peripheral stimulation, complaints are made of headache and other functional troubles. Those who complain of headaches when only the central portion of the field of vision is illuminated, as, for instance, by a reading lamp, find that they are able to read in comfort when the room is illuminated as well.

Reversal of Colour Fields.—We have an easy explanation of this in the fact that there are two definite physiological processes in the retina, one corresponding to the photo-chemical decomposition of the fluid surrounding the cones which has been sensitized by the visual purple, and the other to the stimulation of the ends of the cones by the decomposition products. Though red light is not nearly so active in bleaching the visual purple as green or blue, when it does produce an effect at all, its action is greater.

Stephenson* makes observations on the transposition of the red and green fields in xerosis conjunctivæ, and states that xerosis is always accompanied by signs of torpor retinæ; therefore we should expect that the action of red would be more affected than that of green. We also find the opposite condition. In hyperæsthesia we should expect to find the red field larger than the blue and this reversal is found in hysteria.

Scintillating Scotoma.—If the supply of sensitized fluid to the fovea ceased we should expect a central scotoma or a fluctuating one if the supply nearly ceased. Higgens found constriction of the retinal arteries in a case examined by him during the attack.

This paper is published in advance so that any member can have an opportunity of bringing forward any fact, if possible, against the theory. Full references to the physiological evidence will be found in *Science Progress*, January, 1915.

THE APOCRITIC PRINCIPLE AND THE EVOLUTION OF VISUAL PERCEPTIONS†

BY

J. HERBERT PARSONS,

LONDON.

WHEN crystals separate out from a solution, certain molecules detach themselves from all others of a different kind, group themselves in a particular manner, and produce or create a mass of material which, while retaining essential characteristics of the original molecules, becomes endowed with entirely new physical properties.

*The *Ophthalmoscope*, March, 1912.

† Communicated to the 1917 Congress of the Ophthalmological Society of the United Kingdom.

When a cat perceives a mouse he receives a vast number of sensory impressions. Visual impressions convey to him the shape and colour of the mouse, and, in addition, those successive variations in shape and colour and relationship to surrounding objects which constitute the visual impressions of movement. Olfactory, auditory, tactile, and other sensations derived from the mouse have their specific characteristics in relationship to the cat. None of these impressions taken alone or in groups, or even altogether, suffice to constitute the perception of the mouse by the cat. The mouse is perceived as a mouse, and indeed as a particular and unique mouse, only when many or all of the sensory impressions are sifted out of their context, and selected and organized into a new complex unit. That unit is a new creation. While it retains many of the essential characteristics of its constituent sensory "molecules," it endows them with entirely new properties. The sensations have been synthesized into a perception, the outstanding feature of which, as emphasized by Professor Stout, is the "meaning" which it carries with it, and which is truly and scientifically described as being created by the synthesis. The perception is as different from the sensory "molecules" as the crystal from the solution.

When a man talks of mice he thinks of the mouse in general, and not of any particular mouse in a particular felt situation. This generalization or universalisation is a concept. It differs as much from a percept as the latter from a sensation. The concept is born as the result of a similar creative process wherein perceptual "molecules" are segregated and re-synthesized.

This creative process, which I call the apocritic principle, is a fundamental process pervading the whole of evolution. It can be analysed, as we have seen, into two consecutive stages, (a) a selective segregation, and (b) a creative synthesis. Doubtless, these stages are only an imaginary analysis; they are in reality a single process. So far as we have gone, the apocritic principle is little more than a somewhat grandiose term for a schematic description of patent facts. If it has no more value than that, our already overburdened scientific terminology might well be spared this further addition. I think, however, that if it is kept in mind as an analytical principle it will be found to possess the truly greater value of a working hypothesis, throwing light on some very obscure problems, and perhaps pointing the way to further research. I propose to illustrate my meaning by applying this touchstone to visual sensations and perceptions.

The fundamental property of living matter, from the lowest organism to the highest, may be termed either irritability or movement according as it be viewed from the subjective or the objective standpoint. Irritability is the property of the organism to respond

to stimulus; movement is the objective response. The stimulus with which we are now specially concerned is light. Light from the objective point of view, consists of the luminous spectrum and the infinite combinations of its parts. It is, however, to be noted that from this physical or objective point of view, the luminous spectrum is only part of a wider gamut which includes heat on the one side and chemical action on the other, and that both heat and chemical action overlap the luminous field. It is equally important from the subjective point of view to remember that the evolution of the sensory organs is a continual differentiation to subserve stimuli of a more precise and specific nature. Thus, the radiant energy which falls upon the lowliest, merely sentient organism must arouse in it a simple sensory response which we may conceive as being more allied to our tactile sensation than any other. In other words, the chaotic congeries of stimuli arouses a sentiency which is simple only from want of differentiation, and this in turn gives rise to a simple motor response. As we ascend the animal scale the differentiation of nerve structures is equivalent to the development of specific resonators. Yet, if we bear the apocritic principle in mind, we shall anticipate (1) that the differentiated sensory response will still retain a substratum of its chaotic origin, and (2) that differentiation will be indissolubly bound up with brand-new and unexpected properties. By (1) I mean this—that if our surmise is accurate that the chaotic stimulus produces a sensory reaction of the tactile type, then the tactile element will not be lost but only submerged in all subsequent differentiations. Doubtless, the more precise the differentiation the more submerged the tactile element, yet I think that neurologists will bear me out in the statement that even in the highest visual and auditory perceptions the tactile element is not wholly absent. With regard to (2) I may make the same vast stride to the highest sensory differentiations and point out that the visual and auditory differentiations give rise to the wholly new phenomena of projicience, marking an advance in the potentialities of the animal comparable only to the later creation of the concept. I need scarcely express my indebtedness to Professor Sherrington's writings in this connection.

By way of analogy, I may mention the differentiation of the cell in its physiological relations. No matter how differentiated a cell may become, it still retains its fundamental cytological characteristics, most obvious in those associated with nutrition, growth, and reproduction. In fact, Dohrn's principle of functional change, the retention of all the fundamental properties of protoplasm by even the most highly differentiated cell, holds good also for those higher functional manifestations with which we are here primarily concerned.

There is reason to believe that the earliest outward and manifest

sign of the differentiation to luminous energy is the development of pigment cells on the surface of the body. They are at first widely distributed, and we can scarcely conceive the sensory response as being other, than a very slight modification of the tactile sense. If, as is probable, it thus early contains the germ of projicience it must be in a very rudimentary manner, manifesting itself only in the more precise motor response—whether positively or negatively phototropic.

With the development of axial symmetry and metamerism, the visual cells, as they may now be called, become aggregated anteriorly and their projicient function becomes accentuated.

When we reach the lower mammals, such as the rabbit, the function of the visual organ is pre-eminently projicient. It is characterised by enormously wide lateral fields. On teleological grounds, if on no other—and they are abundant—it must be conceded that the appreciation of *movement* is the prime function of these organs. The tactile element has become specialised to respond to luminous stimuli. Just as the finger passing over the skin arouses the appreciation of movement, so the light passing over the retina; but whereas one is referred to the immediate environment, the other is projected into the outer world. The physiological characteristic of each is the successive stimulation of serial end-organs. The psychical equivalent of the tactile stimuli is first—"something touching," next "something touching which moves." In its primitive form we must regard any other perceived qualities as vague and chaotic, such as we ourselves can only dimly conjecture. With increased differentiation appreciation of size, shape, and temperature are successively born out of the void. So too the primitive light sense arouses the vague appreciation of "something bright" and of "something bright which moves." The pigment cells absorb the heat and actinic radiations as well as the luminous, and the transformed energy *must* produce effects—partly nutritive and metabolic—perhaps also effects in consciousness—but if so, effects which are vague and chaotic and undifferentiated. Very early, however, the something bright is a something in the outer world, and, moreover, in a definite position in space with regard to the organism. Similarly its movement in space is more or less accurately referred to its spatial relations with the individual. Only with increasing differentiation does the something become more or less definitely endowed successively with size and shape and colour, contemporaneously, with ever increasing precision, with more accurate localisation and tri-dimensional qualities.

Let us now turn to the fully developed visual functions of man, so far as we have yet been able to elucidate and analyse them. It is customary in our text-books to divide visual perceptions into

three categories, dependent upon I, the light sense; II, the form sense; and III, the colour sense. This is a convenient, and for physiological and clinical purposes, a satisfactory classification, except that it leaves out of account the important IVth sense—the sense of movement, which we have seen to be primitive. Obviously, so far as visual psychology is concerned, the light sense is the fundamental and most primitive element in consciousness. Applying the apocritic touchstone, it is a segregation of those tactile qualities of delimited areal sensations which are due to a certain group of radiant stimuli from those which are due to other groups of stimuli produced by radiant energy, all of which enter into the production of the primitive chaotic tactile sensation. Owing to the differentiation of the nervous structures, this selective segregation is not only rendered possible, but their re-synthesis into a new complex is potentialised. This re-synthesis emerges in consciousness as a newly-created light sense which, while retaining the areal characteristics of the primitive tactile chaos, has become endowed with the functions of projicience and the discrimination of light and shade.

The same touchstone may be equally applied to the form sense. The primitive chaotic tactile sense already possesses dim adumbrations of form or areal delimitation:—this is the really primitive form sense, and it has no visual properties in consciousness. The second stage in its visual development is the vague sense of form which accompanies the visual perception of a bright moving object on a dark ground or vice versâ. But the term “form sense” as commonly understood and applied refers only to the precise discrimination of the form by central vision. This is the third stage of the development of the form sense, and itself is divisible into degrees of lower and higher development. In this third stage structural differentiation and concomitant functional development—the type and arrangement of the cones in the macula, on the one hand, and the increased precision of temporal and spatial induction, etc., on the other,—so alter the segregated elements and their final re-synthesis that a hitherto unknown precision in the perception of areal delimitation is acquired. At a later stage this newly acquired “sense” is correlated with other newly acquired psychological attainments: these interact with and facilitate each other, so that the perception of letters, etc., is facilitated. It is these higher grades of the still so-called form sense which are investigated in the clinical estimation of visual acuity.

Throughout its evolution and development the form sense retains all those characteristics of the primitive tactile sense which have been segregated by the light sense, and, moreover, they also retain them in the re-synthesized form in which they appear in the light sense.

The evolution of the colour sense precedes in order of time the third stage of development of the form sense. Many theories, none of them wholly satisfactory, have been advanced to account for the phenomena of colour vision. Complex as these phenomena are, they undoubtedly show that the number of "resonators" which have been differentiated to subserve them, are far fewer than the innumerable diverse stimuli which produce them. Whatever may be the difference of opinion as to the segregation of the stimuli and their re-synthesis there can be no doubt as to their occurrence; and here, as in the form sense, all the features of the light sense are present, with others incorporated—and not merely added.

My chief object in drawing attention to this method of viewing visual perceptions is to show that it helps to explain certain difficulties.

1. *Central Vision*.—It has been shown by Riccò and confirmed by Charpentier and others¹, that in order to produce a luminous sensation at the fovea, the total quality of light, *i.e.*, the product of the area and the illumination must attain a certain value, and that that value is constant for a given condition of adaptation. Here we have a precise mathematical law, and it is associated with the most highly differentiated structures. Asher found that for the range of light intensities used by him, the apparent size up to a visual angle of 2' to 3', depends entirely on the quantity of the light. By varying the area and the intensity of the light, smaller areas may be made to appear larger than really larger areas. It is well-known that the apparent size of points of light varies with the light intensity. The so-called "magnitudes" of the stars depend upon this fact.

Similarly with regard to colours, Charpentier showed that the chromatic threshold also depends upon the area stimulated; and it can be readily demonstrated that the hue changes as the area is altered. As we should expect, for the more highly differentiated colour sense, the law associating area stimulated with intensity is not so simple as for white light. Further, as Abney has pointed out, as the intensity of the light is diminished gradually to extinction of the sensation, a coloured square or disc becomes first an ill-defined fuzzy patch of grey and appears finally to depart almost as a point.

It appears to me that these liminal stimuli reproduce the characteristics of primitive chaotic sensations, in which size and colour and other qualities are as yet undifferentiated.

More instructive are the threshold values of so-called visual acuity². If we take as our criterion the discrimination of two points of light as disparate, the minimum visual angle is little less than one minute. A very much smaller difference of position can however be easily recognised. Hering showed that if a black and a white surface are separated by a vertical line, the lower half of the black surface being moveable over the white, a movement of 10" can be discriminated.

Hering therefore distinguishes between the visual sense of position (*optischer Raumsinn*), the visual resolving power (*optisches Auflösungsvermögen*), and the form sense (*optischer Formensinn*). Three corresponding criteria have been suggested:—(1) minimum visibile; (2) minimum separabile, and (3) minimum legibile or cognoscibile. The enormous effect of variations in the illumination on the discrimination of test types is well known.¹ Throughout it will be found that the form sense, whatever its stage of development and whatever the criterion, becomes merged at the threshold into a primitive type of light sense, in which the qualities of form, colour, etc., cannot be differentiated.

The obliteration of the discrimination of form and colour at extremely high intensities of illumination is perhaps to be explained in the same manner.

2. *The Field of Vision*.—Enough has already been said to show that the very common practice of calling the field for white the field for form is much to be deprecated. It is true only of the form sense in what I have called above the second stage. But the form sense in ordinary parlance means the capacity for distinguishing complex forms, such as letters, etc., and this is practically absent even under normal conditions with ordinary perimetric observations. Dor has shown that at 10° around the point of fixation, visual acuity is reduced to 1/15th., and is practically negligible beyond.

With regard to colours it is true that with intense degrees of illumination they can be distinguished almost, if not quite, to the extreme periphery. Under normal conditions, however, there is a peripheral totally colour-blind zone, separated from the central trichromatic area by a dichromatic zone. Now, it is well recognised that the periphery of the retina is particularly sensitive to the appreciation of *moving* objects. For teleological reasons it has retained this primitive characteristic in a very pronounced manner. A careful consideration of the functions of the peripheral part of the retina (including of course the whole of its nervous mechanism—central as well as peripheral) shows that we have here in its least differentiated form the primitive chaotic light sense, with its predominant feature—capacity to appreciate movement—least submerged. From this point of view we should expect that, in recovery from lesions which abolish peripheral parts of the field, the appreciation of *movement* in objects would be first restored.

There is evidence that such is the case. Wilfred Harris³ in 1897 pointed out that in cases of transient hemianopia following epileptic attacks he had observed that the appreciation of movement of objects returned before that of “form” or colour. Recently G. Riddoch⁴ has brought forward still more conclusive evidence, derived from war injuries of the occipital lobes. From the preliminary account of his observations he concludes (1) that the

consciousness of a "something moving" should be recognized as one of the visual perceptions; (2) that it may be dissociated from the perception of a stationary object; (3) that where recovery of vision occurs, the perception of "movement" precedes that of the object; and (4) that recovery of "movement" vision begins at the periphery. He expresses an opinion that a wider conception of what vision is might be obtained if it were considered, not as a special sense, but as a part of general sensation. His cases indicate some visual defects which resemble disturbances of sensation, such as (1) dissociation of primary visual perceptions of light, movement, stationary objects, form, and colour; (2) inability to localize an object seen and to estimate its length; (3) inability to appreciate "difference"—relative lengths and distances; (4) inability to distinguish between a flat disc and a sphere.

It appears to me that Riddoch regards these dissociations too narrowly from the purely pathological point of view. The wider conception of what vision is, which he very rightly emphasizes, can only be attained if these dissociations are regarded from the broad standpoint of evolution. It will then be found, as I have tried to indicate, that they are always *relative*, whether viewed, as it were, in longitudinal or transverse section. In longitudinal section we have the apocritic process at work differentiating each perception in turn from the primæval inchoate—broadly speaking, "tactile"—sensation or perception. Here the differentiation is eminently adaptive and practically effective, yet never complete, but only relatively dissociative. The same general characteristics appear in transverse section—the physiological condition of the individual animal—no matter what the stage of evolution. In the highest stage, man, the same relative dissociations appear, fusing into the primitive chaos at the low intensities of scotopic vision and in the extreme periphery of the field, selectively segregating in various degrees at the higher intensities of photopic vision, all fusing again into quasi-pathological phenomena at the highest intensities.

REFERENCES.

1. See **Parsons**. *An Introduction to the Study of Colour Vision*. (Cambridge University Press, 1915)
2. **Parsons**. *R. Lond. Ophthal. Hosp. Rep.*, Vol. XI, 1914.
3. **W. Harris**. *Brain*, Vol. XX, p. 307, 1897.
4. **G. Riddoch**. *Proc. R. Soc. of Med. (Section of Neurology)*, Nov. 23rd, 1916.