III. A paper was in part read, entitled "Ocular Spectres and Structures as Mutual Exponents." By JAMES JAGO, A.B. Cantab., M.B. Oxon., Physician to the Royal Cornwall Infirmary. Communicated by W. J. HENWOOD, Esq. Received December 26, 1854.

The paper opens by stating that for want of a methodical elimination of ocular spectres from one another—a want which its aim is to meet—physiological optics remain to this day without any real foundation; and even when we have followed the rays of light through all the refracting media of the eye, we cannot safely assert what sensations belong to them until we have detected everything connected with the *percipient membrane* which may obstruct the action of light on it, or which may originate sensations *as of light* through other sorts of impulses. Our eyes in many important respects provide us with an opportunity for microscopical research that no optical instrument employed on the dead eye can rival. We may thus gather a variety of information, physical and physiological, solve points of ocular structure that escape other means of investigation, and bring a profusion of ingenious speculations to a termination, by showing that the phenomena (and this is especially true of the retinal phenomena) which have occasioned them are simply exponential of anatomical facts; and important physiological laws may be arrived at by like means.

The first step in the author's task is to determine the conditions which render objects existing upon or within the eye visible by their shadows, and to obtain optical principles by which we may examine the interior of our own eye with facility, so as to recognize in what lenticular structure, and what part of it, the cause of any shadow or "diffractive image" resides. He shows that we may make every measurement of interest, may decide all the points just alluded to, at the instant, as it were, by mere inspection; and he illustrates his optical principles by appropriate experiments.

The paper then commences its actual elimination of ocular spectres from one another, starting from the appendages of the eye and going on through the ocular tissues in succession to the retina, under several heads, as—

Optical Effects of the Eye-lashes, Eye-lids, and Conjunctival Fluids.

These produce phenomena of reflexion, refraction, and inflection. They may multiply the images of objects which are without or which are within the eye, and occasion us to see the latter. The conjunctival fluids render apt illustrations of "recondite" diffractive shadows.

Optical Structure of the Crystalline Lens.

It is shown that the stelliform figure of our crystalline lens is distinctly visible in divergent light. The lens contains numerous bodies displaying a series of diffractive fringes. The fringes of the border of the iris are likewise conspicuous. Whenever light radiates into the eye from a near point, all these things happen. Hence when a line of radiants (an edge of any body) is before the eye, a mosaic fringe of these coloured shadows will be formed; and there is an *ocular* fringe, as well as the fringe on the edge of a body by light inflected at the body. The ocular colours mentioned seem to have been the cause of the belief that it can be *proved* experimentally that the eye contains no provision for the correction of chromatic dispersion; whereas the colours spoken of should only be compared with those that are produced by *flaws* in the glasses of optical instruments.

The Structure of the Vitreous Body derived from Optical Phenomena.

On this head the author arrives at the following conclusions.

In the vitreous body are innumerable vesicular globules, ranging in size from 0·0008 to 0·005 of a line, which are arranged in unbroken series, in tubes more or less transparent. These tubes precisely resemble veins and arteries in their mode of ramification; they frequently anastomose and are united to one another by capillary plexuses, and they are of less specific gravity than the vitreous fluid. The trunks of this peculiar system of vessels probably arise in the region of, or *at* the base of the optic nerve, and ramify in the vitreous humour; the larger branches passing circumferentially within a limited distance of the hyaloid membrane, and yielding again many branches, which, after repeated subdivisions, end in a capillary network exceedingly subtle and close. Many of the terminal loops of the capillaries are attached to the hyaloid membrane, so as to con-

fine the majority of the branches in a lax manner to its vicinity. A true idea of this system may be gained by conceiving that the veins and arteries here existing in the fœtal eye have in after life been developed according to the growth of the body, but also metamorphosed into these light, peculiar, globule-holding, transparent vessels, and deprived of all foreign support except at their roots and a part of their capillary loops. The intricate ramifications of these vessels have the mechanical effect of in a great degree restraining the relative motion of the humour which fills the hyaloid capsule, and compelling it to concur in the various movements of the eye-ball, so as to obviate the risk of concussion from eddies of the fluid in rapid movements of the eye, and consequent disturbing effects on the lens, the retina and its vessels.

The paper goes on to take this subject up in detail; supplies the dynamical laws which must be kept in view in the application of previously obtained optical methods to the required examination; shows that it is the system of ramifications described which has given rise to the peculiar appearances simulating concentric lamellæ in the vitreous humour previously subjected to chromic acid, so differently interpreted by microscopists. Here too the hitherto vagrant *muscæ volitantes* are, for the first time, invested with form, disposition and office. They are now shown to be the essential element in the structure of the vitreous body; and certain radical misconceptions, as to the nature of these appearances and the constitution of the vitreous body, are pointed out.

The Optical Anatomy of the Retina.

The existence of the *vasa centralia retinæ* in the substance of the retina, and the movements of the blood therein, occasion diversified phenomena. We may examine these vessels in our own eyes, in their minutest distributions, by means of a pin-hole, lens, &c., *in movement across the eye's axis*, in virtue of a physiological law hereafter determined. Currents of blood in these vessels, by pressure upon the nervous matter *at their sides*, produce remarkable phenomena, differing for the superficial and deep vessels (that is, according to the place of the vessel in the five layers of the retina lately discovered by microscopists). These phenomena may all be distinguished from one another, and assigned *with precision* each to its cause.

The phenomena of this kind are *always* before us by daylight and night. In every use of the organs of sight these effects may be observed. In twilight, and *into* night, the pressure of the blood-currents on the retina first equals and then *excels* the impression made by the *failing* external light; and the whole circulatory system may be seen, with proper attention, definitely figuring itself in white or golden colour. A great concentration of light appears at the middle of the retina, which requires a bountiful supply of blood, and owing to the pointing of vessels towards the *foramen centrale*, there is an apparent gyration of *light* currents round a darker pivot. The whole conduct of the retinal circulation may be traced by the *blood-light*. And the manner in which the blood flows through the retina may be equable, or irregular and fitful; it may be very slow, and it may roll with great rapidity. A rhythmical or recurrent circulation of the retinal blood is very frequent, and produces very singular phenomena. We may produce the uncommon states of the retinal circulation at pleasure, by artifices described; and it is shown that it is the retinal circulation which is the cause of all the phenomena which have been taken to prove spontaneous, vibratory, &c. sensations of light.

From these elementary facts being overlooked, fundamental errors as to the conduct of the retina proper have prevailed on all hands. When external light is so faint that the retinal light from blood-pressure exceeds it, *the middle of the retina is so occupied with retinal light* as to be, comparatively with other parts of the retina, unavailable for the usual purposes, and we do not see *anything* with direct nearly so well as with oblique vision; and this inefficiency of the centre of the retina is not limited to the case of "stars of the last degree of faintness" (Herschel and South), but all small objects that are quite visible by "lateral" inspection appear to be "suddenly blotted out" by the eyes being turned directly upon them.

The rhythmical waves of light, or rhythmical progression of the retinal blood (and the mode of movement of the retinal blood as rendered by optical phenomena can be observed by other means), may occur, in a certain sense, spontaneously, or may be produced at will. The retinal circulation may be excited to show astonishing luminous effects.

Among other ways of causing a rhythmical or recurrent movement

of this blood, is that by simple fatigue of the retina by overstraining the sight, when the retina, more or less suddenly (or after a few oscillations), becomes flooded with blood, and complete obliteration of all objects having less than a certain luminosity ensues. This circumstance has misled Brewster and Purkinje, separately, into the belief that they had discovered that a sensation excited in one portion of a retina may be "extended" or "irradiated" to an adjacent portion. Other cases which are imagined by J. Müller and Brewster to support this view are subjected to examination; the real cause of each of the phenomena mentioned being pointed out. Some peculiar effects of retinal light are given; and it is determined that *the rigid correspondence of the limits of sensation with those of the painted image*, is a physiological law literally *absolute*.

Unsuspected difficulties of a solitary eye, and certain well-known phenomena are explained upon the foregoing principles.

May sensation be excited in the trunk of the optic nerve, or centrifugally?

The arguments which have been presumed to prove the affirmative are shown, one by one, to be fallacious, while there is presumption of a negative sort. Observations are offered as to the correct explanation of various physiological points which have been otherwise interpreted, and reputed physiological contrasts of colour are considered.

Images of external objects are painted on the limitary membrane, and perceived by the radial fibres.

This head commences with the quotation of a passage from Sir David Brewster's 'Optics' which he offered towards an explanation of the difficulty of seeing a very faint star by direct vision; and it is shown that the retina is not liable, as Brewster imagines, to be thrown into a state of "undulatory" perception by our looking through the teeth of a "fine comb" or through a single "narrow aperture." The paper points out that the effect observed in these circumstances is produced by our looking near the edge of any body whatever, provided, *and only then*, that the object *move*, be it never so little, *across the eye's axis*. It shows that the same effect is produced by light radiating from a point, by a flame, by lenses, curved reflectors, *whilst they are in the act of moving across* the eye's axis; or by the movement of the eye itself, merely in relation to the light

entering it,—even the naked eye along the sky. The effect produced is shown to be simply owing to this; that the retina, under such action, ceases to perceive in the spaces corresponding to its blood-vessels and capillaries, so that they completely display themselves in the semblance of black bodies (or lines); and the law is arrived at, that the images of external points which are painted on the vessels and capillaries are not perceived when the retina *loses light from one point of space and receives light from another point of space within a certain interval of time,* or that the percipient points lying in front of the vessels *require a certain time to perceive.* A physiological hypothesis is suggested to account for this phenomenon, on the presumption that the "radial fibres," which project from the layer of rods and cones and end in the limitary membrane, are the ultimate percipients of light.

It is pointed out how wonderfully close we may find the correspondence between the microscopical and optical anatomy of the retina. Each pair of identical fibres of the two optic nerves must be regarded as one nerve. Another supposed anomaly to the simplicity of nervous action being explained on anatomical principles, a statement of ordinary optical nervous action is made, and a summary evinces how the anomalies in visual experience are due to the complex additions to a simple organ of sight.