OCULAR SPECTRES AND STRUCTURES

AS

MUTUAL EXPONENTS.

&c.

OCULAR SPECTRES AND STRUCTURES

AS

MUTUAL EXPONENTS.

A Treatise.

EUSTACHIAN TUBE, WHY OPENED IN DEGLUTITION.

A Paper.

BY

JAMES JAGO, A.B. CANTAB, M.B. OXON.

PHYSICIAN TO THE ROYAL CORNWALL INFIRMARY, AND THE PHYSICIAN TO THE TRURO DISPENSARY.

LONDON:
JOHN CHURCHILL, NEW BURLINGTON STREET.
MDCCCLVI.

LONDON:
G. J. PALMER, SAVOY STREET, STRAND.

CONTENTS.

OCULAR SPECTRES AND STRUCTURES AS MUTUAL EXPONENTS.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

ERRATUM.

Page 14, line 8 from bottom, for diffracted read refracted.

OCULAR SPECTRES AND STRUCTURES AS MUTUAL EXPONENTS.

CHAPTER I.

INTRODUCTORY.

The properties of light called the laws of optics have been so well ascertained that those who are versed in them meet with little difficulty in deciding whether a given appearance is objective or subjective in its nature. The latter sort of phenomena, whether caused at the protective coverings of the eye, in its lenses, in its nerve, or in the sensorium, are here called *spectres*; because to those who are ignorant of their character they seem to indicate the presence of objects external to the person. All these spectres, as optical illusions in general, command universal interest, and, depending, as they do for the most part, upon the functions of the organ of sight, have a direct bearing upon a variety of problems in what may be termed Physiological Optics. Proficients in the physical science have pressed to the aid of experienced physiologists in sifting the purposes that the several portions of the visual apparatus subserve; and anatomists, with untiring zeal, have ever been penetrating further among the elements of these structures.

Yet notwithstanding the profuse labour and skill bestowed upon the researches just touched upon—rewarded as they have been by a copious accession to our knowledge in these departments—a number of the questions which attracted the efforts of the earliest inquirers remain without solution.

However, amidst all this perseverance no one has ever undertaken a *methodical* elimination of ocular spectres from one another. Tracing isolated ones to their source has indeed been done; but something more is meant by the remark now made. It is here affirmed that no one has hitherto devised and put into practice *any plan or plans* of exploring the visual organ, capable of leading to the detection of the respective causes of these spectres.

Nevertheless, if there be anything upon the eye, or in the structure of its lenses which may turn a ray of light from its otherwise presumable path—and we overlook the fact of such special interference—we shall certainly, in our experimental observations, charge upon the eye, as a lenticular combination (if we confound not other and retinal phenomena), effects which are not justly *thus* attributable to it.

And even when we have accompanied the rays of light up to the percipient points themselves (wherever they may be situated), we cannot accurately state what sensations ensue from such rays until we have discovered every channel through which the percipients may be excited, *as if by light*, through other sort of impulses; or through which the action of light on them may be modified or obstructed.

In a word, a preliminary investigation is demanded before the consideration of the main questions of Physiological Optics can be safely proceeded with.

Impressed with such views, the author of the foregoing remarks has laid upon himself the task of endeavouring to accomplish the elimination here spoken of. Nor can he deem the time so occupied wasted, if he does not deceive himself as to the results he has obtained. He finds that in the transparent ocular media structural spectres are created, which have begotten erroneous opinions upon these media; and that certain anomalies incidental to the use of the organ of sight, which have been regarded as evincing a capricious conduct in the retina, optic nerve, or brain, are purely mechanical in their origin. Insomuch that, contrary to what is commonly believed, the laws which regulate the action of the special sense implied are absolute and simple.

Further, since certain objects existing in the ocular lenses can in no way be rendered visible in the dead eye, and yet, as will be explained, are made by inflection of light conspicuous in our own eyes—yielding images exceeding the objects themselves in diameter, with a wide retinal expanse as a field of view—the eye is in many important respects, if we can rightly use it for self-scrutiny, a microscopical instrument of unrivalled power. And we can thus determine structure, where all other means have failed. And the many obligations owing to histologists in these researches, will, in part, be repaid; whilst the title, "Ocular Spectres and Structures as *Mutual* Exponents," will be justified.

In the practical solution of the first question,* that we have to deal with in this undertaking, that of finding the place of any body in the eye which casts a shadow (the images which we shall meet with in the course of our inquiry, if not mere shadows may temporarily be considered as such, as being in the line of the light admitted into the eye), on the retina—as well as in informing ourselves as to the character of such a body—we make observations with divergent and convergent pencils of light, as well as with focal light. As so much depends, therefore, upon a correct appreciation of the conditions of vision under the circumstances referred to, it will be well to begin with a few remarks on these in the instruments we shall employ.

* Some years ago, two papers were published, either independently of the other, assigning *muscæ volitantes* to the vitreous humour upon optical principles, and further discussing their character; one by Sir D. Brewster (Transactions of the Royal Society of Edinburgh, Vol. XV. : or London, Edinburgh, and Dublin Philosophcial Magazine, and Journal of Science, Vol. XXXII.); the other by the writer (London Medical Gazette, Vol. XXXVI.). But even on this previously trodden ground, this Essay possesses all the essentials of present originality; for though the perusal of Sir David's paper has now been of service to me, there will be found but small accordance between its contents and what is now being set forth; and if my own paper in a partial sense were a germ of the present production, it was, at best, but a rude one.

In seeing through a minute hole pierced in a card, of the slender pencils which alone are admitted to the retina from each point of the field of view, that which proceeds from the central one only is constituted of centrical and less divergent rays. From all other points such rays are shut off by the card—as well as all more divergent eccentrical rays, except a fine bundle, as it were a single ray, which reaches the eye by *crossing* at the card the common axis of the hole, field of view, and pupil; a greater angle being made with this axis, as the crossing rays emanate from points of the field of view further removed from its centre. Thus an *inverted* image of every object in the field, and of the field itself, are, by the intervention of the card, painted upon the retina by the decussation of eccentrical pencils at the hole; and not, as in ordinary vision, by the decussation of the axes of centrical pencils, at the "centre of visible direction." Hence a shadow formed by the interception of light entering the eye through a puncture, *can* only be in "the line of visible direction," when it appears in the centre of the field of view—assuming that this line at any point coincides with the axis of the pencil which paints the image there in ordinary vision. In whatever part of the bent course of an eccentrical pencil an object may intercept it, the shadow appears in the same direction.

Again, nothing can be plainer than that if a small object be inserted between the place where the pencils of rays which paint the respective images of the points of the field of view decussate and the retina, it will appear to approach from an opposite direction, and will cast an erect shadow or image of itself upon that membrane, or will show itself inverted; and that if a shadow be formed by the object being introduced before the decussation described, the object will show itself erect and its real and apparent motions be the same.

When, therefore, we take a pin by the point and, whilst we are looking through a punctured card at the sky, pass its head in between the aperture and the cornea, and observe that a large inverted black pin exhibits itself at the opposite margin of the field of view, and traverses it in the direction contrary to that of the motion of the hand which carries the pin—whereas if we pass the pin on the outside of the card a large erect black pin has the same motion as the hand—we have an experimental proof that the hole is the place of decussation.

If we let light, derived from a distant luminous disc, into the eye through a convex lens, held further than its focal length from the cornea, the pin passed in as before will seem to be either erect or inverted, according as it enters between the focal point and the lens, or between that point and the eye; also according as one or other of these things is done to have its real or apparent motion: or such a lens in watching the shadows of bodies occurring within the eye may be regarded as a mere puncture placed at its principal focus; and if the lens be applied to the eye, so that the rays afterwards diverge from a point within the organ, we must suppose the simple aperture to be placed at that point.

Should a radiating point be before the face, the rays which the eye receives from it may be considered to have passed by decussation through a puncture placed at the point of radiance.

In any one of the cases an object introduced at the point of decussation will block the rays; and if it only approximates to that point, on either side of it, will yield a diffused shadow barely indicative of the body's contour.

It must be added that in the instance of a punctured card held near the eye—though for the sake of obtaining a divergent pencil we shall commonly have to use a *minute* orifice—the size of the aperture, or even its shape, has but an inappreciable effect upon that of the field of view; for the extent of the latter, owing to the pencils being eccentrical, depends upon the degree of dilatation of the pupil; so that the image of the field of view on the retina is bounded by an erect (appearing as an *inverted*) shadow or image of the edge of the iris, and is therefore round—the circular illuminated area, in short, being nothing more than a projection of the pupillary opening upon the same principle that the shadows we have been discussing are projected, and geometrically we may regard it as such a shadow. The ensuing experiment elucidates the fact now stated :—If, whilst gazing at a bright light through a small hole with one eye, we keep the free hand over the other, the pupils being large, the hole will appear to have a considerable size; but as soon as we expose the other eye to the light both pupils will contract, and as instantaneously the hole appear to do the same. If light enter the eye from several neighbouring holes the apparent effect will be increased by these holes successively running into and retreating from each other. It follows, too, that the more divergent the pencil is, or the closer the card is to the eye, the larger is the field of view.

If by means of a lens we throw the point of decussation between the pupil and the retina, we get, provided the pupil be filled with light, an inverted image of the edge of the iris upon the retina, occasioning the pupillary opening to appear erect.

Should it be thought advantageous in some instances to use a puncture and a lens together, with the idea of limiting the amount of light thrown into the eye by a lens of considerable focal length, it must be borne in mind that the point of decussation in such a combination will not be, as might be fancied, at the focus of the lens, nor will be within the eye, but will occur at the puncture, as direct experiment shows. Of course curved reflectors may be made to take the places of lenses, but the instruments spoken of suffice for our purpose.

Upon optical principles to discriminate between objects visible by their shadows which are upon, and in different parts of, the eye; and between these and a blind spot in the retina. A blind retinal spot can under no circumstances exhibit itself in more than one spot in the visible field. But if we have two punctures in a card so near to each other that the fields of view thus obtained touch or encroach upon one another, we shall get two shadows of every object lying in both beams of light.

Starting from the retina, where these shadows coincide, the distance between the two shadows continually increases as the object is removed from the retina.

Though none of these variations are strict proportionals, yet as the image of the field of view, when the card just touches the eye-lashes, has a diameter which may be taken as about equal to that of the pupil, we may assume for any end we aim at that the rays from either hole in traversing the vitreous humour are parallel to one another, *and that therefore within that humour these variations are proportionals.*

But inasmuch as by the time the vitreous has been entered the rays have undergone all the refractions, we may not consider the previous variations as proportionals; and the pairs of shadows of objects placed in the more anterior parts of the eye will differ so little in their respective distances that we can hardly rely upon the means thus far before us for ascertaining the relative places of these objects. Since the area of light from each puncture is limited by the pupil, and images it, the distance between the two shadows of an object situated in that opening would appear to be equal to the apparent distance from each other of the central points of the field of view, or that between the margins of the fields on the same side. Thus, the object would seem to occupy a corresponding region in either field, or a like place in either hole. And, although there must be a slight deviation from this one way or other, according as the object is without or within the pupillary space, much the same thing may be said of all objects occurring between the vitreous and conjunctiva, or upon the latter. An object decidedly in advance of the eye, between it and the aperture, as an eyelash, will display two shadows decidedly more apart than those of an object in the pupil. But, leaving the special consideration of the anterior bodies for a moment,—

If, instead of the two punctures in a card, we confine ourselves to one, and move about the card perpendicularly to and across the optic axis whilst gazing steadfastly with the solely open eye at a fixed mark on a luminous ground—as the apex of some terrestrial object against the sky—we may affirm, in general terms, that a dark spot, owing to a blind spot in the retina, will not move; and that the shadow of an object will move in the same direction as the card, from the smallest velocity when the object verges on contact with the retina upwards, until for an object situated between the vitreous humour and eye's surface, it has about the same velocity as the margin of the field of view, so that it gives the impression of being *stuck in the hole.* The shadow of an object between the card and the eye travels faster than the edge of the hole, and quickly goes out of the field of view.

From the repetition of the foregoing proposition in the latter form it will be evident that we may gain a ready notion of the relative distances of objects from the retina by the movements of a lens, if we have only a care to consider where the point of decussation is with such an instrument. It will transpire in the course of this essay, that the movements of punctures, lenses, &c., across the eye's axis, in virtue of a certain physiological law which will be inquired into, *render the vasa centralia retinæ blind retinal marks,* so that the mode of examining the ocular interior by the *cross* movements spoken of has peculiar advantages; and may be practised with facility. But if we place two candles about a foot or so distant from each other, and about six or eight feet from our person, and apply, say, a lens of half-inch focal length (such as an object-glass of a microscope) to the eye, we shall obtain two beams of light, one from either candle-flame, through the lens—yielding as many images of the pupillary opening, and shadows of each object upon or throughout the eye; and whatever has been asserted of the pairs of the shadows from a couple of punctures may be assumed to hold good in this case also.

Lastly, from the fact that we can with a convex lens place the point of decussation within the eye, we have thus a means afforded us, for all the purposes we require, of determining the place of any body situated in the anterior structures of the organ. Forasmuch as the eye consists of an alternation of fluid and solid media, we may come to safe conclusions on all such objects of any consequence in the simplest manner, having only to distinguish between the *three* fluids on the one hand, and the two solids on the other. If we look at a candle burning at the other end of the room through, say, an object-glass of a microscope of an inch focal length, as we carry the lens towards the eye, an object on the conjunctiva or cornea will be at the point of decussation long before one in the crystalline lens or its capsule; and thus there will be a considerable interval between the moments of dissipation of their shadows. Moreover, when the point of decussation is between such objects, and we move the lens about across the eye's axis, those that are between the point of divergence and the retina and those anterior to the point of convergence will move so differently that the lens will gain upon the latter and leave them behind, whilst the former will gain upon the lens. Besides, the posterior ones will appear inverted and the others erect. Thus, if we take the instance of the eye-lashes of the upper lid, which are apt to obtrude upon the field of view, with a lens (or a puncture) at a distance they appear from below, and excel the instrument in rate: as the lens approaches the eye they vanish, and then reappear from above, and are left behind by the lens as it is moved across the optic axis. It may be subjoined, that the various bodies found in the ocular interior furnish for each other points from which to estimate locality, and enable us still more nicely than the above sketch expresses to assign the place of each.

The point of decussation within the eye depends upon the distance of the disc from which we derive the light, as well as that of the lens, from the eye. Hence, if we apply the lens to the eye, and beginning close to the light walk backwards, the objects at different depths in the substance of the eye will come successively into the resultant focal point. But the instrument and plan particularized in the last paragraph will prove very generally convenient.

On the conditions which render objects existing on or in the eye visible.—Had we to speak of mere shadows, we might say that in the ordinary use of the organ of sight the pupil is filled with a pencil of rays from every visible point, which afterwards meet again at the image of that point on the retina; and that thus a small opaque object situated in the anterior regions of the eye will exclude nearly as much light from one visible point as another, and therefore cannot project a shadow of itself upon the retina: whereas, if the opaque body be near the retina, it may obscure or entirely obliterate some points otherwise visible, and substitute its own shadow in their place. And though the images we have commonly to deal with differ from such shadows, as being chiefly due to diffraction of light at the edge of the body, if light passes the body from many sides the diffractive effects will be blended, diffused; and lost to view; so that virtually the remark made on pure shadows will hold good in the actual cases. Hence to witness the diffractive phenomena from objects *throughout* the ocular media we must have recourse to small beams of light. The precise manifestation in any given instance results from a combination of conditions—the fact, and degree, of divergency or convergency of the beam of light, the shape and size of the disc from which the eye primarily obtains light, the form and sectional outline of the body figured, its being opaque or transparent, &c. Hence it must be understood that in the descriptions which follow, the distinctions are drawn in accordance with essential differences only, and do not pursue the phenomena into all possible phases. Premising this, we will now enter upon the actual exploration of the ocular apparatus; as it is by studying the appearances we thus meet with that we shall be best able to appreciate the mode in which they are produced.

CHAPTER II.

OPTICAL EFFECTS OF EYELASHES, EYELIDS, AND CONJUNCTIVAL FLUIDS.

If we look towards a candle-flame through an object-glass of a microscope, we may observe a series of diffractive fringes round the shadow of the opening of the metallic tube. The shadow of any obstacle to the passage of light existing in the substance of the lens displays a series of like *external* fringes, and shadows of small obstacles are white in the middle. We must always be careful not to confound ocular phenomena with similar ones produced in the instruments we are using.

If an eyelash intrude between the eye and the lens, whether in convergent or divergent light, it will in like manner display externally to its shadow an alternation of coloured and dark fringes; whilst usually, as the hair is a *narrow opaque* body, a *white* line (perhaps indications of other exquisitely fine lines parallel to this are within the shadow) bisects the shadow proper. The luminosities in diffraction may be regarded as always making a *compromise* between the shapes of the sources of light and the object which casts the shadow. Hence the effects here touched upon are best shown when the hair and flame are parallel to each other.

If the lubricating fluids are equally diffused over the eye's surface, as is very commonly the case, the retina cannot recognise their presence. Then, on having recourse to any one of the instruments we have provided, we find a shaded figure which cannot be destroyed by sweeping the eye with the lids, and, therefore, cannot be occasioned by fluids which are easy to displace. These fluids frequently enough assume an unequable distribution, but, at any time, by bringing the lids together and parting them again with more or less force and frequency, we may so disturb the fluids lying along the lids, or change the three secretions in relation or absolute amount, as to get them in a state to project images. Or if we keep the lids closed for awhile by pressing upon them, the marks of the Meibomian glands, perpendicular to the edge of the lid, will be impressed upon the superficial fluid. Hence we can always procure a choice of objects lying upon the eye's surface for examination, or as points from which to estimate the position of bodies which are plunged in the ocular interior.

With divergent light, and fitting examples present, we may perceive on the eye, apparently, both opaque and transparent drops of fluid. In reality this is a difference in form and not in quality—the former drops being elevated and the latter depressed in the middle, whilst both are equally translucent. In convergent light the black blots become crystal tears, and vice versâ. Hence, in using a lens, we have only to cause the point of decussation to fall on the other side of the conjunctival fluids to that which it before occupied, to essentially change into the adverse guise the whole conjunctival shading. But, of course, every object (save a central one) will reappear in its new type transposed through the centre of the circular field of view. As the focal point is being passed through the drop, or the transmutation of aspect occurring, the image is dissolved and spread into a bright light, and not into a broad shade, as would happen were the drop impervious to light.

If we now gradually withdraw the lens or puncture from the eye, so that the light received diverges from points at increasing distances from the organ, both sort of images will display round them a series of alternations of bright and dark fringes—two or three alternations, or may be, as many as ten, or twice this even, if all the fine lines could be counted. The clear drop had the boundary of its shadow or image originally marked with a darker line; this line has remained as the broadest and withinmost of the series of dark concentric and similar figures, and encloses an area much more strongly illuminated than the *ground* yielded by the diffused light we employ. Were the tear *round* and *opaque* the central luminosity caused by inflected light would be white, and just *equal to that of the ground*, as if the inflecting object had been pierced through the middle: the additional central brightness in the example before us is due to light which goes through the tear; wherefore, the middle joint luminosity may usually be seen to wear a yellowish hue. A mode of distinguishing between opaque and transparent ocular objects has been given just above, and here we have another characteristic difference in their phenomena always available—and since both the tears and the majority of the ocular objects we meet with are round, for the most part, with all the strictness now stated. In the instance of the dark image with its luminous margin, it has continued so as the light diverges from a point more removed from the eye; whilst the alternation of dark and bright fringes have succeeded about the figure. In every case the fringes are sharp lines disposed to become finer as they are further from the image.

In the convergent light of the lens too a series of alternations of like fringes may be observed, though usually of more limited number.

In the diffused light of day every luminosity of centre or fringe will be true to the shape of the body causing them; but if we derive our light from a candle, the central luminosities may be discerned to be elongated in the parallel direction to that of the flame's length, and the portions of the fringes which lie so parallel to be much better marked than the portions which lie parallel to the flame's breadth.

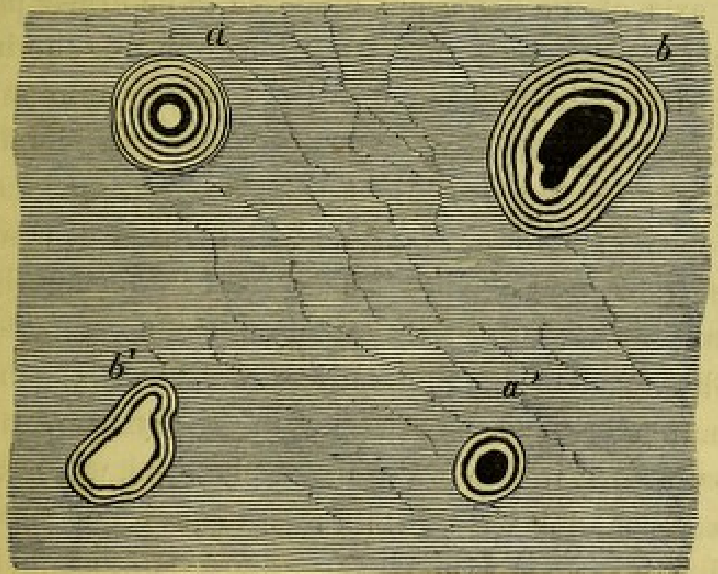


FIG. 1.

In Fig. 1 *a* and *b* are two drops of conjunctival fluid as seen in divergent light, *a'* and *b'* the same as seen in convergent light.

Furthermore, whilst using divergent light let us cause an eyelid to carry the bar, or prism, of fluid always lying along its margin over the cornea, so as to form a chord to the pupil.

Then a number of fine beams of light may be observed to pass between the lashes of the lid, and the whole space corresponding to the fluid bar to be resolved into a series of bright and dark lines parallel to the lid. If the lid be quickly withdrawn, a fluid ridge will linger behind for awhile, retaining several of the bright and dark lines. Thus the phenomena witnessed are produced by diffraction of light at the lashes (with splitting of it there), lid, and fluid on it, and the passage of some through the fluid bar. In convergent light the space corresponding to the fluid bar appears dark, but bears bright and dark lines.

The appearances thus far described are every day spectres in various scales and fashions. If we look at a candle-flame, or any moderately sized luminous disc, any hair that obtrudes itself upon the view will occasion a long line of diffractive effects, or broken repetitions of the flame, besides reflect light into the eye (the hair and axis of the flame are supposed to be nearly parallel to each other; if there be a great deviation from this the images of the flame will be repeated lengthwise, and fuse into one stream of light). The appearances extending over considerable space because the pupil receives light from some directional range. The very drop of conjunctival fluid which gives us a succession of fringes, if brought against the centre of a distant flame, will place round it a corona of richly coloured rings separated by dark ones. The image of the flame being indicated in such portions of the luminous rings as are parallel to the flame. A number of tear drops, or unevenness of the superficial fluid, will mix their effects together, and at least form a misty halo round the flame.

And the lid armed with its lashes and fluid, against a bright disc—especially a remote one—shows large streams of diffracted, with partially reflected, light; the under lid one upward from the disc, and the upper lid one downward from it. The stream in either case being prolonged across the true disc by a series of *compromised* images of it and the lid, separated by like dark fringes, and terminated (unless the disc, measured in the plane that passes through the middle of the eye and each lid, and intersects the disc, subtend too large an angle at the eye) by a perfect image of the disc, the brightest example of the bright series. But even if the disc be pretty much (angularly at the eye) prolonged in the direction just excepted, it does not hinder a tolerable image of it from being exhibited; for the rays from the top and bottom of the disc, &c. meet with like treatment at the lid, and the image is rendered at the expense of the spaces in other cases possessed by the dark fringes. A crescent moon, when having nearly the direction of the lids, and a full one, offer good illustrations of the distinction here made.

The lids are apt, of their own accord, to so far infringe upon the pupillary opening as to occasion us to see a repetition of the edges of all bodies which are before the face, when their edges are parallel to the lids. Finally, in experimenting by intent gazing, the eye is apt to become irritated by the accumulation of its surface fluid, and the lids thereby to be stimulated to approximate—or the orbicular muscle to contract—forcibly; and thus we may be led to see even three legible lines of print in the place of one, or other effects of a like order. To be guarded against a future source of error it will be needful to bear the fact here stated in mind.

It is to be added that the several instances just cited, of reflection, refraction, and diffraction, from points so near the eye, render to its media a bountiful supply of *divergent* light, and occasion the various visible objects situated in the depths of the eye to reveal themselves in the midst of the preceding phenomena by appropriate shadows. A vivid picture of the ocular interior hangs upon every hair that shields the eye, if the light of the sun so falls upon it as to radiate therefrom through the pupil; whilst diffractive colours strongly array themselves round the shadows of other hairs seen in such reflected light. A very magnified and beautiful exhibition of the ocular contents may be witnessed in the halo or corona above noticed, especially of the more posterior objects (the anterior ones are hardly embraced by such a narrow pencil), when the light from the tear on the eye's surface has spread abroad near the retina. And in the great streams of light produced at the lids a perfect command of the same objects is at our service.

If we cause the lids to approach each other, we may behold the fluid between them to be thrown into convex (chiefly) and concave drops or patches. Light being thus admitted into the eye from different directions—and passing between the hairs contributes to such result—ocular objects, anterior ones more especially, may project more than one shadow. But recollecting this, it will be found that one of the most efficacious ways for examining the anterior contents of the eye—after some acquaintance has been formed with them by other means—is by the divergent light obtained by imperfectly closing the eye; as with the direct light of the sun, the diffused light of day, or a candle-flame placed very near the face.

That the diffractive phenomena may be affected by the circumstance that the rays of light which have got beyond the diffracting body have afterwards to pass near or through another body may find ready elucidation here also. If we bring the shadow of an eyelash in divergent light across that of a tear, especially one with a depressed middle, we may observe the long shadow to bend at the other. And frequently should the corona of colours be displayed about the flame of a candle, and we move the head so that a shadow of an eyelash may cross the tear, when the middle line of the hair's shadow becomes a diameter of the corona, at the centre even the shadow proper of the hair will have a certain breadth, which breadth will rapidly increase in the opposite directions along the diameter imagined. The fringes of the long shadow will regularly in like manner diverge from their several fellows. If the head be now moved, so that the hair get to either side of the axis of the beam of light which proceeds from the candle to the tear, the two similar limbs of the long shadow will bend apparently on the same side of the said axis towards each other, while their truncated apices still meet in the middle of the corona, and so on, until the luminous fringes arch to meet each other, and finally meet to form luminous ovals, whose small ends are at the middle of the corona, and large ones among the corona's outer rings.

CHAPTER III.

OPTICAL STRUCTURE OF THE IRIS, AND OF THE CRYSTALLINE LENS.

In the cornea and its lining membrane as well as in the limpid aqueous humour, there seems to be nothing capable of transmitting a discernible shadow to the retina.

But if we reflect the light of the sun into the eye from the head of a pin, receive light through the imperfectly closed lids, or from any one of the instruments we are employing, we may have a very clear view of the diffractive fringes formed at the free edge of the iris; from three alternations to very many. The fibrous structure of the iris may be perceived at its edges. The iris being the boundary of the field of view is not favourably circumstanced for being fixed in the order of ocular depths by our introductory rules. But if we hold a lens of an inch focal length to the eye so as to have in view a *segment* of the pupil only, and then carry the lens *in a straight line*, to or from the eye, as may be required, to cause the resultant focal point to fall on the other side of the iris, the segment of the pupil will reappear on the opposite side, apparently, of the illuminated circular area. Thus we can decide by the succession in which the objects pass the point of decussation, that the iris lies pretty distant from a tear, and that it is somewhat in advance of the most superficial of the nearest of the objects next to be adduced.

I fall upon many objects, fixed between the iris and the vitreous humour. These objects must, therefore, be connected with the crystalline lens.

In my left eye I could enumerate from thirty to twice as many (or three times, for aught I know, if the pupil were dilated to the utmost), small objects resident in this region; in my right eye they are not so numerous, though it contains the largest examples. They are all either exactly round, or slightly oval. In divergent light they may be seen to have each a white centre of the brightness of the ground-light used—except a few in which the central luminosity is brighter, and proportionally larger—within a wide black ring (this ring, in the greatest cases, shows coloured indications, if not a subannular series), which is again within an alternation of fringes. In strong light I have counted in a large example full ten such alternations (see fig. 2; and fig. 3, the same in convergent light). In convergent light they *all*

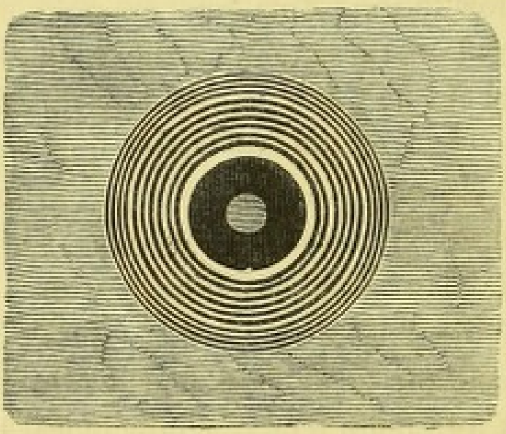


Fig. 2.

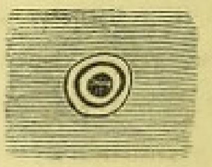


Fig. 3.

present a small black spot within two or three fringes, of either kind. And when the point of decussation is passed through the space occupied by these bodies, the few excepted will be dilated and dissolved in light, and all the others in shade. Hence the few are transparent and the many opaque.

The opaque bodies, when tested as to depth in the eye, are found to be many of them shallower than others, through a difference fully equal to what I should imagine correspondent to the whole thickness of the lens. It is certain, therefore, that these bodies are scattered through the lens, and it is probable that examples are located on the surface of that substance. Whether they are earthy concretions—any foreign bodies the accident of years—or a normal deposit in the lens, I am unable to affirm. I am, however, pretty well satisfied, from my remembrance of the uneven cloudiness in a puncture, that there must have been opacities in my crystalline lenses when I first explored my eyes with divergent light, though I had then my attention absorbed with another part of the eye. The two adjoined transparent ones, which I am going to speak of, attracted my particular notice by their peculiar aspect and situation in a puncture, at the very beginning of my attempts of this sort of ocular examination. The bodies now expatiated on do not damage usual vision in any appreciable manner, and I should presume that no eyes are without such. The opaque ones in the average run do not exceed in diameter the breadth of a filament of the vitreous humour, and the transparent ones do not surpass this standard in size. The extreme examples of the opaque kind may present shadows of three or four times the average measurement.

The transparent couple just now singled out are as near the cornea as the nearest of the opaque ones. There is a group of four of like kind in my right eye, as remote from the cornea as the deepest opaque one. Kölliker states that the epithelial cells of the capsule of the crystalline lens are "polygonal," in diameter "of 0·006—0·001‴, with round nuclei," but seems to imply that there are none in the posterior half of the capsule. I should otherwise have guessed that these transparent bodies might have been instances of extraordinary development or extrusion of such cells.

These objects in the lens will be of use in the sequel; for could we accurately measure the distance of an object floating in the vitreous humour from the retina,—since we cannot be sure of the precise place of the lens in the eye,—we cannot accurately tell its proximity to the lens; but by means of these lenticular objects we can directly observe this relation and test our measurements.

Had it not been for the unavoidable rotation of the eyeball, when its lenticular combination adapts itself for another focal distance, I should imagine the idea of rendering such means as we have at our disposal capable of detecting a change in distance anywhere between the tears, iris, the objects in the crystalline lens, and the retina, and thus determining in what portion of the axis the eye's length alters, or if the lens changes its form, not to be altogether vain. It may be that the difficulties to be overcome, in order to realize the idea suggested, may not be insurmountable.

But not only are the objects fixed by the crystalline lens visible, but the "stelliform" structure of the lens itself.

In either eye, in divergent light, I find nearly a dozen and a half, with about two-thirds of the number more strongly marked than the remainder, of strongly luminous nearly white lines issuing from a like spot, in or near the centre of the pupil, and going towards its circumference in a slightly crooked or undulating manner; thus radiating, as it were, to a little beyond the margin of the pupil. The figures in my two eyes do not precisely resemble each other.

These bright slightly yellowish lines are evidently the diffractive images of so many transparent objects. In a finely divergent intense pencil coloured and dark fringes to these images may be perceived.

As we bring the point of divergence from a distance close to the eye, the bright lines dilate and become faint; but they may still be discerned when the focal point has passed well through a tear, and must, therefore, be produced at the only solid substance in the optic axis, between the cornea and retina. I can even thus make out that two or three of the strongest lines are due to causes situated behind the pupil, and even most of the objects embedded in the lens. In either eye a couple of these radii go laterally, making *apparently an upward* bend at starting (and which about equal in breadth the bright middle of the filaments of the vitreous humour that lie nearest to them), which I can see nicely between the nearly shut eyelids: I will not be positive that any other of the radii can, at all, be seen in this way. These couples are most notable, too, for diffractions; and alone yield appreciable shadows in convergent light. Wherefore, though they occupy the paths of well-known principal radii, or limbs, of the star on the posterior face of the lens, I will not undertake to say that there may not cross the lens along them, under the capsule, some very fine object, such as a duct, or a nerve.

But if we proceed with due caution, we may satisfactorily see that the objects in the lens, the more advanced decisively, rest in front of, and can be made to glide over, nearly a dozen strong radii; and, indeed, it is not too much to say, through these radii, discern the posterior face of the lens itself, its vertex being shown as the origin of the radii. Nevertheless the same cannot be affirmed of the anterior face. The remaining limbs so fade away on the approach of the radiant point, that I am unable to discern to which face they belong, by testing in like method. Still, they may become very distinct, but only at a distance, for the radiant too great for testing them with other apparent objects, as to precise ocular depth. They seem as if they came from a vertex, which is covered by the conspicuous one. So that, upon the whole, although nearly as many limbs as I meet with have been recorded by microscopists as being occasionally found in the posterior face of the lens, I am inclined to infer that the weaker limbs are those of the anterior face. The weak and strong lines roughly alternate, as by the twisting of the "granular homogeneous" lines, through the substance of the lens, in which the tubes or fibres of the lens blend, do the limbs of the two stars. Like Young, I *can* get full twenty-two strong limbs in an eye. Since these lines have been described as "grooves," perhaps the differing appearances of the concave and convex tears may somewhat enable us to account for a variety in the phenomena of the two stars.

In the Bakerian Lecture, On the Mechanism of the Eye, Phil. Transactions, 1801 (see also Phil. Trans. 1793), Dr. Young furnishes a number of drawings of the star we see, from a lucid point at different distances from the eye, and among the comments he makes, he states that the figures on both aspects of the lens are visible, implying, equally so, and makes a few other inferences to which it will be seen I demur. But notwithstanding the great value of those elaborate researches, they are not without defects. Thus, he fell into the not unimportant oversight (if his having delineated an example at the iris without bethinking him of the cause does not forbid the word) of neglecting ocular inflections of light. Nor had he the means of finding the ocular places of the causes of spectres. Hence he cannot quite free the stelliform figure from objects in the lens. In the impression left by the lids at the conjunctiva after the eye has been kept closed by pressure, he finds, and draws a "curdled" appearance which he regards as indicative of temporary depressions made upon the surface of the lens, by certain hypothetical "glands," and, therefore, of the elasticity of the lens, if not exactly of the focal accommodation of the eye being accomplished by a change in the form of the lens, the only possible mode, according to him. The large streams of light refracted by prisms of fluid at the lids (of page 14), he tells us are caused by reflection at the lids; not noticing that the light is not cast from the lid, but warped into the region of its shadow. We may observe how reflection at a lid acts, by a scanty beam, which may be thus made to *point towards* the side of the flame *opposite* that from which the stream *issues*. Excepting the faint radiations from the hairs, it is not possible to gather from his remarks that he ever saw, at the surface of the eye, anything beyond these streams, as bare "radiations which seem to adhere to a candle viewed with winking eyes."

I find the eccentricity of the pupil, and want of symmetry in ocular refractions, observed by Young; so that the image of a lucid point seems to fall with that of the vertex, but according to my observations the posterior one, of the lens; whilst this common point of these images, generally, is not the apparent centre of a pupillary circle. In calling the pupil round it is never meant to be strictly so.

Corollary:—Multiple images. Chromatic Dispersion. Hold the edge of a penknife (suppose it white) so that each pencil of rays from it may spread over an easily observable retinal space, as by nearness of the knife to the eye, or better still, by straining vision through a more distant knife. In this case, I find the vertex of the lens decidedly nearer the apparent bottom of an oval pupil, and in my left eye, slightly nearer the left side of it. Note the fringes of the iris, and the star on the point of the knife, and look from them along its edge. Thus we see these fringes and limbs of the star, wherever any portions of them happen to be parallel to the knife, arrange themselves along it, as psuedo-fringes of its edge; nay, even approximately parallel limbs, or the circumferential ends of those that are not so, more or less perfectly carry lines along by the sides of the knife (not to say the images of small ocular objects do so). Or neglecting more subtile lines along the knife—as well as dark pseudo-fringes or interstices—the first bright fringe of the iris renders a boldly coloured image of the knife (the second bright fringe a weaker one) without, whilst between the knife and it lie two or three sharp white images furnished by the limbs of the star. By making the knife revolve slowly round its point, we may mark the successive operations of the limbs; the effects being most evolved above the knife, when it is held transversely to the eye. Two limbs nearly parallel to each other and to the knife may occasion an illusion, as if the edge of the knife were two edges of two knives, side by side.

In the case of strained vision more particularly, the flame of a candle may be surrounded with coloured pseudo-fringes of its edge, whilst narrow brilliantly white images of its edge may fall within the disc of the flame. Thus, too, a small letter in a book may have attached to it, either coloured or other spectres of itself. Whilst a whole page of print may be reproduced in coloured letters, standing above the black ones. If we regard a series of white and black lines, such as represent fringes in some of the figures accompanying the text, the coloured and white images of adjacent or neighbouring white lines will coincide, intersect, &c., and a fine display of hues, and devious lines, running from the true ones in a style of regulated diversity, result.

In any of the above cases, we have only to pass the finger across the eye, to cut off, for each radiant point, the apparitions it yields, in order, in the direction opposite to that traversed by the finger.

With a single vivid radiant point, we observe, in general terms, that the first fringe of the iris contains the seven colours, the red being outmost, the violet inmost, and the other colours being more or less crowded together upon an intermediate climax of white. The next bright fringe still holds some of the less refrangible colours. Whilst from this ring up to the image of the radiant we have a series of white and black concentric circles in an atmosphere of violet. Thus the sweep of hues from margin to centre is expressive of chromatic dispersion. So that we have, it is to be presumed, a prismatic spectrum of the radiant, in which fall lines of interference from inflection. Or, as interference must give rise also to colour, the question of chromatic aberration in the eye is not so uncomplicated as it has been usually assumed to be. For the instance before us is the elementary one into which all others resolve themselves. If we look over the nose, or hand, through a narrow segment of the pupil only, we may witness a very broad display of ocular coloration, at the borders of the shadows of distant objects, seen against the sky, the less and more refrangible colours on their opposite appropriate sides.

Again, these pervading colours affect the character of all the partial images and diffractive shadows, and we must exercise a little circumspection in correcting our ideas of the latter accordingly. Also in the multiple images just treated of we may, at once, recognise the nature of any one by its tints, and their sequence.

As the best eye is unable to again gather a pencil of rays to a focus, a margin of the various effects considered is always shown, upon the retina without ordinary attention being attracted to them, or their being at all practically injurious in the common use of the eyes.

CHAPTER IV.

STRUCTURE OF THE VITREOUS BODY DERIVED FROM OPTICAL PHENOMENA.

Enunciation.—From innumerable points of the wall of the posterior chamber of the eye, as far as the hyaloid membrane extends, though in no instance from the remaining part formed by a portion of the capsule of the crystalline lens, there spring fine beaded threads,—or fibres, consisting of rows of transparent globular and equal (or exceedingly nearly so) cells, of less specific gravity than the fluid which fills the chamber. These threads quickly unite in pairs (or occasionally otherwise); single (or a less number of) threads proceed from the knots thus made, to join again other threads, as before; from which knots again in diminished number of threads, the process is repeated, and so on. Thus a lax irregular, sometimes decussating, network is woven from the hyaloid membrane, beginning with very small meshes and extending into the interior of the chamber by others of continually increasing size; but not so far into the chamber as to occupy its middle portion. The network is completed anteriorly by being woven from the surrounding part of the hyaloid and threads prolonged from more distant portions, across the back of the crystalline lens, so as to float freely over its capsule.

Whenever the eye rotates, this filamentous peripheral system will be drawn with the relatively (counter) rotating fluid, and whilst in the act of yielding, and when dragging at its full stretch upon the hyaloid, check the movements of the fluid along the wall of its chamber; above all by the buoyancy of the web, the perpetual obstruction reiterated in the vicinity of the wall will be most efficacious in the most important or horizontal direction. The middle of the chamber not being liable to rapid movements of fluid, and such movements there being comparatively harmless, is left void of impediment; whilst a practical concurrence in the ocular rotation is ensured near the hyaloid, and in a less degree near the lens. And thus in the incessant movements of the eye, head, and person, the wall that confines the fluid, can suffer no severe concussions from eddies in the latter. Or, in other words, since care is taken that the capsule of the lens is not a point of resistance for the web, but on the contrary, is spanned by it, we have herein a provision that the lens may not be shaken, and that quasi-lights may not be ever assailing us from impulses of the vitreous fluid impressed upon the retina; possibly that this delicate tissue may not suffer direct injury, and that the circulation in the retinal vessels may not be deranged therefrom.

Investigation.—In making the nice observations required for the verification of the foregoing proposition, it will lessen our task if we are well provided with light. Especially, it is convenient to be able to look down upon a strong light; because under this condition the objects in the vitreous will not be disposed to oscillate from their buoyancy, and the eye will have a direction to which it is accustomed.

Any instrument we may use must be kept for a minute or so to the eye, before the objects within the organ will be best seen, that is, that the retina may accommodate itself to the new degree of light.

It would be well, therefore, to enter upon our observations, if with a punctured card, on a bright day, whilst we stand on an elevated position, with a luminous ground in front of and beneath us: as a clear sky, or a smooth white wall of a house; and a sheet of smooth limpid water, or a road illuminated with the sun. It would perhaps be better still if we reflect the image of the sun upwards from a mirror, and examine the objects we are going to consider, amongst other modes, through a lens, whilst looking at the sun's reflected image, as well as at the sun itself. The examination should be made frequently by all the plans of Chap. I. One main point is to *get up* the filamentous appearance so as to be able to recognize by its aspect and relations, any given portion, in any position. Then, the web above characterized becomes, it is hardly too much to say, as plain as a similar thing large enough to be visible when placed before the face, and may be easily inspected with all the ordinary lights.

On the roughest applications of our methods of exploration we discover that all the bodies floating within the eye, are posterior to the crystalline lens; and that they yield diffractive images; as also by closer attention, that in divergent light the smallest shadow belongs to objects nearest the retina and the largest to those next the lens, and that the intermediate sizes belong to objects at corresponding intermediate positions; or that the increase of size in accordance with that of increased distance from the retina is regular and constant, whilst objects at equal retinal distances have equal shadows. So that we must conclude that all the objects in question, filaments or globules, have the same breadth, whatever be those of their shadows.

If we fix our attention upon one of the smallest images, and move the eye about gently, we note that the globule thus expressed accompanies the ocular movement, whilst others near this one with broader shadows, pass over it and float about. If the eye rotate through a small angle, the globules with smallest shadows do the same: whilst the other sort just referred to remain at rest; *not yet* having been set in motion. And when the eye rotates sufficiently to cause the mass of globules near the retina to move in space, they will proceed even after the eye has ceased to move, and will then regain their places, by *recoil;*

whereas the globules we are specially considering, move if not exactly, nearly, with the eye and stop with the eye. Any one of such globules, has a pair of images apart from each other, not more than one-sixtieth of the angle, apparently separating the centres of two punctures; which would indicate extreme proximity with the hyaloid membrane, or rather with the percipients of light. If we find any difficulty by quickly directing the eye on a distant fixed point after a sudden rotation in settling whether a globule, with the smallest shadow of those we observe, glides at all over the retina, that difficulty will vanish when we come, by-and-bye, to avail ourselves of the fixed marks furnished by the retinal *blind* spots and the visible flow of the blood in the *vasa centralia retinæ*. We thus determine that the globules before us are not actually fixed, though they have but an exceedingly small liberty of movement.

In studying the conduct of the floating objects, we may note that if we turn the head in either direction about the optic axis, or any axis parallel to that, those in the back of the eye always appear finally to sink more or less; therefore they must actually rise; and would thus seem to be of less specific gravity than the fluid in which they reside. To make an observation nice enough to eliminate the effects of difference in specific gravity from those of disturbance of the fluid in its chamber for objects near the crystalline lens, so as to obtain trustworthy results, is no easy matter. The eye is scarcely to be kept *clamped* to another position of the head, and an instrument scarcely to be kept relatively still before the eye during the movement, and the slightest relative movement of this and the eye considerably affects the apparent conduct of the anterior objects. Besides, in such a system as that *enunciated*, the whole amount of web posteriorly far excels that anteriorly, and as the ultimate position in which the parts of the web will rest is influenced by its connections, the superior buoyancy of those behind may check, by acting along the sides of the chamber, the disposition of those in front to float. But we may rest assured, that as regards specific gravity, bodies precisely alike in the same fluid are in the same position.

In considering the motions of objects so circumstanced floating within the eye, it must be remembered that when the eye rotates the fluids within it will relatively rotate. No matter about what axis the rotation occurs, whether about one through the eye's centre by its movement in its orbit, or about any other by the movement of the head or the whole frame, the vitreous fluid will tend to abide absolutely at rest, or, translation of the orbit apart, rotate within its chamber, about the centre of it, through the same angle. But in consequence of the connections of the objects, if not from some viscidity of the fluid, the result must be modified. So the objects in the vitreous will move in the direction of rotation, but commence their movements at later respective instants than the beginning of that act. Then move equally with the rate of rotation. And when the ocular rotation is arrested these objects will continue theirs awhile longer, through the *inertia* of the now rotating fluid, until they reach the end of their tethers; when they will balance a moment and then regain their original places by retraction, or by being dragged back by their attachments.

Since when we hold a puncture near the eye a practically cylindrical beam of light, in section, of the size of the pupil, traverses the vitreous, the apparent linear rates, *across the beam*, of rotation of the objects fairly evinces the actual, and the amount of such linear excursions' *in this beam*, are properly represented. Also the real motions of them all, relative to that of the optic axis, are opposite the apparent. Hence the objects behind the centre of the vitreous will seem to lag behind the eye at the outset, whilst those before will seem to get a start of it, and for the first instant outstrip it. Both will then go with the eye; but in the recoil the real, and therefore the apparent, directions of the anterior and posterior ones will again be contrary. Nevertheless, by a lens of considerable focal length we may throw the point of decussation within the anterior objects, and then the apparent and real motions of these being the same, they seem to move in all respects as the posterior ones.

If we wish to investigate the effects of rotation uninfluenced by buoyancy, we must perform that act horizontally. If we rotate the eye by any mode upwards, the bodies after their respective instants will rotate with the eye, and when the eye stops the posterior ones will go more or less beyond; not only because the inertia of the now rotating fluid so wills it, but because there is no immediate obstacle to their being carried in that direction. After resting a moment, the posterior objects will seem to drop more or less swiftly, for different distances from the retina; whilst the anterior ones return upwards. If we fix the eye upon some high point for awhile and then depress it round any axis through any angle, the posterior objects, with reservations as before, will accompany the eye, but will stop almost simultaneously with it, and will scarcely recoil at all. Because, through their certain degree of buoyancy, they were at the commencement of this experiment swinging at anchors, which cannot be raised by the rotating fluid.

We observe in addition that the objects closest to the back of the lens, are not like those nearest to the retina, scarcely capable of excursion, but enjoy much freedom. This intimates that, somehow, there must be connections with the wall of the chamber, and that the length of tether mainly decides the amount of independent play of the objects. Should we meet with an object approximating in position to the centre of the chamber we find its amount of linear excursion small, as must needs be the case: but were there no impediment all those nearest the walls of the chamber would be the freest to move—whereas, for the posterior ones at least, the reverse is the case.

We have thus evidence accumulating that the objects in the vitreous are involved in some scheme, and an inkling of its essential character, without having made any special scrutiny of its parts for the purpose of ascertaining the exact machinery for securing such ends. However, availing ourselves of the dynamical rules just obtained, we can set about the inquiry methodically.

In quite casual observations the shadows of objects in the vitreous seem to indicate both globules and filaments: let us first see whether these have any necessary relation to each other. Perhaps it will be most convenient for this purpose if I simply describe instances from my own eyes.

With a lens of not less than an inch focal length I pass the resultant focal point through the anterior filaments and find that they are eminently transparent.

By bringing this focal point gradually up to these filaments, for which purpose a lens of half-inch focal length is preferable, though the images yielded may usually appear as made up of parallel lines, I encounter filaments, having some inclination to the back of the crystalline lens, whose images consist of mere rows of contiguous circles, of a soft shadowy sort in the circumferences, but luminous within, as in fig. 4.

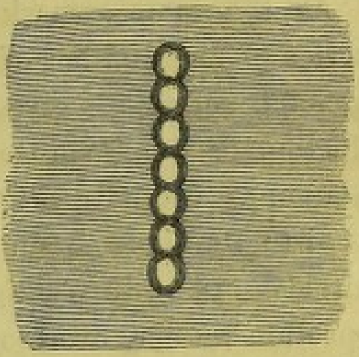


FIG. 4.

If I throw the point of decussation a little within these filaments, though many may appear as irregular linear or bandlike shadows with a shady fringe on either side, I can easily get counter examples to those just figured in a series of dark circular areas linked together, as in fig 5.

FIG. 5.

In divergent light we have for the figured example a chain of black rings with very luminous central spaces, and along by the margin of this chain a series of bright and dark fringes, sharply defined, and dipping towards the points of juncture of the circles, as in fig 6.

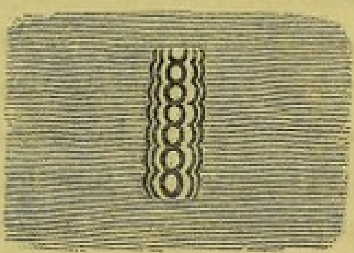


FIG. 6.

Towards illustrating the ultimate character of these images of a filament, draw, as in fig 7, a series of pairs of concentric circles in such a way that the small ones form a chain by contact, and that the large ones be completed by dots only, instead of by continuous lines, wherever they intersect any other circle. It will at a glance be observed that if the white central space, and the white ring were assumed to belong to the image of a globule, the dotted line will fall upon the luminous parts of the adjacent image. Nor can we fail to perceive that if we take away the dotted parts of the outer circle we arrive precisely at the type of fig. 7.

As the same remark will hold good for a series of any number of concentric circles, the geometrical figure gives us the mode of production of the image of the above considered filament. Moreover, the image of any filament is virtually made up of a series of concentric circles. In ordinary light and superficial inspection we may overlook the black circles as soon as they intersect the luminous spaces; but we may nevertheless, especially in direct solar light, for a filament having an inclination to the retina, discern the complete black circles, only in a more subdued tone where they traverse the luminous spaces; for the diffractive images of two small ocular objects may be both completely seen when overlying one another. In a filament parallel to the retina some allowance must be made for the parts of its beads in contact with others.

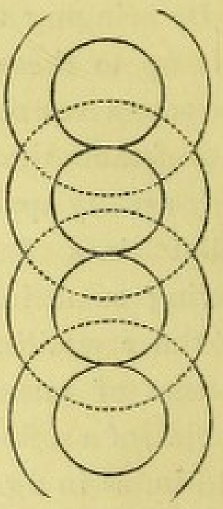


Fig 7.

In a line of beads it depends upon the manner in which each bead is presented to the retina, as regards the completeness of the black rings in breadth at parts of the image corresponding to the points of junction of the beads. If one happen by a sharp bend of the filament at the point to offer itself, particularly in the line of the admitted light to the retina, its circles will be of full breadth and complete: whilst the width (in the longitudinal direction of the filament) of the divisional line will be diminished wherever the adjacent images equally encroach upon each other. But the lateral parts of the circular images must always be developed in their full amount. If the filament presents a part of its length to the view, in the direction of the rays

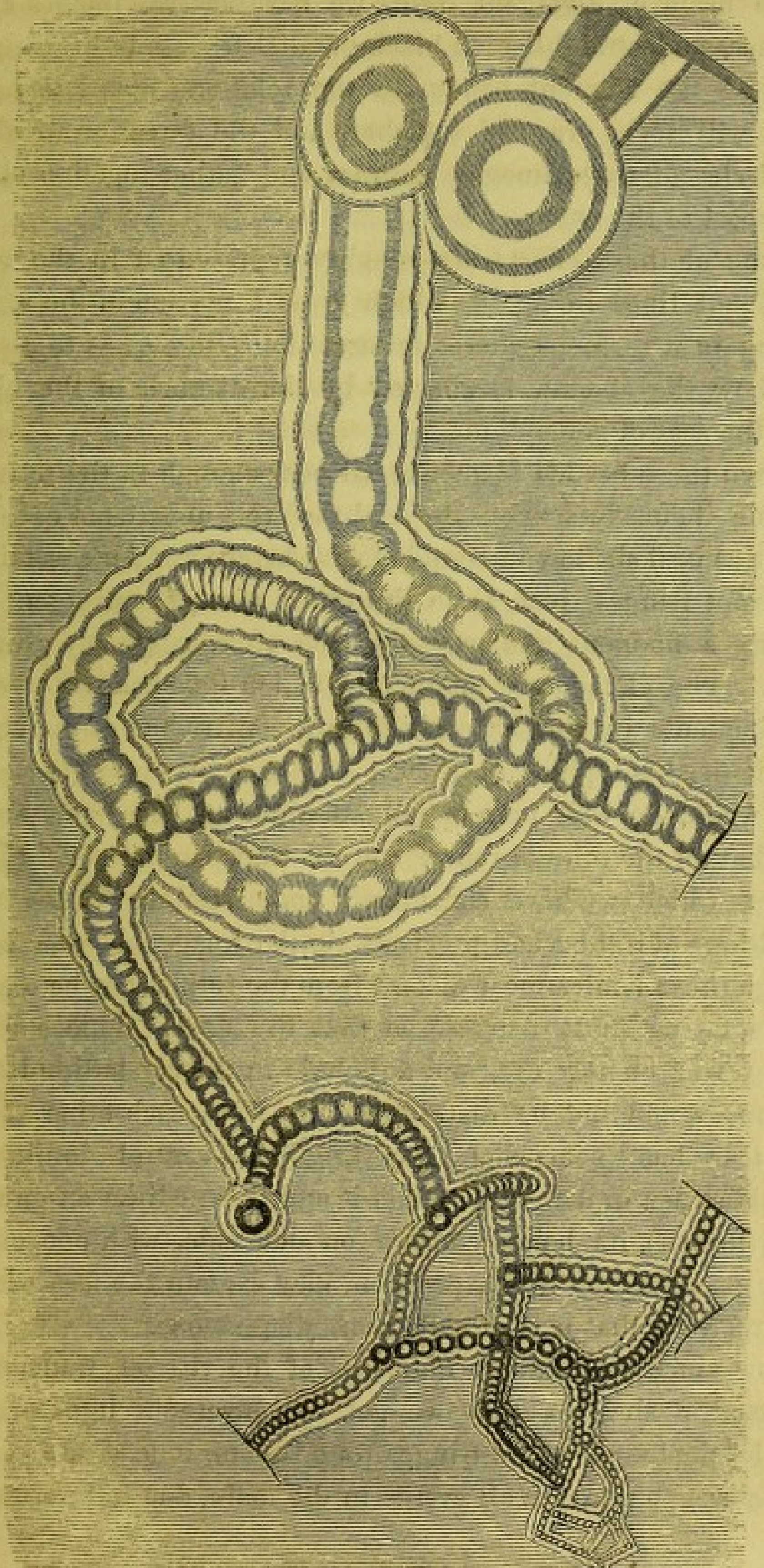


FIG. 8.

of the beam of divergent light, we have several images fused together, and straight thick black parallel fringes indicating the fact. As the filament bends, in the relations mentioned, the beads will seem crowded together, and the direction in which the circles of their images contract and gather together shows the aspect of the curve.

Some of these effects are roughly represented in the usual prominent lines in fig. 8, which gives a portion of the web as coming in a tortuous course towards the retina, so as to display also how the shadow is affected by the distance of the object from the seat of perception.

When these beaded filaments fall near enough to the retina to obtrude themselves upon the sight of the unassisted eye, they show a central shadow surrounded with bright and dark shadings, or abrupt fringes, just as in the other case of convergent rays passing a filament and meeting soon after, as already given in fig. 5. The elementary manner in which the shadows of bending filaments in convergent light are constructed of the circles here noticed is typified in fig. 9.

Fig. 9.

It would be well here to call attention to the fact that all the minute round convex transparent bodies, which we have considered, under similar conditions of light, yield precisely similar images, though those bodies most distant from the retina may be capable of displaying most fringes, so that by aspect alone a round convex tear on our eye, and a globule in the crystalline lens or vitreous would not be distinguishable from each other. Or if the tear has somewhat the brightest central luminosity, the difference in density between it and the medium on one side of it (the air), its being concave on one side, with one or two other peculiarities in its position, may explain the fact without our inferring that it is actually more diaphanous.

Now since we find the filaments of the vitreous transparent, the central shadows that we get in convergent light are not simple shadows—as the fringes round them, indeed, are present to declare—but are, at all events in the main, due to interference of the rays of light passing through and round the bodies comprised in such a beam of light. Again, if we observe how the alternations of dark and bright fringes have step by step diminished in number and breadth as we have got from the largest to the smallest images, and the central luminosity become faintly marked from the darker ring which encloses it, we cannot but comprehend that a globule revealed by the very smallest shadow would not have been indicated at all if it had been, *merely by the extent of its own diameter*, closer to the retina. Hence, when we observe a filament floating about in the interior of the vitreous over an extremity which approaches excessively near to the retina, but still are sure that the smallest shadow of all those of its constituent beads,—which one we take to indicate its end,—belongs to an object that enjoys a *little* motion, and know that the filament might reach the hyaloid membrane by a few more beads without our being able to perceive them if they existed, there can scarcely be risk in assuming that it is directly attached to the membranous wall in this manner. Besides, microscopists find on the hyaloid on the side which is towards the vitreous, " decumbent nuclei," that is, nuclei as if glued to the surface of the membrane. They have been unable to divine their purpose. If each of these is the last link in a concatenation of beads, left behind when the filament was broken, which we can hardly be wrong in conjecturing, their purpose is found.

With the information now at our command we can readily rid our minds of the prevalent error that there are myriads of isolated globules in the deepest ocular humour. Fix upon any globule we will, we may find it to be a link in a chain; if it thrust itself upon the attention, as it were, alone, it is from causes stated; and if we cannot, with actual conditions, seize the consecutive globules, we may easily do so on a proper movement of the eye; for the filament has only taken a turn at the part disclosed, or so involved itself with other filaments as to produce relations unfavourable to the visibility of the prolongations. I have spoken of the beads as equal throughout the eye. I would not by this insist that they *must be absolutely so.* It may be that a difference in the breadths, or contrasts of the parts of the images, by which we are enabled to recognize, almost always, globules here and there in certain positions in the filamentous system, may be occasioned by a minute deviation from the current size, and not *always wholly* from a bend in the filament.

A great portion of the web enunciated lies before us in the ordinary erect position of the person, and by taking advantage of the apparent sinking when we turn our head on either side, or invert the head, we may summon into view a considerable portion ordinarily situated at the sides, or which are *apparently* beneath the optic axis. If we look down upon a light, especially if the head has been previously kept inverted for about a minute, and then rotate the eye about, if not without this movement, filaments before *really* above the optic axis will be thrown down into the depths of the eye, and we have a bird's-eye view of a graceful tree, as we look upon a filament tapering and branching out to attach itself to the hyaloid membrane near the centre of the retina. In like manner we may inspect the filaments that, standing out from the retina, have a lateral direction. Some of the closer network near the retina, in my case, lie out, beautifully distinct, like a capillary system in space. And if there be apparently a confused mass of globules resting on the retina, I have only to give, commonly, a gentle or, at all events, a rapid rotation of the eyeball to throw the meshes clearly out like a fan, or brush of capillaries. The filaments projecting further from the retina, in a rapid rotation, traverse the vitreous *over* the finer meshes from which they proceed; and this appearance of bodies traversing space in parallel lines on a rapid orbital movement, is not due so much to the lingering of sensation as to the fact just mentioned.

In investigating the filaments in the anterior parts of the vitreous we may employ convergent light, and see the objects erect with their actual movements; or inspect them in divergent light, when the images will be broad,—as, for instance, in looking at these objects through the nearly closed lids, when we know at once, without measurement, the relative retinal, or lenticular distances from the width of the images. I can thus assure myself that the web springs in no instance from the capsule of the lens, for the point of origin must be obvious if it did, and indeed clearly see the condition of the anterior part of the web *enunciated*. The opposite currents of the anterior and posterior filaments may be thoroughly surveyed by the divergent beams of chapter II., and movements of the head.

The filaments in the front and back may be seen passing upwards, and downwards, and sideways, from the portions of the vitreous that are hid from examination. I should say that the front and back filaments do not extend, for their mean places, to further than about one-sixth of the diameter of the vitreous from its wall, though in my right eye some of the web in front may be within one-third of the length of the vitreous from the crystalline lens. In either eye there are parts projecting inwards further than the average run of the most centrally disposed threads, and the laxity of the threads is such that, under strongly disturbing influences, some of them go far towards the centre. The reticulations in my two eyes have no more than a systemic resemblance to one another, as would have been anticipated;—and as extension towards the centre can hardly materially affect the mechanical uses of the web, different eyes may present some variety in such respect.

In estimating the actual size of the constituent bead of the fibre, we obviate the difficulty of the uncertain relation as to diameter of it, and its diffractive shadow, by counting a few in a row—the more the better—in a fibre near the retina, and parallel to it, and observing the angle subtended by the length of fibre between the centres of the extreme instances of the counted number. Assuming that objects and their retinal images subtend equal angles at a point at a half-inch from the retina, I found the diameter of the bead to be 0·003‴ at least. Kölliker gives 0·002‴ as the diameter of the finest capillary of the vasa centralia retinæ; and the bead seems greater than a capillary as made visible in the manner already hinted at. It may, at a future day, be found possible to have still further means of deducing the size of the bead by obtaining microscopic measurements of some objects anterior to it, and making use of these

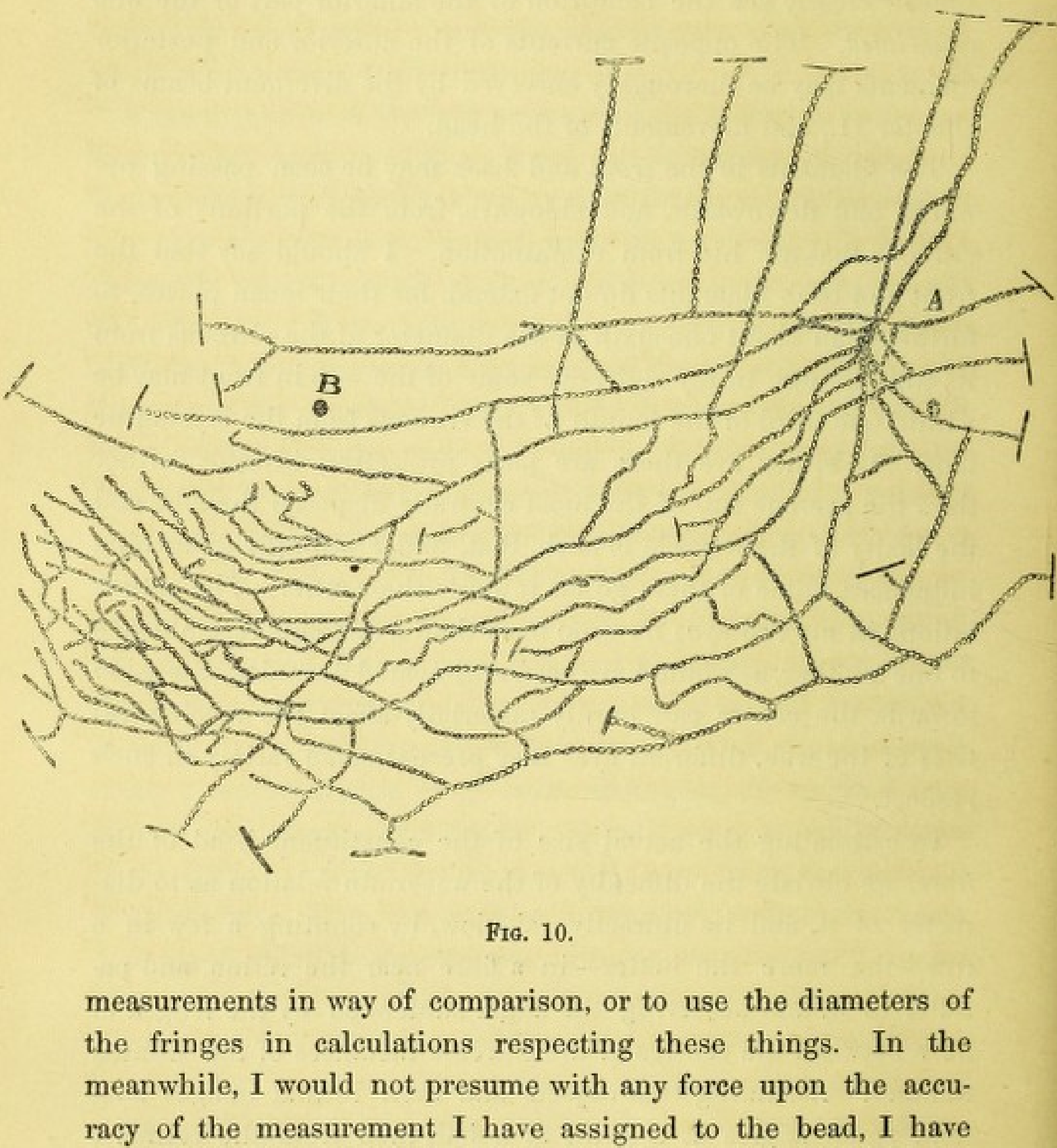


Fig. 10.

measurements in way of comparison, or to use the diameters of the fringes in calculations respecting these things. In the meanwhile, I would not presume with any force upon the accuracy of the measurement I have assigned to the bead, I have adopted the best mode I could devise, but to take a small angle subtended in this fashion correctly, or to otherwise insure strict accuracy, I can in nowise pretend to. For this reason, too, I have not attempted to actually *calculate* the precise position in the chamber of any bead, at any moment. I have contented myself with solving the question simply, so as to attain all purposes that can be of real interest.

The accompanying figure (10) represents a portion of the web supposed to be placed in the focus of an eye (in sitû before the face) capable of seeing it. The portion of web as to distribution is magnified to twenty diameters, whilst the thread (if 0·003‴ be its breadth) is magnified to one hundred diameters in order to show the bead. Yet if the fibres are five times too stout, they are in all probability five times fewer than in the original, so that this portion of the web drawn in two scales, for its own, is not burthened with an undue *amount* of thread. The drawing gives the style of a portion of web from my right eye, which is supposed to be directly projected, as it actually appears to be, on a sheet of paper: that is, the knot A, which *really* usually rests a little without the punctum cœcum, is drawn to the right of that part of the reticulation which is here cut off a little on the nasal side of the foramen centrale, at B. The knot at A is remarkable among all instances furnished by my eyes for the number of filaments that meet; but I have detected that it is not strictly one knot, but two held together by the threading of a filament. True nodular points of three or four concurring threads are not rare. The meshes about the knot are of good size, as it swings pretty freely in the fluid from its hyaloid connections being distant. It is only beneath B that the hyaloid attachments are attempted to be indicated. The lines across the ends of the other threads mean that such have been cut off arbitrarily from the adjoining network. The web divested of its diffractive appearance is only a fragment of that which occurs in this region; immediately anteriorly to it another reticulated gathering of threads (with many vertical ones) crosses this and inosculates with it, especially above and below, &c., &c.

The disposition and movements of the web are such as to be incompatible with the division of the vitreous humour into cells, whether we imagine the threads of the web to pierce, or to run in, the walls of such cells.

In Kölliker's Manual of Human Histology (Sydenham Society)

Vol. II., pp. 387—9, may be seen a summary of the researches of microscopists into the structure of the vitreous body. It is, I submit, impossible to doubt that the web described in this chapter clears up the slender results they have obtained. By the accident of the existence of the web within the ocular lenses we have an apt illustration of the limits of the power of our present microscopes. Here is a fibre conspicuously bead-built, so immersed, diaphanous, or tiny, that, with the best instruments, barely can a glimpse of any part be obtained, and, therefore, offering the strongest support ever obtained to the opinion of those who regard all fibres to be constructed of cells.

However, Bowman finds that "the vitreous body of the new-born child" exhibits "a very distinct and peculiar fibrous structure, consisting, in fact, of a close network of fibres." Virchow meets with a similar condition in the eye of a fœtal pig, with "nuclei at nodular intersections." Kölliker himself only finds "numerous round, elongated, granular, nucleated cells in fœtal human eyes, 0·004—0·01‴ in size, and 0·01—·02,‴ or 0·03‴ apart," (may not *nodular* points of the fœtal web have shown themselves?)

In the adult eye, in chromic acid preparations, Hannover traces peculiar dissepiments and "rays;" Bowman "a few concentric lamellæ externally, to which succeed very irregular, radiating septa, and lastly, an irregular central cavity." Kölliker remarks that "these lamellæ cannot be demonstrated as true membranes," and do not "prove much." (They are, we may presume, occasioned by coagulations about the threads of the web, or by some action of the acid on them.) This last author, averring that he could never find any indication of membranous dissepiments, still in the vitreous of the adult notices "cells in many instances, though rare and indistinct, particularly in those parts of the organ bordering upon the lens, and the hyaloid membrane in general," and "concludes," from his own observations, that "the vitreous body, at an early period, presents a sort of structure most nearly approximated to embryonic cellular tissue, but that subsequently all trace of such a structure is normally lost, and it consists merely of a more or less consistent mucus."

Finally, it is plain that the peculiar modes of fracture of the vitreous, and of the leaking of the fluid from the ruptured hyaloid, which first gave rise to the idea of cellular division, are owing to the close network we have been considering.

Muscæ volitantes.—The preceding investigation has ascribed to the hitherto vagrant muscæ volitantes (proper) such form, disposition, and office, as to make them the essential element in the structure of the vitreous body; and this essay, directly physiological as it is in its nature, has pointed out all the circumstances which can lead to their manifestation. I should, therefore, have thought it of little interest any further to refer to that term, had it not been for the fact that the recent introduction of ophthalmoscopic studies has promoted muscæ to more than their ancient importance,—from a symptom of disease in the patient into a sign visible to another person.

We can now readily understand, from the foregoing method of ocular exploration, and the exposition of the optical illusions furnished by the beaded fibre, on a reference to Sir D. Brewster's paper already cited, how he fell into the error that muscæ volitantes are fragmentary tubular filaments containing, indifferently, groups of contiguous globules, or solitary ones, floating in a few large cells, and liable to become folded into complicated adherent "knots," and how, even he carefully makes a drawing of such an entanglement as permanent, which we may be sure could not exist as he has figured it, and anything like which the ocular movements would not suffer to persist, notwithstanding the frequency with which parts of the lax web transitorily become hitched together. And how, even he fancies that his drawing suffices to show that a period of four and a-half years has produced an increase of the "knot," and a diminution of the lengths of the filaments springing from it; though he was not only unconscious that the filaments had not free ends, but, by the very drawing, had no means of marking any lengths in more than one of them, and certainly had no means of measuring the filaments had he marked lengths for guides. Had Sir David's observation been trustworthy, it would only demonstrate a reduplication of the knot at the expense of the filaments, and no increase of foreign substance in the vitreous fluid.

Such a fibrous tissue as that which has been now found to exist in the vitreous is of the lowest organization, requires little sustenance, and is, as is well known, scarcely capable of diseased action; and, therefore, we should not anticipate that the web should be ever the cause of foreign deposit in the posterior chamber, which might be visible through an ophthalmoscope.

On the other hand, it must be remembered that in ophthalmoscopic observations the contents of the examiner's eye must become conspicuous to himself. There is a bright pencil of rays from the patient's cornea, not to say light from deeper parts of his eye, radiating directly into the examiner's, also from the lamp behind the patient, which, whether the examiner uses a lens at his own eye or not, must tend to the same effect. Here are sources both of divergent and convergent pencils of light entering the examiner's eye. Hence a person can only safely set about such a plan of observation when he has made himself so familiar with the aspect of the objects resident in the lenses of his own eye as to know them at sight. A lack of the previous information here recommended appears on the very face of such monographs on the use of the ophthalmoscope as have fallen in my way. Filaments, and their individual beads of the vitreous humour, small objects in, and even the stelliform figure of, the crystalline lens of the examining eye, have all been imagined to be things in the examined eye. By giving a convenient divergency to the rays issuing from an illuminated retina, in a convergent manner, back through a cornea, we gain, of course, a sight of the bottom of another person's eye, or of the retinal vessels, &c., much as we should were a retina of a dead eye before us. And if there be any objects of similar size in the depths of the eye, we may likewise see them by light reflected from their anterior surfaces. But it will hardly be pretended that the ophthalmoscope upon this principle (or by what is termed transmitted light, in microscopical language) will enable us to see things that cannot be even discerned by the microscope. And if diffractive images of minutest objects within the examined eye, by the light repassing them, could be conveyed to such a distance as our own retina, we have been neglecting a mode of constructing instruments for observing minute objects which would throw our microscopic contrivances into the shade. In using the ordinary microscope there is an apparition of multitudinous objects in our eye, but persons who are unaware of the presence of such images, by habitually moving the eye, and the slide that holds the objects surveyed, usually avoid confounding the external objects with the others. It is contrariwise with the ophthalmoscope, with it, when the patient by a movement of his eye makes a "shred" or "flake," float about in his vitreous humour, the examining eye follows the movement, and the filaments (simulating such shreds) in it float about, offering different examples, and different aspects for any one, or removing them seemingly from view. Hence a difference of shreds, or absence of shreds for different patients. Wherefore, there is need of caution in receiving published accounts of muscæ thus seen, and in accepting such phraseology as "*dissolved*" or "disintegrated" vitreous humour.

CHAPTER V.

OPTICAL ANATOMY OF THE RETINA.

From the microscopical discoveries of Bowman, H. Müller, Kölliker, and others, it appears that we are to view the retina as comprised of five layers; or reckoning from the hyaloid membrane outwards. "1. Limitary membrane; 2. Expansion of the Optic nerve; 3. Layer of grey nerve-substance; 4. Granular layer; 5. Layer of rods and cones." To which they append that the last layer is annexed to the first by "radial fibres," issuing from the centres of the rods and cones, penetrating the other layers, and terminating by a feathery expansion on the limitary membrane, &c., &c.

According to Kölliker "the vessels of the retina are derived from the *art. centralis retinæ*, which enters the eye enclosed in the optic nerve, and begins to ramify from the centre of the *colliculus nervi optici* in four or five main branches. Lodged at first only beneath the *membrana limitans*, these vessels penetrate through the layer of nerve-fibres into that of grey nerve-substance, ramify in an elegant arborescent mannèr as far as the *ora serrata*, and pass by their terminal prolongations on all sides into a rather wide-meshed network of very fine capillaries (0·002—·003‴), which is lodged chiefly in the grey layer, but partly also in the expansion of the optic nerve. In animals the veins commence with a complete circle, *circulus venosus retinæ*, at the *ora serrata*, accompany the arteries in single trunks, and converge to the *vena centralis*, which quits the eye together with the artery. No large vessels exist in the 'yellow spot,' where there are only numerous capillaries."

The central vessels of the retina show themselves as black objects *whenever it is exposed to an instantaneous succession of light from different radiant points.* The machinery for the conveyance of blood to and from the retinal tissues will hold a prominent place in these researches, and we must learn to distinguish vessels in one eye from those in the other, and we will therefore begin our study by making acquaintance with the vasa centralia in our own eyes, as they reveal themselves in a fundamental experiment proposed long ago by Purkinje. He noticed that if a lighted candle be moved from side to side just before the face for a short time, the vasa centralia retinæ are thrown upon the ceiling and walls of the room as black ramifications.

In trying this experiment upon the eyes singly, I find that the veins and arteries, which are alike seen, by crossing each other in their subdivisions, occasionally display meshes, that except from distribution, and perhaps breadth, we cannot discriminate between them, no pulsation marking the arteries from the veins; that the capillary connection between the veins and arteries is not wholly discernible, but that both classes of vessels ramify from their trunks and subdivide until they almost appear to terminate in twigs; some of which end almost abruptly, or with a short attenuation, some bifurcate into thinner shoots before they disappear, or even divide further into fine threads. These approximate terminations occur all over the retina, but towards the *foramen centrale* they are remarkable. The fine capillaries of the "yellow spot" cause it to appear as a grey or dotted ground, towards which many vessels point in a somewhat radiating fashion. In my left eye I can follow two or three of these vessels very near to the *foramen centrale* straight among the capillaries. In my right eye the vessels on approaching the central capillary region seem nearly suddenly to be buried by them. In a word, the impression conveyed to the mind is that the vessels which are thus more especially made visible are those which Kölliker describes as being the more superficial as regards the ocular lenses.

Again, it is not at all necessary, as has been imagined, that the candle be *often* waved before the eye. To a prompt observer *one* transit of it is enough. If we look rather above the flame, and hold the candle, as to the person, still, and turn ourselves round a little, the vascular phantom may be discerned. Indeed we cannot walk about holding a candle in advance without producing this effect. And it is not easy when we are stationary to keep a light in the hand so steadily, or so to prevent the flame oscillating by the draught of our own breath, as to absolutely obviate this consequence.

Some years since, I mentioned that Purkinje's expedient is not the only one by which these retinal vessels may be spread before us; let us now review those other modes, and see whether we have the means at our disposal of determining the physiological law, the fact of whose existence is thus disclosed.

If we look through the coloured shadowy fringe (see Chap. III.) resting on the edge of any body held near the eye, as long as both eye and body remain perfectly still, there is no indication of the vascular figure. But the instant there is a relative motion of the object *across* the eye's axis, or a movement of both eye and object perpendicularly to the latter's edge, every branch in the vasa centralia which lies approximately parallel to the edge of the object, at once shows itself as a black line or band, and all the capillaries as black dots, along the lines of the luminous fringes resting, in alternation with dark ones, on the object; during the act, *and no longer*, of the movement of the object *across* the eye's axis, or of their joint movements in this direction, thus yielding the appearance of undulating black broken lines preceding or following the edge of the object.

If we look through the "crested" fringes on the end of a narrow object (as the point of a pen-knife), as long as it and the eye are still, we see nothing but the peculiar terminal dark and bright fringes; but no sooner does the object make a movement, be it never so little, perpendicularly to the optic axis, or both eye and object move in such direction, than the fringe is occupied, whatever part of the retina it passes over, by so much of the vascular figure.

We may also get a sight of these vessels and capillaries in a linear fashion by the movement of the axis of a prism *across* that of the eye, or of both it and the eye in such direction. The linear tendency of the apparition occurring parallel to the axis of the prism.

If we reflect light into the eye from the head of a pin, and move the pin *across* the eye's axis (or vice versâ) or both eye and pin in such way, and only then, the same appearance results; the vessels crossed by the movement are seen fully, and the capillaries as black dots in the illuminated tract of the retina.

If light radiate into the eye from a small puncture, having the said, and only then, relative motion, or both puncture and eye having it, the same thing occurs.

If light enter the eye from a curved reflector, on similar conditions of *cross* movement, and only then, the same phenomenon happens.

If light enter the eye from any luminous disc through a convex or concave lens, on such relative or joint movements across the optic axis, that is *parallel to the retina*, but not without such movement, the vasa centralia are conspicuous.

In all these cases it must not be forgotten that it is only those vessels whose course in the retina is nearly perpendicular to the line of movement across the eye's axis, which display themselves completely, and that their black images apppear to have at their sides about an equal breadth of ground less dotted than the average ground now before us. The majority of the vessels supplying the "yellow spot" in my eyes are vertical rather than horizontal. Hence the dotted appearance of that spot is manifested forcibly in vertical movements, but the dots have a prolonged vertical appearance when the movements are horizontal. But if we move any one of the objects above cited,—except the edge of a long body, or a prism, which act rather in a linear fashion in a sole direction,—in a circular manner before the eye, as for instance a lens from which the eye receives the light of a candle, we obtain a most beautiful view of the central retinal vessels and their capillaries; owing to the quantity of light thus obtainable, far more effectually than by the waving of a candle before the eye. The capillaries seem to load the branches of the vessels like an abundant minute fruit. If we reverse the circular movement, a singular confusion seemingly results from parts of the retina retaining impressed sensations being thus again acted upon *at unequal intervals of time*. But in the establishment of this counter-motion a good view of the finest capillaries is procured. The axis of the eye in these circular movements being crossed perpendicularly from all sides, the interspaces of the vascular figure appear of an uniform brightness.

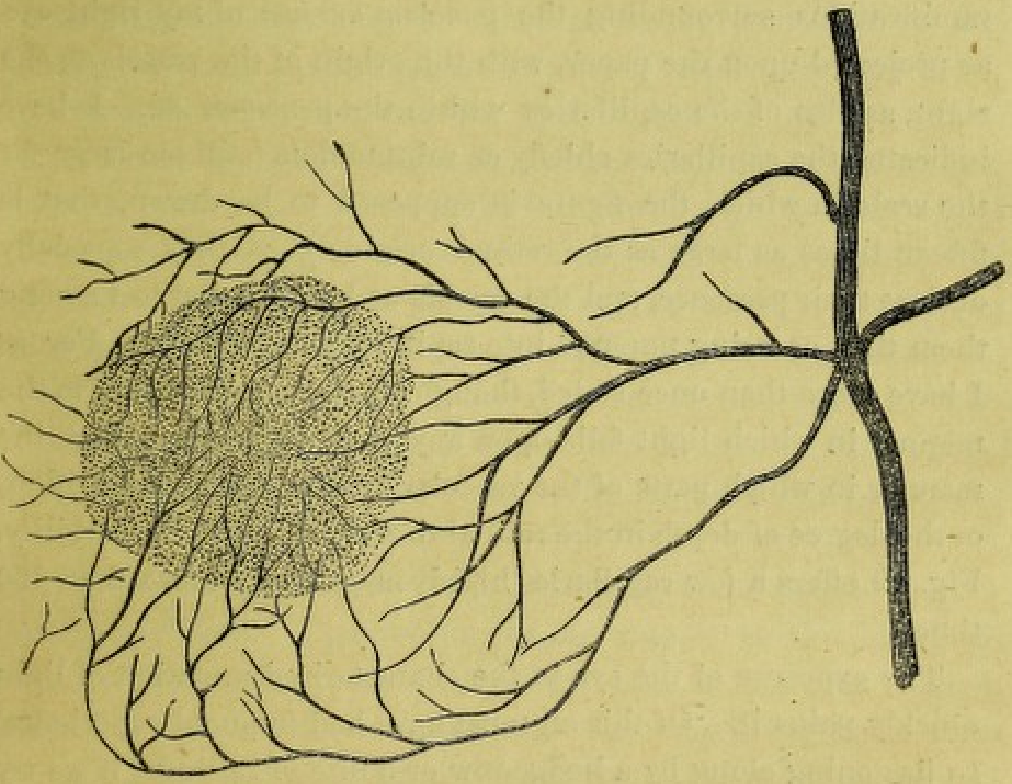
Do we move a flat reflecting surface which throws light into the eye, or a flat piece of glass which admits light to the eye, parallel to the cornea, or a prism along its own axis across the eye, never so much, no indication of the phenomenon in question accrues. When we have two punctures in a card close enough to have a common field of view, it is difficult to produce the effect in the common portion.

But with any one of the instruments adapted for the purpose it is immaterial to that end whether the direction in which the light approaches the eye changes, or both the instrument and eye are carried across the approaching light, or if the eye and instrument move across each other.

Thus if we wear one of the instruments, say the punctured card, as an eye-glass is worn, every time we *turn* the head we have the vascular apparition. Further, if we close the eye partially so as to look between the eyelashes and eyelids, as we move the head across their edges, we get, in a fair degree, the effect. If we rotate, even, merely the open naked eye quickly over the sky, the same sight may be observed, though rather imperfectly. In the beams of light begotten by the lids and the fluids they carry, by sliding the lids up and down over the eye we may discern the figure. In the case of the oscillatory candle flame it is plain that its image is perpetually traversing the retina, and the rays reflected from the walls of the room fall upon the eye ever from new points, and at new angles of incidence.

From a consideration of these various modes of eliciting the vascular spectre, I have come to the conclusion that the essential condition, the more exactly any one of the devices detailed accomplishing such condition, the more complete and instantaneous being the result, is that every point of the affected section of the retina must *lose light from one external point and receive light from another, within a very limited time*, perhaps an indefinitely small time.

To determine nicely how much of the vascular network thus reveals itself is not an easy business. For though the slightest appropriate movement produces the effect, no sooner is there no movement than the phantom has vanished; so that the scrutiny now suggested has to be carried on under a condition which fatigues the eye. If we use a distant bright ground, as the sky,



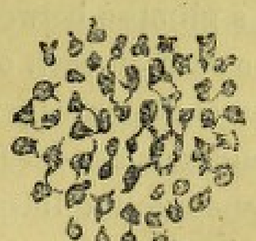


FIG. 11. FIG. 12.

or a white cloud, the capillaries show themselves, when their loops are not complete, as comparatively large dots, of more or less ragged border; if we obtain our bright ground from a near light the dots become the merest black points. Owing to the manner in which the capillary loops are placed in the retinal layers, very commonly, one portion of the loop, no doubt that nearest to the limitary membrane, presents itself rather than the rest, or is alone disclosed. The vessels which are placed superficially are very obvious. In order to convey an idea of the appearance yielded, I have endeavoured in fig. 11 to copy not every vessel much more not every capillary (a waste of perseverance, though to take an exact copy might not be quite impossible), but the general style of the ramifications surrounding the *punctum aureum* of my right eye as projected upon the paper, with the origin of the vessels to the right, as also of the capillaries within the *punctum*, &c. I have indicated the capillaries chiefly as minute dots (still too large for the scale in which the figure is supposed to be drawn, that is fifteen times as large as the retinal original), as they especially declare their presence, and the vessels as being rather lost among them than as being pursued into capillary development. For as I have more than once stated, though effects vary according to the manner in which light falls upon any part, it is clear that the manner in which parts of the vascular system overlie each other, or the degree of depth in the retinal tissues, affects their visibility. Fig. 12 offers a few capillaries highly magnified—more than 200 times.

The exposure of the eye to the characterized mutation of light quickly pains it. Of this all must have had frequent experience. In hastening along by a hedge-row or a line of railings, if we try to get a glimpse between these objects, the vascular apparition may be seen on each of them as it passes the sight. And should the sun shine directly through such rows of objects upon our face, and we close our eyelids as we move onwards, the potent rays will penetrate the lids, and interrupted by their elements will of course impinge upon the retina in *manifold* accordance with the law required for the display of the vascular system, which is therefore manifested. We all know that to proceed under such circumstances torments the eye past endurance. If we now open the organ fragmentary spectra of the sun will be impressed by the transit of the objects over its surface, which is (and was before) an additional, though perhaps a minor difficulty for the eye. In the continual visual transitions, the muscles of the orbit in endeavouring to respond to the uncertain or contrary requirements of the eye, act irregularly against one another, and become fatigued, the chief source of painful annoyance.

Orbital mobility of the eye-ball. A striking illustration of our instinctive, if not of reflex, movement of the eye-ball, a general fact which we should do well never to forget in a wide range of ocular experiments, may be obtained in the course of our last study. Putting another person to wave a candle, through excursions of about two feet, near my face, in spite of my utmost effort to rivet my gaze straight on a given small object and to prevent the movements of the eyeball which I feel, I see the retinal vessels go *oppositely* to the course of the candle, and considerably from the object, wherever the candle passes, laterally, upwards, or downwards. Nevertheless, this (as well as the allied experiments) performed gently through short excursions, evinces that the middle of the *punctum aureum*, as determined by the capillary region, is in the optic axis. The next series of observations do the same.

The central vessels of the retina are displayed and defined by their currents of blood. The swelling of the vessels as the blood advances creates phantasms, which are not, as has been fancied, usually of an undefinable character. In considering them let us bear in mind that length and velocity in the retina, when referred to an external surface, are vastly multiplied, insomuch that if the surface be only distant four feet the apparent amounts to one hundred times the real. Hence, without allowing for the lingering of each sensation of light, the progress of the merest drop of blood will show itself as a more or less continuous line.

The effect of depth in the retinal layers as regards the phenomenon exhibited is again illustrated here. For let us look at a bright blue sky at noon, then a pulsation in a vessel will announce itself, if not in a blue, as a *grey, dun, or darker* round spot, beginning at a point and dilating to a certain size; whilst around this darker spot will appear an areola *much brighter* than the sky, beginning at a small circle round the grey point, and enlarging as the grey spot increases. If we look suddenly at an excessively illuminated surface, as at the sun through a lens, or with the naked eye to the vicinity of the setting sun, the whole of the glowing surface will for about a minute—until the excitability of the retina has been diminished by the retention of the *spectrum* of the glowing ground—be notably studded with round darker pulsations. But to return to the simple bright sky, we also notice long portions of vessels exhibiting themselves in a similar style with the phenomenon now described, as the blood swells through them, simulating shorter or longer grey-dun or darker bodies, tortuous or serpentine, provided all along their sides with a vivid white as the foam or phosphoresence of their tracks, of about their own breadth, cleaving the azure depths. (see Fig. 13 for a few arrested examples of the appearances in course of being de-

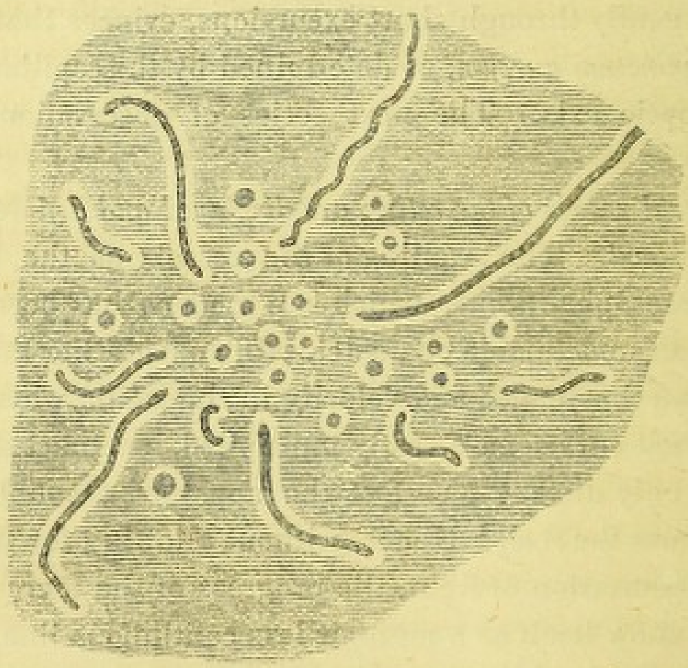


Fig. 13.

scribed). By the method of mutation of light already given, we can determine the very vessel in which the phenomenon is occurring. It happens over the whole of the retina, but in such vessels as those which I have noticed in my left eye, large ones approaching the foramen centrale, in the midst of the most sensible part, the results are particularly brilliant. The more luminous the ground we regard, the greater the amount of contiguous phosphorescence. But even when twilight is fading into night, we may still observe the figures we are passing in review, with a proportionally less striking difference between the dull middle and bright sides.

Since the *crests* of the vessels when projecting from the concave surface of the retina seem grey, whilst from the points which mark the angle of their rise above that surface, superior luminosity is displayed, we may safely affirm *here* that nervous matter must have been *especially compressed in that angle*. (The reasons of the contrasts in brightness here marked will be fully considered hereafter.) And that these effects are greater when the matter compressed is at the same time stimulated by the impingement of light.

Thus, besides that one picture is passive and the other active, there is a remarkable difference between the white borders of the vessels obtained by mutation of light, and that in the spontaneous apparition of an individual one; inasmuch as in the latter case, instead of being of the same luminosity as the average ground in use, it is of a redoubled or greatly higher; whilst there is usually an equally remarkable difference in the images of the vessels in the two cases. In the artificially begotten example, it is black as if the retina were covered by, or *blinded* in the course of the vessel. In the other case the vessel's crest is rather a dun of varying intensity, as if perception were not destroyed, but were rather *blunted* more or less where the vessel runs. Yet, strictly this distinction does not meet the case, for a careful consideration of all the circumstances in individual examples, shows that we rather simply see the sky of its proper brightness right on the middle of the vessel, in which region perception is not blinded, or the middle line appears no duller than the space without the phosphorescence, unless this outer ground receive an adventitious light from numerous capillaries in play. Nay, to speak with absolute correctness, it should be affirmed that all parts of the retina are lit up with blood-pressure, but the middle of the vessel, only in a minutest degree.

So far, attention has only been drawn to a few partial prominent expressions of the blood-currents in the retinal vessels. But the fact is, that, in the flickering dancing fashion of the partial apparitions instanced, the whole of these vessels are continually exhibiting themselves. Only under ordinary use of the eye, the impression made by the images of external radiants so preponderates over the mechanically produced images of the vessels, that the actual presence of the latter nevertheless, escapes the notice of the incurious. What really exists before us is a lively compound vascular figure of the duplicate field of the retinæ. If we shut both eyes towards bountiful light, so that the lids may permit the stimulus to impinge upon the retina without painting images thereon, the double vascular figure may be seen in full activity; every vessel and every capillary joining in the impatient picture, mainly by the lateral compression spoken of. If we have well studied this picture we may find that in absolute deprivation of light we have in a less luminous guise this double picture always at work, so that we really have no experience of a state of darkness. If in daylight we look at slightly reflecting surfaces, or shaded darkish spots, the quasi-lights from blood-pressure will excel the faint light that enters the eye, and consequently the double vascular figure be seen very distinctly. In all these cases the capillaries show their luminosities in dancing points, or by busy tremulous waves where they are crowded together, and the vessels in the resultant retinal field intersect one another, and traverse capillary districts—insomuch that the host of images tend to destroy one another, and the animated blood-light is roughly equalized over the visual field.

Notwithstanding, we have it in our power to analyse the joint vascular figure; for the quasi-lights are stronger in a retina expōsed to light in proportion to the amount of this. Hence we have only to expose one eye to the light in such a way as to prevent its retina from being occupied by images of external radiants, and the vascular figure of this eye will so dominate that we may view it as if it were alone. Thus we shut both eyes and cover one also with the palm of the hand, and turn towards good daylight. Then, after a minute or so, the eye from which light is imperfectly excluded will render its vascular figure very conspicuously, whilst that of the other eye will cease to embarrass us. Again, the sensibility of the more stimulated retina has been impaired, and if light be now completely shut off from this one also, the vessels of the other will luminously display themselves; or if the eye that was first thoroughly covered be opened towards a faintly illuminated surface, the whole scheme of its vessels, to their minuest details, will play brightly upon this surface. In either eye we may, in either of these modes, see the vessels defined by the current of blood circulating glowingly round the light of the central capillary region, or punctum aureum, towards which they radiate, and turn variously from, as if gyrating round a white central pivot hurriedly; for the seeming haste of the blood in the retinal vessels, when we have thus a sight of the circulation, is singular—one unabating, vigorous flow. In the daytime, if an eye has been shut off from the light for a few minutes, and we open it towards the sky, the pre-existing luminous tract of, at all events, the larger vessels will remarkably abide for some seconds on the sky, until external radiants exceed blood-pressure in retinal effects. In twilight and ordinary starlight the quasi-light fairly rivals the actual; yet if one eye be closed, the latter will so combine with the former in the open eye, as to strongly manifest the vasa centralia retinæ of this organ on the clouds, sky, or road; whereas, when both eyes are open, we have only a fiery haze of an indefinitive character.

It must not be overlooked that all images begotten in the retina by direct mechanical impulse, or anyhow once painted thereon, are quite independent of the form of the eye for their visibility. Wherefore, if we take care that the eye shall not acquire the form requisite to refocalize light on the visual percipients, we may pour upon these a flood of light of any intensity without extinguishing the vascular images; on the contrary, with much augmentation of their brightness. So, if we place a very shining surface almost close to the face—not to say if we aid the anticipated effect by looking, as it were, far into distance—the vascular figure will play beautifully on a surface whose radiant points are blended upon the sole retina permitted to receive the rays.

Again, we may not only thus successfully experimentalize with an eye properly adjusted for one distance, whilst the radiants before it are situated at another; but we can actually in addition press the eye into *irregular* form, so that different parts of the retina shall, in different degrees, be removed from the appropriate position for the reception of refocalized rays; or this state may exist whilst parts may remain where external radiants accurately paint themselves.

We can grasp the eyeball firmly between the fingers and thumb, pushed as far back along the walls of the orbit as we can get them, and squeeze the globe of the eye, whilst we look strongly at a given point, and thus occasion objects before us to vanish, though the rays of light from them are not shut out from the pupil, and whilst this is happening, the vessels of this organ's retina to come just as much into view; and this in all the phases implied in the statement of the last paragraph.

A like effect can be obtained from the sole action of the ocular muscles. If, in daylight, we shut one eye, and continue to gaze intently into infinitude, we observe, dating from the very beginning of the act, more and more of the vessels, as in fig. 13, to appear on the clouds or sky. If we merely wink the eye, or casually suffer the orbital muscles to relax, in an instant all the *extraordinary* phenomena have vanished. But if the strain is resolutely kept up, in spite of the reiterated efforts made by the muscles to escape from the task the will has imposed upon them —as indicated both by certain uncontrollable movements of the eyeballs, which can easily be followed either by observation or the feeling, and the oscillatory phases of the phenomena just hinted at—a moment will come when the eye will have reached such an exceeding departure from its usual form, that external radiants will more or less completely cease to be discernible by more or less of the retinal expanse, whilst in the room of the images of such radiants we have those of the retinal vessels.

The partial effects, for example, may be manifested in the middle of the retina, or in the regions which are without, above, or below it. Thus, the vascular images may be substituted for those of things which lie straight before the eye, or on the nasal side of it, or below it, or above it, or for all these together; whilst we may still clearly see by that portion of the retina which lies about the base of the optic nerve, or see things which lie without the eye. Yet notwithstanding that a part of the retina enjoys a comparative immunity from the effect we are dwelling on, the consummation may be so complete as to involve the whole visual field.

There is no doubt that by pre-arranging for a general want of correspondence between ocular focal adjustment and the distance of objects we are contemplating, we may facilitate the main result, but the partial effects proclaim that something beyond mere loss of proper focal adaptation takes place here. If there is a special muscle provided for the movement or compression of the crystalline lens for focalizing purposes, it has been long known that there is, commonly, if not necessarily, a consentaneous action between such muscle and the muscles of the orbit (and the iris, though it has been ascertained that the pupil does not necessarily alter its size on an alteration of the eye's focal length. And in the experiment before us, the pupil may remain unaffected), and therefore the total result may be owing to united actions of the orbital and lenticular muscles. And if the supposition that focal adjustment is due to a change in the eye's length through the sole action of the orbital muscles be preferred, it will be equally easy to explain the result. We cannot say that this experiment enables us to decide what is the apparatus furnished for affecting focal adjustment, we have only proof from the *sectional* exhibition of the peculiar phenomenon that the orbital muscles are capable of greatly altering the form of the eyeball; we may refer, moreover, to the consequences of aiding the muscles by squeezing the eyeball between the fingers in proof of the efficacy of pressure upon the external tunic of the globe for altering focal relations.

The portion of the retina which it is most difficult to affect in the manner described, is that which lies between the four straight muscles, and which is held to the orbit by the optic nerve and accompanying vessels, whilst it is the region which the attachments of the superior, the external, and inferior, straight with those of the two oblique muscles occupy or embrace, and which is in no other manner connected with the orbit, that is, in varying degrees, peculiarly prone to the phenomenon we are discussing. And the slightest consideration of the distribution of the attachments of the muscles named to the sclerotic coat and their lines of contraction will satisfy us how readily they must, when pulling against one another, give an irregular form to a portion of the globe of the eye. And it would be by no means impossible by exactly observing the phenomenon in any partial appearance to assign the actual muscular movements which must have concurred in its production. The straight and oblique muscles inserted before and behind the eye's equator, pulling against each other (the pressure of the fingers would aid such result), would seem to tend to shorten the eye's axis, and to prevent even parallel rays from reaching foci on the retina. This effect seems often to contribute a portion of the phenomenon; but the eye's form changes unequably by the pressure of the atmosphere, the different bulgings of the muscles in the orbit, and their pulling against one another. Even the lens may thus be made to shift in the eye, but unless there be some compressible machinery in its region, not without an alteration in the whole form of the ball, whatever muscles do it. If the lens were turned on its edge slightly, it would *scatter* light much, and suffice for the grand effect. All vision, oblique freely, strained densely, immerse flames in a fog of stray rays. Essentially then we comprehend the change in form which yields results of such moment that it were well to be able to comprise all ocular focal inaptitudes under one epithet, such as *diffocal*.

The sensation of fatigue in the orbital muscles, after such a severe exertion on their part, is precisely similar to that in other muscles, and may be so great as to painfully remind us of the demands we have made upon them for many hours after the event.

By covering both eyes after the experiment, or opening the previously idle eye against a faintly illuminated surface, so vastly has the sensibility of one retina been impaired, that we have for a short time a splendid view of the circulation in the other.

The experiment succeeds equally well with near objects, such as a printed page, as with remote ; as it progresses, in an oscillatory recurrent fashion, the letters will fade from view, the vascular figure floating over them, and then the latter images yield to the former, and so on. By and by, in a greater or less portion of the retina, this figure entirely replaces the images of the black letters and their white interstices. And should we persist in keeping the only open eye towards the letters, it will recover its form and lose it again and again, to a repetition of the phenomenon with a short rhythmical interval.

It is difficult, if not quite impossible, for the eye thus to lose sight of an abruptly defined very luminous disc, as the sun. But by practice it is wonderful with what facility and completeness we can realize the characteristic effect.

If we operate with both eyes together we get, of course, the blended vascular figures of their two retinæ, a picture far less notable for distinct images than that presented by a single eye. Besides, the eyes sustain each other, or relieve each other by alternating in their action with much obstinacy, so that it becomes a much harder matter to accomplish a perfect substitution even of the resultant vascular figure of the two eyes for those of the external objects, nor can I say that I have ever been able to do so thoroughly. However, I have not much persevered in such trials, and have little doubt that by practice the effect may be accomplished to a higher degree.

We must not imagine that the direct intention of straining the light is indispensable to having the experience spoken of. If we have only one eye in use we shall soon find that it will begin to perpetually depart from the form required for our visual purposes, until at last it proves scarcely capable of recovering transitorily from the state which exhibits its vasa centralia retinæ. If we are in a condition of bodily fatigue, or unfit for muscular effort in any way, as by a heavy meal, we shall still sooner feel the truth of the remark now made. Exercise, or whatever else may augment the circulation of the blood, will moreover give increased force to the luminous vascular figures.

Persons who have a solitary eye, I am led from some inquiries to believe, rarely, if ever, get so accustomed to their condition in this respect as not to suffer from the ocular tendency we have been examining into. The fact of their having before them an unobliterated or complete picture of one set of central retinal vessels is a serious misfortune too. So that loss of half of the light from the field of view, and the injury done to the power of judging of distance and form, are not their only deprivations.

Images of objects which press upon the retina through the coats of the eye. If we place the point of a nail, or a top of a finger, upon, or if either be laid flat along, the lid over the sclerotic coat, it must be done lightly indeed (short of the slightest feeling in the sclerotic coat), especially if as far towards the most sensible parts of the retina as we can reach, if we do not perceive an image of the object thus applied. This image consists, in all cases, in all attainable parts of the retina of a comparatively very slight, or almost inappreciable, luminous appearance corresponding to the extent of surface pressing upon the eye (the proper image), terminated by a brilliant circumference marking the *limits* of the applied surface, or the edge of the pressing object.

When we rotate the eyes sharply in their orbits at night the flashes of light witnessed always present a *very faintly lighted space within a resplendent ring,* the edges of the ring being more or less ragged or rayed.

It has been commonly believed that a flash occurs every time the eyes turn in either at the same instant, certainly in "non-identical" parts of the two retinæ, perhaps at the base of the optic nerves. (J. Müller.) But the truth is that we have here two coincident phenomena, whose seats are the middles of the two retinæ.

If we rotate our eyes along the bright sky we may see, by the vessels which then appear, the middles of the two retinæ lighted up by an internal cause. If we take a mark against the sky and rotate our eyes from it, or up to it, we shall find that the flash occurs in the middle of the visual field. In twilight we cannot open the eyes at all and look at the road or sky without having an opportunity of observing a quasi-light straight where we look. If we get a spectrum, say of the setting sun, upon the eyes by directing them just above its upper margin, and then rotate them along another part of the heavens, the flash will be seen to happen, invariably, immediately above the spectrum. Indeed, if we shut one eye and then turn the globes strenuously in their sockets as far as we can draw them, we may determine that it is the eye which is pulled towards the nose that particularly yields the broad effect now witnessed.

In the darkened eyes the phantom is most noticed at the commencement and end of a rotation, and the quickness of succession of these events is such as to have produced the impression of two instantaneous manifestations. If we experimentalize under this condition, with a spectrum in the retinal position above stated, the attention will be attracted by the sudden flash at the outset of the turn, and dwell upon the abiding spectrum at the arrest of the motion, and the illusion that these two contiguous retinal images are separated by a considerable space, without the nicest perception, is complete, and furnishes a good elucidation of the origin of the physiological error pointed out.

Now in turning the eyes by contraction of their muscles, both of the balls must specially bear upon the posterior parts corresponding to the most sensible portions of the retinæ. And bountifully cushioned with fat as the sclerotic surface lying between the muscles is, as a provision against unequable pressure, we discover from these observations that we cannot change the direction of the optic axis in the orbits without in a greater or less degree affecting the rotundity of the back part of the globe. For it is plain that we are now examining into an effect precisely like that yielded by pressing an object upon the retina through the lid; the image in the section of the retina pressed upon being very faintly rendered, whilst the boundary line of this spot is very brightly displayed. (See fig. 14 for a typical representation.) Usually a round spot of about equal size in either retina

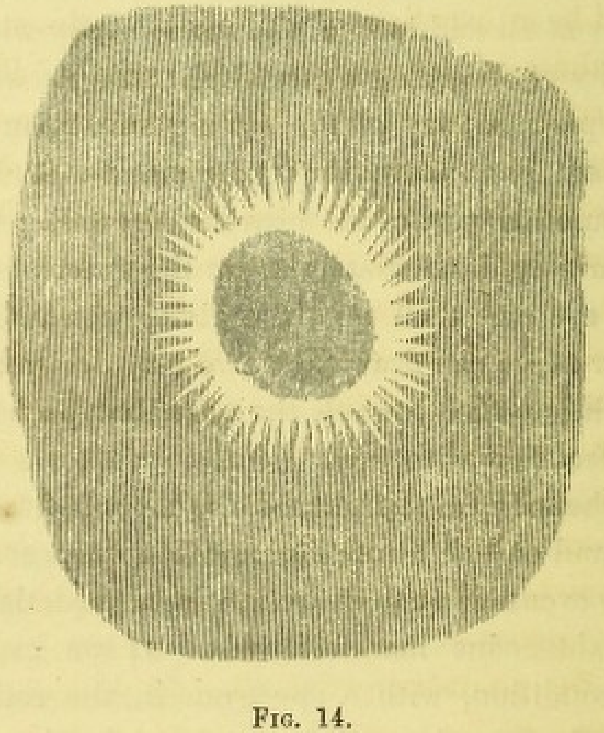


FIG. 14.

is pressed upon, hence a coalescence of the faint spots, as also of their bright margins. If we forcibly bring the eyelids together and rotate the globes at the same time, a greater extent of surface is depressed and the appearance dilated. It may be made to occupy a retinal area of 0·08—1‴ in diameter.

We gather from the series of facts recorded that it is not, or at any rate scarcely at all, by immediate pressure upon the retina that the sensations above implied are created. It is where the portion of the globe which has been thus flattened, or hollowed towards the orbit, passes into the remainder, that preserves the globular form, that is where the retina is bent towards the vitreous humour at an angle as if to make a fold or crease on that side, from which, of course, will radiate perpendicularly short folds. This fact would seem to indicate that it is only by *crowding into closer space the elements of the internal (at all events of an inner) surface* of the retina that sensations are begotten, for if crowding together those on the outer surface would produce this effect, we should have the brightness at the bottom of a hollow or depression.

We now perceive that the mode of production of the images we have last been expatiating on, is exactly the same as in the instance of those of the central retinal vessels. The images of objects pressing through the ocular tunics, however rapid the process, begin also with a grey, or dun, or dark point which expands, always carrying a brilliant areola. These images perhaps wear a little light from capillaries within their limits. The images at the yellow spot most.—Besides, as there are always two in this instance, coalescence of the images cannot be so perfect as to prevent some diffusion of light in them from this cause, nor are these images imparted by a projecting hard body; hence, absence of light in the image proper is not so nearly approached here. Altogether the only fear is that we should ascribe too much light to the image proper when a hard abrupt object presses on the tunics.

Again, in the production of the last cited images the fibres of the optic nerve as they spread out from its base to supply the retina with percipients, must be both pressed upon and bent, just as happens in the other retinal layers, and yet not the slightest light is discernible, in any instance, in distant percipient regions which the fibres pressed upon or bent provide for, that is literally, in no part of the retinal field beyond the limiting areola. Hence, it is palpable that the sensations are excited only in the visual precipients. Therefore these precipients are in an *inner* stratum of the retina. And this inner stratum lies between the vasa centralia and the vitreous humour; for these vessels divulge themselves in all respects like objects pressing from without the globe,—by pushing towards the vitreous such portion of the stratum as covers them, they crease that at their sides and compress its elements there.

With these hints we will here drop the question of what are the percipients of light, but will hereafter resume it.

Since the eye, for the purpose of carrying off its surplus occasional fluid &c., moves, whether it be open or shut, from moment to moment, the consequent depression at its punctum aureum obtrudes phenomena upon us that everybody notices.

If we are in a very drowsy condition, or suddenly recall our senses when we are dropping off to sleep, or if a nap be broken by a nod of the head, and we watch with closed eyes for events, the abrupt but now gentle rotations of the eye-ball will impress a rich orange colour upon the middle of the space before only occupied by the double vascular figure in its yellowish or whitish garb. And as the eyes will carry in the succeeding instant all their own and retained lights with them, and we are now unthinking or ignorant that the optic axes have changed direction, and therefore project in our imagination all these appearances as if we kept looking straight before the face, they will seem to advance over the visual field from its sides. The eyes are very apt to respond by a small jerk to the pulse. Not unfrequently they move in preference pretty nearly with one of the acts of respiration, as if the motor nerves of their orbital muscles sympathized with those of respiration or *expression*. Whilst from time to time the balls give a quicker or stronger turn in or sweep round their sockets. The general consequence is a disposition to rhythm in the phenomena now alluded to.

The patches or waves of light seem to follow one another at intervals across the visual field, and the succession of light and darkness is well calculated to surprise the uninitiated, in bed hours. I have only mentioned the middle retinal light in this sketch.

But the other parts of the globe are not so smoothly cased that an appreciable visual sensation can be produced nowhere else than in the back of the eye. Besides being liable to be squeezed by the two orbicular muscles, twelve others are inserted round the resultant retina, and as the slightest impression upon the globe suffices for the production of a spectre, we may, as would be anticipated, seize effects, though inferior, in parts of the retina further removed from the foramina centralia.

If the light of day fall upon the eyes when we are in the state described, the phantasms obtain a richer yellow, and the retinal field bears a bluer, or white hue, and the waves become a succession of yellow and blue, or yellow flowing over blue. This phenomenon of the drowsy state may be observed in twilight, with open eyes against the ceiling of the room. The phantasms now touched upon have been the subject of endless speculation.

Persistent sensation—"*spectra.*" If we fold a silk handkerchief into a smooth cushion and lay it on a shut eye, and commence a gradually increasing pressure upon the globe, we shall soon make such a difference between the brightness of the busy vascular images of the two retinæ as to be able to discriminate between them. We shall find also that by a difference of force used we can produce any colour at the bottom of the eye, what may be orange with a mild pressure may be blue with a strong. I have thus by severe pressure begotten a rich pea-green of sufficient intensity to give a like colour, though as it were diluted, to paper, which, viewed with the other eye, was quite enough illuminated with white light for the reading of ordinary print. And whatever image or spectrum exists in one retina may always be seen as if by the other when the white light received by the other organ has been diminished to a certain extent. And whenever spectra, as those of the sun impressed upon one retina, are seemingly seen on the other, it is owing to their vividness being such as to emulate the impression made by the white light present on the other. From such experiments it is clear that there are "identical" points in either retina, and that the sensorium may receive a coloured and a white impression at the same time by the two channels, and make them practically mingle, if not fuse; or allow one to preponderate on the attention, much as may be done, as we have found, with two such impressions made at the same point in the same retina.

Authors have long ago recorded experiments, such as looking through two pieces of glass of complimentary colours—through one with either eye—at the same time, to show that the two retinæ cannot combine the colours received separately, but that sometimes one colour prevails with the sensorium and sometimes rather the other; in the special case alluded to, white never appears. To this we may add, that if we look quickly with one eye from colour to colour, no combination of such ensues; and if we obtain, as may readily be done, a brilliant yellow spectrum of a candle-flame in the eye, and look at a blue ground, the same kind of thing happens as with the two pieces of glass, and white is not seen. But these observations prove nothing but that, though differently coloured rays falling *together* on the retina produce a mean effect, sensations in the course of their being conveyed to the sensorium cannot be made to mix like the undulations of light which produced them. In sonorous vibrations if two of one set equal, in length, three of another, they harmonize, *provided* that the two equal lengths coincide. The above observations in no way evince that the employment of two retinæ operates differently as to blending of colour from that of one. They seem to indicate that the optic nerves, like others, will carry separately different sorts of impressions to the brain. And they afford an argument in favour of explaining spectra by the doctrine of a temporary exhaustion as to special colour acting upon the retina.

However, the spectra existing in the retinæ, or in nervous matter, are quite independent for their distinctness of the form of the eye, and therefore, like the vascular figures, gain in distinctness when the eye loses the proper focal adaptation for the ground before us, and become more faintly marked as the eye relieves itself to examine the ground, or the spectra as resting on that ground. And as our eyes rotate slowly, whilst our mind dwells upon the primary position of the visual field, they, as it were, unawares carry the spectra out of sight.

Again, as spectra may be produced, in any colour and intensity, by mechanical means, as well as by the action of light, and as they are in nervous substance acted upon by the stimulus of retinal blood-currents, as well as concussions from ocular rotations, it is possible, and probable, that some of the transmutations observed in them in the darkened eye, are due to one or both of the ocular mechanical causes named—effects comparable to those we note to be due to the stimulus of other light. And whatever causes act in the shut eye must operate in the open.

Thus it does not follow, unless we have assured ourselves by a diligent regard to the sources of fallacy now pointed out, during an investigation of the phases of the spectra, that the changes observed in them, if not traceable to the immediate action of additional light, must have arisen spontaneously in nervous substance. For instance, it does not follow that the fitful disappearance and reappearance of spectra are from unsustained nervous action.

These spectra have had a number of diligent inquirers into the laws which regulate their conduct. I am not in a position to offer anything positive in addition to what they have written, I have only endeavoured to suggest the manner in which the researches we are now engaged in may affect the general question of spectra. The subject is a very broad one, and by taking into consideration the degree of force requisite to produce them by pressure upon the retina a further means of elucidation would be at our disposal. The limited number of observations I have made on these spectra lead me to the suspicion that we shall not thoroughly understand their deportment without careful attention to the hints here thrown out, or that we may arrive at still juster ideas upon them than at present prevail.

It will be convenient for us to bear in mind at a future stage of this essay that these spectra always confine themselves to the portion of the retina stimulated, and that one of any colour becomes of the accidental or complimentary colour on exposure to white light. Also in closing one eye to experimentalize for any purpose with the other, we must be careful not to press, because we may thus create colours or images which may be fancied to be before us in the open eye. The same caution is necessary that we do not perplex our observations with spectra in the open eye from the action of light.

Apparent displacement of objects by movements of the eyeball. When we see duplicates of an object by looking beyond it, or duplicates differently related to the two eyes by looking within it, these pairs recede, each one from its fellow, as the point regarded recedes from the object, and approach one another, as the point regarded approaches the object. Also in pressing round one eyeball whilst we look at any object, we can occasion a second, spectral object, to revolve with the rotation forced upon the globe. These facts, with their geometrical explanation, are familiar.

Now when we are striving by intent gazing to call up the visual phenomena for ocular diffocal form, the eye will be *palpably and visibly* warped about by its muscles, as they severally gain a transitory mastery over the others. The eye will thus present at each consequent rotation another portion of its retina, to receive the shadow of a terrestrial object intervening between it and the sky. And thus, in a roughly rhythmical style, the seat of the shadow in a whiter guise, will project from one side of the object and then from the other, and so on. Also above and below it, in the same sort of way. If we have a bright disc on a dark ground, the luminous spectrum of the disc will transgress the margin of the true disc, fitfully, or more or less in sustained manner, round about.

Similarly, these ocular movements are obvious by an apparent displacement of objects. If we are straining the gaze in the manner mentioned with both eyes at one time, the articles of furniture in a room will seem to move about, to and fro, or in crossing directions, or even to revolve round some centre. Or when the pattern of a carpet blends its parts, and the retinal circulation seems to play vigorously over its surface, this surface will rise and fall and undulate like the waves of the sea, glide from side to side, and in other directions. Nay, if we close one eye, the substantive part of these results accrue from the movements of an only eye in its socket:—even if a single eye rotate about its axis whilst that revolves, the objects on the opposite sides of that axis will seem to move in adverse directions. Geometrical consequences easy to assign in each case.

It is not solely in struggling to rivet the attention in a given way that effects such as these happen. If we sit in a mere contemplative humour our eyes will habitually turn about and incline to and recede from each other in an equivalent mode to that described. If we rest the eyes upon a candle flame and get a spectrum of it, and then turn away from the candle, unless we make incessant efforts to rally the eyes to a given point, they will continue to carry the spectrum all about the room, and even, illusorily, out of sight. The disposition of the eyes to roam, unless we are almost momentarily bringing them back to a point, especially to fall down to a given inclination with the cheeks, should be noted, as we might be otherwise deceived in certain of the experiments which fall in our way.

Negative uses of the preceding analysis.

Alleged "sensations of rotation." (J. Müller's Physiology by Baly, end of vol. I) "Certain influences acting on the brain give rise, not to rotatory motions, but to sensations of rotation. These are the revolving sensations of vertigo, of which we are principally conscious by the sense of vision. It is a well-known fact that if any person turns round quickly upon his own axis for a short time, he not only begins to lose his recollection, but also, when he ceases to move, seems to see the objects around him still revolving in the same direction. Purkinje has made some very curious observations relative to this phenomenon. It would appear from his experiments that the direction which the revolution of the images shall take can be regulated by the position of the body, and particularly of the head while turning round, and by the position of it afterwards when we have ceased to move round." I have carefully observed the consequences of such rotations, and find that no movements of objects appear other than those produced by the rotation of the eyeballs in their sockets. In a word, that the instance of "vertigo" is an exact illustration, for we can by mere contemplation of vacancy, to use conventional phraseology, or by the muscular management of the eyeball, which some practice will furnish us with, whilst sitting in a chair, witness this phenomenon whenever we feel inclined to. There is certainly some foundation for the conclusions come to by Purkinje, inasmuch as the muscular contractions in the orbit are disposed to associate themselves in direction with general muscular movements in which the frame is involved. But the dizzy head being unable, on our stopping, to regulate or control the conduct of the muscles, the eyes are made to bob about or to struggle through remittent rotations; and we are apt to follow the revolutions of surrounding objects during such ocular rotations, and to wink the eye or overlook the quick adverse turns. As motion is merely relative, a current of spectra of external objects impressed upon a retina, carried by the *roaming* eye over present objects, may occasion an illusion of revolution in the latter. Also the lively vascular figure floating over objects may make it seem that there is motion in them. These effects, which must accrue at the same time, may help to create confusion. But it is only a lack of adequate attention which leads to the idea of any semblance of movement beyond those of the explanation here given.

Alleged false location of objects by an act of the sensorium, &c. An experiment of Mr. Wheatstone's has been instanced as having a bearing of this sort. I quote from the account of the experiment as interpolated by Dr. Baly in his translation of Müller's Physiology (p. 1206). In a stereoscope he presents to one eye a "vertical" strong line and to the other eye an equal line inclined "some degrees to the perpendicular. A line is seen, the extremities of which appear at different distances from the eye." If "a faint vertical line, intersecting the inclined line at its centre, be now drawn, the two strong lines will still coincide, and the resultant perspective line will occupy the same place, while the faint line, though it occupies the same part of the retina as the vertical line, appears in a different place, namely, at the intersections of the planes of visual direction of the two eyes. Here it is evident an action of the mind, employing the impressions on the retina merely as suggestions of its judgment, which determines the image perceived, and the idea conceived."

I construe this experiment quite differently, viz., thus :—Two lines exactly equal and similar being presented to the eyes separately, the mind is impressed with the idea that they should be one, or that it is experiencing an instance of deviation from the habitual consent between the two eyeballs : and therefore influences their muscles in such a manner as to compel them to rotate adversely until the two strong lines actually do fall upon identical parts of the two retinæ. If we draw two such lines inclined to each other on paper, not more than a quarter of an inch apart at their more distant extremities, and hold a sheet of cardboard both between the lines and between the eyes, in such a way that either eye can only see the line on its own side, not only will the eyes palpably, and by the index of neighbouring objects visibly, attempt to make these lines fall upon two identical retinal ones, a far more difficult contortion, but will even accomplish it frequently, and hold themselves, too, in their constrained positions for many consecutive instants.

This observation and the one on rotatory movements last considered are the only ones deserving notice, as far as I know, as arguments in favour of the supposition that the mind enjoys a discretion within certain limits of *placing* an object whose image is painted in a given part of a retina. It is obvious that these observations afford no basis for such a conclusion; an hypothesis, not only not required in Physiological Optics, but, to me at least, incompatible with its whole tenor, and with that of correspondent anatomy.

Alleged retinal extension of sensation beyond the boundary of the painted image. Brewster (Optics, p. 416), and Purkinje (Müller's

Physiology, p. 1186), from the obliterative phenomena of strained vision, the substitution through ocular diffocal form of the vascular images for those of external objects, separately fell into the mistake " that luminous impressions must extend themselves to adjacent parts of the retina," so as to cover the seat of the images of vanishing objects, or that an " irradiation of sensation " ensues, and all succeeding physiologists have followed in their track. The true state of the case has been so amply descanted upon that it is needless to do more here than to refer to what has been already written.

However, Brewster adds that " when the object seen obliquely " (a necessary condition as this author thought) " is luminous, such as a candle, it will never vanish entirely, but it swells and contracts and is encircled by a nebulous halo." He mentions certain " yellow " and " pale blue " colours seen round such a flame. We may have diffractive colours from the eye's appendages, occasional fluids, or from its lenticular depths, some indications of a difference in the hues of the vascular picture may possibly rest about such a flame, and the spectrum of the flame by the ocular orbital movements will transgress the boundaries of the image. These phenomena are easy to distinguish from one another. Of these only one is here notable, and Sir David's details are so characteristic that we can have no hesitation in deciding that the phases noticed were owing to vibration through the diffocal state, with a concurrent action of the iris, whose first fringe supplied the colours. (Chapter III). There is no fact known which in the remotest manner militates against the accuracy of the statement that *rigid correspondence between the limits of sensation and those of the painted image is a physiological law literally absolute.*

Alleged anomalous psychological and other effects through the instrumentality of vision. By inducing a person to rest his gaze steadfastly upon our looks, or to dwell upon near waving movements which his eyes cannot follow, such as those of our hands, we can lead him into the experiment of causing or allowing his eyeballs to assume a form unsuited for vision, or to shut himself off from the external world, involved in the mist of his own retinal quasi-lights. If his curiosity has been aroused, he will still make supernatural efforts to attend to our proceedings,—which are purposely nearly of an uniform character, that his eyes may not be diverted in their gaze,—though the fact of his using both organs together prove a hinderment to the most complete result. That confiding subjects, when kept wrapt in darkness, should lapse into sleep is not astonishing. Besides the feeling of tension (fatigue) in the back of the eye or orbital muscles makes the head or eyes very heavy. It has already been stated with what quickness by some practice we can effect the ocular alteration in form; so that we may expect to succeed in getting the eyes of some individuals into the required state with much facility. Thus the same liability of the eye which occasioned the error of retinal "extension of sensation" has made the name of Mesmer celebrated. Mr. Braid was quite right in his conjecture that the transitory loss of sight produced by converging the two eyes upon the point of a sharp instrument held in our own hand near the nose is of the same nature as that imagined to be begotten in us through the action of another person.

Anomalies in the superiority of direct over oblique vision. "A rather singular method," say Sir J. Hirschel and Sir W. South, "of obtaining a view and even a rough measure, of the angles of stars of the last degree of faintness, has often been resorted to, viz., to *direct the eye to another part of the field.* In this way, a faint star, in the neighbourhood of a large one, will often become very conspicuous; so as to bear a certain illumination, which will yet totally disappear, as if suddenly blotted out, when the eye is turned full upon it, and so on, appearing and disappearing alternately as often as you please. The lateral portions of the retina, less fatigued by strong lights, and less exhausted by perpetual attention, are probably more sensible to faint impressions than the central ones; which may serve to account for this phenomenon."

Sir D. Brewster, from whose Optics (p. 418) I take this extract, suggests another hypothesis, but he elaborates it from several distinct phenomena, which, for want of our preceding analysis, he regards as identical in character. By looking "through the teeth of a fine comb held close to the eye, or even a single aperture of the same narrowness," he fancies that "undulations parallel" to the aperture are produced in the retina proper, not once suspecting that they were the *vasa centralia*, or the real cause of the phenomenon to lie in movement of the aperture across the eye's axis. He next adds: "An analogous effect is produced by looking steadfastly, and for a considerable time, on the parallel lines which represent the sea in certain maps. These lines will break into portions of serpentine lines, and all the prismatic tints will be seen included between the broken curvilinear portions." There may be witnessed in this experiment the spontaneous picture of the vasa centralia retinæ, or indicated ocular concussion from rotation. From his wrongly entertaining the persuasion that the foramen centrale may be transitorily "rendered visible by its properties," the latter of these phenomena, at least, seems to have caught his notice. But I can detect no other sign that his attention was ever directed to these apart, or, indeed, at all. In the semi-diffocal states they are subordinate, in daylight, to those which he here adduces, which are plainly again not retinal, but effects explained in the corollary of Chapter III. Sir David then collates with these the variations in the apparent size of a candle obliquely gazed at, which example has been already discussed. We need not consider the theory built upon these observations.

The explanation of the comparative central invisibility of the faint star is literally obvious. To such a degree is the middle of the retina invaded by light from the centripetally pointing vessels and the capillaries crowded there, besides being subject to the light from rotation, that singular apparent anomalies beset its supreme distinguishing properties. The sensibility of that region is certainly the highest, but that for this very reason must have the largest supply of blood, and be more affected by its transit. And the moment that light from an external point makes a much weaker impression on the central region than the pressure of blood that concentrates thither, the radiant point is lost sight of. The fusion or congregation of vascular images, in all their energy, at the punctum aureum, are as plain in the day as in the night, and may much obscure, with an active circulation, the letters of a book or a pane of glass. The same cause that makes the middle of the road, especially, one blaze when we walk vigorously at night, prevents our seeing a stone, if we stop to look at one with direct inspection, though with oblique it is plain to see. Or if in twilight we place a large and a small piece of paper near each other on a mahogany table, they will appear clearly as two if we regard them sideways, but the small will be joined to the large or quite blotted out if we turn our eyes upon it. The fact being that neither a stone in the road, nor such a piece of paper is at all seen, or but barely at all, unless large; but the quasi-lights of the middle of the retina float over and suffice to hide it. Finally, the vascular lights are at night about coincident with stellar lights in hue and range, and lavish on the spangled heavens an adventitious stellar gauze; and supply an illusory canopy of starry light when fogs or clouds conceal the heavens from us.

On the alleged power of determining by the eye alone the direction of the plane of polarization. Mr. Haidinger's brushes may be found described in Brewster's Optics, p. 245, being two opposed sectors of yellow light in the middle of the eye, seen "when we look intently upon polarized light." There may not be an impossibility of some mysterious influence of polarized light upon the retina, or some undetected influence of the lenticular eye upon polarized light, but I have not been able to observe these brushes, and the fact of the constant appearance of a patch of light with brush-like edges from the concussion of ocular rotation, with other retinal light, in the very spot, round the optic axis, assigned to the brushes, without Mr. Haidinger and subsequent observers of the brushes having any suspicion of the existence of this common phenomenon, seems to me to indicate a high probability that the common phenomenon has misled them.

May sensations be excited in the trunk of the optic nerve? J. Müller joins in the current opinion of the direct sensibility of the fibres of the optic nerve in any part of their course, besides from analogies drawn from the nerves of touch, from the following independent grounds:—1. Pressure upon the brain has frequently been observed to cause sensations of light. 2. Luminous spectra occur in cases of complete amaurosis. 3. Such were produced with galvanism by Alex. Von Humboldt at the root of an extirpated eye. 4. Lücke relates the case of a patient who was plagued with such for several days, succeeding to an extirpation of an eye.

Now in 1, the pressure is likely to stimulate the motor nerves supplying the orbital muscles, and their contraction will, as we know, produce flashes of light. As regards 2, it may be remarked that in old cases of amaurosis absence rather than presence of subjective luminosities is the rule. The ophthalmoscope by disclosing the retina and all its vessels floating from the choroid in cases that would heretofore have been classed among palsies, evinces, that diagnosis is not yet so perfect, or our understanding of amaurosis, pathologically, so clear, that we may be sure that a sensibility of the percipients to mechanical impulse may not remain some time after the action of light on them has been obstructed. Moreover, our present study has brought to our knowledge that there may be practical blindness from mere diffocal state of the eye, and when vision is impaired, the eye may no longer respond with the focal demands, any more than its iris to the varying amount of light. But, further, it seems to me that the account given by intelligent blind persons of the flashes of light they see makes it certain that they are the flashes produced in and about the punctum aureum on ocular rotation, and that the flashes still reveal themselves to some persons deprived of light, on the accident of a quick or vehement turn of the globe in its socket. We have discovered in the course of our optical dissection that when we have eliminated the quasi-lights of blood-pressure, and those of pressure upon the coats of the eye, the healthy eye has no experience of any other false light, or that a person of sound health is never troubled with such light from a cause residing essentially in nervous matter. And it is not likely that this nerve in state of paralysis should yield a result unknown to the healthy one; above all, at long intervals, occasioning surprises—surprises just as we should anticipate if arising from compression of the rotating globe. To these objections we may append the question, what security have we in the ordinary run of reported cases of amaurosis that ideas have not been mistaken for sensations? The distinction is not easy, and to make it requires some accurate acquaintance with ocular phantoms in the medical reporter, not to say in the patient. And we have no reason to believe that the necessary information has ever existed in either. 3 and 4 are examples of persons with a solitary retina, and therefore with a lively display of the images of all parts of its vascular figure. In addition, circumstances have placed either patient anxiously on the alert for visual phenomena, this and the neighbouring excitement kept up are certain to impress themselves upon the movements of the remaining eyeball, and individuals, who would be now disposed to be astonished at the spectral appearances common to the mass of mankind, have thrown before them unusual lights from the circulation of retinal blood, and brilliant flashes from the extraordinary movements of an eye in its socket.

So that direct evidence in support of the opinion that sensations of light may arise posteriorly to the retinal percipients can scarcely be said to exist.

On the other hand, we have the fact that the optic nerve contains an arterial trunk in its substance, besides being associated with other large vessels. Had the optic nerve fibres been very sensible we should have expected, when violent pulsations are excited, at any rate, to experience luminous effects from this cause, spreading more or less completely throughout the field of vision. Yet healthy persons, at least, may in vain look for, or try to induce, such manifestations.

Again, we have already found when we press upon or bend the fibres of the nerve, in the only portion of their tract we can reach, in their retinal expansion, as much as circumstances permit, which is not of little amount, no sensations of light are the consequence. Although the slightest compression of the percipients of light elicit such sensations. Finally, light falls in the eye upon certain naked fibres of the optic nerve at its base, without yielding sensations in a particular set of percipients. In the case of sonorous undulations, they will often travel freely through a given medium, but can only be communicated from another medium to that, in any quantity, by the intervention of a third; nor is it inconceivable that the minute and rapid undulations in the medium in which light is propagated, or the consequences of this in the optic nerve, can only be introduced into its fibres by a series of preparatory media; or in a more refined meaning, what the membrana tympani, ossicula, fluid of the labyrinth, are for the auditory nerve, the compound retinal layers may be in some respect for the optic nerve. Or, though the illustration suggested will not bear a close application, the supposition that mechanical impulses to produce the same effects as light in the nerve must reach it through the same channel that light does, seems to have nothing impossible in its nature.

But then we must not slight arguments from analogy. Such experiments as may have been relied upon as demonstrating the capability of the other special nerves of being stimulated, elsewhere than at their extremities, to yield their sensations, may, for aught I can say, be found as open to doubt as this instance before us. At all events little can be gained from them to augment the force of the arguments furnished by the nerves of touch and motion. In the nerve of common sensation the irritation of a fibre anywhere along its length yields much the same result, though sensation may possibly be easier to excite at its extremity. The office of these nerves is chiefly, if not exclusively, to recognise mechanical pressure, and nervous vibrations or currents may be of some much grosser sort in these than those which specially traverse the optic nerve, and require no medium of introduction into the substance of the nerve. The same may possibly be true of the nerves of motion as of those of touch. These speculations merely venture the question how far we are bound to frame our ideas of the properties of special nerves from those observed to prevail in those spread throughout the body. In concluding this topic I wish to go no further than what appears on the surface:—The analogy referred to may possibly not hold good for the nerves of sight:—There is proof that sensibility is a much harder matter to effect in them than in the percipients, whether by the appropriate stimulus, the waves of light, or by mechanical impulses; without our being able to ascertain that there is a limit to this difficulty.

May sensation be transmitted in the optic nerve from the brain? Because spectra residing in one retina have apparently been seen with the other, some have imagined that the second optic nerve had been affected through the first—a reaction of one nerve, and, thereby, a true sensation in the second retina. But we have seen that there is no reason for imagining the sensations indicative of the spectra to have reached from the first retina further than to the sensorium.

There are those who maintain that the idea of a thing produces the same change in the retinal percipients as its painted image does: as well as a similar doctrine of the other nerves. And if we object that we cannot at any rate feel, through an idea, exaggerated sensations, reply, that we have not originated the idea. All we can say to this is, that the assumption is gratuitous and cannot admit of proof.

Before, however, I had familiarized myself with the internal luminosities, and even since, I have often been amazed at the persistence of the forms which my mind had conjured up as I was falling off to sleep. But I have since observed (others have recorded their detection of subjective lights as being a cause of the kind here mentioned), that not unfrequently the ground of such visions (incipient dreams) are the retinal quasi-lights. In deciding on the nature of which my mind has used its experience of the world clumsily. In a luminous patch due to ocular rotation, I recognized the features of an old acquaintance, and wondered even in incipient sleep that I had never before been struck with the brilliant orange of his complexion. On coming to my recollection I had time enough to survey the whole retinal field and ascertain the exact fact. On another occasion such a central light among the vessels was to me a fine lump of sugar on a table-cloth. I could relate endless examples of this kind, from the most grotesque to the most agreeable,—from a rhythmical activity of the muscles of the orbit a restless accession of such. Frightened and superstitious minds are much in the state of that which dreams, unable to employ what sound ideas are in a store properly. In cases of delirium, patients perplex and distress themselves as to the character of the drapery and furniture of their room, and if they cannot apprehend these familiar things rightly we need not imagine that they have anything more than the usual quasi-lights, that is in addition to, with probably an inefficiency of the optic nerve, perturbations of memory, &c., or disorder of the cerebrum. In our dreams and in delirium, a staple appears to be misinterpreted actual impressions upon the senses, though the ideas which have recently occupied the thoughts will probably be used by the judgment to explain the impressions, the resultant ideas in their turn helping to originate others. I would merely express my belief that sometimes events occur in the way now supposed. But oftener it is quite impossible to trace our vision to any picture existing in the retina, the image we have conceived may seem to us as much fixed in the visual field, as the lights from pressure upon the retina, and seem to have a form uninfluenced by them. Though at times a compromise between the idea and such sensation may seem to be effected, as if the idea were primary, but had been modified by the sensation. It is true we can, at will, call up, in daylight, images, which the imagination will keep as strongly before the eyes; the difference being that in light we discriminate instantly between the idea and the visible field by changing the latter, whilst at night the quasi-visible field cannot be thus got rid of. Nevertheless all this is no proof that the idea reacts through the nerve, and destruction of the nerve does not annihilate the faculty of generating such ideas.

May excitation of one portion of a retina by any colour cause sensation of the accidental in another portion? If there be two holes in a window shutter, one of which admits freely the light of day, whilst a piece of coloured glass covers the other, the shadows of objects in the light which has entered the room through the medium are of the accidental colour to that of the glass. Or if by candle-light we place some opaque objects to stand on a sheet of white paper, and hold a piece of coloured glass near the flame, so that the shadows of these objects shall be formed in the light passing through the glass, the shadows will seem to wear the complimentary colour to that we employ.

Whatever be the cause of this appearance, it is not a mere creation of the accidental colour in parts of the retina contiguous to those impinged upon by the coloured rays, for every observer of the phenomenon has remarked that the *space of the shadow must be illuminated with white light*, or if we prevent this from occurring, that the accidental colour does not show itself. Hence the portion of the retina belonging to the shadow has its own stimulus.

Let the nature of the phenomenon be what it will, we can understand that it may essentially happen in sole white light. Shadows in such cases, themselves white, beside whiter spaces, we regard as black. Or since every coloured ray in the general white light has its complimentary colour in the white light of the shadow, we may regard the phenomenon here, as so many pairs of the primary phenomenon (of a colour with its shadow of the accidental colour), as there are constituent colours in white light. And thus we may view the phenomena, whatever their character, as a class governed by an uniform law. Attempts have been made to explain the apparition of the accidental colour both physically and physiologically, but it is commonly agreed that it should be done somehow in the latter way, and that the solution of the difficulty remains to be found.

Now with a deliberate survey of the faculties we employ, and a consideration of the conditions in operation in the experiment, I think we may glean the explanation. It is a well-known fact that in the case of sound, we judge of the nature of any tone we hear greatly by comparison with other tones. For instance, we should not know a tone, if presented to us alone, on a second occasion, to be the same. The tone is determined by a certain number of sonorous vibrations in a certain time, and a *characteristic* sensation results therefrom, but though persons who devote themselves to the study of tone may be able to do more in this way than others, the idea of such sensation cannot at a future time be recalled so as to enable us to distinguish the said tone from others, unless their number of sonorous vibrations in the given time differ widely from it. Yet we can distinguish nicely between tones, provided that we hear them in quick succession, so as to obviate the defects of memory. Hence, the use of tuning forks as standard measures of tone. The same may be said of quality of tone, or *timbre:* as also of the amount of tone, or sound. Similar statements of the nerves of taste, smell, or touch, would equally hold good. It is speaking of them as adjuncts of the same sensorium.

So in dealing with colour we are in a like predicament, we cannot affirm a colour to be the same that we had seen on a former occasion. We cannot carry in the memory the sensation due to a given rate of undulations of light, nor *thus* distinguish by sensation different rates, unless the rates range greatly from one another. Without the colours of the solar spectrum, or some standard references for colour, we should soon confound all shades of them together; nor can the memory deal more successfully with amount of illumination. Hence, whenever we use our sight, we instinctively look about for indications of colour, or of illumination, as sources of comparison, to find, if possible, something whose colour we are familiar with to guide us in estimating the hues we observe, and some index for judging of an amount of illumination.

Wherefore, in the event of shadows falling on white light, the difference in quantity of light is perceived without an idea of colour being generated, and the spectrum of the brighter ground, showing a diminished sensibility in the portion of the retina, much exposed, is equivalent to a diminished illumination within the bounds of the shadow.

But when the shadow is flung in coloured light, the eyes pass from the white ground of the shadow, to the coloured one around. And the mind, always uncertain as to hue, is prone to give a tint where there is none from an idea of contrast. Here, too, the idea of the accidental colour is cast upon the sensorium, by such portions of the spectrum of the coloured ground as the eyes carry within the limits of the shadow, the consequence of the stimulation of this portion by the white light of the shadow *necessarily* being a *quite instantaneous* impression of the accidental colour. Thus the idea of colour for the shadow is taken from its edges, and as fast as it has faded, so fast we renew it by fresh glances beyond the sides. And if we carry the eyes which have glanced with direct look upon the coloured space over the region of the shadow, wherever they there range, they bear the accidental colour. In short, the phenomenon involves that of the occurrence of the accidental colour of a primitive, when a spectrum is placed in white light, where our faculties are further bothered by a difference of illumination. I am satisfied that whoever will cautiously study the phenomenon of coloured shadows will perceive that the above is a correct account of what transpires. Indeed, if we turn from the coloured ground to a surface illuminated by white light, but much more than the former is by coloured, we may still in a faint style, discern the sequence we have been enlarging on. The explanation here offered applies equally to all the cases which have been cited as manifesting the accidental colour in juxtaposition with the primitive, so that we may have no hesitation in giving a negative to the question with which we set out.

At page 438, of his Optics, Brewster quotes from Mr. Smith, surgeon, of Fochabers, what he calls a "remarkable phenomenon," of physiological accidental colours, by exposing the two eyes to very different conditions of light. This experiment, if correct, would be entitled to consideration. But I cannot verify it, though I have exposed one eye both to the sun and to a candle-flame, as instructed, until the eye has lost its form and the retinal vascular figure prevailed, or with an unsteady flame until the passive black vascular figure has resulted. I cannot help believing that one of these appearances has caused an illusion, and therefore can see no utility in going into the details of the experiment referred to.

I am not aware that I have omitted to mention under this heading, any observation of presumed authority bearing upon the subject-matter in hand, which has been deemed to require a peculiar physiological doctrine to account for it. If there be any observations that their authors have thought to be indicative of peculiar principles which have not been noticed, it is because, the tenour of the foregoing remarks too obviously meet such instances, to make it necessary to particularize them. I have been obliged to go here just where my predecessors lead me, or there may appear to be a deficiency in arrangement in this part: some of the points herein I have brought forward chiefly because they appeared to be of general interest, and came for explication within the compass of our optical dissections. But generally, I am satisfied, the criticism here concluded has not been carried beyond the need direct or implied of the propositions to be maintained under the final heading.

Positive uses of the preceding analysis.

Images of external objects are painted on the limitary membrane and perceived by the radial fibres. In an early part of this chapter we determined that for the *black* vascular figure to appear, "every point of the affected section of the retina must lose light from one external point and receive light from another, within a very limited time, perhaps an indefinitely small time." Such a statement makes us think of waves of light reaching the back of the eye, by different lengths of paths, or suffering different amounts of retardation, and to speculate whether light could be reflected from the surface of vessels buried in the retina so as to interfere with direct light, producing darkness (without colours), over such vessels. However, I am unable to see that the phenomenon can be accounted for on such physical grounds, and imagine if there be any sort of interference it must bear a physiological character.

But a further affirmation may be made, namely, we have here (an unique combination) a diffocal eye from changing light, and one at due adaptation for the surface we view from light of the usual kind, so that we try to comprehend whether the black spectre can be owing to the pressure of the vessels upon lateral nervous matter when such matter endures a diffused stimulation, and to account for the absence of play or pulsation in them by presuming that such manifestations are extinguished by the force of painted images, and that the great darkness of the vessel arises from contrast. I have an inkling that the pith of the phenomenon lies therein, but as things are not very clear, let us for a moment take for granted that perception occurs in front of the vasa centralia, and that *radiating* fibres of some sort convey the impressions of the images of points painted immediately upon, or over, the vessels *round* these impediments to reach finally the fibres of the optic nerve, whilst the radiating fibres that convey impressions received at the interstices of the vessels, there being then no hinderment to such a course, go *straight* to a like destination; and let us assume that, 1, when a radiating fibre meets the hyaloid or the "limitary" membrane at right angles it perceives light with facility, but that, 2, when a radiating fibre meets that membrane differently, in proportion to the magnitude of its angle of incidence (angle made with the perpendicular to the membrane), it requires *a greater time* to perceive, or that light from two radiants be not presented to it within so short a time. Or that through want of directness a physiological interference may ensue in the transit of sensation along the crooked fibre. With these suppositions we have framed an hypothesis which is a physiological expression of the law of mutation of light which brings the passive vessels into view, and embraces the observations made upon the effects of the depth of the vessel in the retinal tissue.

However, we will build no argument upon an hypothesis, but will content ourselves with the position that the apparition under the physical condition ascertained, seems to be inexplicable by physical optics alone, so that it appears that the vasa centralia retinæ are placed on the orbital side of the proper lenticular eye, and lie where physiological laws proper, in contradistinction to physical, operate.

Nevertheless, the vasa centralia are not situated in the refracting media of the eye. For were they so, they would be seen under whatever conditions would render opaque objects placed in the back of the eye visible by their shadows. Were the percipients at sufficient distance behind the vessels, the diffractive shadows or images so abundantly treated of, would be conspicuous. And were the percipients close behind the vessels, and the opaque choroid has prevented any one who has looked for the percipients posteriorly to where the vessels lie from implying in their theories, more than the minutest interval between their places, the black vascular figure with which we have become familiar, would always be before the eye; for the vessels must thus throw full-breadthed shadows of themselves, and no perception could possibly take place wherever a vessel or a capillary might lie. We are sure that we do not live under such an embarrassment as this, and can, as we know, by an artifice put ourselves at any instant in a position to judge by experience of the extent of inconvenience that would be entailed upon us by such a disposition of parts.

There is a sole way of escaping this conclusion, which is by assuming that we are actually *blind* in the lines of the vascular distribution, and that we see only the images of points which are painted at the *interstices* of the vessels, such images being expanded somewhere in nervous substance, or so projected into space *as to fill among them the blind seats of the vessels;* in which case the physiological law indicated by the effects of mutation of light would operate by annulling the principle by which these images are expanded. But we may readily convince ourselves by direct scrutiny of external surfaces that vision is not performed in such an extremely coarse mosaic. Indeed, we may clearly see radiants whose images rest on the middle of vessels which are expressed to us by their pressure upon the retina, or on vessels that are imperfectly rendered as black spectres of themselves by an imperfect performance of the experiment of mutation of light. Such an idea of "irradiation of sensation," or projection of images, as has been here conceived is *obviously*, untenable. And monstrous in its very nature; for did the state repudiated exist over the whole vascular arborescence—a full third of the retinal expanse, over so much, we should be afflicted with phenomena now only known as characteristic of the base of the optic nerve.

When we obtain spectra of the *vasa centralia* by pressing resolutely on the surface of the eye through a cushion, the middle line of the vessel appears in as luminous an aspect as the sides, perhaps more so, showing that if there be percipients in front of the vessels they are as sensible to direct stimulus as the neighbouring ones. And again, unless the supposition which we have just regarded as absurd, have foundation there must be percipients in front of the vessels.

Furthermore, we long ago concluded that the mode of production of the images of the vessels by blood-pressure is precisely the same as that of objects that offer themselves to our sight by pressure through the ocular tunics. And that the fact of the boundary line of the pressing surface, in either class of examples, being resplendently lit up, whilst the surface applied imparts light hardly, or not at all, compels us to admit that a *creasing* of the stratum which bears the percipients at the sides of the object, which effect the projection of an object placed without them into the vitreous humour must produce, and a consequent compression of the percipients there existing, must be the cause of the exceedingly luminous margins.

Nor can I hit upon any way of eluding the inference here drawn. The choroid and superimposed coats will resist the expansion of a vessel posteriorly, and leave it to find room for itself into the vitreous humour. And we know by inspecting the vessels in other eyes, of the living or of the dead, that such is the real state of the case. Should we imagine the marginal brightness to accrue by tension of radial fibres, in the example of the vessels, by separation of the retinal layers lying on either side of the vessels from one another, the objection is plain that no such separation, but the contrary, ensues when a body presses through the tunics. In a word, resort to any hypothesis we please, and they all fall before the first act of scrutiny, confined, as it may be, to the consideration of the two classes of images now before us, without our trying to reconcile such notion with the other observations above arrayed. But if we agree to allow that the vessels must be necessarily on the orbital side of the percipients, which both cover these vessels and fill up the spaces between them, that is, as clearly on the orbital side of them as the objects which yield images of themselves by resting on the tunics are, the two classes of effects before us mutually explain one another, and we take our stand upon a principle which declares itself in strict conformity with the whole series of observations that can be brought to test its accuracy.

Wherefore we may sum up by affirming that we have a combination of proofs, each of which is in itself irrefragable, that the percipients extend, by successive contact with each other, all over the inner surface of the retina, so as to cover the vessels, and to fill up the spaces between them.

Now, the only retinal layer that covers all the vessel is the limitary membrane; and, therefore, the percipients must be in that membrane, or lie upon it. But according to histogists the membrane has no character about it which makes it calculated for any office beyond that of supporting neighbouring parts. However, a sort of web remains for our consideration: in the region we have determined on, they observe the radial fibres (to reverse their description) to commence by feathery roots from all parts of the limitary membrane, and, infinite in number, to end, after penetrating the intermediate retinal layers, each in a rod or cone, which, by being placed side by side, form a compact layer of normals to the ocular tunics. And these rods and cones they find to be of true nervous matter.

Hence, here is the very sort of structure we are in quest of, in the very place where we would wish to find it, and it exists alone. There are absolutely nothing but the radial fibres which pass from the front of the vessels between them into the other retinal layers, that is, into the fibres of the optic nerve, the only possible channel to the brain for visual sensations.

Wherefore the limitary membrane belongs, properly, to the lenticular eye, of which it is the last part; the extremities of the roots of the radial fibres which spring from it are the percipients, or belong to the nervous eye of which they are the commencement.

H. Müller and Kölliker, from the nervous character of the rods and cones, and from the fact of the base of the optic nerve (where the fibres of the nerve are naked and exposed to light) being blind, and a correspondence, as they find, between the diameters of these bodies and the *discriminating* powers of the retina (smallest distance from each other of two distinguishable retinal images), infer that the rods and cones are the ultimate percipients. These arguments have equal force for the feathery terminations of the radial fibres. The last observation they quote, looks as much like a test of the ability of the lenticular eye to accurately focalize rays from radiant points on the percipients. But then a faculty in the retina of discriminating beyond the nicety of this focalizing power being useless, the comment just made does not weaken whatever force this argument possesses.

Microscopic researches upon the retina have, in the last few years, made immense advances; but the structure is so delicate and intricate that much remains to be achieved in its investigation. The radial fibre has been traced into a connection with the optic nerve fibres; and had this not been done we might have been sure that such must be the fact from optical observations. So now we may safely anticipate the microscope in some essential points of retinal structure, because structure must be consistent with optical phenomena. We may also make some general statements as to constituent requirements of the retina.

Our histogists have recorded that the radial fibres are usually, always as far as circumstances appear to permit, straight in their course, and perpendicular to the retinal surfaces. On the now old supposition that vision occurs as a refined mosaic by innumerable separate perceptions, it would become of paramount importance that the percipient fibres should be normals to the surface where perception is affected. Thus only could the fibres, or such portion of them as must be larger, as the rods and cones, be stowed in the least space; and the areas of the sections of the fibres by the imagined surface be the smallest possible, or the maximum number of percipients be secured. And if indirectness of the path of the radial fibre has ought to do, as before conjectured to be possible, with the black vascular phantasm, there is another need of the closest possible adherence to the arrangement into normals.

Again, presuming that all the constituent parts of the retinal layers, and the layers themselves, in their order and size, are necessary to the fulfilment of its functions, we may gather why the scheme by normals to the surface of perception has been at all departed from. The grey vesicular layer, required in the interior of the compound tissue to inspire vigour equal to the demands of incessant acts of perception, must enjoy a supply of blood equal to its emergencies. The vessels now break the continuity of packed normals at a sole spot, from which they ramify within the substance of the retina, and form a thick arborescence, without again piercing a surface of it, but, thereby causing many radial fibres to approach the limitary membrane by a crooked path. The visual detriments ensuing from the present mode of lodging the vessels we have gone through. The only other way by which they could have reached their destination, without hiding the percipients, would have been by closely repeated intrusions between the rods and cones from behind—from the choroid vessels—by which the number of percipients we have now at our service would have been diminished by half!

That we may not be annoyed unnecessarily with a black round spectre through the punctum cœcum, consequent upon a break in the continuity of normals (we find that when any object vanishes from view by its image falling upon the base of the nerve, we do not see black in its place, unless the object is situated in the midst of black, but whatever colour surrounds the object), the percipients round about are so associated with the sensorium that *visible direction thereabouts*, an end of easy accomplishment, covers the blind spot with contiguous impressions. A matter of no consequence where it happens, but a serious evil if repeated all over the visual field.

We judge of the angular distance between two points by the observed rotation of the eyes, head, or body required to carry the regard from one point to another.—But before I speak of the angular distances between points in a picture painted in an eye, it should be premised that it has not been thought necessary to meddle with the standing subject of debate, the precise nature of the "law of visible direction;" because it matters not for the physiological inference herein drawn, whether the law is such as accurately to preserve the proportions of the visible field in the retinal picture all over the retina, or only at the middle portion. Our language, with our aims, may be safely admitted to be correct when we speak of the law as that of vision in normals to the retina.—Now, in the retinal pictures, we know that the optic axis pierces the image of the field at the point towards which we look, but the mind can only become acquainted with the proportions of the field by the retinal places of the images of its respective points. For as there is no moveable apparatus in the retina, like those spoken of just now, for determining angles, or apparent size, it must be accomplished by fixed provisions. In other words, *no more* means of making such observations *can* exist than there are retinal points in direct *isolated* communication with the sensorium. And thus it stands, to common apprehension, that vision *must* be of a *mosaic* cast, and efficient in immediate accordance with the number of retinal points in communication as stated.

The microscope so far has only made out that what seem to be the ultimate fibres of the optic nerve are, at least, fifty times less numerous than the rods and cones, and that the radial fibres again split at their ends in a feathery fashion. The mosaic implied by imagining fifty radial fibres to have but one avenue to the brain, is at least as many times rougher than what our observations evince our distinguishing powers to be. We may revert here to the fact of our being able to get, by artifice, glimpses of our finest retinal capillaries (images independent of the lenticular eye), whose size pretty well agrees with the average of rods and cones, in confirmation of the opinions quoted, that the ultimate percipients probably agree in diameter with these. The only question that can remain is whether the ultimate percipient is not something smaller than such bodies, or than the feathery end of the radial fibre, such as one of the fibrils of that end. Such evidence as we have, however, appears to weigh in behalf of the radial fibre rather than of its fibril.

If the ultimate percipient end with a brush or ganglionic enlargement, or merely by the area of its own attachment to the limitary membrane, and a stimulation of a portion of such extremity, as will probably be the fact, is enough to produce sensation, the acting radiant will seem to have the same size, as if it had stimulated all parts of the extremity. Hence the necessity recognized of estimating the sizes of our ultimate percipients by our faculty of visual discrimination.

The optic nerve is a bundle of optical nerves absolutely independent of one another. Let the microscope fail at what point it may, it is none the less certain that there must be as many *insulated* channels of communication from the retina to the brain as there are ultimate percipient fibres. That virtually there must be as many independent optic nerves in the trunk optic nerve as there are percipient divisions in the retina.

In the auditory, olfactory, and gustatory nerves it matters not that we know by them beyond the fact that we do hear, smell, or taste, and this end is obtained alike whichever twig into which the trunk nerve spreads is stimulated. Nay, further, it is of no consequence whether we know, directly, which of a pair of nerves has been acted upon. We turn our head round, consciously, that we may ascertain by the strength of a sound into which ear it comes. We stop one nostril to try in which of the two we smell. We use one or two other senses to inform ourselves *where* the stimulus has been placed, if we would try what portion of the surface supplied by the gustatory nerve is most sensible in tasting. So that either pair of nerves in question may be viewed as a tree ramifying over appropriately situated surfaces copiously, for the sole sake of multiplying the opportunities for perception, all the twigs throwing the facts they seize into one lap indiscriminately, carrying them to one spot (or conjugate spots), in the sensorium, which receives them, but takes no account of the road by which they severally arrive. As if insulation of nerve-fibres from the percipient surface all the way to the brain, at all events brain substance calculated to recognise such insulation, were a superfluous provision. Whilst generally, at any rate, nerves of touch must be directly distinguishable in the performance of their duties from one another.

But the *optical* (as we will call them for distinction's sake) nerves imagined, the ultimate constituents of the optic nerve, must resemble the nerves of touch in being literally separate nerves, nay, can have no more influence one upon another than the nerves for quite different senses (as the auditory upon the olfactory) have upon one another. It has been commonly felt that this condition must hold in the current services rendered by our eyes, but so little belief has there been in its stringency that the supposition of a temporary suspension of the law at the beginning, middle, or end of these *optical* nerves, has seemed to offer a ready mode of accounting for phenomena occurring under embarrassed exercise of the sight. But it has been shown in detail that none of these phenomena furnish the shadow of a cause for impugning the absolute authority of this law.

We may go further, and assert (for under the marginal heading of *persistent sensation*—"*spectra*," we have disposed of the semblance of objection to such an affirmation), that the *optical* nerves that proceed to the brain from points equidistant vertically and horizontally—but in the latter case taken on the nasal side for one nerve, and on the temporal for the other, so that these nerves may be placed to receive impressions from the same radiant (representing identical retinal spots)—are actually or virtually one nerve, and meet at one or conjugate points in the brain, each pair having its own origin in the brain, as certainly as each pair of nerves for the remaining special senses have theirs apart from the origin of any other pair.

Summary. Every nerve has its phenomena of fatigue, and such phrases as palled, dulled, blunted, deadened, &c., &c., which express that other nerves have had their ability of responding to a given stimulus impaired by having been but recently exposed to its action, may be used figuratively of these *optical* nerves. Any one of them, if excited by any colour, is incapable, until it has had time to recover from the consequent exhaustion, of noticing the same colour of the same intensity in an equally acute manner. Though it is just in as ready a condition for dealing with another sort of stimulus, as any nerve of another kind would be after having been exercised upon a particular one to an equivalent amount. In other words, these *optical* nerves fairly emulate the efficiency of the other kinds. The phenomena of fatigue in the *optical* show themselves in what are technically called spectra, and they indicate which of the nerves have been at work, and the degree, and colour, and duration of action of light (or its equivalent in pressure or other stimulus) that has operated upon them severally. There are no other spectres developed in the *optical* nerves.

The organ of hearing is the one which after that of sight comprises the greatest diversity of contrivance. But its percipients rest upon fluid which cannot be shaken in its narrow labyrinthœal canals ; and the slightly moveable apparatus in the remainder of the ear assists the movements of the head in regulating, for all tones, the quantity of sound which reaches the percipients, the secretions of the ear are of slow nearly uniform flow, the two ears act together whichever way the sonorous waves arrive; and, as it were, a single nerve is employed—one nerve and approximate fixity of relations being the virtual characteristics. But in the eye the portion of the back of the transparent media possessed by an *optical* nerve is its cochlea, vestibule and semicircular canal together, whilst the faculty possessed by lenses of again gathering to points rays that have issued from points enables the ocular system to provide each distinct minute percipient space, with its own ultra-labyrinthœal ear for collecting appropriate stimulus. Similar remarks would hold good of the nostrils and mouth and their special nerves.

Yes, what an accumulation of active mechanisms constitutes the organs of sight! an aggregation of numberless nerves whose fellows are to serve in pairs: many muscles to twist the mosaic percipient pavement about and about, so that counter parts may always be presented to the same radiating points: a set of lenses furnished with the means of still focalizing light upon the percipients as the radiants oscillate to and fro: a diaphragm for admitting more or less light as occasion requires: fluids to lubricate the eye's surface, &c., with the muscles ever on the alert to sweep them duly over the globe: lids, lashes, &c., to shield the organ. Then again the crystalline lens is made up of countless superimposed parts, varying its density, and perchance endowing it with a prompt elasticity: there is a peculiar precaution taken that surges of fluid in the large rounded chamber behind the lens shall not concuss the sole percipient points, so nearly exposed on that side: and for a parallel purpose, among other uses, thick ocular tunics have buffer masses of fat upon them: blood is brought to feed the rapid waste of tissue. It were perplexing to attempt to catalogue all the special appliances involved in this organ. And it were vain to dream of justly portraying the order and concert that must reign among the multiform movements.

What wonder then, amidst all these mutating cordinations, that visual iregularities should haunt us! It seems to pervade all experience, that each commodity gained entails a consequent incommodity of a certain magnitude. It is in contributing to the efficiency of the organ by arming it further and further, that visual incongruities arise; whether directly from particular apparatus, or from parts falling out of gear, in the complexity of concurring machinery.

But the visual nerves themselves, or the sensorium in its connection with them, are no more chargeable with inconstancy than such representatives of any other sense. Nay, though a stupendous host of distinct nerves are in this instance associated in office, the phantasms that ensue *intrinsically* therefrom, or from them, are, emphatically none.

EUSTACHIAN TUBE, WHY OPENED IN DEGLUTITION.

The opinion that the Eustachian tube is a rigid canal, by which a constant communication between the faucial and tympanic air is ensured, prevailed generally, until its accuracy was questioned, a few years since, by Mr. Wharton Jones. Among the inquirers who have appeared in the new path, Mr. Toynbee has satisfied himself, from copious dissections in mammalia, birds and reptiles, that the walls of the guttural extremity of the tube cease to be in contact at the instant of deglutition, through the contractions of muscular fibres arranged round its mouth purposely for then dilating it, whilst Mr. Jones believes that an opportunity for the mucus accumulating in the tympanum to escape into the throat, and for the pressure of the air on the two surfaces of the membrana tympani to be equalized, is a necessary consequence of the main muscular movements in swallowing. Whether these muscular movements suffice,—for I cannot doubt that they tend to open the tube,—or must be aided by special ones will not affect the physiological views here submitted :—

There must be a provision against the ingress of aerial undulations from the throat into the tympanum, which, if admitted, would threaten the membrana tympani with incessant oscillations, and endanger both its integrity and that of the complex and delicate apparatus in connection, and violate the peace of the labyrinth, *via* this sudden route, with all the sonorous impulses impressed upon the animal's breath.

Therefore the moment seized for bringing the tympanum into communication with the fauces must be one in which there can be no respiratory current.

The only instant compelling a suspension of respiration is that in which the act of swallowing is practised, and must therefore be embraced for the service just named.

Finally, the same rule secures the typmanum against the intrusion of gastric gases, evolved through the fauces. (These propositions are an extract from a paper by the writer, printed in the Report of the Royal Institution of Cornwall, for 1853.)

The discovery of the ordinary state of closure of the Eustachian tube has led Mr. Toynbee to physiological conclusions very different from those now enunciated. He infers that it is physically essential to a perfect organ of hearing that its drum be a shut chamber; for that the existence of any outlet whatever would give vent to sonorous vibrations, and thus abstract from the resonant qualities of this cavity, through which, according to him, it exercises a paramount acoustic influence. And he dwells upon its anatomical conditions to show how peculiarly it is adaped for the reflection of sonorous waves from its walls. (See his pamphlet, On an Artificial Membrana Tympani. Dr. G. Bird and Mr. Brooke concur in these views—see their Natural Philosophy pp. 244 and 247.)

Preliminarily, we will take a survey of Mr. Toynbee's treatment of aural physiology, to try to ascertain how far he is warranted in building it upon the novel principle just adverted to. First of all he supports the view that the Eustachian tube is ordinarily occluded and that swallowing opens it, by the feeling of necessity under which a person descending in a diving-bell resorts to repeated acts of swallowing, in order to keep the air in the drum of an equal elasticity with that upon the outer surface of the membrana tympani. Again, he says, "if an attempt is made to swallow while the nostrils are closed with the finger and thumb, a sensation of fulness and pressure is experienced in the tympanic cavity, in consequence of air having been forced, during the act of deglutition, through the open tube into the tympanum; and this sensation continues until, by another act of swallowing, the tube is re-opened and the confined air escapes into the fauces." The experience of the diving-bell, though few of us can have opportunities of verifying the observation, seems very justly quoted in corroboration of the facts implied. According to my trials, we may by much attention perceive that the Eustachian tube does open when we swallow, especially if we do so several times in quick succession, whether the nostrils be stopped or not, and that it is dubious whether we can detect the fact better by closing those channels. The following artifice strikes me as yielding as complete evidence as any, for the purpose in question :—Let the mouth and nostrils be stopped after a deep inspiration, and then let an effort be made to force air into the tympana. It will be found that an obstacle to this exists; insomuch that small force does not suffice. At the instant of proper management, a rush of air into an Eustachian tube is felt and heard, and the membrana tympani flies before it, popping, as far as its attachments permit, into the external canal. The drum now is of unusual volume, and contains air of unusual elasticity, and yet this is so plainly incarcerated that, if we refrain from swallowing, the excess will not be lost for a very appreciable interval; the escape commonly being accomplished in distinct jets, so palpably is there a struggle between the passive force of collapse of the tube and the expansive force of the imprisoned air. If acts of deglutition be performed under the circumstances here detailed, several must be employed before the membrana tympani will return to the curved aspect it habitually has.

To see what need we have of new acoustic laws, to account for the care taken to keep the tube usually shut, let us cast a glance at the principles that guided physiologists before it was imagined that the tube was ever otherwise than open. Succinctly, it was taught :—that sonorous vibrations are readily imparted to one another by water and solid conductors, though not so by either of these and air; nevertheless that if membrane intervene between such unsociable media the event alluded to is much facilitated. (J. Müller.)

Particularly see Müller's Physiology, by Baly, pp. 1266-8, for the details of a contrivance which imitates capitally all that portion of the ear which lies without the labyrinth. If a vessel be prepared with two holes closed by stretched membrane (fenestræ) on one side, and one on the opposite side connected by a rod (ossicula) with one of the former, and situated at the bottom of a short pipe (external auditory canal), and the side with the two fenestræ be then immersed in water (labyrinth), the fundamental note of the pipe is heard with striking intensity as conveyed to the water by the rod; and with much less as conveyed by the air in the vessel to the water through the other fenestra (rotunda). If the interior of the vessel communicated with the atmosphere in supposed copy of the Eustachian tube, or was quite close, the results were the same.

In fine, from appropriate experiments, physiologists have been led to construe the work of the aural apparatus thus:—sonorous vibrations spreading in the atmosphere fall upon the pinna, pass up the trumpet-shaped canal, condensing as they go, are concentrated on the membrane at the bottom, and therefrom received by the ossicles and passed into the labyrinth in an invigorated shape, dissipation of them being prevented by the ossicles not touching anywhere the wall of the tympanic cavity, the chief office of which is to insulate them. Still, as this cavity must contain air, that as little waste of waves as possible may take place, the fenestra rotunda renders to the labyrinth such waves as that air may get either from the membrana tympani or ossicles.

Mr. Toynbee, ignoring these conclusions and the investigations from which they issue, starts the opinion that the ossicles and fenestra ovalis are insignificant as means of carrying sonorous waves to their destination, compared with the tympanic air and the fenestra rotunda, owing to the pre-eminently resonant properties, as he believes, of a perfectly-shut chamber. He makes no attempt to elucidate this elementary principle by mechanical contrivance, which we should have thought easy of accomplishment if it be correct, any more than offer a reason for slighting Müller's elaborate researches of this sort. Mr. Toynbee rests all his arguments upon two orders of facts.

He brings forward cases of partial or complete destruction of the membrana tympani, accompanied with dulness or loss of hearing, and ascribes this mischief to the circumstance that the drum has ceased to be a close chamber. But surely if we revert to the duties supposed to belong to the membrana tympani, we should have anticipated that a breach in it would be prejudicial to its discharge of them, and that its absence would affect the hearing more or less considerably:—and that the substitution in its place of a suitable foreign body resting against the ossicular chain, or even against the stapes if left alone, should act more or less completely as a remedy, would be in nowise surprising.

Besides the foregoing he enlists the well-known fact, that if sonorous vibrations exist in the bones of the head, as from a "tuning-fork" resting on it (a person's own voice is a familiar example), and we cover one meatus auditorius externus, they become decidedly louder, even then re-appearing if they had before become too feeble to be otherwise audible. This augmentation arises, he affirms, from the meatus being converted into a close cavity, and shows by analogy that a great multiplication of sound must be caused in the drum if it be shut. But according to the views of his predecessors, the vibrations in the cranial bones must extend into the whole wall of the ultra-labyrinthæal ear, and by the form of the meatus externus a portion of the waves must be going off into the atmosphere; by occlusion these are arrested, and, together with some thrown off from the occluding surface and received from the pinna, are sent straight up the ear to undergo the concentration described awhile ago.

So that in neither of Mr. Toynbee's instances is a new acoustic theory required, as the effects observed are readily comprehensible, without resorting to any novel mode of explanation. Further I am disposed to think that the analogy we have been discussing is altogether an illusion. For, I should say, the membrana tympani transmits sonorous vibrations so freely, and reflects them in so trifling a proportion, that it may practically be considered in regard to resonance as not differing widely from the air it displaces, and that the middle and external ears should be looked upon in respect to resonance much the same as such a recess not divided by a membrane, so that virtually there is no shut chamber for air to resound in; and did any such resonance as that imagined prevail, a person's own voice would be afflictive. But we will not digress on the general problem of resonance in the whole or portions of the ultra-labyrinthæal ear; for at the very best, whether the ossicles or tympanic air contribute most to the final effect, the observations evoked by Mr. Toynbee beg the question really at issue, and his views are incompatible with a series of uncontradicted experiments.

We might have fancied that a catheter pierced diametrically a little way from its end, or a fragment of a tube soldered to a convenient wire or stem, might have been inserted into the mouth of one's own Eustachian canal, and the effects of a faucial opening into the tympanum subjected to experience; for if that recess has been syringed in other persons, a manipulator would meet with no insuperable difficulty in operating upon himself.

I am in a position to ascertain the effects alluded to, without troubling myself to try to introduce an instrument into my own Eustachian tube, for I happen to have a personal advantage in this study which throws the information which we seek at my door. The peculiarity I allude to is that the guttural extremity of the Eustachian tube of my right ear is so gently closed, or so little of the wall's length remains collapsed, that a very trifling force overcomes the impediment thus afforded. And at times, as when, perchance, the moisture contained by the mucous membrane is lessened (the membrane itself contracting), or but little secretion goes on, especially on abstinence or exhaustion, the orifice becomes permeable, or widely spread, even abiding so, if I choose not to interfere, for an hour's duration, putting opportunities in my way of noting particulars at my leisure. This accident befals me more or less frequently, at intervals of months, weeks, or days; or repeats itself more quickly, even to incessant attacks.

In its slightest form, in expiration, a jet of air unawares insinuates itself into the tympanum, pushing the membrana tympani before it, the Eustachian tube instantly closing behind it. On such an occasion one or more acts of deglutition may possibly be the means of reducing the membrane to its place; but this, as we might anticipate, since it is only in inspiration that the pressure of the air in the external auditory canal exceeds that of the air in the fauces, is a very uncertain mode. The only sure process is, after an expiration, to cover the mouth and nostrils, and lift the ribs as if for inspiration, when the undue quantity of air contained in the drum having a tension superior to that of that in the throat, plus the trivial collapsing power of the mouth of the Eustachian tube, will dilate the passage into the throat, and its elasticity fall decidedly below the barometric pressure, and therefore the membrane regain its inward convexity.

Things now being put to rights, the tube may not fail again just then to exclude the air in the expiratory act from the drum, or it may commit the same fault immediately, until I am tired of applying the above remedy. Under such an embarrassment I have the comfort of knowing that the next meal I take will restore the collapsing force, owing, as I imagine, to the greater turgescence of tissues and stimulation of secretion. Possibly the muscles which act upon this orifice may be at times excited to some unwonted contraction, but I am not conscious of this, nor likely to be.

But let us suppose an opportunity to occur for keeping the tube open for a lengthened time, or rather by non-interference so to suffer it to remain, what is the effect on the auditory apparatus? When it is dubious as to the tube continuing dilated, lifting the palate has just power enough to decide in favour of openness.

At each expiration (more especially), and inspiration, I *feel* the air playing strongly against the anterior and posterior margins respectively of the faucial orifice of the Eustachian tube, and vibrating all the way up the tube even to the membrana typmpani. On each expiration, this membrane, projecting outwards, is rudely pushed upon and drags at its line of insertion. On each inspiration, the air in the drum undulates, and the membrane, relieved from pressure upon its inner surface, exhibits an inclination to resume its inward convexity, and sometimes quite does so, with the certainty of resilience at the turn of the respiratory tide.

In expiration, the pressure of the air in the chest excels that of that which envelopes the body: in inspiration the relation is reversed. Hence the membrana tympani, with the Eustachian tube expanded, is similarly circumstanced to a clapper of a pair of bellows, and should therefore, during respiration, suffer perpetual oscillation, or jutting in and out.

The explanation of my not experiencing an unintermitting rhythmical oscillation in ordinary respiration depends, I take it, upon the following facts :—that the pressure of the pulmonary air does not thus differ much from the barometric, that convex arches have a power of resistance, and, above all, that the Eustachian tube enters the fauces laterally just behind where the arches of the palate converge towards the pendulent uvula, by which situation it is in some degree protected from the oral and even nasal currents of inspiration, whilst that of expiration is turned into it. However, in the mildest breathing, the membrane is palpably sensitive to the ebb and flow, and shows the tendency here related in a decided manner.

I will subjoin that the effects in common sensation of explosive expirations, as in speaking, coughing, sneezing, &c., are of a painful cast, and in the more spasmodic of them the air seems so violently determined on seeking vent by the external auditory canal, as to severely tax the strength of the membrana tympani.

I never had any experience of the kind here described, until about eight years ago, when seemingly all the faucial tissues were in a permanent state. But I will mention, that, though I enjoy the firmest health, about sixteen years since I had a small portion of an extremly elongated uvula removed, the trunk of which did certainly decrease very gradually in apparent size. The uvula is still rather a large one than otherwise. Perhaps some may be inclined to see the origin of the affection in that operation distant as it was from the occurrence of the peculiar phenomena spoken of. I have no opinion upon this point, but know of no other cause for an alteration in the conduct of those parts.

About two years ago a young woman applied at the Truro Dispensary to be treated for symptoms which characterize inopportune openings of the Eustachian tube. She had a slightly anæmic look, with perhaps rather a relaxed condition of the mucous membrane lining the throat. That is, it was doubtful if there were any departure at all from good health. She gave her tale in such a way that I at once perceived her case to be precisely parallel with my own; she even resorted to the very mode adopted by myself of reducing the membrana tympani when it had popped into the external canal. She was one of a church choir, and was not usually prevented from singing by the inconvenience she suffered, though sometimes she had been troubled with all the signs of a patency of the tube of some continuance. She then only attended at the dispensary two or three times. But a few months since she made her appearance again for another purpose. The aural symptoms had not changed in the mean time. The aural defect in this case, or mine, is rather a matter to tease by its occasional untowardness than anything deserving the designation of an infirmity. But should a person labour under constant patency of the tube he would find it a serious affliction. Much relaxation, swelling, destruction, puckering, &c., of faucial structures are met with, and it seems possible that rigid patency of the tube might, from some such source, be produced, if more seldom than obliteration of its orifice. However, I have adduced the only two instances which have fallen under my observation, which seem indicative of such a possibility, though I have often enough heard persons speak of aural effects which must have arisen from an accidental opening of the tube at an improper moment. Indeed I think I trace all the prominent features of my experience in a picture which J. Müller, in his Physiology, (p. 1264), has drawn, in symptomatic terms, of an abnormal state which he can beget in his own ears by "elevating the palate;" so characteristic are the traits that I feel myself warranted in the conjecture that he can at any time produce the very relation of these parts which befals me (with a slight reservation as to a power of turning the balance as related above), not only apart from my will, but in spite of it, and to which I have not the power of giving existence at pleasure. He avows his inability to surmise in what the material disturbance consists, and only concludes that it is extraordinary by a peculiar and constant set of phonetic signs.

But now, to proceed with my own observations, I will detail the sonorous phenomena that are created by an open Eustachian tube. At each elevation and depression of the ribs, particularly in the latter act, the rippling of the air upon the rim of reflection of the lining membrane of the throat into this tube, expresses itself by a *souffle* like that from blowing into a bottle. Also as air expelled from the chest is split at the soft palate into its three streams, from the commencing border of the nearer of the posterior nares waves run into the drum and give utterance to a harsher *souffle* or *bruit*. Müller, whilst relating the aural effects that arose from the, to him, unknown (the prevalent idea of a permanently expanded tube precluded him from all chance of perceiving these things aright) modifications produced in his own ears by muscular effort, uses this language:—"The sound of one's own voice by this means acquires the intensity of the tones of an organ," &c.

I can testify that this is not mere flourish; and if there be here no exaggeration, what illustration would he have found, could he have tried, under such conditions, the utmost strain of voice, as in the act of shouting? Again, what could he then have been seized with violent sneezing or coughing? I will do my best further to characterize the acoustic phenomena consequent upon an open Eustachian tube. If another person puts his lips close to our ear and speaks, not to say shouts, &c., right into the external meatus, we all know how great a shock is produced. Such effects are of the same kind as those from speaking into our own ear through its Eustachian tube. However, besides condensing sonorous vibrations, the external meatus is capable of carrying to the drum a much larger volume of air (or more sound) than can find entrance thither through the very small channel of the tube that leads from it into the throat. Nevertheless, though a much heavier blow may be conveyed to the labyrinth through the external tube than through the other, the auditory nerve may be very severely struck by sonorous impulses reaching the tympanum through the Eustachian.

Let any one meditate upon the foregoing sum of evils, and he will own what a happy correlation it is that the glottis and guttural extremity of the Eustachian tube should never be open together, so that when the latter is subservient to the tympanum we cannot speak, sing, cough, sneeze ; nor sigh, sob, or hoop : no *souffles* as above described be engendered, and no waves or surges of air be felt against the membrana tympani, and when it cannot respond to ever alternating pressure. As movements are appointed the most vehement expiratory explosions lay hold upon us, and thin membranes and tiny bones with delicate articulations and muscles carry on their functions with impunity, and we are not stunned and distracted with tumultuous waves falling *via* the Eustachian, upon the inner ear.

It has been recorded that the membrana tympani has been ruptured in hooping cough. If so it could not have happened in the hoop ; but the Eustachian tube must have been open, or forced open, during an act of expiration of a very expulsive sort.

Hence I have gone through the propositions with which I started, for that eructated gas is kept out from the drum by the opening of the tube being limited to deglutition is too plain to need comment. Still it may not be amiss to state that in three attacks of acute deafness—such as happens from exposing the organ to a cold draught of air, and terminates in at most a few weeks. (two being in my left ear which has nothing peculiar in its ordinary behaviour, and one in my right)—I have found that during the complaint, especially on two occasions, one for either ear, eructated gas almost always intruded itself into the tympanum, taking me quite by surprise, and painfully stretching the membrana tympani, whilst I could most frequently hear the progress of the air through mucus more or less tenacious. From the moment when the crack in the ear occurred by which such deafness always announces its sudden departure, this gas ceased to find unusual entrance into the tympanum. At the crack, mucus which encumbered the aural apparatus involved in the middle ear had certainly been removed, and the functions of the part restored, whilst the noises in the head were dispersed; the same condition which impeded hearing, throwing vibrations—as those from the circulation of the blood—engendered about the tympanum, upon the labyrinth. In not one of these attacks, though eructated gas found such free ingress, was there any increased tendency of the respiratory currents to get into the drum. There is a little liability for eructated gas in the healthy ear to gush unawares into the tympanum, and there are muscular contractions somewhat akin to those in deglutition during the reverse act; but I am not clear as to the immediate or exact cause of a phenomenon which I have often enough noted to feel safe in registering as a fact.

I have purposely left the consideration of sonorous vibrations in the atmosphere, falling on the person, until the above results had been expatiated on.

Here my direct observations are totally antagonistic to Mr. Toynbee's notion, that there cannot be acuteness of hearing with an open Eustachian tube, and are quite in keeping with the acoustic principles deduced by J. Müller, from his elaborate experiments. For after a series of the most careful trials, repeated again and again, with the canal in question in the most favourable state for making them, I am able to say that the faculty of audition is not immediately deteriorated by the tube being patent, in any degree whatever. In the midst of all the phenomena I have enlarged upon, if I suspend breathing (the tube all the while fully dilated), my right ear, which is a capital organ, performs its functions admirably; just as at a time when the tympanum is perfectly shut off from the throat. And let breathing recommence, and even amidst the tremblings of the membrana tympani, and the *souffles* above mentioned, sounds from without are still heard distinctly and completely, with no other trouble than usually accompanies the disentanglementof sounds, when more than one reaches the sensorium at the same instant, or approximate instants.

In short, as regards outer sounds, the capabilities of the ear are perplexed and confounded by inner ones, but not abated.

Hence, too, I take it, that sonorous vibrations that enter the tympanum through the Eustachian tube impress themselves upon the labyrinth rather backwards mediately through the membrana tympani and ossicula, than immediately through the fenestra rotunda.

It would seem to emanate from the facts brought forward, that, provided the membrana tympani be so lax as not to be liable to *reciprocate* any tone, it is immaterial for hearing how the surface of that membrane be warped. For I can hear just as well whether it be convex or concave outwardly, or neither one nor the other. And I cannot help thinking that the principle here asserted obviously stands to reason, and that Müller should have interpreted his experiments with more strictness than he has done in this sense—absolutely as to the inapplicability of a membrane tense enough to reciprocate any tone for the office of reception and transmission of all tones. The very thing which the membrana tympani must never do, is to act like the parchment head of the instrument called a drum, after which it is named.

Why then is the ossicular chain furnished with muscles and articulations? Mr. Toynbee suggests, that they partially determine the quantity of vibration entering the fenestra ovalis. We may assume that this hypothesis is much more plausible, when the ossicles are supposed to be the high road of the vibrations than under his own acoustic views. He remarks (On an Artificial Membrana Tympani p. 13); " the tensor tympani muscle not only, as its name implies, renders tense the membrana tympani, but also compresses the fluids of the labyrinth, while the stapedius muscle has a directly opposite action in relaxing the membrana tympani, and in placing the contents of the labyrinth, in a state to be affected by the most delicate sonorous undulations. The base of the stapes moves to and fro in the fenestra ovalis, as a piston in a cylinder."

This graphic description of the mobility of the stapes, would as far as my judgment goes, be peculiarly happy were it used in support of the opinion of Dr. Young (among others), that the ossicles, as inelastic rods, bodily obey the vibrations of the membrana tympani, the joints and muscles preserving the perpendicularity of the stroke, and, if needful, moderating its amount. And even if the bones act by elasticity alone—as Müller maintains, perhaps rightly, though he certainly does not take due care that his experiments shall be unobjectionable in this particular—some movement of the stapes must be required.

But without entering into the question of the precise mode of propagation of the vibrations by the ossicles, the essential object of the apparatus, I believe, announces itself, by the order of the parts. Thus:—the membrana tympani, balanced, loosely, by air of equal density on either side, assumes readily the vibrations of the stratum of air it displaces: and by vibrating throughout its extent is enabled to impart stronger vibrations, by the ossicles, to the labyrinthæal fluid, than a membrane of the size of the fenestra ovalis, (even if having fluids of equal density on its two aspects)—could receive directly from the aerial undulations.

However, I must take leave of these collateral topics, as my design has not been to treat generally of aural physiology, but to relate the observations I have had the opportunity of making in elucidation of the ordinary state of occlusion of the Eustachian tube.

THE END.

LONDON:
G. J. PALMER, SAVOY STREET, STRAND.

London, New Burlington Street,
January, 1856.

MR. CHURCHILL'S

Publications,

IN

MEDICINE, SURGERY,

AND

SCIENCE.

"It would be unjust to conclude this notice without saying a few words in favour of Mr. Churchill, from whom the profession is receiving, it may be truly said, the most beautiful series of Illustrated Medical Works which has ever been published."—*Lancet.*

"All the publications of Mr. Churchill are prepared with so much taste and neatness, that it is superfluous to speak of them in terms of commendation."—*Edinburgh Medical and Surgical Journal.*

"No one is more distinguished for the elegance and *recherché* style of his publications than Mr. Churchill."—*Provincial Medical Journal.*

"Mr. Churchill's publications are very handsomely got up: the engravings are remarkably well executed."—*Dublin Medical Press.*

"The typography, illustrations, and getting up are, in all Mr. Churchill's publications, most beautiful."—*Monthly Journal of Medical Science.*

"Mr. Churchill's illustrated works are among the best that emanate from the Medical Press."—*Medical Times.*

"We have before called the attention of both students and practitioners to the great advantage which Mr. Churchill has conferred on the profession, in the issue, at such a moderate cost, of works so highly creditable in point of artistic execution and scientific merit."—*Dublin Quarterly Journal.*

MR. T. J. ASHTON,

SURGEON TO THE BLENHEIM-STREET DISPENSARY.

I.

ON THE DISEASES, INJURIES, AND MALFORMATIONS OF THE RECTUM AND ANUS. 8vo. cloth, 8*s*.

II.

A TREATISE ON CORNS AND BUNIONS, AND IN-GROWING OF THE TOE-NAIL: their Causes and Treatment. Post 8vo. cloth, 3*s*.6*d*.

MR. ATKINSON.

MEDICAL BIBLIOGRAPHY. Vol. I. Royal 8vo. 16*s*.

ROYAL COLLEGE OF PHYSICIANS.

DR. WILLIAM BALY, F.R.S.,

ASSISTANT PHYSICIAN TO ST. BARTHOLOMEW'S HOSPITAL; AND

DR. WILLIAM W. GULL,

ASSISTANT PHYSICIAN TO GUY'S HOSPITAL.

REPORTS ON EPIDEMIC CHOLERA, its Cause and Mode of Diffusion, Morbid Anatomy, Pathology and Treatment. Drawn up at the desire of the Cholera Committee. With Maps, 8vo. cloth, 16*s*.

DR. BARLOW,

PHYSICIAN TO GUY'S HOSPITAL.

A MANUAL OF THE PRACTICE OF MEDICINE. Fcap. 8vo. cloth, 12*s*. 6*d*.

MR. RICHARD BARWELL, F.R.C.S.,

DEMONSTRATOR OF ANATOMY AT ST. THOMAS'S HOSPITAL.

ASIATIC CHOLERA; its Symptoms, Pathology, and Treatment. Post 8vo. cloth, 4*s*. 6*d*.

DR. BASCOME.

A HISTORY OF EPIDEMIC PESTILENCES, FROM THE EARLIEST AGES. 8vo. cloth, 8*s*.

MR. BATEMAN.

MAGNACOPIA: A Practical Library of Profitable Knowledge, communicating the general Minutiæ of Chemical and Pharmaceutic Routine, together with the generality of Secret Forms of Preparations; including Concentrated Solutions of Camphor and Copaiba in Water, Mineral Succedaneum, Marmoratum, Silicia, Terro-Metallicum, Pharmaceutic Condensions, Prismatic Crystallization, Crystallized Aromatic Salt of Vinegar, Spa Waters; newly-invented Writing Fluids; Etching on Steel or Iron; with an extensive Variety of *et cætera*. Third Edition. 18mo. 6*s*.

MR. LIONEL J. BEALE, M.R.C.S.

THE LAWS OF HEALTH IN THEIR RELATIONS TO MIND AND BODY. A Series of Letters from an Old Practitioner to a Patient. Post 8vo. cloth, 7*s*. 6*d*.

MR. BEASLEY.

I.

THE BOOK OF PRESCRIPTIONS; containing 2900 Prescriptions. Collected from the Practice of the most eminent Physicians and Surgeons, English and Foreign. 24mo. cloth, 6*s*.

II.

THE DRUGGISTS' GENERAL RECEIPT-BOOK: comprising a copious Veterinary Formulary and Table of Veterinary Materia Medica; Patent and Proprietary Medicines, Druggists' Nostrums, &c.; Perfumery, Skin Cosmetics, Hair Cosmetics, and Teeth Cosmetics; Beverages, Dietetic Articles, and Condiments; Trade Chemicals, Miscellaneous Preparations and Compounds used in the Arts, &c.; with useful Memoranda and Tables. Third Edition. 24mo. cloth, 6*s*.

III.

THE POCKET FORMULARY AND SYNOPSIS OF THE BRITISH AND FOREIGN PHARMACOPŒIAS; comprising standard and approved Formulæ for the Preparations and Compounds employed in Medical Practice. Sixth Edition, corrected and enlarged. 24mo. cloth, 6*s*.

DR. O'B. BELLINGHAM.

ON ANEURISM, AND ITS TREATMENT BY COMPRESSION. 12mo. cloth, 4*s*.

DR. HENRY BENNET,

LATE PHYSICIAN ACCOUCHEUR TO THE WESTERN GENERAL DISPENSARY.

A PRACTICAL TREATISE ON INFLAMMATION AND OTHER DISEASES OF THE UTERUS. Third Edition, revised, with additions. 8vo. cloth, 12*s*. 6*d*.

MR. P. HINCKES BIRD, F.R.C.S.

PRACTICAL TREATISE ON THE DISEASES OF CHILDREN AND INFANTS AT THE BREAST. Translated from the French of M. BOUCHUT, with Notes and Additions. 8vo. cloth. 20*s*.

DR. JAMES BRIGHT.

ON DISEASES OF THE CHEST AND AIR PASSAGES; with a Review of the several Climates recommended in these Affections. Second Edition. Post 8vo. cloth, 7*s.* 6*d.*

MR. ISAAC BAKER BROWN, F.R.C.S.,
SURGEON ACCOUCHEUR TO ST. MARY'S HOSPITAL.

ON SOME DISEASES OF WOMEN ADMITTING OF SURGICAL TREATMENT. With Plates, 8vo. cloth, 10*s.* 6*d.*

MR. BERNARD E. BRODHURST,
ASSISTANT SURGEON TO THE ROYAL ORTHOPÆDIC HOSPITAL.

ON LATERAL CURVATURE OF THE SPINE: its Pathology and Treatment. Post 8vo. cloth, with Plates, 3*s.*

DR. BUDD, F.R.S.,
PROFESSOR OF MEDICINE IN KING'S COLLEGE, LONDON.

I.

ON DISEASES OF THE LIVER.

Illustrated with Coloured Plates and Engravings on Wood. Third Edition. *Preparing.*

II.

ON THE ORGANIC DISEASES AND FUNCTIONAL DISORDERS OF THE STOMACH. 8vo. cloth, 9*s.*

DR. WILLOUGHBY BURSLEM,
SENIOR PHYSICIAN TO THE BLENHEIM STREET DISPENSARY.

PULMONARY CONSUMPTION AND ITS TREATMENT. Post 8vo. cloth, 5*s.*

DR. CARPENTER, F.R.S.

I.

PRINCIPLES OF HUMAN PHYSIOLOGY. With numerous Illustrations on Steel and Wood. Fifth Edition. 8vo. cloth, 26*s.*

II.

PRINCIPLES OF COMPARATIVE PHYSIOLOGY. Illustrated with 300 Engravings on Wood. Fourth Edition. 8vo. cloth, 24*s.*

III.

A MANUAL OF PHYSIOLOGY. With numerous Illustrations on Steel and Wood. Second Edition. Fcap. 8vo. cloth, 12*s.* 6*d.*

IV.

THE MICROSCOPE AND ITS REVELATIONS. With numerous Engravings on Wood. Fcap. 8vo. *Ready in January.*

MR. ROBERT B. CARTER, M.R.C.S.

I.

ON THE INFLUENCE OF EDUCATION AND TRAINING IN PREVENTING DISEASES OF THE NERVOUS SYSTEM. Fcap. 8vo., 6s.

II.

THE PATHOLOGY AND TREATMENT OF HYSTERIA. Post 8vo. cloth, 4*s.* 6*d.*

DR. CHAMBERS,

PHYSICIAN TO ST. MARY'S HOSPITAL.

DIGESTION AND ITS DERANGEMENTS. Post 8vo. cloth, 10*s.* 6*d.*

MR. H. T. CHAPMAN, F.R.C.S.

I.

THE TREATMENT OF OBSTINATE ULCERS AND CUTANEOUS ERUPTIONS OF THE LEG WITHOUT CONFINEMENT. Second Edition. Post 8vo. cloth, 3*s.* 6*d.*

II.

VARICOSE VEINS: their Nature, Consequences, and Treatment, Palliative and Curative. Post 8vo. *In the Press.*

DR. G. C. CHILD.

ON INDIGESTION, AND CERTAIN BILIOUS DISORDERS OFTEN CONJOINED WITH IT. Second Edition. 8vo. cloth, 6*s.*

SIR JAMES CLARK, M.D., BART.,

PHYSICIAN TO THE QUEEN.

THE SANATIVE INFLUENCE OF CLIMATE. With an Account of the Principal Places resorted to by Invalids in England, South of Europe, the Colonies, &c. Fourth Edition, revised. Post 8vo. cloth, 10*s.* 6*d.*

MR. J. PATERSON CLARK, M.A.,

DENTIST EXTRAORDINARY TO HIS ROYAL HIGHNESS PRINCE ALBERT.

THE ODONTALGIST; OR, HOW TO PRESERVE THE TEETH, CURE TOOTHACHE, AND REGULATE DENTITION FROM INFANCY TO AGE. With plates. Post 8vo. cloth, 5*s.*

DR. CONOLLY.

THE CONSTRUCTION AND GOVERNMENT OF LUNATIC ASYLUMS AND HOSPITALS FOR THE INSANE. With Plans. Post 8vo. cloth, 6*s.*

MR. BRANSBY B. COOPER, F.R.S.

LECTURES ON THE PRINCIPLES AND PRACTICE OF SURGERY. 8vo. cloth, 21*s.*

C. REMIGIUS FRESENIUS.

ELEMENTARY INSTRUCTION IN CHEMICAL ANALYSIS,

AS PRACTISED IN THE LABORATORY OF GIESSEN. Edited by LLOYD BULLOCK, late Student at Giessen.

QUALITATIVE; Fourth Edition. 8vo. cloth, 9*s.*

QUANTITATIVE. Second Edition. 8vo. cloth, 15*s.*

MR. FRENCH, F.R.C.S.,

SURGEON TO THE INFIRMARY OF ST. JAMES'S, WESTMINSTER.

THE NATURE OF CHOLERA INVESTIGATED.

Second Edition. 8vo. cloth, 4*s.*

MR. FOWNES, PH.D., F.R.S.

I.

A MANUAL OF CHEMISTRY;

with numerous Illustrations on Wood. Fifth Edition. Fcap. 8vo. cloth, 12*s.* 6*d.*

Edited by H. BENCE JONES, M.D., F.R.S., and A. W. HOFMANN, PH.D., F.R.S.

II.

CHEMISTRY, AS EXEMPLIFYING THE WISDOM AND

BENEFICENCE OF GOD. Second Edition. Fcap. 8vo. cloth, 4*s.* 6*d.*

III.

INTRODUCTION TO QUALITATIVE ANALYSIS.

Post 8vo. cloth, 2*s.*

IV.

CHEMICAL TABLES.

Folio, price 2*s.* 6*d.*

DR. FULLER,

ASSISTANT PHYSICIAN TO ST. GEORGE'S HOSPITAL.

ON RHEUMATISM, RHEUMATIC GOUT, AND SCIATICA:

their Pathology, Symptoms, and Treatment. Second Edition. 8vo. cloth. *In the Press.*

DR. GAIRDNER.

ON GOUT;

its History, its Causes, and its Cure. Third Edition. Post 8vo. cloth, 8*s.* 6*d.*

MR. GALLOWAY.

I.

THE FIRST STEP IN CHEMISTRY.

Second Edition. Fcap. 8vo. cloth, 5*s.*

II.

A MANUAL OF QUALITATIVE ANALYSIS.

Post 8vo. cloth, 4*s.*

MR. ROBERT GARNER,

SURGEON TO THE NORTH STAFFORDSHIRE INFIRMARY, ETC.

EUTHERAPEIA; or, AN EXAMINATION OF THE PRINCIPLES OF MEDICAL SCIENCE, including Researches on the Nervous System. Illustrated with 9 Engravings on Copper, and Engravings on Wood. 8vo. cloth, 8*s.*

DR. GAVIN.

ON FEIGNED AND FACTITIOUS DISEASES, chiefly of Soldiers and Seamen; on the means used to simulate or produce them, and on the best Modes of discovering Impostors; being the Prize Essay in the Class of Military Surgery in the University of Edinburgh. 8vo. cloth, 9*s.*

DR. GLOVER.

ON THE PATHOLOGY AND TREATMENT OF SCROFULA; being the Forthergillian Prize Essay for 1846. With Plates. 8vo. cloth, 10*s.* 6*d.*

DR. GRANVILLE, F.R.S.

ON SUDDEN DEATH. Post 8vo. cloth, 7*s.*

MR. GRAY, M.R.C.S.

PRESERVATION OF THE TEETH indispensable to Comfort and Appearance, Health, and Longevity. 18mo. cloth, 3*s.*

MR. GRIFFITHS.

CHEMISTRY OF THE FOUR SEASONS—Spring, Summer, Autumn, Winter. Illustrated with Engravings on Wood. Second Edition. Foolscap 8vo. cloth, 7*s.* 6*d.*

DR. GULLY.

I.

THE WATER CURE IN CHRONIC DISEASE: an Exposition of the Causes, Progress, and Terminations of various Chronic Diseases of the Viscera, Nervous System, and Limbs, and of their Treatment by Water and other Hygienic Means. Fifth Edition. Foolscap 8vo. sewed, 2*s.* 6*d.*

II.

THE SIMPLE TREATMENT OF DISEASE; deduced from the Methods of Expectancy and Revulsion. 18mo. cloth, 4*s.*

MR. KNAGGS.

UNSOUNDNESS OF MIND CONSIDERED IN RELATION TO THE QUESTION OF RESPONSIBILITY IN CRIMINAL CASES. 8vo. cloth, 4*s*. 6*d*.

MR. LAWRENCE, F.R.S.

A TREATISE ON RUPTURES. The Fifth Edition, considerably enlarged. 8vo. cloth, 16*s*.

MR. LAWRENCE, M.R.C.S.

THE DIAGNOSIS OF SURGICAL CANCER. The Liston Prize Essay for 1854. Plates, 8vo. cloth, 4*s*. 6*d*.

DR. HUNTER LANE, F.L.S.

A COMPENDIUM OF MATERIA MEDICA AND PHARMACY; adapted to the London Pharmacopœia, 1851, embodying all the new French, American, and Indian Medicines, and also comprising a Summary of Practical Toxicology. Second Edition. 24mo. cloth, 5*s*. 6*d*.

MR. EDWIN LEE.

I.

THE WATERING PLACES OF ENGLAND, CONSIDERED with Reference to their Medical Topography. Third Edition. Foolscap 8vo. cloth, 5*s*. 6*d*.

II.

THE BATHS OF FRANCE, CENTRAL GERMANY, &c. Third Edition. Post 8vo. cloth, 6*s*. 6*d*.

III.

THE BATHS OF RHENISH GERMANY. Post 8vo. 2*s*. 6*d*.

MR. HENRY LEE, F.R.C.S.,

SURGEON TO THE LOCK HOSPITAL.

PATHOLOGICAL AND SURGICAL OBSERVATIONS; including an Essay on the Surgical Treatment of Hemorrhoidal Tumors. 8vo. cloth, 7*s*. 6*d*.

DR. ROBERT LEE, F.R.S.

I.

CLINICAL REPORTS OF OVARIAN AND UTERINE DISEASES, with Commentaries. Foolscap 8vo. cloth, 6*s*. 6*d*.

II.

CLINICAL MIDWIFERY: comprising the Histories of 545 Cases of Difficult, Preternatural, and Complicated Labour, with Commentaries. Second Edition. Foolscap 8vo. cloth, 5*s*.

III.

PRACTICAL OBSERVATIONS ON DISEASES OF THE UTERUS. With coloured Plates. Two Parts. Imperial 4to., 7*s*. 6*d*. each Part.

MR. LISTON, F.R.S.

PRACTICAL SURGERY. Fourth Edition. 8vo. cloth, 22*s.*

LONDON MEDICAL SOCIETY OF OBSERVATION.

WHAT TO OBSERVE AT THE BED-SIDE, AND AFTER DEATH. Published by Authority. Second Edition. Foolscap 8vo. cloth, 4*s.* 6*d.*

MR. EDWARD F. LONSDALE,

SURGEON TO THE ROYAL ORTHOPÆDIC HOSPITAL.

OBSERVATIONS ON THE TREATMENT OF LATERAL CURVATURE OF THE SPINE. Second Edition. 8vo. cloth, 6*s.*

M. LUGOL.

ON SCROFULOUS DISEASES. Translated from the French, with Additions by W. H. RANKING, M.D., Physician to the Suffolk General Hospital. 8vo. cloth, 10*s.* 6*d.*

MR. JOSEPH MACLISE, F.R.C.S.

SURGICAL ANATOMY. A Series of Dissections, illustrating the Principal Regions of the Human Body.

The singular success of this Work exhausted the First Edition of 1000 Copies within six months of its completion.

The Second Edition, now in course of publication, Fasciculi I. to XI. Imperial folio, 5*s.* each.

MR. MACILWAIN.

ON TUMOURS, THEIR GENERAL NATURE AND TREATMENT. 8vo. cloth, 5*s.*

DR. MAYNE.

AN EXPOSITORY LEXICON OF THE TERMS, ANCIENT AND MODERN, IN MEDICAL AND GENERAL SCIENCE, including a complete MEDICAL AND MEDICO-LEGAL VOCABULARY, and presenting the correct Pronunciation, Derivation, Definition, and Explanation of the Names, Analogues, Synonymes, and Phrases (in English, Latin, Greek, French, and German,) employed in Science and connected with Medicine. Parts I. to IV., price 5*s.* each.

DR. WM. H. MADDEN.

THOUGHTS ON PULMONARY CONSUMPTION; with an Appendix on the Climate of Torquay. Post 8vo. cloth, 5*s.*

DR. MARTIN.

THE UNDERCLIFF, ISLE OF WIGHT: its Climate, History, and Natural Productions. Post 8vo. cloth, 10*s.* 6*d.*

MR. J. RANALD MARTIN, F.R.S.,

LATE PRESIDENCY SURGEON, AND SURGEON TO THE NATIVE HOSPITAL, CALCUTTA.

THE INFLUENCE OF TROPICAL CLIMATES ON EUROPEAN CONSTITUTIONS. Originally by the late JAMES JOHNSON, M.D., and now entirely rewritten; including Practical Observations on the Diseases of European Invalids on their Return from Tropical Climates. Seventh Edition. 8vo. cloth, 16*s.*

DR. MASON,

INVENTOR OF MASON'S HYDROMETER.

ON THE CLIMATE AND METEOROLOGY OF MADEIRA: Edited by JAMES SHERIDAN KNOWLES; to which are attached a Review of the State of Agriculture and of the Tenure of Land, by GEORGE PEACOCK, D.D., F.R.S.; and an Historical and Descriptive Account of the Island, and Guide to Visitors, by JOHN DRIVER, Consul for Greece, Madeira. 8vo. cloth, 18*s.*; royal 8vo. £1. 11*s.* 6*d.*

DR. MASSY,

4TH LIGHT DRAGOONS.

ON THE EXAMINATION OF RECRUITS; intended for the Use of Young Medical Officers on Entering the Army. 8vo. cloth, 5*s.*

DR. CHARLES D. MEIGS,

PROFESSOR OF MIDWIFERY AND THE DISEASES OF WOMEN AND CHILDREN IN JEFFERSON MEDICAL COLLEGE, U.S.

A TREATISE ON ACUTE AND CHRONIC DISEASES OF THE NECK OF THE UTERUS. With numerous Plates, coloured and plain, 8vo. cloth, 25*s.*

DR. MEREI,

LECTURER ON THE DISEASES OF CHILDREN AT THE CHATHAM STREET SCHOOL OF MEDICINE, MANCHESTER.

ON THE DISORDERS OF INFANTILE DEVELOPMENT AND RICKETS: preceded by Observations on the Nature, Peculiar Influence, and Modifying Agencies of Temperaments. 8vo. cloth, 6s.

MR. JOHN L. MILTON, M.R.C.S.

PRACTICAL OBSERVATIONS ON A NEW WAY OF TREATING GONORRHŒA. With some Remarks on the Cure of Inveterate Cases. 8vo. cloth, 5s.

DR. MILLINGEN.

ON THE TREATMENT AND MANAGEMENT OF THE INSANE; with Considerations on Public and Private Lunatic Asylums. 18mo. cloth, 4*s.* 6*d.*

DR. MONRO,

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS.

I.

REMARKS ON INSANITY: its Nature and Treatment. 8vo. cloth, 6*s.*

II.

AN ESSAY ON STAMMERING. 8vo. 2*s.* 6*d.*

III.

REFORM IN PRIVATE LUNATIC ASYLUMS. 8vo. cloth, 4*s.*

DR. NOBLE.

I.

ELEMENTS OF PSYCHOLOGICAL MEDICINE: AN INTRODUCTION TO THE PRACTICAL STUDY OF INSANITY. Second Edition. 8vo. cloth, 10*s.*

II.

THE BRAIN AND ITS PHYSIOLOGY. Post 8vo. cloth, 6*s.*

DR. J. NOTTINGHAM,

SURGEON TO THE ST. ANNE'S EYE AND EAR INSTITUTION, LIVERPOOL.

PRACTICAL OBSERVATIONS ON CONICAL CORNEA, AND on the Short Sight, and other Defects of Vision connected with it. 8vo. cloth, 6*s.*

MR. NOURSE, M.R.C.S.

TABLES FOR STUDENTS. Price One Shilling.

1. Divisions and Classes of the Animal Kingdom.
2. Classes and Orders of the Vertebrate Sub-kingdom.
3. Classes of the Vegetable Kingdom, according to the Natural and Artificial Systems.
4. Table of the Elements, with their Chemical Equivalents and Symbols.

MR. THOMAS W. NUNN,

TEACHER OF PRACTICAL ANATOMY AT THE MIDDLESEX HOSPITAL.

A DEMONSTRATION OF THE ARTERIES OF THE UPPER AND LOWER EXTREMITY; or, a New Classification of those Vessels facilitating their Study. Fcap. 8vo. *Just ready.*

MR. NUNNELEY.

A TREATISE ON THE NATURE, CAUSES, AND TREATMENT OF ERYSIPELAS. 8vo. cloth, 10*s.* 6*d.*

MR. PIRRIE, F.R.S.E.,

REGIUS PROFESSOR OF SURGERY IN THE UNIVERSITY OF ABERDEEN.

THE PRINCIPLES AND PRACTICE OF SURGERY. With numerous Engravings on Wood. 8vo. cloth, 21*s.*

PHARMACOPŒIA COLLEGII REGALIS MEDICORUM LONDINENSIS. 8vo. cloth, 9*s.*; or 24mo. 5*s.*

IMPRIMATUR.

Hic liber, cui titulus, PHARMACOPŒIA COLLEGII REGALIS MEDICORUM LONDINENSIS. Datum ex Ædibus Collegii in comitiis censoriis, Novembris Mensis 14to 1850.

JOHANNES AYRTON PARIS. *Præses.*

PROFESSORS PLATTNER & MUSPRATT.

THE USE OF THE BLOWPIPE IN THE EXAMINATION OF MINERALS, ORES, AND OTHER METALLIC COMBINATIONS. Illustrated by numerous Engravings on Wood. Third Edition. 8vo. cloth, 10*s.* 6*d.*

*** This Edition has been most carefully revised by Professor MUSPRATT, and received from him considerable additions.

THE PRESCRIBER'S PHARMACOPŒIA; containing all the Medicines in the London Pharmacopœia, arranged in Classes according to their Action, with their Composition and Doses. By a Practising Physician. Fourth Edition. 32mo. cloth, 2*s.* 6*d.*; roan tuck (for the pocket), 3*s.* 6*d.*

DR. JOHN ROWLISON PRETTY.

AIDS DURING LABOUR, including the Administration of Chloroform, the Management of Placenta and Post-partum Hæmorrhage. Fcap. 8vo. cloth, 4*s.* 6*d.*

SIR WM. PYM, K.C.H.,

INSPECTOR-GENERAL OF ARMY HOSPITALS.

OBSERVATIONS UPON YELLOW FEVER, with a Review of "A Report upon the Diseases of the African Coast, by Sir WM. BURNETT and Dr. BRYSON," proving its highly Contagious Powers. Post 8vo. 6*s.*

DR. RICHARD QUAIN,

PHYSICIAN TO THE HOSPITAL FOR DISEASES OF THE CHEST, BROMPTON.

MATERIALS CONTRIBUTED TOWARDS A BETTER UNDERSTANDING OF THE NATURE, DIAGNOSIS, AND TREATMENT OF TUBERCULOUS DISEASES OF THE LUNGS. 8vo. *Preparing.*

DR. EVANS RIADORE, F.R.C.S., F.L.S.

I.

ON SPINAL IRRITATION, THE SOURCE OF NERVOUSNESS, INDIGESTION, AND FUNCTIONAL DERANGEMENTS OF THE PRINCIPAL ORGANS OF THE BODY. Post 8vo. cloth, 5*s.* 6*d.*

II.

THE REMEDIAL INFLUENCE OF OXYGEN, NITROUS OXYDE, AND OTHER GASES, ELECTRICITY, AND GALVANISM. Post 8vo. cloth, 5*s.* 6*d.*

III.

ON LOCAL TREATMENT OF THE MUCOUS MEMBRANE OF THE THROAT, for Cough and Bronchitis. Foolscap 8vo. cloth, 3*s.*

MR. ROBERTON,

FORMERLY SENIOR SURGEON TO THE MANCHESTER AND SALFORD LYING-IN HOSPITAL.

ON THE PHYSIOLOGY AND DISEASES OF WOMEN, AND ON PRACTICAL MIDWIFERY. 8vo. cloth, 12*s.*

DR. W. H. ROBERTSON,

PHYSICIAN TO THE BUXTON BATH CHARITY.

I.

THE NATURE AND TREATMENT OF GOUT.
8vo. cloth, 10*s.* 6*d.*

II.

A TREATISE ON DIET AND REGIMEN.
Fourth Edition. 2 vols. post 8vo. cloth, 12*s.*

DR. ROTH.

ON MOVEMENTS. An Exposition of their Principles and Practice, for the Correction of the Tendencies to Disease in Infancy, Childhood, and Youth, and for the Cure of many Morbid Affections in Adults. Illustrated with numerous Engravings on Wood. 8vo. cloth, 10*s.*

DR. ROWE, F.S.A.

NERVOUS DISEASES, LIVER AND STOMACH COMPLAINTS, LOW SPIRITS, INDIGESTION, GOUT, ASTHMA, AND DISORDERS PRODUCED BY TROPICAL CLIMATES. With Cases. Fourteenth Edition. Fcap. 8vo. 2*s.* 6*d.*

DR. ROYLE, F.R.S.

A MANUAL OF MATERIA MEDICA AND THERAPEUTICS. With numerous Engravings on Wood. Second Edition. Fcap. 8vo. cloth, 12*s.* 6*d.*

MR. WADE, F.R.C.S.,

SENIOR SURGEON TO THE WESTMINSTER DISPENSARY.

STRICTURE OF THE URETHRA; its Complications and Effects. With Practical Observations on its Causes, Symptoms, and Treatment; and on a Safe and Efficient Mode of Treating its more Intractable Forms. 8vo. cloth, 5*s.*

DR. WAGSTAFF.

ON DISEASES OF THE MUCOUS MEMBRANE OF THE THROAT, and their Treatment by Topical Medication. Post 8vo. cloth, 4*s.* 6*d.*

DR. WALLER,

LECTURER ON MIDWIFERY AT ST. THOMAS'S HOSPITAL.

ELEMENTS OF PRACTICAL MIDWIFERY; OR, COMPANION TO THE LYING-IN ROOM. With Plates. Third Edition. 18mo. cloth, 3*s.* 6*d.*

MR. HAYNES WALTON, F.R.C.S.,

SURGEON TO THE CENTRAL LONDON OPHTHALMIC HOSPITAL.

OPERATIVE OPHTHALMIC SURGERY. With Engravings on Wood. 8vo. cloth, 18*s.*

DR. WARDROP.

ON DISEASES OF THE HEART. 8vo. cloth, 12*s.*

DR. EBEN. WATSON, A.M.,

LECTURER ON THE INSTITUTES OF MEDICINE IN THE ANDERSONIAN UNIVERSITY, GLASGOW.

ON THE TOPICAL MEDICATION OF THE LARYNX IN CERTAIN DISEASES OF THE RESPIRATORY AND VOCAL ORGANS. 8vo. cloth, 5*s.*

DR. WEGG.

OBSERVATIONS RELATING TO THE SCIENCE AND ART OF MEDICINE. 8vo. cloth, 8*s.*

MR. T. SPENCER WELLS, F.R.C.S.,

LATE ASSISTANT SURGEON IN MALTA HOSPITAL.

PRACTICAL OBSERVATIONS ON GOUT AND ITS COMPLICATIONS, and on the Treatment of Joints Stiffened by Gouty Deposits. Foolscap 8vo. cloth, 5*s.*

Printed by W. Blanchard & Sons, 62, Millbank Street, Westminster.