesia does not extend quite so far back as the anæsthesia, especially with regard to the tragus. Fig. 20[2] illustrates the most marked separation observed of the posterior limits of these fields at the upper

[1] Case 13. [2] Case 6.

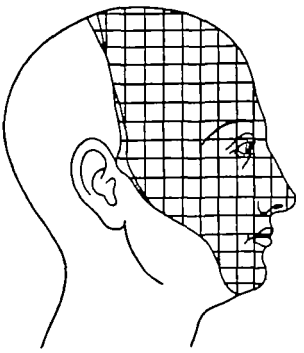


FIG. 21.

Type "Z."—Vertical shading showing the relation to Type "D."—Horizontal shading.

and lower borders, and their closest approximation at the tragus.

Closely allied to "Y" is type "Z" (fig. 21), which depicts the relationship of the analgesia to the anæsthesia in the two cases,[1] in which the anæsthesia was of the "D" form.

In those cases[2] of "A" seen whilst the changes to camel-hair anæsthesia were in progress, the posterior

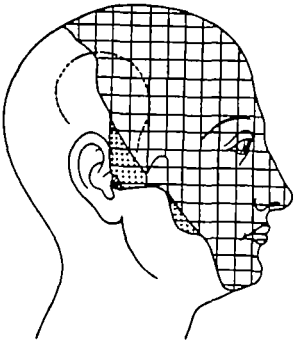


FIG. 22.

Case 30.—Twelfth day after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.
Dotted area.—All temperatures from 50° C. to 0° C. called warm.

[1] Cases 15 and 20.

[2] Cases 21, 22, 23, 25, 26, 27, 28, 29, 30.

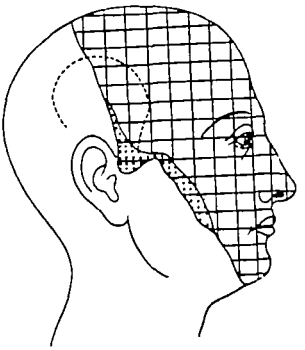


FIG. 23.

Case 30.—Thirty-fourth day after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.
Dotted area.—Temperatures from 50° C. to 0° C. variously recognised. At times differences of 10° C. accurately recognised; at other times temperature of 26° C. described as hotter than temperature of 45° C.

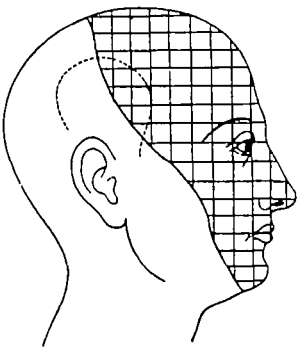


FIG. 24.

Case 30.—Seventieth day after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.
There was no paræsthesia to heat or cold.

margin of the analgesic zone is generally found to be at a variable slight distance in front of that of the anæsthetic area; and as "A" shrinks to "B" or "C," the analgesia recedes in front of it, but more slowly, until the two fields correspond.

In figs. 22, 23, and 24, are shown the relative conditions and changes which took place in the several sensations in

Case 30 between the twelfth and seventieth days after the operation.

Blunting of the sensation of heat and cold.—In these three figures just referred to, it will be seen that, in addition to the areas of absolute anæsthesia and analgesia, there is also a zone posterior to the analgesic, but contained within the anæsthetic field, in which there is a perversion of the heat and cold sensations. As the areas of loss of the various sensations reach their final form, this patch of impaired reaction to thermal stimuli diminishes and finally disappears.

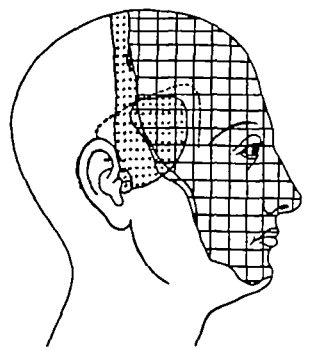


FIG. 25.

Case 9.—Three years and seven months after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.
Dotted area.—All temperatures from 0° C. upwards called warm.

In some of the patients, however, this area of thermal perversion has been found present even after two or more years. In Case 9 (fig. 25) the loss of heat and cold sensations is complete over the greater part of the analgesic area, but over a portion of the operation flap, and a strip posterior to this (dotted) all temperatures down to ice are called warm.

Two other patients likewise show an area of perversion of the thermal sense. In Case 17 there is a band one and a half centimetres wide running in front of the posterior border of the analgesic and pressure-touch area, and slightly overlapping the sensory field below, over which all degrees of cold down to ice are described as warm. More interesting still,

however, is Case 16 (fig. 26). This patient, when seen two years after operation, exhibited the "B" type of anæsthesia and the "X" type of analgesia; yet behind this was an area occupying almost exactly the area between the "A" and "C" forms of anæsthesia, on which all temperatures above 40° C. were considered warm, those below 5° C. cold, whilst intermediate temperatures were not recognised. Whilst another patient, when examined one year, seven and a half months after the operation, was found to have anæsthesia of the "B" variety, analgesia of the "X" variety, and complete loss of sensation for all temperatures over an area corresponding to that of the "A" type of anæsthesia.

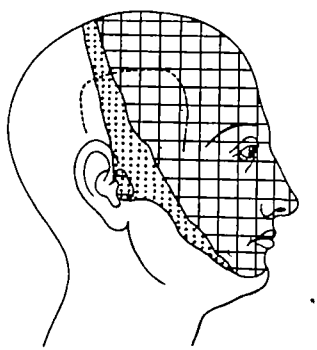


FIG. 26.

Case 16.—Two years after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.
Dotted area.—Temperatures between 5° C. and 40° C. not recognised.

The evidence afforded by these cases is too small to permit of discussion of this condition, but would nevertheless seem to show that they form still further intervening types between "A" and "C."

The greater part of the observations upon which this paper is founded were made before Head's [39 and 40] recent publications on the peripheral nervous system. Nine of the cases have been investigated, however, in the light of these researches. It was obvious from the first, however, that two groups of sensory loss were to be found within the

field of disturbance of sensation, and not necessarily occupying areas of the same size. These two groups which have been referred to as anæsthesia and analgesia consist respectively of loss of sensibility to light touches and of loss of sensibility to pressure, pain, heat and cold. They show, therefore, a general resemblance to the grouping of sensations found in the limbs by Head (loss of epicritic and loss of protopathic sensations respectively), but they present certain marked differences. For example, in the intermediate areas between the limits of total anæsthesia and that of loss of sensibility to light touches only, there were none of the features described by Head as being characteristic of regions which have protopathic sensibility only, there was no disturbance of the thermal sense, and there was no exaggerated discomfort resulting from painful stimuli.[1]

With regard to the relation of these two sensory losses, three main groups can be recognised.

(1) Cases in which anæsthesia and analgesia coincided, *i.e.*, there was a single area of total loss of sensibility, with a definite margin at which there was an abrupt transition to normal sensibility.

(2) Cases in which loss of sensibility to light touches was more extensive than the loss to pain, pressure, heat and cold; each of these two areas had a definite margin, and in the intermediate region the only abnormality was a failure to recognise light touches (types "A," "B," and "D.")

(3) Certain cases in which, to the disturbances found in the second class just mentioned, were added partial interferences with the thermal sense in areas which for the most part lay outside the distribution of any other sensory loss,

[1] Hyperæsthesia and hypalgesia have been noticed by some observers, *e.g.*, Friedrick [29], who gives two diagrams. The first (forty-seven days after operation) shows some hyperæsthesia and hypalgesia over the chin and a narrow strip in front of the upper area of distribution of the third division of the fifth. In the second figure (102 days after operation) it is seen that the area supplied by the first division is no longer anæsthetic and analgesic, except for a small area on the forehead; also that there is some retraction of the posterior border of anæsthesia on the cheek, whilst there is extension of this area over the chin. These areas of diminished anæsthesia and analgesia are now, however, hyperæsthetic and hypalgesic. Garré [31], also mentions a case in which there was hyperæsthesia in front of the ear, and over part of the upper jaw and gum on the hundred and eighth day.

and were, therefore, not intermediate areas in the sense used by Head. These thermal sense losses were very irregular in kind, and nothing was found corresponding with the localised loss of discrimination of temperatures between 22° C. and 40° C., which were described by Head as characteristic of areas which have protopathic sensibility only. In one case, however (fig. 26), there was inability to discriminate amongst temperatures between 5° C. and 40° C.; the area in which this loss was found lay for the most part outside the region in which sensibility to light touches was absent. For diagrams illustrating some of the disturbances in the thermal sense see figs. 17, 22, 23, 25, 26.

In no case was it established satisfactorily that there was any extension of the analgesic area beyond the anæsthetic.

Attention may here be called once more to the fact that on the mucous membranes, anæsthesia and analgesia invariably and precisely coincided.

Dana [15], in a patient in whom the third division of the fifth was cut intracranially, found that there was a single area of total loss of sensibility on the face and in the mouth.

It may be added that deep sensation was invariably absent in regions where there was total loss of sensibility of the skin; this would seem to be satisfactory evidence that sensory fibres from the muscles of the face travel in the fifth nerve.

(c) *Paræsthesiæ.*

All the patients experience some kind of abnormal sensation on the side of the face, eye or mouth, after the operation, and they make use of various terms to express their sensations. The most common complaint is that of a "burning" sensation, and this was most marked in Case 23. The face was not universally affected, but the burning was localised to a series of patches, as shown in the accompanying diagram,[1] where it will be seen that these areas are not confined entirely to the area devoid of sensation, although they are included within the field of the original anæsthesia. There is also

[1] Fig. 27.

indicated in the diagram that part at which a "boring" pain was experienced. The burning was, however, most marked in the mouth, along the left side of the tongue, throat, and palate. In another case[1] there were some parts of the face which felt burning, and at the same time others which felt icy cold.

Some patients complain of the sensation of pins and needles, of tickling and of stinging. Most of them complain

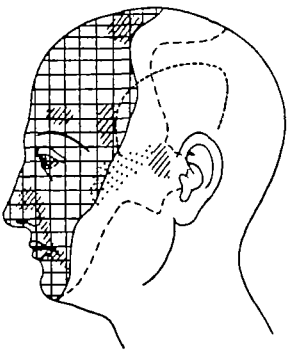


FIG. 27.

Case 23.—Hundred and ninetieth day after operation.
Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.
Oblique shading indicates the seat of "burning sensation."
Dotted area indicates the seat of "boring pain."
Broken line marks posterior limit of the original area of anæsthesia.
This patient was extremely neurasthenic.

of the affected side of the face as feeling numb, drawn or shrinking, and of the mouth as feeling swollen or woolly. Others, again, feel that the face is flushed, or that the lateral angle of the eye and mouth is twitching, even when nothing of this kind is apparent on examination. One patient writing to me described his sensations as follows:[2] "The most general is that which feels as though a fly were walking about the face; this, at times, seems to be multiplied to a score of flies, running in all directions, specially down side of nose. Another has the feeling of violent itching. Another is a

[1] Case 15.
[2] Case 13.—This description was written two years after the operation.

tremulous sensation specially round right eye, and in upper and lower lids. Another time a most acute stinging sensation, which occurs in left corner of right eye along the right side of tongue, and on the right side of both lips, when this occurs the inside of the mouth swells. Another is a jarring sensation as though I had bitten something, and my teeth had come together with a snap. I also get a general shock, which involves the whole of the side affected."

Whilst another patient[1] wrote that he had a "buzzing sensation in the left ear, which changes to a sharp pain across the top of the head, and a creepy-crawly sensation in the right cheek. I do not get the burning tic-douloureux like I used to before the operation . . . . . at times I get a burning sensation in the right eye, and a film of water spreads across it."

Both these patients were extremely neurasthenic.

Neurasthenia is commonly found in these patients after the operation, and this makes it difficult to estimate how much these sensations of discomfort must be attributed directly to loss of function of the fifth nerve. There is no reason to suppose that in these cases neurasthenia is more frequent than in other cases of equal severity, or that it has anything to do with the nature of the operation.

(2) Distribution to the External Auditory Meatus and Membrana Tympani.

Method.—In all these cases, the examination of the drum has been carried out by means of fine horse-hair. A speculum is inserted into the external auditory meatus, and after it has been retained there for about a minute the patient is able to dissociate the sensory stimulus set up by the speculum from stimuli induced by the horse-hair on the drum or the deeper part of the meatus. When a sensitive drum is touched with horse-hair, the patient usually rapidly withdraws the head and complains of two distinct sensations: one auditory, a loud tap being heard, and the other a feeling

[1] Case 10.—These symptoms were detailed three years after the operation.

of a very painful pin prick; whilst, if the horse-hair is drawn along the surface of the membrane, an irritating sensation is set up. In these cases, in which the membrane is insensitive, only the auditory stimulus is perceived. The outer part of the meatus is examined, after the withdrawal of the speculum, either by means of the horse-hair or a fine camel-hair pencil. Occasionally the hairs springing from the posterior surface of the tragus have to be cut away.

Krause [50] states that the external auditory meatus, especially the anterior wall at its commencement, is anæsthetic, but believes with Frohse [30] that this canal is supplied to a variable extent by the auricular branch of the vagus, and that the drum always derives its sensibility from that nerve. Cushing [12 and 13], who alone has made a careful clinical study of the anæsthetic boundaries of these parts, finds that in most cases the upper and anterior walls of the canal are anæsthetic, and the drum also to a greater or less extent.

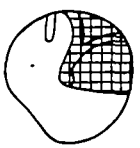
The results of my examination of the auditory canal and tympanic membrane in twenty-five[1] cases, show that no uniformity in the anæsthesia exists, and that not even is there any correlation possible of the range of involvement of these parts with the different types of facial anæsthesia. This is well illustrated by the fact that in the four cases[2] where no anæsthesia of the meatus was present, and in all[3] those in which there was no anæsthesia of the drum, each of the four types of facial anæsthesia was represented.

Anæsthesia, partial or complete, was found to be much commoner of the meatus than of the drum, as can be seen by referring to the appended tables; whilst in every case, where there was any loss of sensation in the auditory canal,[4] the anterior wall was affected; and except in Case 12, in which the outer opening of the meatus alone remained sensitive, those walls which were anæsthetic were involved along their whole length.

[1] Cases 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30.
[2] Cases 16, 20, 22, 28.
[3] Cases 3, 4, 6, 17, 20, 22, 24, 25, 26, 28.
[4] Cases 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 21, 23, 24, 25, 26, 27, 30.

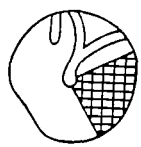
Five cases[1] showed complete anæsthesia of the drum and of the whole of the external auditory meatus, including the posterior aspect of the tragus; whilst two others,[2] in which the tympanic membrane was totally devoid of sensation, had almost complete anæsthesia of the canal. In three cases[3] the auditory canal and membrane showed no loss of sensa-

FIG. 28.



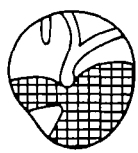
Case 10.

FIG. 29.



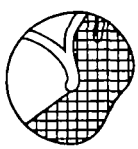
Case 21.

FIG. 30.



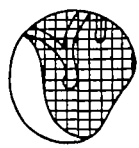
Case 13.

FIG. 31.



Case 15.

FIG. 32.



Case 23.

Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.

tion. Seven[4] of the patients had no affection of the tympanic membrane, but had anæsthesia of the meatus in varying degrees, from complete insensibility in Case 4 to affection of the anterior wall only in Case 3.

The remaining eight cases[5] exhibited great irregularities

[1] Cases 1, 7, 8, 14, 27.
[2] Cases 9, 30.
[3] Cases 20, 22, 28.
[4] Cases 3, 4, 6, 17, 24, 25, 26.
[5] Cases 10, 11, 12, 13, 15, 16, 21, 23.

in the distribution of the sensitive and insensitive areas; three only need special mention. Case 16 had anæsthesia of the superior and anterior parts of the tympanic membrane, but the whole of the external auditory canal was sensitive. Case 23[1] showed anæsthesia of the whole drum except the anterior part, whilst in the auditory canal the posterior wall was the only one which had not lost its sensation. Case 12 is of special interest as the tympanic membrane had been destroyed by otitis media many years before. The greater part of the external auditory meatus was anæsthetic, but beyond the site of the membrane horsehair stimulation produced the feeling of light touch, and no auditory sensations were obtained. Figures 28 to 32 illustrate the anæsthesia on the membrane of Cases 10, 13, 15, 21, 23.

In none of the cases even when seen at varying periods up to one year was there any change.

It has only been possible to investigate analgesia on the walls of the meatus, and here it was found to correspond exactly with the anæsthesia.

Anæsthesia of the External Auditory Meatus according to the Number of Walls Involved.

4 walls.	3 walls.	2 walls.	1 wall.	No anæsthesia.	Total.
10	4	5	2	4	25

Relative Affection of the various Walls in the 21 Cases which showed Anæsthesia.

Anterior.	Posterior.	Superior.	Inferior.
21	12	16	15

Anæsthesia of Tympanic Membrane.

Complete.	Partial.	None.	Total.
7	7	10	24

(3) Distribution to the Mucous Membrane.

After the removal of the Gasserian ganglion the mucous membrane of the cheek, the lips, of the gums of both upper and lower jaws, the roof and floor of the mouth, the anterior

[1] Fig. 32.

part of the tongue, and the nose on the same side, as far as the middle line, invariably become anæsthetic to all forms of sensation. The limit of the insensitive area on the tongue posteriorly and the line of its reflection on to the soft palate, the involvement of the anterior and posterior palatine arches of the nasal portion of the pharynx are, however, subject to considerable variations.

Krause [50] states that the palato-glossal arch and the palatal fold are usually anæsthetic. Cushing [12 and 13] traces the limit of sensory loss along the middle of the tongue almost as far back as the foramen cæcum, then outwards along the circumvallate papillæ to the root of the tongue laterally where individual variations exist, though in the greater number of cases the line follows the palato-glossal fold to the upper part of the anterior pillar of the fauces, and continues along this to the uvula; thence curving round the free margin of the soft palate traverses its roof to reach the lateral pharyngeal wall and turn upwards bisecting the Eustachian orifice to reach the midline of the pharynx and so return by the posterior edge of the nasal septum to the soft palate. The posterior pillar of the fauces, the lower portion of the anterior pillar and the tonsil remained sensitive in all the cases.

I have found considerably greater variations in the anæsthesia of the soft palate in the twenty-six cases I examined[1] from this point of view. These variations may be divided into three groups to each of which a sub-group is added.

In group 1 (fig. 33) the anæsthesia extending down the midline of the hard and soft palate, reaching the tip of the uvula, sweeps outwards along the margin of the uvula and of the anterior palatine arch to the lower end of the latter and then to the floor of the mouth. In these cases, therefore, the posterior palatine arch and the tonsil retain their normal sensibility. The difference in the sub-group is that, opposite the tonsil, the margin of the anæsthesia is

[1] These examinations were made at periods varying from nine days to seven years after the operation.

slightly anterior to the edge of the palatine fold. There are seven examples[1] of group 1, and two[2] of its sub-group.

Group 2 (fig. 34) also contains seven cases.[3] In it the uvula is anæsthetic, but the whole of the free margin of the palate, of the anterior pillar, along a strip half a centimetre wide, retains its sensibility, together with the tonsil and posterior arch.[4] In the sub-group, of which there are two examples,[5] the uvula also is sensitive.

Group 3 (fig. 35), which has five examples,[6] shows the greatest range of anæsthesia. The whole of the soft palate, the uvula, the anterior and posterior pillars of the fauces, and the tonsil have lost their sensibility. In the sub-group, two patients[7] have retained sensibility along the extreme edge of the posterior arch and of the tonsil, together with the lower third of the latter; whilst in one case[8] the border of the anæsthesia running along the free margin of the palate suddenly turns outwards across the upper third of the tonsil, and then continues down the edge of the anterior pillar.

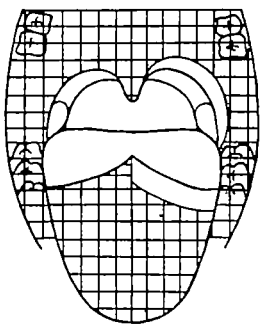
In only one patient[9] did the anæsthesia fail to reach the middle line. This man had had a second operation for recurrent pain, when some strands of connective tissue containing nerve filaments, which were found crossing the cavum meckelii, were cut away. When examined two and a quarter years later, he was suffering from neurasthenia, and complained of various abnormal sensations, including one of pain[10] on the same side of the face. The anæsthesia on his face was of the "C" type, and was complete up to the middle line. The anæsthetic area in his mouth is shown in fig. 36.

In those cases which fall under groups 1 and 2, in which the free margin of the palate remains sensitive, a palatal reflex can be obtained by stimulating this edge; in the other cases no reflex is obtained.

[1] Cases 6, 12, 14, 16, 21, 25, 28.
[2] Cases 3, 7.
[3] Cases 15, 18, 20, 23, 24, 26, 27.
[4] Krause notes a similar condition in the case of one of his patients, Frau, Prof. R.
[5] Cases 8, 19.
[6] Cases 1, 4, 11, 29, 30.
[7] Cases 17, 22.
[8] Case 13.
[9] Case 10.
[10] See p. 22.

The anæsthetic area of the tongue is more uniform. In eighteen cases[1] the lateral half as far back as the circumvallate papillæ was affected (fig. 33); whilst in six[2] the

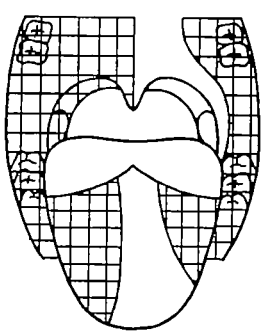
FIG. 33. FIG. 34.



Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.

posterior limit ceased one centimetre in front of this (fig. 34). Only three were exceptional. In Case 12 there was a strip half a centimetre wide along the median line of the dorsum which retained sensibility (fig. 35). In Case 15[3] no anæsthesia

FIG. 35. FIG. 36.



Horizontal shading denotes anæsthesia.
Vertical shading denotes analgesia.

[1] Cases 1, 3, 4, 7, 8, 11, 16, 17, 19, 20, 21, 22, 23, 26, 27, 28, 29, 30.
[2] Cases 6, 13, 14, 18, 24, 25. [3] Examined one year after the operation.

of the dorsum could be detected. Krause [50] mentions that in one of his patients, when seen two years after the operation, light contact was distinctly felt on the lip and upper surface of the tongue. Case 10 (fig. 36) has already been mentioned.

As in the anæsthesia of the auditory meatus and drum, so in the anæsthesia of the buccal mucous membrane, no change in the original areas has been found to take place.

(4) Distribution to the Deep Structures.

(*a*) *To the Dura Mater.*

The fifth nerve is mainly responsible for the innervation of the dura mater on the same side. Certainly no pain is experienced by the patients when the drainage plug is withdrawn from the deeper parts of the wound on the day after the operation. Cushing [12] had a case in which the ganglion was removed, together with the greater part of a basal neoplasm; the wound was left open for the application of the X-rays, and the dura of the middle fossa and temporal regions, which was exposed, was found to be completely insensible to any kind of stimulation.

Another interesting result of this anæsthesia of the dura is that headaches never occur on the side of the operation, but are confined entirely to the normal half of the cranium. Only one patient,[1] who had severe neurasthenia, complained of bilateral headaches after extirpation of the ganglion.

(*b*) *To the Subcutaneous Parts of the Face.*

Whilst sensation to the camel-hair brush and pressure touch is absent in the areas already indicated, deep pressure is occasionally appreciated in them. If the lip is pinched or compressed against the false teeth, the patient is quite oblivious of the action, so, too, if the ala nasi on the side of the operation is seized by a pair of forceps without causing any movement of the opposite nostril. Pressure on the eyeball through the closed eyelids gives rise to no sensation

[1] Case 23.

either of touch, pain, or light. When, however, the finger strongly compresses the soft tissues on to the underlying bone, the patients usually state that they can feel a slight touch, yet, if asked to indicate the spot, the localisation is extremely imperfect, the forehead or chin being pointed to instead of the cheek, or *vice versa*.

In four cases various operations had to be performed, and these admitted of an investigation of the sensibility of some of the deeper parts. In Case 26 five teeth were extracted from the upper and lower jaws on the side of the operation; no anæsthetic was administered and no pain was felt. Case 25 had her eye excised on account of neuropathic keratitis, which, owing to the patient's neglect, had led to panopthalmitis; no pain was experienced during any part of the operation, there was no alteration in the pulse when the optic nerve was cut, nor was any sensation of light observed, although the patient had been told before the operation to note carefully any sensation she might experience.

Another patient,[1] who came up to see me at my request, one year after the left ganglion had been removed, stated that he had a hole in the left side of his mouth. A large ulcerating cavity was found on the inner side of the alveolar margin leading into the antrum, the skin also on the outer side of the cheek was discoloured and breaking down. He was found to have a carcinomatous growth, primary of the alveolar margin, and invading secondarily the maxillary antrum. The tumour was inoperable, but owing to the foul state of the patient's mouth he was taken into the hospital. An incision was made over the zygomatic arch, which was affected, part of this bone was removed and the whole growth curetted; the greater part of the external and inferior walls of the superior maxilla had been destroyed, but neither during the operation, nor previously to it, had the patient suffered any pain.

In the fourth case,[2] the left Gasserian ganglion had been extirpated, together with an endothelioma which was growing from it. Three months later, owing to an extensive recurrence, a horizontal incision was made at the level of

[1] Case 15. [2] Case 18.

the lower border of the external auditory meatus. At a depth of three-quarters of an inch beneath the surface, a cavity was found which extended up to the zygoma, and from which a sequestrum was removed; no pain was felt during this operation.

Lynn Thomas [87] removed an epithelioma from the lip of one of his patients without causing any pain.

(*c*) *Muscle Sense.*

See section 6A.

(5) Distribution to the Organs of Special Sense.

(*a*) *Taste.*

Method.—The examination of the sense of taste is difficult, partly because the patient very rapidly becomes tired, and partly because even in a normal person some practice is necessary for the accurate recognition of the substance applied.

The procedure adopted in all the cases I have examined has been as follows: The tongue having been protruded, the surface is carefully dried, and the end of the organ is then held by the examiner to assist the patient in keeping it outside the mouth. The substance to be recognised is then applied by means of a glass rod. As soon as the patient appreciates a taste, he holds up his hand and the tongue is then released. Care must be taken that the sensation experienced, whilst the tongue is protruded, is expressed. Between individual applications the mouth is thoroughly rinsed out with water. The first few series of observations are not recorded, but they enable the patient to understand his part of the performance and afford him the necessary preliminary practice. Both sides of the tongue are always tested, and the examination, when possible, is not conducted for long at a time.

The substances used have in all cases been :—

(1) Saturated solution of salt.
(2) Sugar in the form of syrup.
(3) A weak solution of quinine hydrochloride.
(4) A weak solution of acetic acid.

The errors that may arise are :—

(1) The spreading of the solution to the opposite half of the tongue.

(2) The patient may experience a sensation of taste, without recognising the substance whilst the tongue is protruded, but appreciating its nature on withdrawing the tongue and opposing the mucous membranes of the tongue and palate, may name the taste in answering.

Much has been written about the course of the taste fibres, and the results published of the investigations of series of cases in which the Gasserian ganglion has been removed ; of isolated examples of destruction of single branches of the fifth cranial nerve or of the entire nerve ; of paralysis of the seventh and ninth cranial nerves, and also of numerous experiments on animals. But our knowledge of the course of the gustatory fibres has been very little increased since three years ago, when Harvey Cushing [14] published the results of his post-operative investigations of thirteen cases [1] of trigeminal neuralgia, and gave at the same time a comprehensive survey of the general literature.

Except for these two papers of Cushing and the monograph of Krause [50], there have been no articles dealing at length with the question of taste in conjunction with any large series of cases of trigeminal neurectomy, and the previous authors have had to be content with the repetition of those cases in which ageusia was observed to follow fracture of the base of the skull, syphilitic lesions of the cranial nerves, and, in a few isolated cases, of tumours involving one or more branches of the trigeminus, or of direct injury to this nerve, together with the evidence obtained from a certain amount of experimental work on animals.

Had not so many definite assertions been made and considered proved by the findings in these cases, it would have seemed unnecessary to lay stress on the slight value of statements definitely attributing the loss of taste to the destruc-

[1] In the *Journal of the American Medical Association*, April 8, 1905, Cushing, in his paper, "The Surgical Aspects of Major Neuralgia of the Trigeminal Nerve," adds his findings in another seven cases.

tion of a certain nerve, when the patient was either suffering from syphilitic gummata or from fracture of the basis cranii, in either of which lesions it is impossible clinically to be absolutely certain that one nerve only is completely destroyed.

In the controversy that exists concerning the course of the taste fibres, practically[1] all are agreed that the glossopharyngeal supplies the posterior third of the tongue, and that the chorda tympani may be the initial channel of conveyance for the fibres from the anterior two thirds. It is in reference to the connection between the chorda tympani and the brain that the great disagreement arises, and there are two parties to the argument; the one regarding the trigeminus as an essential in the course of these impulses, the other upholding the facial or the glossopharyngeal route.

Among those in favour of the fifth nerve hypothesis may be mentioned Erb [22, 23, 24], who gives three cases in which loss of taste accompanied lesions either syphilitic or traumatic of the trigeminus; Salomonsohn [76], who found ageusia in a patient with a malignant metastatic deposit involving the superior maxillary branch of the fifth; Scheier [79], in whose article the views of many previous authorities are carefully detailed, and who quotes two cases of injury associated with loss of taste; he is uncertain, however, by which branch of the trigeminus the taste fibres reach the Gasserian ganglion. Schmidt [81] and Kron [56], their views also mainly based on cases in which the lesion was traumatic or syphilitic, are of the same opinion. Ziehl [100] considers that the fibres on leaving the geniculate ganglion of the facial, pass either by the small superficial petrosal, or by the tympanic plexus (*R. communicans N. facialis*) perhaps by both to the otic ganglion, and so enter the Gasserian ganglion by the inferior maxillary division; he also suggests that they may pass by the superior maxillary branch of the trigeminus, the route varying in different people. Potts and Spiller [69] mention a case of solitary tubercle of the pons, in which ageusia of one side of the

[1] Wolfe [99] holds that the chorda tympani supplies only the anterior third of the tongue, but Schulte [82] considers that in Wolfe's case the chorda tympani was only partially divided.

tongue was present; at the autopsy, marked degeneration of the trigeminus and facial of the same side was found, whilst the abducens nucleus and "probably" the facial nucleus, were unimpaired; from this the authors conclude that the taste fibres run in the trigeminus.

In this country Gowers [32, 33, 34, 35] is the great advocate of the fifth nerve hypothesis; and in addition to the two cases of disease of the trigeminus associated with ageusia, he gives the results of four cases operated on by Sir Victor Horsley and one by Mr. Ballance, in all of which taste was completely absent [35]. In his "Diseases of the Nervous System," Gowers further says that in all cases which he has seen where disease of the fifth nerve existed, there was loss of taste both on the front and back of the tongue on that side, and on the arches of the palate; the course of the taste fibres to the posterior part of the tongue he traces through the communication of the sphenopalatine and otic ganglion with the glossopharyngeal, by a branch from the great superficial petrosal, and the small petrosal nerves to the tympanic nerve of Jacobson.

Much stress has been laid on the case published by Fergusson [27], in which there was loss of taste for two years prior to the patient's death. At the autopsy, an exostosis was found in the scaphoid fossa, which, pressing on the posterior opening of the Vidian canal, had destroyed the Vidian nerve. Fergusson says that degeneration could be traced along the Vidian and its two branches, through the geniculate ganglion up to the point at which the chorda tympani was given off, thence could be followed through this nerve and finally along the lingual branch of the third division of the fifth. But as Cushing [14][1] says: "No mention is made of any histological demonstration of evidence of degeneration, nor are the methods of studying what must have been a most difficult and arduous problem even suggested. In view, therefore, of the isolarity of this case, and of morphological studies which show that the superficial petrosal is an outshoot of the *G. geniculatum*, the observa-

[1] P. 72, foot note 13.

tion hardly deserves the keystone position which it has been given."

Stewart [83] and Turner [93] are both of the opinion that the fifth nerve conducts the gustatory fibres. J. Hutchinson, jun. [45], mentions a case in which after excision of the Gasserian ganglion and its second and third divisions, taste was lost. Blüher [2] found this also in a case where Schlange had divided the inferior maxillary branch intracranially.

Finally, the support afforded by certain experiments must be given. Schiff [80] found that section of the central root of the Gasserian ganglion abolished taste, but that this did not occur if the first and third divisions of the trigeminus were alone cut, nor if intracranial section of the facial was performed: section of the second division of the fifth, however, just in front of the ganglion, and lesions implicating the facial in the petrous bone were associated with ageusia: further, that section of the lingual above its junction with the chorda tympani was accompanied by complete loss of tactile and painful sensations and partial loss of taste. Schiff concluded, therefore, that the fibres travelled from the Gasserian ganglion down the superior maxillary branch to Meckel's ganglion, thence by the great superficial petrosal to the geniculate ganglion, from which two sets of taste fibres passed off; some travelling by the chorda tympani to the lingual, the others reaching that nerve through the small superficial petrosal and the otic ganglion. Vulpian [95], working with M. Prevost, of Geneva, found no alteration in the great superficial petrosal, nor in the chorda tympani after excision of the sphenopalatine ganglion; section of the intracranial part of the facial was only occasionally followed by slight degeneration in the chorda tympani, but this nerve was always degenerated after section of the fifth branches (in rabbits).

The course of the taste fibres, according to these authorities, is then through the lingual, the chorda tympani and facial to the geniculate ganglion, thence either by the great superficial petrosal and the sphenopalatine ganglion to the second division of the trigeminus (Erb, Gowers, Schiff), or

through the small superficial petrosal and the otic ganglion to the third division of the fifth (Ziehl, Schmidt).

In direct opposition to this are Cushing and Krause, whose views, based on a series of cases of trigeminal neurectomy, will be considered presently. Morat [65] discussing "Gustatory Sense," says :—

"The opinion which has prevailed concerning the function of the small root of the facial or nerve of Wrisberg is, that it represents an aberrant origin of the glossopharyngeal nerve, which is destined for the tip of the tongue by the path of the chorda tympani . . . . Intracranial paralysis of the facial and section of the chorda tympani are accompanied with *a marked diminution of taste at the tip of the tongue, and of the pillars of the soft palate.*"[1]

Dixon [19 and 20] has shown that the chorda tympani in early life is unassociated with the lingual, and probably carries impulses to the geniculate ganglion of the facial; similarly the great superficial petrosal is an outgrowth of the cells of this ganglion, and Jacobsón's nerve which is derived from the ganglion of the glossopharyngeal, conducts impulses to it. "Can we resist," then, he says, "the conclusion that the taste impulses reach the brain by seven and nine?" Strong [85] states that the seventh nerve is undoubtedly the nerve of taste in the lower vertebrates. Haycraft [38] bases his objection to the part played by the fifth on developmental and morphological grounds, also on the small percentage of cases in which taste is lost after resection of the Gasserian ganglion and its second and third branches. Lussana [61] favours the seventh and the pars intermedia as the path for gustatory impulses; whilst Hermann [41] believes it to be in the glossopharyngeal. According to Landois [58], who is supported by Carl [6], the taste fibres pass from the glossopharyngeal to the chorda tympani by various routes.

(1) Through the intermediary portion of Wrisberg.

(2) By a small filament (ramus communicans) from the digastric branch of the facial, which joins the glossopharyngeal near the stylomastoid foramen.

[1] P. 176.

(3) In the tympanum by a filament uniting the small superficial petrosal of the facial, and the tympanic branch of the glossopharyngeal.

(4) By small filaments connecting the trunk of the facial in the Fallopian canal with the petrous ganglion of the glossopharyngeal.

Schulte [82] found that section of the seventh or fifth at the base of the skull produced no loss of taste, and therefore concluded that the fibres ran in the ninth. In addition, there is the evidence afforded by the reports of observations in four isolated cases. Pope [68] mentions a case of loss of taste associated with pressure on the glossopharyngeal in a patient suffering from thrombosis of the vertebral artery. That of Lehmann [59] showed ageusia, following a traumatic lesion of the seventh, eighth, ninth, and twelfth nerves. In Cassirer's [7] case the ninth, tenth, eleventh, and twelfth nerves were paralysed owing to trauma, and the lesion was accompanied by loss of taste; whilst in a most interesting case of fracture of the base of the skull, noted by Bruns [4] on the one side, the lesion implicated the whole trigeminus without any affection of taste; on the other side the paralysis of the facial was associated with complete loss of the sense of taste.

The best evidence dealing with the relationship of the fibres of taste and the trigeminus is derived from the examinations made of patients after the removal of the Gasserian ganglion. The table given below will show at a glance the condition found in all the published cases of Gasserian ganglion extirpation, in which a report on the taste was made. Krause [50] found in his six cases that taste was abolished in two, was partially affected in three, and in one was wholly unimpaired. From these positive results Krause concludes that the trigeminus contains no taste filaments, and that these are altogether derived from the glossopharyngeal. Cushing's [13 and 14] results are more conclusive evidence against the importance of the fifth. In his first series of thirteen cases, although in practically all there was either complete abolition or blunting of taste after the operation, yet in only one instance (in which only one

examination was made six days after the operation), did he fail to demonstrate complete return of this sense. Cushing's second series of cases is as interesting as his first. Five showed no impairment whatever; in one case there was marked affection at first, but considerable though not complete return later, whilst in one case the lingual had been previously divided, and so the sense of taste was necessarily absent.

In the twenty cases [1] I have examined, in only one [2] was there complete loss of taste on the side of the operation, and this loss was found to affect also the posterior third of the tongue and the palate on that side; it was then two and a quarter years since the operation. In sixteen [3] of the cases seen at varying periods of nine days to seven years after the operation practically no permanent difference in the two sides could be detected, especially when the patients had had a little training. Of these some, however, showed marked deficiency shortly after the operation, but when seen later this was no longer apparent.[4] One case,[5] indeed, was most striking and repeatedly proved that the sense of taste was better on the side from which the ganglion had been removed. In the remaining three cases [6] there was certainly less accuracy in the recognition of flavours on the side of the operation than on the other, but of two of these patients [7] only one examination of each had been made, and that within the first fortnight of convalescence. With the exception of Case 8, mentioned above, no difference was found in the perception of taste on the posterior third of the tongue or palate on either side.

An examination of Table I. given below shows that of 107 cases in which the condition of the taste has been given after the removal of the Gasserian ganglion, in forty-six

[1] Cases 1, 3, 4, 6, 8, 10, 12, 13, 14, 15, 16, 17, 19, 21, 22, 23, 24, 25, 27, 30.
[2] Case 8.
[3] Cases 1, 3, 4, 6, 10, 12, 13, 14, 16, 17, 21, 22, 23, 24, 25, 27.
[4] This was most noticeable in Case 23, who on the ninth day had absolute ageusia on the side of the operation, but two months later had completely recovered, and taste was then excellent on both sides.
[5] Case 17.
[6] Cases 15, 19, 30.
[7] Cases 19 (thirteen days after). 30 (fifteen days after).

the sense was unaffected as opposed to thirty-four,[1] in which complete ageusia was present, whilst twenty-seven suffered from some affection on the side of the operation. In Table II. are collected those cases examined by Krause, Cushing and myself, at a period of one month or more after the operation. Of the forty patients in this list, thirty-three have suffered no impairment, whilst three[2] have lost their sense of taste, the remaining four showing a varying degree of affection.

In the face of these figures it is obviously impossible any longer to consider the trigeminus as the normal channel through which taste fibres reach the brain.

There are yet two questions to be considered :—

(1) Why is there sometimes a disturbance, either temporary or permanent, in the sense of taste after removal of the Gasserian ganglion ?

(2) What is the course of the taste fibres ?

In answer to the first, Krause emphasises that the lesser superficial petrosal, which connects the geniculate ganglion with the glossopharyngeal, may readily be injured in stripping up the dura mater to reach the Gasserian ganglion, or it may later on be caught up in scar tissue, and, as he considers it very probable that the gustatory fibres reach the mouth by the communicating branch, this injury might explain the loss of taste in certain cases. Krause also considers it possible that the path for taste fibres may vary in different individuals. Dixon [19 and 20], who also gives these two views, states that in some cases the geniculate ganglion is separated from the middle fossa by dura mater only, and that, therefore, it is quite easy for some injury to happen to the cells of this ganglion, and so to abolish the central connections of the chorda. Cushing considers that "this temporary loss of function may possibly be occasioned by some interference with chordal transmission brought about by a mechanical or toxic disturbance due to degeneration of the N. lingualis."

[1] In many of these cases the examination was made within a week or two of the removal of the ganglion.

[2] Krause. Frau, Prof. R., six weeks; Frau, W., six months; the author, Case 8, two and a quarter years.

Whilst it is quite possible to conceive that considerable damage might occur to the chorda tympani at the geniculate ganglion, yet one would scarcely expect to find a series of cases showing marked injury to the fibres of this nerve through a lesion of the ganglion of the facial, without there being some implication also of part, at any rate, of the seventh. By Cushing's hypothesis, on the other hand, a temporary or permanent abolition of taste impulses is more easily accounted for. Sir Victor Horsley has suggested to me that the unilateral furring of the tongue often so noticeable in these patients, and generally lasting for many days after the removal of the ganglion, may to a great extent be the cause of the temporary diminution in the perception of taste.

The answering of the second question is still more difficult, and the results of histological investigations are not wholly in accord with the more recent clinical work. The latest contribution on the subject is an article by Nageotte [66], who shows that the so-called gustatory nucleus in the brain is connected with fibres from the trigeminus, the pars intermedia of the facial and the glossopharyngeal,[1] consequently he assumes that all these nerves are associated with the sense of taste. He details the case of a man who suffered from right facial paralysis and who was found at the autopsy to have a metastatic malignant tumour in the Fallopian aqueduct below the geniculate ganglion. The observations on the condition of taste having been lost, Nageotte assumes on general knowledge that ageusia was present; certain it is that the chorda tympani and facial were degenerated below the lesion; furthermore, the pars intermedia in its intrapontine course also showed complete degeneration of its fibres, and this was traced to the gustatory nucleus "situated in the prolongation of the anterior cornu of the crescent which is formed by the descending root of the fifth pair." No mention is made, however, of the condition of the intramedullary fibres of the trigeminus. From the observations on this

[1] The close connection of the fibres of the trigeminus and glossopharyngeal with the gustatory nucleus has been previously demonstrated by Ramón y Cajal (71).

case, and those made by Wallenberg [96] on a patient, who had a tumour affecting the hypoglossal and a part of the trigeminus only, accompanied by hemiatrophy and loss of taste on the back of the left side of the tongue, and in whose brain degenerated fibres were traced down to a small mass of grey matter which corresponded in position with the gustatory nucleus, Nageotte is convinced that this nucleus is for the reception of the gustatory impulses. Sapolini [78], however, has traced the connections of this bulbopontine nucleus by the pars intermedia with the chorda tympani.

Clinically, evidence has been brought forward which affords support to those who hold the view that the fibres pass by the pars intermedia, as well as to those who favour the glossopharyngeal as the path of the gustatory impulses. But including the evidence of morphological, developmental and histological observations, I am inclined to the opinion that the gustatory impulses reaching the geniculate ganglion by the lingual and chorda tympani pass thence to the brain in the pars intermedia.

Further clinical investigations and experimental work can alone solve the problem.

TABLE I.

List of Cases in which the Condition of Taste was observed after Resection of the Gasserian Ganglion.

Recorded by.	Total.	Taste unaffected.	Taste impaired.	Taste lost.
Blüher (3)	1	... —	... —	... 1
Cahen (5)	1	... —	... —	... 1
Coelho (9)	1	... 1	... —	... —
Dandridge (16)	1	... —	... 1	... —
Depage (17)	1	... —	... —	... 1[1]
Erdmann (25)	1	... —	... —	... 1
Eskridge and Rogers (26) ..	1	... —	... —	... 1
Garré (31)	1	... —	... 1	... —
Hutchinson, J., Jun. (45) ...	1	... —	... —	... 1
Knock (49)	1	... —	... 1	... —

[1] Depage says: "Le goût semble avoir disparu dans les deux tiers anterieurs de la langue du coté opéré," p. 693.

Recorded by.	Total.	Taste unaffected.	Taste impaired.	Taste lost.
Kruger (57)	1	... —	... 1	... —
Marchant et Herbet (63) ...	1	... 1	... —	... —
Monari (64)	1	... —	... —	... 1
Stewart, R. W. (84)... ...	1	... —	... —	... 1
Thomas, Lynn (87)... ...	1	... 1	... —	... —
Weeks (97)	1	... —	... 1	... —
Winslow (98)	1	... —	... —	... 1
Draudt (21)	2	... —	... 1	... 1
Friedrick (29)	2	... —	... 1[1]	... 1[1]
Rose (74 and 75)	2	... —	... 1	... 1
Thomas, H. M. (86) ...	2	... 1	... —	... 1
Keen (47 and 48)	3	... —	... 1	... 2
Maier (62)	3	... —	... 2	... 1
Pruschinin (70)	4	... —	... 3	... 1
Gowers (35)	5[3]	... —	... —	... 5
Lexer (60)	6	... —	... —	... 6
Tiffany[4] (88, 89, 90, 91) ...	6	... 4	... —	... 2
Tiffany[5] (89 and 90)... ...	10	... 4	... 6	... —
Krause (50)	6	... 1	... 3	... 2
Cushing (13 and 14) ...	19[6]	... 17	... 1	... 1
Davies[7]	20	... 16	... 3	... 1
	—	—	—	—
Total	107	46	27	34[8]
	—	—	—	—

[1] The first examination was made by Friedrick on the fourteenth day, and taste was found to be considerably impaired. The second examination was made by Perthes (67) three years later; taste was then found to be much impaired on both sides.

[3] The only examination was made on the twenty-ninth day. The sense of taste was found absent on the side of the operation, whilst on the other side sweet and bitter only were recognised.

[3] All these cases had been operated on at the National Hospital for the Paralysed and Epileptic, four of them by Sir Victor Horsley and one by Mr. Ballance. In Mr. Ballance's case, taste appeared to be present on both sides one week after the operation, but a fortnight later there was complete loss of taste.

[4] These are Tiffany's own cases.

[5] These are personal communications to Tiffany: Two by Abbé, one by Chambers, four by Hartley, two by Murphy, one by Richardson.

[6] Cushing gives twenty cases, but one of these is not given in this list as the lingual nerve had been previously divided.

[7] These twenty cases were operated on in University College Hospital—nineteen by Sir Victor Horsley, and one by Mr. Bucknall.

[8] In many of these cases the examination was made within a week or two of the operation, and the ageusia noticed may therefore have been only temporary.

TABLE II.

Cases examined by Krause, Cushing and Morriston Davies more than one month after the operation.

Examined by	Total.	Taste unaffected.	Taste impaired.	Taste lost.
Krause ...	5	1	2	2
Cushing ...	18	17	1	—
Davies ...	17	15	1	1
Total ...	40	33	4	3

(*b*) *Smell.*

Method.—The substances used in testing this sense were ether, ammonia, peppermint, cinnamon, valerian, and phenol. These solutions were held at some distance from the nose and gradually brought nearer; the one nostril being held firmly closed, while the patient inhaled through the other.

According to Krause [50], who agrees with Magendie, the branches of the fifth through their connections with the olfactory nerves share in the faculty of smell; whilst Cushing [13] considers this sense to be unimpaired.

I examined seventeen patients,[1] of whom fifteen[2] showed no difference in acuity of perception on the two sides; in one patient[3] the time taken to recognise any substance placed against the anæsthetic nostril was a little longer than when held to the other side of the nose, and in another case[4] there was some hesitation in the recognition of cinnamon, peppermint, ether, and ammonia on the side of the operation. Five[5] of these patients were tested both before and after the removal of the ganglion, and none of them showed any change.

I also heard from fourteen patients, whom I was unable to examine personally; of these ten stated that they could notice no difference on the two sides; three said that they were unable to smell quite so well on the side of the operation, whilst one affirmed that she could not smell at all.

[1] Cases 3, 5, 8, 10, 14, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 30.
[2] Cases 3, 5, 10, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26, 30.
[3] Case 19.
[4] Case 8.
[5] Cases 21, 23, 24, 25, 26.

(c) *Hearing.*

Method.—Patients were tested with a watch, tuning fork, and Galton's whistle; the membrana tympani was also examined so as to note its condition, and to see if any retraction or bulging was present.

There is no evidence to show that the sense of hearing is in any way impaired after the Gasserian ganglion has been removed. Neither Krause nor Cushing found any noteworthy impairment in their cases; and in patients of this series who were tested both before and after the operation, no alteration in capacity of hearing could be discovered. The question of the paralysis of the tensor tympani will be discussed when dealing with the motor paralysis resulting from the operation, but to repeat, no change in the position of the membrane, no increase in the power of recognising the high-pitched sounds emitted with a Galton's whistle, and no deficiency in the appreciation of lower-toned notes were made out. The majority of the patients themselves acknowledge no loss of this sense when examined, though not a few complain of dulness of hearing.

(d) *Vision.*

Method.—The width of the palpebral fissure, the relative sizes of the pupils, and their reaction to light and accommodation, were noted. The eyes, when possible, were tested both before and after the operation; the distant and near vision were examined with and without correcting glasses, and the near point of vision was found. Finally, the fundus was examined with the ophthalmoscope.

If the eyes be examined immediately after the operation, it will be found that the pupil on the side of the operation is smaller than the other. In nearly all cases, however, this contraction has passed off by the next day, and no change can be detected afterwards. I have on several occasions had the opportunity of seeing this phenomenon in monkeys, on whom the operation of excision of the Gasserian ganglion with evulsion of the sensory root has been performed by Sir Victor Horsley. Krause was not able to note this change in

his patients, whilst Cushing [13] observed in eight of his cases a pupillary contraction which lasted for some weeks. In some of his cases also there was a slight narrowing of the palpebral fissure; this I have observed, since in almost all cases there has been a varying degree of ptosis present, owing to the anterior end of the scalp incision dividing the upper branches of the facial, and causing drooping of the eyebrow.

None of the patients have ever shown any defect in their power of accommodation subsequent to the neurectomy.

In several cases I was able to test the eyesight and near point of vision, both before and after the operation; in four[1] of these cases the examination after the operation was unhampered by neuropathic keratitis[2] or opacities of the cornea, and in none of them was any diminution of the acuteness or alteration in the near point of vision observed.

(6) Motor Distribution.

(*a*) *Muscular.*

After excision of the Gasserian ganglion and the motor root of the fifth nerve,[3] the muscles of mastication on that side are paralysed and wasted; these muscles are the temporal, the masseter, and the external and internal pterygold.[4] But it has been asserted that certain other muscles are innervated by the motor division of the trigeminus, and that these, therefore, also undergo degeneration; they are the mylohyoid and anterior belly of the digastric, the tensor tympani and the tensor palati. Both Krause [50] and Cushing [13] maintain that the wasting of the mylohyoid and

[1] Cases 21, 22, 24, 26.

[2] Dr. Hall and I hope shortly to bring out a paper on Neuropathic Keratitis, in which the bacteriological hypothesis will be especially considered.

[3] These two are nearly always removed together; but in one case in which Sir Victor Horsley had already removed one Gasserian ganglion, and in which he had to extirpate the ganglion of the other side at a later date, he endeavoured to preserve the motor root at the second operation, but was obliged to plug the foramen ovale with a portion of the temporal muscle to stop the hæmorrhage after removing the ganglion. The motor root, however, degenerated, and the patient is unable to actively close the mouth.

[4] In Case 15 the temporal muscle only appears to have atrophied, and the lower jaw is not laterally deflected when the mouth is opened.

anterior belly of the digastric is recognisable on palpating the floor of the mouth, although giving rise to no symptoms, but I have only been able to detect in two[1] out of twenty-six[2] cases that the floor of the mouth felt more flabby on the side of the operation. The supposed innervation of the tensor tympani by the fifth has been more universally discarded, as no change has been observed to follow excision of the Gasserian ganglion, either as to the tenseness of the drum or the increased power of the individual, when tested with a Galton whistle, to appreciate high-pitched sound, nor has any discrepancy in the accurate recognition of low notes been noticed. Both Krause and Cushing, however, have had one patient each who complained of a ticking sound in the ear. No cause could be found for it.

The innervation of the palatal muscles has not been so definitely established. Krause found no special alteration in the symmetry of the palatal arches. Cushing, acknowledging that the accessory branch of the vagus is at least a partial source of supply, considers that the trigeminus also contributes motor fibres. In four of his cases a marked asymmetry of the velum appeared after the operation. "The abnormal position consists," he says, "in a tilting of the uvula toward the side of the neurectomy, in a narrowing and heightening of the arch on the sound side, and with a broadening and lowering, apparently from relaxation, of the arch on the operative side" [13], this condition not being always apparent except on phonation, especially of the sound of a prolonged "eh." He further considers that the noises occasionally heard in the ear may be due to the Eustachian tube remaining closed during deglutition owing to paralysis of the tensor palati. If this is the case, it is surprising that so few of these patients suffer from diminution in their power of hearing. Gowers [33], in a patient who had paralysis of the fifth nerve, noted that the palate moved symmetrically and gave equal electrical reactions; Ferrier [28], in another case, found no difference on the two sides.

[1] Cases 21 and 26.

[2] Cases 1, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30.

In only five[1] out of twenty-six[2] cases did I find any inequality of the palate; in each of these the velum was about one-eighth of an inch lower on the side of the operation, with the uvula a little inclined to the opposite side. In three patients operated on by Sir Victor Horsley, the peripheral ends of the roots of the fifth nerve were electrically stimulated, but whilst the mouth tended forcibly to close, no movement of the palatal muscles could be observed. Cushing states that in one of his cases, when the ganglion had been extirpated, stimulation of the stump of the mandibular division produced contractions and deflections of the palate.

In monkeys and dogs, when the motor root is stimulated, although no movement of the palate takes place, the back of the tongue becomes heaped up; and Beevor and Horsley [1] have proved that the motor innervation of the palate is by the vagal accessory. Vulpian [94], experimenting on dogs, has shown that no movement of the palate is produced by stimulation either of the fifth or the seventh, but only on stimulation of the spinal accessory or accessory vagus.

The balance of evidence seems to show that the fifth nerve has nothing whatever to do with the nerve supply of the palatal muscles. Two patients in this series exhibited facial paralysis on the day after the operation; in one[3] the paralysis was complete and involved equally the upper and lower segments of the face—it was still evident when the patient left the hospital on the twenty-fifth day, but was improving rapidly. In the other case[4] there was only a paresis of the whole side of the face, and when I saw the patient over three years after the operation all signs of it had disappeared. Cushing [13] observed in one of his cases, a few days after he had removed the Gasserian ganglion that there was complete inability to perform movements of the face on that side, and that apparently a Bell's palsy existed; this patient also recovered completely.

[1] Cases 3, 12, 17, 19, 27. (None of these unfortunately were examined before the operation.)
[2] Cases 1, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30.
[3] Case 28.
[4] Case 6.

The partial facial paralysis which is always observed to affect the upper face must not be confounded with the condition just mentioned. The anterior extremity of the incision invariably divides some of the upper branches of the seventh nerve, and as a general result there is inability to wrinkle the forehead or frown on that side, the eyebrow droops, and consequently the upper eyelid is slightly lowered and the palpebral fissure narrowed. To avoid this, Cushing [10] has lately slightly altered the line of his skin incision and his method of approach to the skull.

Other changes which can be seen are the flaccidity of the lips, a little drooping of the corner of the mouth and a flattening of the naso-labial fold, together with occasionally a slightly less active play of the facial expressions on the side of the operation. This has been ascribed to a general loss of tone of the facial muscles; but it may be the persisting remnant of the habit of facial immobility adopted by the patient whilst suffering from the neuralgia. I have never seen the muscular twitching which, according to Krause and Cushing, occasionally occurs, although some patients complain of a "feeling of twitching" at the angle of the orbit and mouth (without such being visible). In six monkeys, who had had the left Gasserian ganglion removed, I could find no noticeable alteration in facial expression, but when eating they never filled the left buccal pouch.

Postural changes of the muscles produced by faradisation or by gentle traction on the lip or nose are not noticed by the patients, nor are they aware when the cheek becomes distended with food, and often complain that food when it is taken into the mouth appears to become lost. Hofmeister and Meyer [42] mention a case in which loss of vision occurred on the anæsthetic side; the patient did not know when the eyelids were opened or closed.

(*b*) *Vaso-motor and Secreto-motor.*

In reference to trophic changes other than those affecting the eye, Krause says that the majority of cases operated on do not, even several years after the operation, exhibit the slightest vaso-motor or trophic anomalies of the skin, nor is

there any indication of glossy skin and the like. The results of my observations are absolutely in accord with this statement and in no case of uncomplicated trigeminal neurectomy have I seen any vaso-motor or trophic disturbance. Two cases are, however, of interest in this connection. The one[1] developed, after the operation of removal of the right Gasserian ganglion, a left hemiplegia. When seen three and a half years later the right cheek looked redder, felt warmer, and sweated more than the left; the hemiplegia had then cleared up except for some weakness in the fingers. The other case was not a true instance of trigeminal neuralgia. Four years before she was admitted to the hospital she had suffered from a very severe attack of herpes over the front and upper part of the right side of the head. When she recovered from this the skin over the upper part of the head and forehead was quite white, whilst the hair in this region and the eyebrow and eyelashes all on the right side were lost. From that date she developed her neuralgia.

The secretion of sweat similarly is unaffected. The great majority of the patients exhibit no difference even when treated by the injection of pilocarpin. In one case[2] only have I noticed that the face has a persistently greasy and moist appearance on the side of the operation. In the patient[3] who had an endothelioma of the Gasserian ganglion removed, a recurrence of the growth had caused complete facial paralysis. In this case although the injection of pilocarpin produced equal bilateral sweating, the inhalation of ammonia, which was administered in order to observe the reflex secretion of tears, was followed by the appearance of sweating on the paralysed side only. The patient about this time developed Jacksonian epilepsy, and the same phenomenon was then observed after each fit.

Krause, who found considerable diminution or delay in the flow of tears in his patients, believes that the fibres which supply the lachrymal gland pass either directly through the branches of the trigeminus, or by way of the superior maxillary division, Meckel's ganglion and the great

[1] Case 5. [2] Case 26. [3] Case 18.

superficial petrosal, to the geniculate ganglion, and thence reach the gland by the upper branches of the facial nerve. The variations observed he considers due to the amount of injury done to the great superficial petrosal at the time of the operation, or the subsequent implication of that nerve in the scar produced in the process of healing between the dura mater and the bony basis of the skull. Tiffany [89] also considers that after removal of the ganglion there is no diminution of lachrymation on the same side. "In some cases no tears have been secreted when the patient has cried."[1]

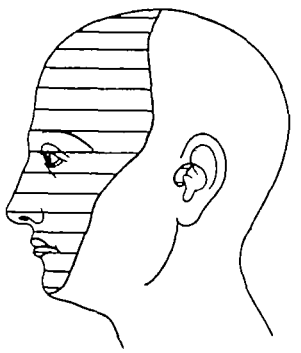


FIG. 37.

Case 14.—Two years after operation.
Shaded areas are anæsthetic.

In none of the cases of uncomplicated trigeminal neurectomy which I have personally examined have I been able to detect any difference either in the flow of tears or in the rate of onset, whether the lachrymation was natural in its origin or artificially produced by the inhalation of irritating vapours. Only in that patient[2] in whom there was associated paralysis of the facial nerve was the onset of lachrymation delayed, and the amount secreted less on the affected side.

The secretion of the salivary glands is certainly not diminished, rather there is occasionally some slight loss of

[1] P. 51. [2] Case 18.

inhibition, as six[1] of the patients I examined or who answered my questions on this subject complained of frequent watering of the mouth on the affected side, but there was never dribbling; the rest suffered no inconvenience either from increase or diminution in the flow of saliva.

In this connection may be mentioned that case[2] in which pain recurred on the same side soon after the patient left the hospital. The attacks were quite characteristic of trigeminal neuralgia, affected the face in the area of distribution of all three branches and were associated with lachrymation, salivation and flushing. The area of anæsthesia, however, of the face,[3] mouth and palate, was typical of a case of complete resection of the Gasserian ganglion, and in addition the patient suffered from neuropathic keratitis. At a second operation some fibrous tissue was removed from the cavum meckelii, but contained no nerve structure. The irritation was probably of central origin, and the case affords additional evidence that the secreto-motor nerves to the lachrymal gland do not pass through the fifth nerve.

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[1] Case 1; 6; J. C.; E. G.; M. J.; R. H. [2] Case 14. [3] Fig. 87.

No.	Initials of patient.	Age.	Sex.	Side.	Number of days or years, after operation, of first examination.	Anæsthesia (to camel-hair brush) of face.	Pressure-touch anæsthesia; analgesia; thermal anæsthesia of face.	Anæsthesia of external auditory meatus and membrana tympani.	Anæsthesia of palate.	Anæsthesia of tongue	Taste.	Number of days or years, after operation, of final examination.	Anæsthesia (to camel-hair brush) of face.	Other changes.
16	A. D.	79	M.	R.	142 days	Type B	Type X	Whole meatus retains sensation. Antero-superior quadrant of drum anæsthetic	Anæsthesia up to free border of palate, and of anterior pillar	Anterior two thirds ...	Unaffected	2 years	Type B	Thermal paræsthesiæ extending between the posterior border of an anæsthesia of type C and one of type A. See fig. 26. Patient not examined for this when first seen.
17	C. R.	50	F.	L.	242 days	Type B	Type X	Anterior and superior walls of meatus anæsthetic. Drum retains sensation	Free margin of palate retains sensation, but upper border of tonsil and of posterior pillar anæsthetic	Anterior two thirds ...	Unaffected	1 year, 11 months	Type B	Posterior margin of anæsthetic zone shows thermal paræsthesiæ. Patient not examined for this when first seen.
18	G. L.	26	M.	L.	109 days	Type A. Ophthalmic division not affected	Type Y	Floor and posterior wall at commencement of meatus are sensitive; the rest together with drum is anæsthetic	Free margin together with both pillars and tonsil retain sensation	Anterior half.				
19	M. P.	53	F.	R.	15 days	... ...	Type X	... ...	Free margin of palate, both pillars and tonsil retain sensation	Anterior two thirds ...	Impaired.			
20	M. T.	55	F.	R.	16 days	Type D	Type Z	Meatus and drum retain sensation	Free margin of palate to within ½ cm. of uvula, both pillars and tonsil retain sensation	Anterior two thirds.				
21	C. B.	50	M.	R.	14 days	Type A	Type Y	Meatus and part of anterior half of drum anæsthetic. See fig. 29	Free margin of palate and anterior pillar anæsthetic	Anterior two thirds ...	Unaffected	55 days	Type B	Type X. No other change.
22	S. C.	60	F.	L.	9 days	Type A	Type Y	Meatus and drum retain sensation	Anæsthesia up to margin of palate including anterior pillar and upper part of tonsil and posterior pillar	Anterior two thirds ...	Unaffected	172 days	Type C	Type X. No other change.
23	M. H.	38	F.	L.	9 days	Type A	Posterior margin considerably in advance of anæsthetic boundary opposite tragus	Anterior, superior and inferior walls of meatus anæsthetic. Posterior three quarters of drum anæsthetic. See fig. 32	Free margin of palate, both pillars and tonsil retain sensation	Anterior two thirds ...	Unaffected	190 days	Type C	Type X. No other change.
24	A. L.	46	F.	R.	9 days	Type B	Type X	Upper and anterior walls of meatus anæsthetic. Drum retains sensation	Free margin of palate, both pillars and tonsil retain sensation	Anterior half	Unaffected.			
25	E. L.	66	F.	L.	10 days	Type A	Type Y	Roof of meatus and the whole drum retain sensation	Anæsthesia up to free margin of palate including anterior pillar	Anterior half	Unaffected	1 year, 7½ months	Type B	Type X. Thermal anæsthesia corresponding to type A.
26	E. B.	47	F.	R.	24 days	Type A	Type Y	Posterior wall of the meatus and the whole drum retain their sensation	Free margin of palate, both pillars and tonsil retain sensation	Anterior two thirds ...	... ...	1 year, 2½ months	Type B	Type X. No other change.
27	T. W.	49	M.	L.	12 days	Type A	Posterior margin considerably in advance of anæsthetic boundary, and resembling Type X	Meatus and drum anæsthetic	Free margin of palate, both pillars and tonsil retain sensation	Anterior two thirds ...	Unaffected	315 days	Type B	Type X, but slightly constricted. Area of thermal paræsthesiæ extending back from this to tragus. See fig. 17.
28	F. C.	52	F.	L.	15 days	Type A	Type Y	Meatus and drum retain sensation	Anæsthesia up to free border of palate including anterior pillar	Anterior two thirds.				
29	W. H. C.	64	M.	L.	12 days	Type A	Posterior margin some way in advance of anæsthetic boundary	... ...	Anæsthesia up to free border of palate including anterior pillar	Anterior two thirds.				
30	L. D.	33	F.	R.	12 days	Type A	Opposite tragus posterior margin in advance of anæsthetic boundary. Area between the two posterior borders shows thermal paræsthesia. See fig. 22	The antero-superior wall only of the first centimetre; the whole of the rest of the meatus, and the drum are anæsthetic	Free margin of palate, both pillars and tonsil anæsthetic	Anterior two thirds ...	Impaired	143 days	Type C	Type X. No other change except that thermal paræsthesiæ, present at first, have disappeared.

Summary of Observations on the Thirty Cases Personally Examined.

No.	Initials of patient.	Age.	Sex.	Side.	Number of days or years, after operation, of first examination.	Anæsthesia (to camel-hair brush) of face.	Pressure-touch anæsthesia; analgesia; thermal anæsthesia of face.	Anæsthesia of external auditory meatus and membrana tympani.	Anæsthesia of palate.	Anæsthesia of tongue.	Taste.	Number of days or years, after operation, of final examination.	Anæsthesia (to camel-hair brush) of face.	Other changes.
1	C. H.	36	M.	R.	7 years	Type B	Type X. But the lower part of the forehead, the eyelids and eye, the nose and chin are sensitive to all forms of touch and pain. See fig. 14	Whole of external auditory meatus and drum anæsthetic	Anæsthesia up to free border including both pillars and tonsil	Anterior two thirds ...	Unaffected.			
2	A. B.	55	M.	R.	21 days	Type A.								
3	T. D.	56	M.	R.	5 years	Type B	Area affected extremely abnormal. See fig. 18	Anæsthesia of anterior wall of meatus only	Free border of palate, tonsil, and area adjacent to this on anterior faucial pillar retain sensation	Anterior two thirds ...	Unaffected.			
4	E. H.	23	F.	R.	4 years, 5 months	Type A	Type Y	The whole of the external auditory meatus is anæsthetic. The drum retains sensation	Anæsthesia up to free border including both pillars and tonsil	Anterior two thirds ...	Unaffected.			
5	A. H.	56	F.	R.	3 years, 5 months	... ...	Type X	... ...	Free border retains sensation					
6	S. A. P.	64	F.	R.	3 years, 2½ months	Type A	Type Y. See fig. 20	Anterior and superior walls of meatus alone anæsthetic	Free border of palate, posterior faucial arch and tonsil retain sensation	Anterior half	Unaffected	4 years, 4½ months	Type A	No change.
7	J. W. H.	70	M.	L.	2 years, 9 months	Type A	Type Y	The whole of the external auditory meatus and drum are anæsthetic	Free border of palate, tonsil and area adjacent to this on anterior faucial pillar retain sensation	Anterior two thirds.				
8	A. H.	26	M.	R.	2 years, 2 months	Type B	Type X	The whole of the external auditory meatus and drum are anæsthetic	Free border of palate, tonsil and posterior pillar retain sensation	Anterior two thirds ...	Lost	2 years, 10 months	Type B	No change.
9	J. J.	61	F.	R.	2 years, 5 months	Type B	Type X	Anæsthesia of drum. Blunting of sensation of whole of external auditory meatus	Mouth cannot be opened sufficiently to admit examination	... ...	... ...	3 years, 7 months	Type B	Thermal paræsthesiæ along the upper half of the posterior margin of anæsthesia. This was the first examination of patient from this point of view. See fig. 25.
10	W. P.	58	M.	R.	2 years, 3 months	Type C	Type X	Anterior and superior walls of meatus and antero-superior quadrant of drum anæsthetic. See fig. 28	Free border of palate, both palatine arches and tonsil retain sensation. Anæsthesia of floor of mouth very abnormal. See text	Anæsthesia of middle and outer third only. See fig. 36	Unaffected.			
11	S. C.	66	F.	R.	2 years, 2 months	Type C	Type X	External auditory meatus and drum anæsthetic, except the postero-superior angle of each	Anæsthesia up to free border including both pillars and tonsil	Anterior two thirds.				
12	A. G.	42	M.	R.	2 years, 1 month	Type C	Type X	Whole meatus, except the external opening itself, anæsthetic. Drum is destroyed	Anæsthesia of free border of palate including anterior pillar	Anterior two thirds except for a strip ¼ cm. broad along mesial border	Unaffected	3 years, 3 months	Type C	No change.
13	J. G.	56	M.	R.	1 year, 9 months	Type A	Type Y	The anterior, superior and inferior walls of meatus are anæsthetic. For anæsthesia of drum see fig. 30	Free border of palate and upper third of tonsil are anæsthetic. Lower part of margin of both pillars retains sensation	Anterior half	Unaffected	2 years, 11 months	Type A	No change.
14	E. G.	52	M.	L.	324 days	Type B	Type X	The whole of the external auditory meatus and drum are anæsthetic	Anæsthesia up to free border of palate and anterior pillar	Anterior half	Unaffected	1 year, 10½ months	Type B	No change.
15	H. B.	67	M.	L.	1 year	Type D	Type Z	The external meatus except the roof, and the drum except the antero-superior quadrant are anæsthetic. See fig. 31	Free border of palate including both pillars and tonsil retains sensation	None	Impaired.			

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