the purpose, that my suspicions of spots were entirely illusory, and that such markings as objective features were invisible to my eye with the means employed. On the worst nights I could easily imagine a mottled aspect of the belts; but with good definition and a steady image, the tone of the belts and bright equator appeared perfectly even and free from noticeable irregularities. In a case of this kind the observer has to be severe with himself. There is a distinct line of demarcation between what is absolutely seen and what is possibly seen or suspected. An object may be only glimpsed, and yet it is certainly seen, for its impressions reach the eye now and then in a form not to be mistaken. But with some objects the experience is different. We fancy they are there, but cannot fix them with certainty; apparently they flit about like an *ignis fatuus*, and are intractable to our utmost efforts. Obviously in such a case the observer has but one alternative, and that is to regard the objects as imaginary.

On Mars, as well as Saturn, small instruments have done wonders. It is well known that the canals and their duplication were discovered by Schiaparelli with a refractor of only 8½ inches aperture. In 1892, during a favourable presentation of Mars, the large American telescopes showed very little either of the canals or of their duplication. During the opposition of 1894 the planet was better placed as regards altitude (but not so near to the earth as in 1892), and the results of observations have been more satisfactory. Mr. Williams with a 6½-inch reflector, and Mr. Brenner with a 7-inch refractor, have recovered many of the double canals of Schiaparelli. Mr. P. Lowell, with the 18-inch refractor at the observatory at Arizona, has also observed many remarkable and intricate details of the planet's topography. This observer remarks that in regard to the visible markings on the inner planets of the solar system up to and including Mars, size of instrument is quite secondary to quality of atmosphere. He draws the "oases" on Mars, and a large number of interlacing lines on the planet, in *Popular Astronomy* for April 1895, and the pictures are very effective. There are many of us who would like to obtain a view of Mars similar to what he has depicted. Mr. Lowell notes that with the 18-inch a power of 420 was as high as the atmosphere permitted to be used with advantage, though drawings were generally made with 370. On the 6-inch refractor 270 showed well, the dark and light markings being more contrasted than in the larger instrument. As affecting the comparative utility of large and small telescopes, Mr. Lowell remarks: "A large instrument is assumed to be necessarily superior to a small one, quite irrespective of what it is that is to be observed. Now the fact is that there are two quite different classes of celestial phenomena—those dependent on quantity of light, and those dependent on quality of definition for their visibility, and the two means to these ends go anything but hand in hand. For the one, the illumination, the size of the instrument is the prime requisite; for the other, the definition, the atmosphere is the first essential. As an object-lesson in this, it is worth noticing that the biggest instruments have not always given the best views of Mars. In matters of Martian detail it is amply evident from the results that observer, atmosphere, instrument, is the order of weight to be given as the factors of an observation."

I have referred to this subject without any desire to take up the cudgels on behalf of any class of instrument, but it is suggestive that the large ones will not bear powers commensurate with their size on planetary details. Thus with the 36-inch at Mount Hamilton a power of 350 has been found the most effective on Mars; a similar power can be used with advantage on glasses of only 8 or 10 inches diameter. It is difficult to understand, therefore, where the superiority of large instruments comes in, as the object is sufficiently bright in small telescopes, and the latter being more easily manipulated and less affected by atmospheric tremors, they obviously possess some distinct advantages. But this interesting and important question is scarcely to be settled by a mere discussion of this sort. It is only to be settled by careful trials of large and small instruments, side by side, upon the planets Mars, Jupiter, and Saturn. If observers having the appliances at command will institute some further comparisons of the kind suggested, the problem might be virtually solved in a short time. Relying upon evidence of fragmentary character is scarcely fair, since differences of eyesight and atmosphere come into play most prominently. The most valuable evidence would be that of an observer who used a number of telescopes of different apertures at one and the same station. Up to the present time it must be confessed that small instruments have somewhat the best of the argument; but if the unanimous testimony of our most trustworthy observers asserted the superiority of large telescopes on bright planets, it is hard to see how they could be disproved, as they alone have the effective means of judging the question on its merits.

W. F. DENNING.

SUBJECTIVE VISUAL SENSATIONS.[1]

THE activity of the cerebral centres which is independent of their common exciting causes, and which is termed "discharge," presents indications of the character and loss of their function which can be obtained from no other source. Foremost in interest and also in importance are the sensations of sight which occur without stimulation of the retina. Of these the most important are two. (1) Those which occur at the onset of epileptic fits, from the "discharge" in the brain influencing consciousness, through the visual centre, before loss takes place. (2) Those which occur as the precursory symptoms of the paroxysmal headaches which, from their one-sided distribution, have been called "hemicrania," "megraine" or "megrim," from the frequent vomiting, "sick headaches," and, from the inhibitory loss of sight, "blind headaches." These two classes form the subject of the lecture.

In what part of the brain does the process occur? The impulses from the retina reach the cortex of the brain first in the extremity of the occipital lobe, where, as Munk first showed, the half-fields are represented in strictly local definiteness. The left occipital lobe receives the impulses from the left half of each retina, produced by the rays of light from the right half of each field of vision. So, conversely, with the right occipital lobe. To each side, impulses proceed from a very minute area around the central point of the retina, the fixation point of the field. But we cannot conceive that the functional disturbance occurs in these centres, for the strict medial division in two halves is absolutely ignored by the subjective sensations. Moreover, the strange but certain facts of hysterical hemianæsthesia, in which there is inhibition of all the sensory centres of one hemisphere, present us with remarkable evidence of the higher visual function in each hemisphere. This is supported by some cases of organic disease, which cause an affection of sight similar to that of hysteria, and by more common cases of hemianopia from disease of the hemisphere, in which there is a precisely similar contraction of the remaining half-fields. The significance of all these is that the early conclusions of Ferrier are correct, and that, in addition to the lower, occipital half-vision centre, there is a higher centre in each hemisphere, situated in the region of the angular convolution. This theory of the double visual centres, consisting of a combination of the conclusions of Ferrier and Munk, was first stated by the lecturer in 1885, and has been confirmed by all the facts he has since met with. It is indispensable for the comprehension of morbid functional action, and, indeed, for that of normal vision, but is not yet recognised by physiologists, even as hypothetical.

The character of the function of this centre, so far as it can be discerned from the facts of its loss, are of great importance for the study of visual sensations. The two higher centres seem to be blended into one in function in a manner that is unique so far as our knowledge extends. If the centre on one side is functionless, there is loss of sight in the periphery of both visual fields; there is vision in the central third of the eye on the same side, and a far smaller central area on the opposite side. The only conclusion is the startling inference that either higher centre can subserve central vision in both eyes, but that peripheral vision depends on the co-operation of the function of both hemispheres. Between the central area for which either centre suffices and the peripheral area for which neither is competent but both are needed, there is an intermediate zone in which vision is subserved only by the opposite hemisphere when acting alone. This gradation of functional capacity enables some facts of subjective sensations to be comprehended which cannot otherwise be understood.

Moreover, the facts suggest that the function of these higher centres is quite different from that of the lower ones, and from that of other cerebral centres the action of which we can study. In the lower half-vision centres function is localised, so that destruction of part causes absolute loss of a part of the half-field, blindness of the corresponding part of the retina. But partial

[1] The Bowman Lecture, delivered before the Ophthalmological Society, by Dr. W. R. Gowers, F.R.S., June 14.

damage to the higher centre seems to lower the function of the whole, as if the function were diffused, and all its elements were represented, in varying degrees, in every part. This conception is so unfamiliar that it may seem inconceivable, and yet it harmonises with many of the facts of subjective sensations. Moreover, in a large part of the brain, local loss of tissue has only the effect of lowering function as a whole. It seems to be only where the sensory impulses reach the cortex, and motor impulses leave it, that the local distribution of function is definite, and limited damage has definite and lasting results.

The spectra perceived before epileptic fits vary widely. They may be stars or sparks, spherical luminous bodies, or mere flashes of light, white or coloured, still or in movement. Often they are more elaborate, distinct visions of faces, persons, objects, places. They may be combined with sensations from the other special senses, as with hearing and smell. In one case a warning, constant for years, began with thumping in the chest ascending to the head, where it became a beating sound. Then two lights appeared, advancing nearer with a pulsating motion. Suddenly these disappeared and were replaced by the figure of an old woman in a red cloak, always the same, who offered the patient something that had the smell of Tonquin beans, and then he lost consciousness. Such warnings may be called psycho-visual sensations. The psychical element may be very strong, as in one woman whose fits were preceded by a sudden distinct vision of London in ruins, the river Thames emptied to receive the rubbish, and she the only survivor of the inhabitants.

The colours seen are chiefly described as red, green, blue and yellow. A yellowish red-like flame is very common. In some cases red changes to green, a curious complementary relation, when we consider that the sensation is due to a primary process in the centre. One obtrusive fact, in these spectra and in those of migraine, is the frequency with which colours extend to the edge of the field of vision. In one case, each fit was preceded by the appearance of a green colour occupying the lower half of the field so completely that the patient said he seemed to be in a field of grass. It is often said that the periphery of the retina is not sensitive to colour, and that red and green are seen only in the centre. But long ago, Chodin and Landolt showed that colour vision extends to the periphery. The peripheral colour spectra led the lecturer to make a careful examination of the peripheral colour vision, especially in regard to area, to which it seems to be related in a greater degree than to illumination.

Red can be seen up to the margin of the field for white, an area in 6 cm. square; green cannot well be discerned within 5° of the margin, but yellow and blue can be seen up to the margin with 4 cm. square. The fields for each area from ·25 to 4 cm. square are concentric with the field for white.

One fact was ascertained which illustrates the mutual influence of the two visual centres. When both eyes are open the two fields correspond, except in the outer temporal third of each field. The nasal half of left field, for instance, extends to 55° of the outer horizontal radius of the right field, the end of which is at 90°. When both eyes are open, not only is the perception of colour intensified in the part where the two fields overlap, but the intensification goes on to the periphery, through the part in which there is no more retinal stimulation than when the right eye alone is open. Thus, in this radius, red is seen in 2 cm. square at 62° with right eye alone, but at 74° if the left eye is also open, although the left field does not extend beyond 55°. The colour is seen in 4 cm. square at 77° with the right eye only, and at the margin of the field only with 6 cm. square, but with both eyes open the 4 cm. square enables the colour to be seen up to the margin, instead of at 77°. There is thus greater sensitiveness in the centres to colour impulses proceeding from the peripheral region, where the field is single, if light from the other eye intensifies their action—a striking instance of their intimate co-operation.

The motor relations of the epileptic spectrum are instructive but too complex for brief description. It is common, in one-sided fits, for an object to appear at the edge of the field of vision on the side afterwards convulsed, and pass across, to disappear at the opposite side. Its appearance, *e.g.*, on the left is followed by movement of the head towards it, by the motor centres of the right hemisphere, but the head then follows the movement of the spectrum, by the action of the centres of the other hemisphere (sometimes with a conscious sense of irresistible compulsion), and then finally deviates strongly in the first direction, as the convulsion comes on, usually with loss of consciousness. A sense of vertigo may accompany the deviation. The eyes move before the head, and may be absolutely fixed when the head can be moved by the will. These phenomena throw instructive light on the relations of objective and subjective vertigo. Inhibition frequently precedes the epileptic spectra, but is always general, never partial, and neither the loss nor the spectrum is ever on one side only. If they appear on one side, it is only to move across the field, apparently as the result of the effect on the visual discharge of the associated motor nature of the epileptic process.

The visual sensations which precede the paroxysmal headaches of migraine differ very much from the warnings of epilepsy. Their general character is limited, but their forms are extremely varied. One has been well made known by the careful study of his own sensations by Dr. Hubert Airey, published in the *Philosophical Transactions* for 1870, reproduced by Dr. Liveing in his classical work on megrim. (Unpublished drawings by Dr. Airey, and several other series of drawings were exhibited. One curious set was made by a mechanical draughtsman who, from sixty to sixty-five years of age, frequently experienced visual sensations, similar to those of migraine, as isolated symptoms, without headache, and always depicted them as objective things, related to his own figure.) In this class of spectra, inhibitory loss of sight is almost invariable, but it is always partial, never general as in epilepsy, and it bears a definite relation to the spectrum. The phenomena are generally on one side, but occasionally medial, although never central, and they never correspond to one half of the field.[1] Even loss strictly limited to the medial line, as in hemianopia due to organic disease, is practically unknown, contrary to the common impression. The special feature of the "discharge" is an angled line of light, the "zigzag" spectrum, single or repeated, sometimes in many, as it were reflected, fading, lines. In round or oval form it has been termed the "fortification spectrum," from resemblance to the plan of a fortress devised by Vauban. The angled line may be of simple bright light or may present colours, red, green, blue, orange, which sometimes alternate in successive segments. It often seems made up of a multitude of minute brilliant points in rapid movement. When a single bright line, it may be banded on each side by a very narrow black line. This feature may be observed in the "phosphene" produced by pressure on the eye, even in the dark, when it is apparently due to a limiting line of loss of the "essential light of the retina," but its presence in a central spectrum raises the question whether this so-called "light of the retina" is not of purely central origin.

The central region is remarkably indisposed to discharge, but prone to inhibition. A medical practitioner, a careful observer, experienced first a spot of central dimness of sight, which enlarged, becoming darker in the centre and ultimately extended from top to bottom of the field, occupying the middle third, banded on each side by a double curve. Sometimes, when the spot had reached half-way to the top and bottom of the field, a bright zigzag line appeared on one side, which extended upwards and downwards, as the inhibitory loss increased, became brighter, but seemed to restrain the inhibition, which extended no further on that side, but was, as it were, reflected back and reached almost the extreme edge of the field on the other side. This illustrates the occurrence of the discharge secondary to inhibition, and limiting it. It is an instance of the way in which all half-field relations are absent in these phenomena. The common commencement is for an angled sphere, or stellate spectrum, to appear in the middle zone of one half of the field, and, expanding, form an oval within which vision is partially or completely lost. The edge is often coloured. The angles are especially developed towards the outer side of the field. Towards the centre of the field the expansion is less, the angles smaller, and the spectrum breaks. Sometimes one limb passes downwards, and the other towards the central point, but in the latter the angles gradually cease, and the spectrum never reaches the centre—an illustration of the resistance of the central region to discharge. In other cases, however, the ends of the broken oval may pass into the other half of the field, one on each side of the central point, enclosing this between them. When they reach the middle zone on the other side, a second star, like that from which the spectrum originated, may suddenly appear for a short time as a terminal feature. These characteristics show how remarkable must be the relation of the centres in which their cause occurs.

1 By "field" is meant the area included by the boundary of the conjoined fields of both eyes, to which alone the central phenomena seem related.

An angled spectrum of curved course may also develop by progression through the middle zone, beginning below, and attaining its chief development in the upper half of that side, passing only a little way beyond the middle line above. In one case this was preceded by a transient angled star near the point of commencement, and its early stage was accompanied by inhibitory loss at the margin of the field, outside the region in which the discharge commenced.

Although discharge never occurs at the central point, it may occur around it, as a circular zigzag, surrounding a round object looked at—an instructive example of the fact that the discharge may be related to the central effect of actual retinal stimulation. Analogous to this "pericentral" spectrum, is one that takes the form of an arch above the central region, which may separate into two parts at the middle line. As an instance of the strong tendency there is to regard the spectrum as an objective thing, a member of the medical profession, when asked to draw that which he saw, sent a drawing of his eye surmounted by an angled corona. These forms again indicate disturbance in centres in which there is no half-field representation. Besides other forms, an angled spectrum sometimes appears near the outer temporal edge of the field, and extends outwards for a short distance and then curves downwards, never upwards. Such a peripheral spectrum always seems to the subject to begin at the extreme edge of the field and extend outside it. In one case it was drawn as attached to the junction of the upper and lower eyelids.

It cannot be doubted that, by the study of these subjective symptoms, much will ultimately be learned regarding the function and mode of action of the cerebral visual centres. Whatever the drawbacks to observation through the consciousness of another person, knowledge can be gained in no other way of the action of the higher centres of the brain, and the time must come when the physiological knowledge which can be gained only through the effects of disease and the disturbance of functional derangement, will receive more attention. The facts of these spectra, when studied in their detail, compel the conclusion that they occur in centres in which function is related to the conjoint fields, and in these to a central and a peripheral region and to a medial zone between the two; that the chief relations are central and peripheral; that outside the central region there is a one-sided relation, but that there is no distribution of function at all corresponding to the division of the fields at the medial line. The dominant relation is concentric, and the indications afforded by the absolute one-sided loss caused by destruction of one occipital lobe, has no reflection, positive or negative, in these results of spontaneous central activity.

HIGH-LEVEL METEOROLOGICAL STATIONS.[1]

ONE of the greatest drawbacks to a full understanding of meteorological phenomena is that the observations on which we base our knowledge are generally made close to the ground in the most restricted air-stratum; whereas the general atmospheric movements, both in velocity and direction, are much modified in the lower strata, and the air surrounding and in contact with the earth differs greatly both in temperature and humidity from the free air. The more strongly agitated upper strata react on the lower in many ways, and a knowledge of the movement of the moderately high atmospheric layers is of great importance for the theory of the general circulation of the atmosphere, and practically for our weather forecasts, since the forces which develop storms have their origin and sphere of action within two or three miles of the earth.

If the atmosphere were only in complete equilibrium, then the few irregular observations, as regards time and place, which have been made in balloons, would give some data on which to base general laws; but, in the actual condition of continual movements and changes in the atmosphere, this can never suffice, and the continuous observations required of all the elements, at all seasons and in all weathers, can only be made on mountains, even though the conditions there only approximate to those of the free air. In this way observations on mountains complete those of the usual low-level stations.

When the earth's surface rises in plateaux, the advantage of elevation above the sea—that is to say, the immersion in the upper strata—is almost entirely neutralised, because still our instruments are placed in air masses which are affected by contact with the earth. For this reason meteorological observatories should be located on high and isolated peaks. The erection of such stations and the discussion of their observations during the last fifteen years have contributed largely to the rapid progress of the science of meteorology.

The chief first order stations (those possessing self-recording instruments, or where observations are made on an extensive scale) which are located on mountain tops in the various countries, will now be briefly described.

The first summit station in the world was that established in 1870, jointly by the U.S. Signal Service and Prof. J. H. Huntington, on Mount Washington, N.H., 6280 ft. above the sea. Probably nowhere else in the world has such severe weather been experienced, the lowest temperature being here often accompanied by the highest winds, unlike the calms which prevail with intense cold at low levels. For instance, in February 1886, with a temperature of 50 degrees below zero, a wind velocity of 184 miles an hour was recorded on Mount Washington. The Government meteorological station on Pike's Peak, at an elevation of 14,134 ft., was for many years the highest in the world. Now both these stations are closed, so that there seem to be actually in the United States but two summit stations where meteorological observations are made throughout the year, viz.: The Lick Observatory, on Mount Hamilton, California—primarily astronomical—and the Blue Hill Meteorological Observatory in Massachusetts, situated at a very moderate elevation. Prof. S. P. Langley's important researches on the nature and amount of solar heat received by the earth were carried on in 1881 upon Mount Whitney, the summit of which is 14,500 ft. above the sea.

It is due to an American institution that the highest meteorological station in the world is now in Peru, where the Harvard College Observatory, several years ago, established an outpost at Arequipa. In 1893, Prof. Bailey succeeded in placing self-recording instruments on the summit of the neighbouring volcano of El Misti, 19,300 ft. high, when a former station on the side of Mount Chachani, near the snow-line, at an elevation of 16,650 feet, was abandoned. It is impossible for persons to remain at these stations, so they were provided with automatic instruments which should give a continuous record of the chief meteorological elements during two weeks. Several times a month one of the Observatory staff climbs the mountain in order to wind the clocks and change the register sheets, at the same time making a check reading of standard instruments. Breaks in the record occur, owing to unforeseen stoppage of the instruments, or inability to make the ascent at the appointed time.

France stands unrivalled in her superb chain of summit stations on the Puy de Dôme (4800 ft.) in Auvergne, on the Pic du Midi (9440 ft.) in the Pyrenees, on the Mont Ventoux (6250 ft.) in Provence, and on the Aigoual (5150 ft.) in the Cevennes, whose construction has cost the national and provincial Governments hundreds of thousands of dollars and years of time. They are generally defective in having no co-operating base stations, and their observations have not been published in detail. In 1890, M. Vallot, a devoted Alpinist and meteorologist, established several stations on and near Mont Blanc, from which records have been obtained each summer since. The highest of these stations, at the Rochers des Bosses, 14,320 ft., is provided with many self-recording instruments operating two weeks without attention, which are looked after by the owner or his guides each week or two during the summer. The Observatory of M. Janssen, sunk in the snow on the very top of Mount Blanc, 1460 ft. higher, is not yet in operation, but a meteorograph has been made for it in Paris, which will continuously record all the meteorological elements during a period of three months without attention. A similar instrument is being constructed at Blue Hill, by Mr. Fergusson, for Prof. Pickering's station on El Misti.

On the Eiffel Tower in Paris are instruments 980 ft. above the ground, which give more nearly the conditions prevailing in the free air than do any others permanently at this elevation. They record at the Central Meteorological Office, a quarter of a mile distant, side by side with similar instruments exposed near the ground.

Among the German and Austrian stations, that on the Sonnblick, a peak of the Austrian Alps, 10,170 ft. high, and the highest permanently occupied observatory in Europe, stands pre-eminent, having furnished very valuable results under Dr. Hann's direction.

[1] Extracted from a paper, by Mr. A. Lawrence Rotch, read before the Boston Scientific Society.