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DISCOVERIES

IN

LIGHT AND VISION;

WITH

A SHORT MEMOIR

CONTAINING

DISCOVERIES IN THE MENTAL FACULTIES.

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DEDICATION.

If this volume did not contain opinions so much at variance with the philosophy of the schools, I should dedicate it to the French Institute—that great scientific tribunal. If I were to select an individual, there is M. Biot, M. Magendie, or Dr. Dutrochet of Paris, and Mrs. Somerville, the Lord Chancellor Brougham, or Mr. Charles Babbage of London—names that are destined to outlive the present generation. But the same cause prevents me from intruding on them, for it would be indelicate to make use of their name when the whole scope of these pages is to question the soundness of certain doctrines held by them in the greatest respect.

Amongst those who may be called men

of science in my own country, I do not, personally, know one who would not shrink from contact with what the world might call heretical opinions. Unwilling, therefore, that they should lose caste by being associated with the work, I have thought proper not to place it under their patronage.

I shall therefore gratify my feelings by dedicating these Memoirs to a friend, one who, I trust, has confidence in my ability to sustain the position I have assumed; and although he may not have devoted himself exclusively to science, yet as a man of letters and of general knowledge, he can appreciate the merits of a work of a much higher scientific grade than the one now presented to the public.

It is to the bard of those noble poems—"The Water Fowl" and "The Past"—to William Cullen Bryant, that I dedicate these Memoirs.

PREFACE.

It appears presumptuous to come before the world with doctrines so diametrically in opposition to those that have received the sanction of the greatest names both of antiquity and the present day. What am I to expect—what do I promise myself, by giving publicity to facts and opinions which, if accepted, would go far to overthrow that part of the theory of Optics which embraces vision—nay, which disputes the fact that light comes in direct rays immediately from the sun.

Perhaps it may be conjectured that I have a reluctance at thus appearing in the character of a reformer, always an odious name until the reformation is effected; and that being so entirely unknown to the scientific world, I would naturally shrink from the attacks of exasperated critics, who are not often the best judges of the merits of the work they condemn. I cannot tell why I am not dismayed; but it is certain that I feel no reluctance, no timidity, no hesitation. When I lately put forth a work of mere fancy, I must acknowledge that I felt great anxiety; but at present I have no fears. I am impelled forward irresistibly; and the apprehension of neglect, the dread of contempt, has no power to discourage or disconcert me. I look upon what is to follow this exposition as evils and annoyances which concern me not; a vista opening into deep time, is present to my view, where depreciating voices are heard no more, where integrity of purpose is fully acknowledged, and where the labours of the patient and faithful experimentalist shall meet with their just reward.

The love of truth and the anticipation of being understood and appreciated at some future period, are strong impelling incentives. I know that when my pretensions are honestly examined it will be found that nothing has been assumed on vague conjecture, and that nothing has been asserted rashly or without proof. All the experiments have been rigorously tested, and the deductions subjected to strict analysis; and to follow me through the whole series only requires an ordinary acuteness, and a facility in performing minute and new experiments.

It is true I have encountered several that are called men of science who could not perform the least difficult of these experiments, simply because they were not laid down in the text books; closet philosophers are these, who rely solely upon the genius of others, and who teach and lecture from the stores of other men's minds. Having never made any contribution to science themselves, they are awkward in performing new experiments. I have met with some who were even unable to keep one eye shut without holding it; some could not place one lens parallel with another; others listened with complacency, promising to continue the inquiry and let me know the result, but never thought of it again; and one eminent man told me that he was so well assured that the theory of the inverted image was the correct one, that he had no desire to see a better.

Even in England, where I first made known the fact that we could see the retina of our own eye, no steps were taken to ascertain its accuracy. Nay, I heard from good authority that it was doubted whether, under any circumstances, the retina could be seen by ourselves. This proves that there is great indifference towards investigations of this kind; for one of the Scotch philosophers of great note for a long time was unwilling to make the experiment.

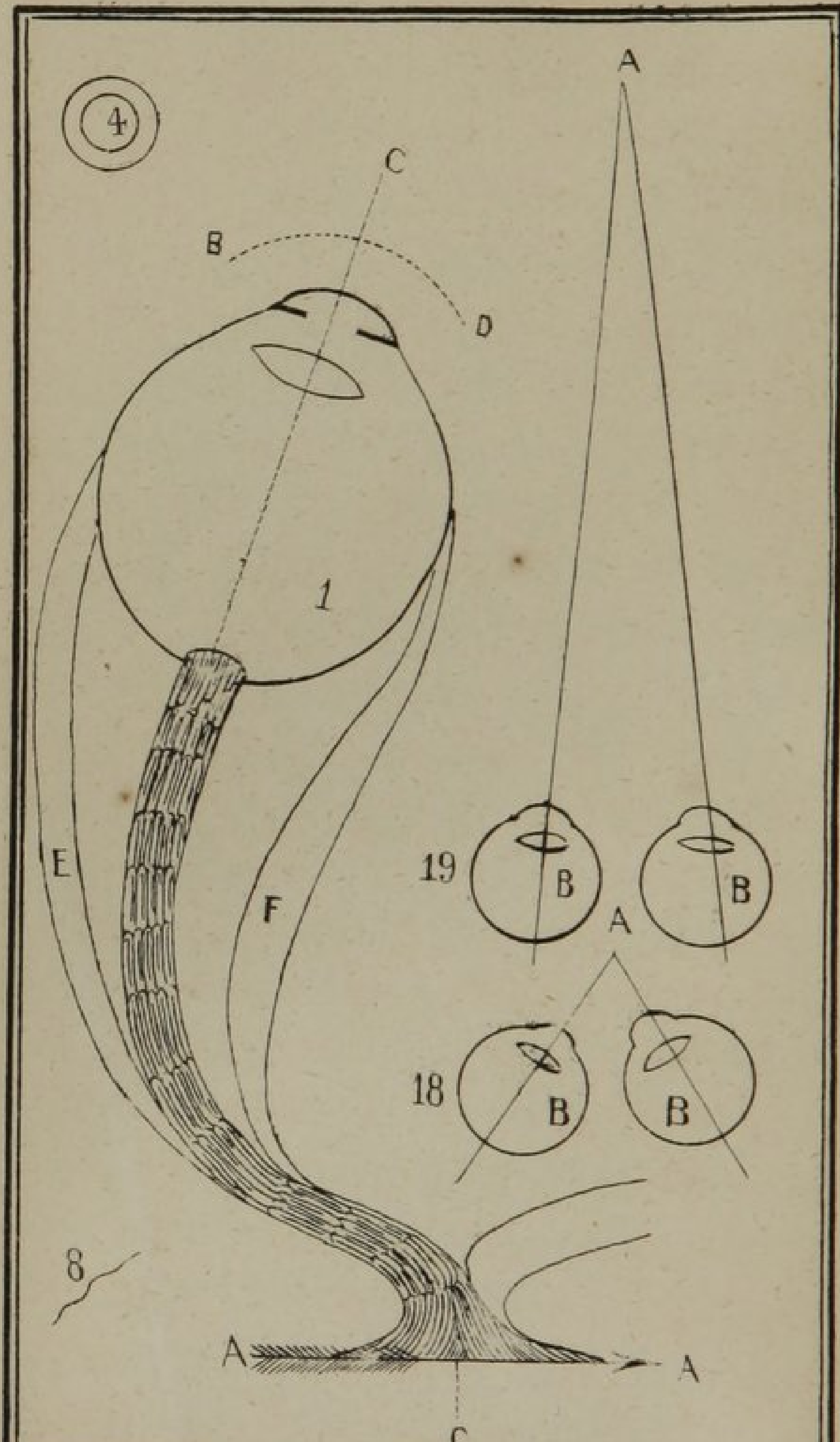
Without aid, therefore, from any man of science, without even sympathy, that great charm which animates, consoles, and rewards the laborious and careful searcher after truth, I have ventured to proceed, nothing daunted, in this perilous undertaking—without fear—without hope. The enchantments, of science, the sudden appearance of new phenomena, the success of experiments, and the remote yet captivating hope of living in after ages—are gratifications and remunerations enough for one life; and are sufficient to sustain me through all the neglect that I may be destined to experience.

But although I have thus far met with no sympathy, yet I should not utter it in the way of complaint; for I know that it requires an initiation like my own to pursue an inquiry of this kind to its utmost limits. It is necessary to unlearn much of what was acquired by hard study before new facts like these can be fully appreciated, for they generally come in opposition to some formula, some accredited rule, which it is dangerous to break. When we have spent our lives in teaching contrary doctrines, how can it be expected that we shall confess that all our knowledge has been founded in error!

Mr. Charles Babbage, in his excellent work on the cause of the decline of science in England, goes very ably and fearlessly into the true merits of the question. He proves incontrovertibly that the decline is mainly attributable to the total neglect of *natural science*, to an indifference towards investigations of natural phenomena. If this be true of England, it cannot yet apply to the United States of America, for here the spirit of investigation is scarcely awakened. I am induced to hope, that as we acquire leisure, that great gift in the power of wealth, we shall direct our attention to natural science, and pursue it as ardently as we do the sciences of mechanics and numbers.

It was hardly fair, therefore, to expect either assistance or sympathy from those who could not appreciate my labours; and would it not be still more unfair to ask them to give the sanction of their name to a theory which would bear so hard on those for whom they have the greatest respect, and from whom they have acquired all their distinction? Sir Isaac Newton fully believed in the inverted image; he believed that all the colours of the solar spectrum could be resolved into one of pure white; that light came in a straight line immediately from the sun; and that the spectrum formed by one eye could travel round and be seen in the other. Could they even read a work that disputed such venerated authority as this?

All that I am therefore entitled to ask, is a little patience, a little forbearance; not so much for my sake as for others. The day is coming when the theories brought forward in these memoirs will be respectfully considered, and therefore the least said in their condemnation will be the soonest recanted. Let haste be avoided, let not indignation at my temerity hurry any one into an intemperate or indiscreet denunciation of these novel doctrines; for the chance is, that on a careful study of them the truth will appear clearly.



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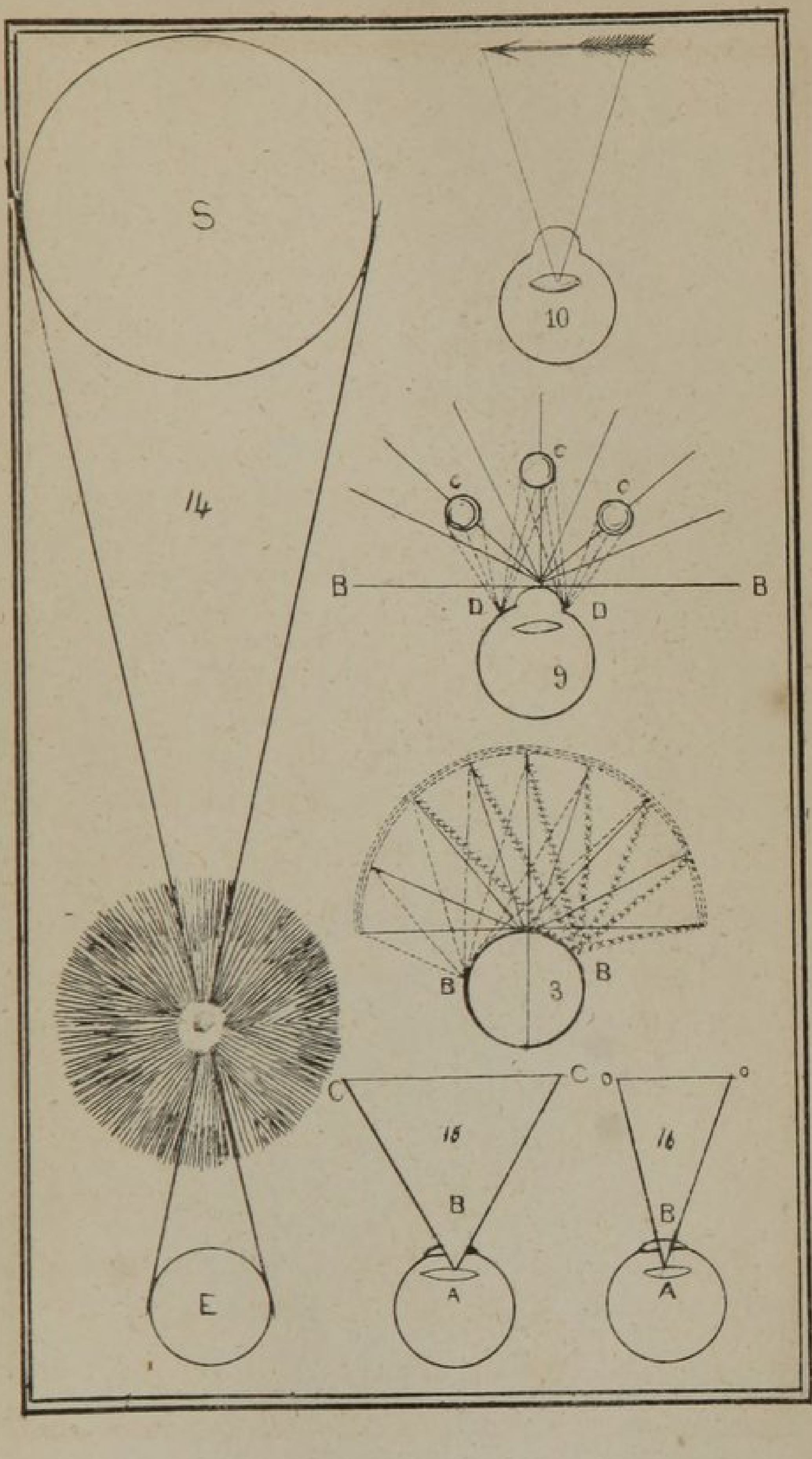
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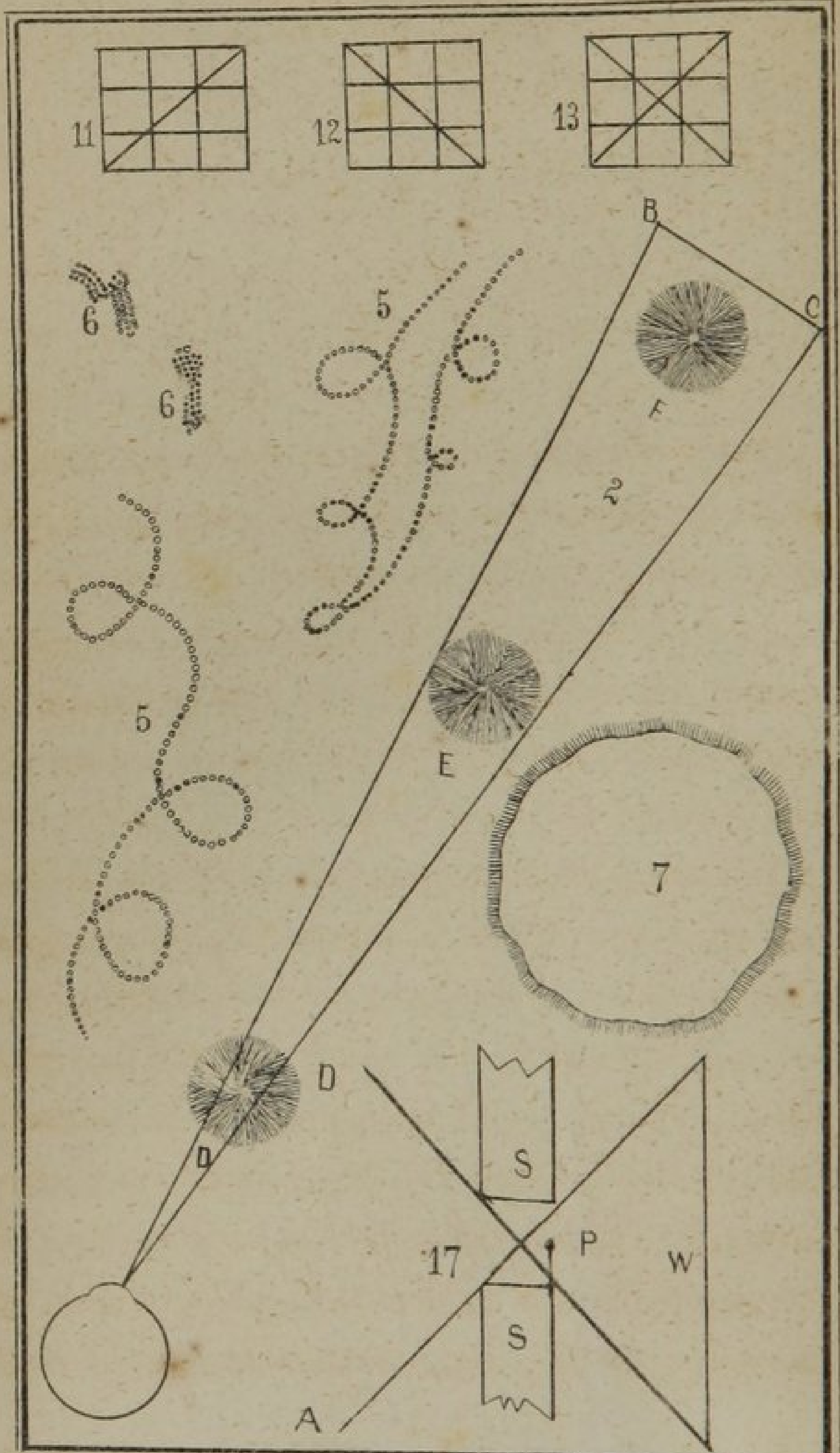

M.G. Lith. Endicott.

OPTICAL PHENOMENA.

No. 1.—Having always doubted the theory of seeing objects in an inverted position, I determined on testing its accuracy. The first moment it was in my power, I made the experiment, and the first eye that I examined enabled me to detect the error under which we had so long laboured.

A very skilful surgeon, at different times, prepared several eyes for me from animals newly killed. The upper part of one was deprived of the sclerotic coat; another had the whole of the optic nerve, and the foramen centrale, as well as half of the retinous expansion removed; and several had a hole of this size, ◯ cut through the sclerotic at the hinder part of the eye. As the experiments of the inverted image only related to the eyes with the hole last mentioned, I shall confine my remarks to them.

I held one of the eyes before the flame of a spermaceti candle, and, as is stated in all optical works, the inverted candle was seen, though dimly. When the whole eye was dipped in water, and again held up, the inverted candle became clear and distinct; thus proving how essential to vision, in the living eye, is the fluid which lubricates the conjunctiva.

But although the image was thus plainly seen only occupying the centre of the transparent hole, I could not imagine why the rays of light, which were emanating from a bright object near the candle, did not convey an impression of that likewise. I knew that all objects within the angle of vision could be impressed on the organs of sight, and there was no reason to suppose that in this particular the eye of an animal was differently constructed from ours. In fact, the human eye is stated to exhibit the same phenomenon; nor was the peculiarity to be attributed to the smallness of the surface, as a whole landscape could be portrayed on the surface of a single drop of water.

Perhaps it will gratify the curious to know by what process of reasoning and experiment I obtained the happy result; I shall state, therefore, the difficulties that were to be overcome. It occurred to me that the crystalline lens having lost its power of adjustment, could not maintain its parallelism with the axis of the eye-ball; and it was not therefore of any use. I concluded that this prostration was owing to the want of elastic action in the ciliary processes and retina. The question, then, was, whether I could produce an artificial adjustment?

I considered, likewise, that an eye must lose its spherical form when taken from the socket, and that it would become still flatter by the pressure of the thumb and finger when held up before the candle. To restore the lens to its perpendicularity seemed the first thing to be done, and the only way to effect it was to give the eye as round a form as it would have had in the socket. The eye under examination was still flexible, and on dipping it again in water to restore its brilliancy, I held it in my hand as if it were a tube, pressing it all around, equally yet gently.

Instead of looking on the *surface* of the hole, as is usually done when making this experiment, I looked *through* it, because, in the case of our own vision, I knew that the rays of light from an external object had to pass through the axis of the eye. At first nothing was seen, even the inverted candle had disappeared from the surface of the hole. Presently a bright light flashed across the animal's eye and disappeared. As soon as I could keep my hand steady, the light again was visible; it proved to be circular and bright, and whilst it was thus stationary, I held a pin before the eye with the head up, and to my surprise and pleasure I found my previous opinions confirmed, for the pin appeared exactly as I presented it to the eye of the animal—when I turned the pin upside down, it appeared upside down too! As soon as I lowered the eye, so that the central rays from the candle did not enter the axis of the animal's eye, then the candle again appeared on the *surface* of the little hole. When I looked *through* the hole, the smallness of its diameter was not observed, the circular light within, in the midst of which the pin appeared, was about three fourths of an inch in diameter.

In less than half an hour the whole eye became dim, and the cornea appeared livid; the experiments, therefore, with this eye, were over. I must advise those who are to follow me in this investigation, to be sure that the eyes are fresh, and, above all things, to have them taken from the socket by a surgeon, who should likewise cut through the sclerotic coat to make the small hole behind. Not only is this to be observed, but there should be great care in handling the eye, as rough handling will cause the humours to mix, and thus render vision indistinct. If I had not commenced the inquiry with a strong doubt of the correctness of the theory of inverted images, and if a skilful surgeon had not prepared the eyes, this discovery would not have taken place at this moment, perhaps not in another century.

As to the explanation of the inverted image, —as to the manner in which it became erect again, so that the mind could see it erect,— I mean with regard to our own vision when no other eye intervened,—this has never been satisfactory. That the theory might appear plausible, two things were taken for granted; first, the fact assumed is that the image *must* appear inverted to us, because the candle is inverted on the *surface* of the hole; and second, it is asserted that the retina is the seat of vision.

As to the retina, it shall be satisfactorily proved that this reticulated membrane or nerve is of an elastic nature, and that it contracts and expands according to the density of light. In No. 13 of this memoir it will be perceived, that when the meshes or interstices of the retina are nearer together, the pupil is larger; and when they are wider apart, the diameter of the pupil is smaller. Close and repeated experiment, such as is described in No. 13, will enable any one to see this contractile variation of the retina, and the fact should not be doubted if not immediately seen. It requires that we should be long in the habit of attending to the operations of the *will* or the external senses, and in examining all the phenomena that arise, either from spectral illusion or real spectra, to perceive the minutiae of a delicate and evanescent spectrum like the retina.

So far from being true that the retina is the seat of vision—so far from being the organ by which the image of external objects is presented to the sensorium—so far from its being the part on which rays of light converge to their foci—this membrane is carefully guarded from the contact of light. Only look at its position; it is imbedded on one side in a black pigment of a soft, pulpy consistence, that the excess of light may be immediately decomposed. On the other side it is covered throughout by a delicate membrane, the outer surface of which is constantly kept moist and flexible by a gelatinous or albuminous secretion called the vitreous humour. The elasticity, therefore, can never be impaired, because it is thus for ever flexible, owing to the two lubricating secretions, the black pigment and the vitreous humour.

No particular part of the eye-ball can be regarded as the seat of vision. It is with this organ as with the others, one part of the apparatus is intimately connected with the rest. It is the *material* that enters the eye which sets the whole machinery of vision in motion. In manufactories, it is neither levers nor wheels that weave the cloth into definite proportions. It is an external material, such as fire, or air, or water, or manual strength, that gives the impetus to the machine; and one part of the apparatus is quite as necessary to perfect the cloth as the other.

The optic nerve is certainly the main spring of the whole apparatus of vision; that is—the whole nerve from the reticulated expansion within the eye-ball to its fibrous expansion within the brain. In the living eye, the retina cannot be injured without impairing vision to a great degree, because it extends around the whole inner circumference of the eye as far as the lens; but the same thing may be said of the lens or the cornea. That the whole of the optic nerve is instrumental in conveying an image, or the impression of an image, to the sensorium, no one can doubt; but if the lens or the cornea are injured, then the image or impression is not distinctly perceived. Let the retina be ever so sound, it requires the healthy action and participation of every part of the apparatus to produce a perfect spectrum. When the whole eye is sound, then every part moves simultaneously at one impulse, and conveys an image, for so we must speak, to the sensorium. *It is on this central ganglion that the image is first formed—it is there that it is first* *perceived—and it is there that the spectra or images remain, when we see them after our eyes are closed. It is from this precise spot that they are conjured up, as it were, when the mind has a desire to recal them.*

It is well known that by the elastic, or rather contractile action of the *external* muscles of the eye, two of which are shown in figure 1, E and F, that the eye-ball is enabled to take a certain range. Surely if these muscles are requisite to the movement of the ball itself, it may easily be inferred that the *internal* apparatus of this eye-ball has a membrane possessing muscularity likewise; although this muscularity may consist in the contraction of a retinous expansion and striated fibres instead of what is strictly termed a muscle.

The crystalline lens, as will be seen in No. 13, is attached to something possessing this elastic principle, by which its motions are adjusted and regulated. The retina, or reticulated expansion of the optic nerve, with the ciliary processes, are the only membranes—if membranes they may be termed—that answer to this description. Although exceedingly delicate and minute in their texture and form, yet it should always be recollected that the apparatus upon which they operate is delicate and minute likewise. When the subject shall be more fully examined, it will be found that the internal extremity of the optic nerve branches off into fibres, every one of which corresponds to some particular ray of light.

But if the question is of the consequence that philosophers pretend, why are there so few cerebral experiments with a reference to the true seat of vision. Of all the organs and parts of the human system, the brain has been the least examined, and yet it deserves our first care and attention. It is not satisfactorily proved that the optic nerves do not communicate; nay, so vague are our notions on this point, that in a late work on Optics the author observes, "It would appear from this that the impression of the Solar image was conveyed by the optic nerve from the left to the right eye."

As it respects my own observation (and I have for many years attended closely to all the optical phenomena relating to vision) each eye throughout its whole organization, *externally* and internally, is entirely independent. I am confident that with the aid of good glasses we shall be enabled to discover the terminations of the optic nerves of both eyes. Will not Mr. George Combe investigate this branch of the subject? he is fully equal to it. He will discover that the apparatus of each eye is distinct, and that no communication could possibly take place—not even by anastamosing or inosculation. There may be a commingling of light *after* the spectra are formed on the internal ganglion of vision within the brain, but in no other way.

M. Mariotte supposed that the base of the optic nerve, within the eye-ball, was incapable of conveying an impression of distinct vision to the sensorium. He inferred this from the fact, that when the rays of light, or, as is expressed, when the image of any external object fell upon the *base* of the nerve, it instantly disappeared. It is yet to be proved that the light *does* fall on that part of the optic nerve. If we yield assent to this,—all other things agreeing,—we must allow that the retina receives an image on some part of its surface. We should then undoubtedly think that the retina was the seat of vision. But other things do *not* agree, as I have proved by the ability of seeing both the erect and inverted image *with the loss of the greater part of the retina*,—a fact of which I am presently to speak.

But there is a much better way of accounting for the curious phenomenon described by M. Mariotte,—*by the law of interference*. It is well known that, in what is called the axis of the back part of the eye, and adjoining the optic nerve, is a bright spot on the retinous membrane, called the foramen centrale, which, although it certainly makes part of the retina, is of a different texture and character, being neither divided into meshes, nor of the like consistency. When light has effected its purpose, which it does by exciting the interior of the eye, and thus imparting motion to the cerebral apparatus of the optic nerve, it converges to this transparent spot, called the foramen centrale, and, diverging thence, escapes into space again. I allude to all rays that the choroids do not decompose. Taking this for granted, may it not be that a pencil of these rays,—as they are called,—issuing from this central hole, will encounter another pencil of rays that is advancing to the cornea from an object at a certain angle? May not the two pencils meet at an intermediate point, and thus neutralize each other?

This takes place with two musical sounds, two waves, and, in fact, with two pencils of rays, as has been frequently proved. Now, by this decomposition of light at a certain point, it must prevent any image from being formed of that object from which the external rays emanated. It not only prevents the formation of spectra or images, but of light itself!

Sir David Brewster, when speaking of the phenomena, observes: "That though the base of the optic nerve is unfit to give distinct vision of those objects whose images fall upon it, yet that it is not insensible to light." This he will find is a hasty conclusion; for, in pursuing the discovery still further, I found that within the whole range of that angle, from the point on the eye where light is *annihilated to the base of the angle, as far as vision extends, no ray of light falls, and, of course, no spectrum or image can appear!*

At the distance of two hundred feet, an object of twenty feet diameter is entirely hidden in what I have called the *dark angle* of the eye, and so on in proportion. All the experiments hitherto made in this discovery of M. Mariotte, have been with wafers or other small objects; I have tried the extent of this angle, and find that its base comprehends more than the diameter of the sun!

Sir David Brewster will find, on further examination, that this law of interference takes place though the *base* of the *dark angle* may be 90,000,000 of miles, provided the length of distance is proportionate. If he had placed a bright lamp at the distance of forty or fifty feet, he would have found that it would be lost in the dark angle. In figure 2, A is the point of the dark angle, (for so I think it should be called,) B C is the base of an object entirely hidden from the eye. It follows, that if two lines are drawn from the two extremities of the diameter of this base, B C, and meet at a point on the cornea, every object that lies within this dark angle, or between these two lines will be entirely lost to vision, whether it be twenty feet or 90,000,000 of miles. When we take into consideration that each eye has this peculiarity attached to it, we can easily imagine how much of the distinctness of the landscape is lost to our sight, and to a person with *one* eye how much is altogether lost. It must be recollected, too, that it is not at the *base* alone at which objects disappear, but in the whole extent of the angle down to the very point on the eye.

When the night is dark, if we look *with one eye* at a bright street lamp which is about thirty feet from us, and then turn the eye slowly from it in a direction towards the nose, the central part of the flame will disappear, but a mass of indistinct, pale light, will still remain perceptible. If we move about ten or twelve feet further from the lamp, and then look at it with *one* eye as before, the whole flame will not only disappear, but every ray of light will be suddenly extinguished. The reason of this is obvious: the dark angle in every case is of certain known dimensions, decreasing till its point touches the cornea.

This being the fact, it follows that at the distance of thirty feet, part of the light of the lamp will fall outside of the limits of the dark angle: thus, in fig. 2, A, B, C, are the limits of the dark angle, and D, E, F, are three distances at which the lamp is seen. When at

D, which we will suppose is thirty feet, some of the rays will fall *outside* of the limits, and it is those rays that we see. It was by placing the candle or lamp in the situation of D that Sir David Brewster inferred that the dark angle was *not* insensible to light. I pursued the length of the angle, and found that within its limits no visual objects are represented; and *light* being an object of sight, becomes extinct equally with the rest.

That this break in vision is not perceptible to the mind, arises from this circumstance: that although all within that dark angle is lost to the vision of one eye, yet it is seen, externally, by the other. On looking steadily at the knob of a folding-door, or at any central object, if we place two square or circular pieces of paper, or two candles, at equal distances from the knob or central object, they will be lost to vision, successively, as the right or left eye is shut. If the left eye is shut, then the right hand paper or candle will disappear from the sight of the right eye; but on opening the left eye, the objects will again be perceptible, because the rays now fall on this eye, which conveys the image to the mind. The right eye conveys no image whatever of those objects that fall within the dark angle. So, in like manner, the left hand candle is lost to the vision of the left eye when the right eye is shut, but on opening it, then the image is conveyed to the mind by this eye.

It is for some wise and benevolent purpose that there is this dark angle in each eye; perhaps if no interference took place between the entering and departing rays, the perpetual and brilliant rays from transparent and radiating objects would soon destroy vision. As it is *now* ordered, there is a certain dimness or indistinctness, which prevents our seeing every point of the field of view. Perhaps, also, this dimness, if it did not take place, the multiplicity of rays would prevent our seeing with clearness the particular object on which the eye rests at that spot called the point of distinct vision. The fact, however, is certain, that there is this dark angle in each eye, and the consequence is, that every part of the field of view is not seen at a glance *by both eyes at the same time*, either by direct or indirect vision. It is entirely owing to the extreme mobility of the eye, that this defect in vision,—if we dare call it a defect,—is not perceived.

If it were true, as M. Mariotte supposes, that the *base* of the optic nerve is insensible to distinct vision, then the same insensibility must extend to the whole expansion or retina, for the *membrane* which covers the base of the optic nerve, is but a continuance of the membrane which completely lines the inner surface of the retina. If this important part of the membrane is impervious to light, then surely the effect of its opacity or insensibility would be to cut off all luminous communication between the more distant part of the membrane and the base of the optic nerve. The whole expansion and the membrane might as well be opaque as this one spot; for, according to the received opinions, the optic nerve is the only medium by which the image of external things could be presented to the sensorium. Neither light nor obstructions, or shade, could be communicated to the optic nerve if the very entering point were insensible, let the seat of vision be where it may.

Light falls on the retina whenever the eye is exposed to its influence, and when it converges to the foramen centrale it is *not* for the purpose of forming an image which the *mind* is to recognize; but, simply, that it may find an easy exit from this spot. When it reaches this focus, it may be called *spent* light, and, as such, it leaves the eye exactly after the manner that it entered. The first touch of light on the cornea gives impulse to the whole of the internal apparatus of the eye-ball as far as the optic nerve is concerned. To say that the retina is the seat of vision in this sense, may be correct, but, instead of calling it the *seat*, it should be called the main-spring of vision. If I depress the spring of a repeater, this spring, on the same principle, might be called the seat of sound and time; yet neither the sound which it excites, nor the time that it indicates, belongs to the elasticity of the spring; nor is either sound or time first made perceptible on the spring; it is no more the seat of time or sound, than the main spring of the eye, called the optic nerve, and its expansion, is the seat of vision.

But, although light is the cause of our perception of external objects, yet I do not contend that the particles of light, themselves, as *luminous* particles, reach the internal organs of vision, and illuminate the spectre there, or *produce* spectra there. When light has effected the *contraction* of the pupil, the ciliary processes, and the external muscles as well as the retina, —by which contraction the lens is either made to advance or recede,—it has performed the part assigned it, and then makes its escape as quickly as possible, to give room to other entering particles. Light, in the character of *luminousness*, acts only upon the apparatus of the *eye-ball*; but that quality of light which we call *luminousness* is useless to the optic nerve, for *this nerve is a non-conductor of light*; we must therefore refer to some other mode by which the continuance of the motion to the very internal extremity of the nerve is effected. Certain it is, that whatever power sets light free in the first instance, is still in force when internal spectra are to be illuminated; and although light, in its free or perceptible state,—which, as I have observed, is *luminousness*,—cannot be transmitted through the nerve, yet the very motion that it gives to the nerve may set light free again internally.

Luminous particles, inasmuch as they are luminous, cannot find their way through the opaque matter of the optic nerve for more reasons than those I have mentioned. Even if they were not thrown off from the eye when they converged to the foramen centrale, even if they were not absorbed by the black pigment, there is a very substantial reason for their not entering or passing through the optic nerve to the sensorium. *The optic nerves are both very much curved*, and the curve is of such a nature as that light could not be bent or refracted through more than one inch of the tube. The agent that sets light free in the first instance, continues in operation throughout, and is always in action, whether in the broad expanse of the universe or in the dark confines of the brain. When this peculiar power is discovered,—as surely it will be,—we shall only the more admire the wonderful simplicity and beauty of the whole apparatus of vision.

That we do not see this power as we do the effects which it produces, is no proof against its existence. If we hold a skein of silk in our hand—cut in certain lengths—we shall perceive that some *latent* invisible power has caused every fibre to diverge, particularly in winter, when the *principle of cold* is more active. If we suppose that the internal extremity of the optic nerve is composed of delicate fibres, lying inert through and around the ganglion or seat of vision, there can be no difficulty in conceiving that these fibres may be acted upon exactly like the fibres of the skein of silk. I do not insinuate that the *same* power stimulates the nerve of the eye and the fibres of the silk—*luminousness*—has nothing to do with the divergence of the latter, for the threads of silk fly off from a centre when in the dark.

We perceive, therefore, that the luminous particles of light need not follow the optic nerve throughout its course to the interior ; for when luminousness is wanted there, the very slightest of all pressures that the fibrous terminations can make is sufficient to disengage light. If the fibrous extremities of the optic nerve, like the fibres of silk, have apparent motion, there must be some cause to produce it ; and, weak though this cause may be compared to our notions of force and power, yet it is quite sufficient to excite correspondent action in an apparatus quite as delicate as the force employed. The fibres of down, when compelled to meet, resist each other in the same proportion as two battering rams would do of two hundred tons power each.

Sight, or vision, is only a mental perception of certain spectra ; it is only a mental perception of certain images or spectra impressed on the external organs of sight called the eye-ball. How is the configuration of spectra or images obtained but by the different densities of the various rays of light converging externally from every point of the visual angle to the cornea? How do we imagine that the percipient acquires a knowledge of the presence of an external object—only perceived when that object is distinctly or obliquely in the field of view? Why, surely through the instrumentality of the optic nerve, which is acted upon, in the first instance, by light or luminousness, as I have several times observed. And how is it that the object is again perceived when we have a desire to recall its form? why, solely through the excitement of the *fibrous terminations* of the optic nerve.

All spectra or images are reproduced in the same way that they were produced, their figures once impressed on the internal organ of vision remain there for ever subject to our *will*. Even if the eye-ball is taken from the socket, the fibrous terminations of the optic nerve are still there, and ready to act if their agency is required, *which is doubtful.* The cutting off of a nerve, externally, does not destroy its internal vitality, for it is well known that when an arm, or leg, or an eye, has been removed by amputation, that a sensation similar to what was felt in the extremities of these parts is experienced by us. The *terminations* of all the nerves are generally in full activity, even when separated from the external parts; and this is fully accounted for when we recollect that every nerve is composed of interrupted vesicles; so that those parts left on the internal organ can exist independently of the other.

I must again observe—for this is a point that cannot be too often brought before us—that as it respects the imagery or spectra impressed on the internal ganglion of vision, the same power which is employed to elicit the luminousness of light in the first instance, can apportion its energies to small as well as great objects. It can set free, in the form of lightning, a mass of light which shall rend the highest mountains; and it can set free a quantity just sufficient to illuminate that something —that nameless something in the brain—which gives intimation of the presence of external objects; and by the same means it can re-illumine the same spot, so that the *images* of things external can be brought again to our mental sight.

That light can be set free without immediate contact with external or visible rays, is well known, not only by chemical experiment, when no light is perceptible, but by the slightest mechanical friction or pressure. Light—or luminousness, is luminousness in the true sense of the word, whether philosophers choose to call it solar, electric, or phosphoric. The light from the sun, from a candle, from fire, from the glow-worm, from rotten wood and putrescent substances, from marine animalcules, from the lampyrus, from spontaneous combustion, from our own eye when pressed or rubbed, are all one and the same thing. It is luminousness *per se*, that we contemplate in all these varieties, whether the power which elicits it be phosphoric, electric, or galvanic, or comes in straight lines from the sun, as *pure solar light.*

I am fully prepared for the ridicule that will follow this hypothesis, but the facts I produce are strong and worthy of investigation. None will condemn these opinions more strenuously than those who have spent their lives in teaching contrary doctrines, and it is from them that I expect the greatest opposition. But of the facts themselves, those who really search after truth, will have no doubt, for they will make the experiment and judge of their accuracy. When they find how long they have laboured under so gross a delusion as the *inverted image*—how long they have imagined that vision must be effected through other lenses than the cornea and lens of our own eye, when in reality the rays from all external objects come in direct lines to *one* focus, the focus of our own eye, without the intervention of any other lens or field of view—when they find how long they have believed that rays can come in straight lines from that solid nucleus called the sun, when there is a point between our earth and the sun beyond which neither light nor other matter can pass without being arrested and made to revolve—when they recollect all this, they will hesitate about condemning me unheard. They will, at least, grant themselves and me *time* before they pronounce judgment. They will then confess that a new theory of vision must be formed, and that the generation of light—or rather, the setting of light free in the interior of the brain, is a consequence incident to the phenomena disclosed.

Only see what a heavy superstructure was raised on the unsound doctrine of inverted images! Philosophers cut a hole through the coats of the eye-ball, and showed the world the inverted candle! They never stopped to inquire whether the inversion did not arise from the change of angle to which the rays were subjected before they could represent the external images to our eye. They never stopped to say that in ordinary vision the rays come from the object itself to a point on our own eye. They presumed, at once, that vision was effected in this way; and it became necessary to account for so curious a phenomenon, and to reconcile it with our common sense judgment. A theory was formed, which, in less than a quarter of a century, will be more the subject of amazement, ridicule, and merriment, than the one I am now anxious to establish. I should not, however, call these insulated facts and opinions a *theory*. What I offer is not yet a whole; it is not what I intend it to be at some more convenient time. I have only broached a few detached parts of it, just sufficient to the comprehension of the facts themselves.

And what is the present theory of vision adopted by all the most learned in the world? Why, that objects are first presented to our sight in an inverted position, and the following is now the only solution that can be given of this monstrous absurdity. The inverted image being granted, then "the lines of visible direction must, necessarily, cross each other at the centre of visible direction, so that those from the lower part of an image go to the upper part of the object, and those from the upper part of the image, to the lower part of the object; so that an inverted image necessarily produces an erect object!"

No doubt that rays crossing each other must necessarily produce an erect object, but this is presuming that the object is seen upside down, a fact which I deny on proof. Two things in the above curious theory and explanation, we perceive, are taken for granted; the one which I have already mentioned, is, that the external object is first presented in an inverted position, and the other, that the retina is the seat of vision. On pursuing the experiment to its fullest extent, it will be found that the inverted candle can be seen on any other part of the vitreous humour, let the hole be cut small or large. It can be seen when the whole of the vitreous humour lies bare, confined only by its hyaloid membrane or capsule. Of course, in this experiment the whole of the retina is removed, as are the pigmentum nigrum, the choroids, and the sclerotica. No one need question this fact, as the experiment is easily tested, if we use watch crystals when the sclerotic coat is removed. As soon as the three coats are carefully cut off from *one* side, a watch crystal should cover it, and the eye be turned over carefully with the crystal, and then the coats should be carefully and delicately cut from the other side until the vitreous humour lies bare, —only confined by the capsule, or hyaloid membrane, which is to remain on. Of course it will be well understood that this requires the hand of a skilful surgeon, such a one as I had in the commencement of the inquiry.

But, even on the supposition that the retina were the seat of vision, do philosophers suppose that the foramen centrale is the focus of all the foci? When the whole field of view is to be represented at once, just as we now see it, do they say that the point towards which the eye is directed in the landscape is the *only* part that touches the foramen centrale? What, then, becomes of those objects which the oblique rays represent, those rays that comprehend indistinct vision? Do they stretch over an area of which the base of the optic nerve forms a part? In all the diagrams, only one object is represented,—either an arrow or a cross; and of course both the arrow and the cross follow the same curve, of which the eyeball partakes, and stretches beyond the circumference of the base.

According to all the theories on this branch of optics, the rays from an object, however they may be supposed to cross *before* they touch the foramen centrale, diverge when they reach it. They are not supposed to come to a point *first*, but that they diverge there and form the inverted image. All writers agree with Dr. Arnott, in his Elements of Physics, "that a whole printed newspaper can be represented in a space on the *retina* not larger than a finger nail." Now this space must be at least half an inch diameter, and, of course, if the foramen centrale is the focus of all the foci,—and it is, of itself, only one line in diameter,—then the image or landscape must extend around the whole circumference of this focus; and, as the base of the optic nerve is within this radius, the image must extend over it.

The fact cannot be too often repeated, that to see the inverted image,—which is simply a candle or lamp when the animal's eye is used for this experiment,—the three coats of the eye must be removed from the hole. Yet philosophers *will* talk of seeing the inverted candle *on* the retina! If the retina, which is the coat nearest the vitreous humour, is left on the hole, the candle is but dimly seen, sometimes not at all. It becomes absolutely necessary to scrape off, not only the retina and its membrane, *but the very capsule of the vitreous humour*, the very hyaloid membrane itself, if we wish to see the inverted candle clearly.

In a memoir, of which I sent copies to Berlin and Paris, I stated that great care should be taken *not* to scrape off the capsule of the vitreous humour. Not having a correct notion of the anatomical divisions of the eye *at that time*, I took the caution upon trust; but after having had more experience, I found, in reality, that this capsule is removed also, and *that it must have been always scraped off by every one that made the experiment.* It should be recollected, likewise, that it is not this capsule alone that I have scraped away, for the image of the inverted candle was seen after removing the base of the optic nerve and the little transparent spot called the foramen centrale!

Does it not appear to us that if it be on this reticulated membrane, called the *retina*, that refracted rays have converged to their foci, that its powers would be very much impaired when so large a portion of its expansion was abstracted. Those very important and essential parts too, the optic nerve and the foramen centrale! If the retina were necessary to the appearance and rectification of the *inverted* image in our own eye, surely it would be quite as essential to produce an inverted or an erect image in the dead eye; and yet we find that it is *not for this purpose* a necessary appendage to the eye.

The truth is, that the mere transmission of light and *shade*, (for what are images but the obstructions of light,) is as easily accomplished by a lens of glass, or a glass globe of water, as by the whole apparatus of the eye-ball; of which apparatus, by the way, *only the humours are necessary to the transmission of light.* No fact in vision, therefore, particularly one that involves so grave a question, and on which so many points in optical science depends, can be deducible from the simple fact of transmission, perceiving that any transparent medium is capable of eliciting the same phenomenon.

The lens of the camera obscura has no such appendage as a retina; the glass globe of water shows inverted figures on its surface without a retina, the inverted candle on the hole over the vitreous humour does not depend on a retina, nor do I pretend that the erect image which I have discovered depends on the retina. I wish it to be distinctly understood, that the pin and other small objects that I presented to the cornea of the animal's eye, were seen through the media of the cornea, the aqueous humour, the lens, and the viterous humour; and that the inverted image came through these media likewise. When we look at the inverted candle, we find it on the *surface* of the hole; but when we wish to see the erect image, we must look *through* the eye exactly in the direction we have to look if the animal's eye did not intervene.

If I hold a small glass globe of water at a little distance from my eye, and present a pin to the outside or farthest surface of the globe, I shall see the pin exactly in the position that I hold it, provided the pin is held *near* the globe. But if I hold the glass at the same distance as at first, and the pin farther off, then the pin is in a position contrary to that in which I hold it. If we look at the large glass globes of co loured fluids in an apothecary's window when we are *inside* of the shop, we shall see the whole panorama of the street, but all upside down. Look which way we will, whether we stand high or low, *as long as we only look at the surface* the moving figures will all be inverted. But if we look *through* the globes, so that the central rays from a short angle come direct to our own eye, then we shall see the object erect.

The inverted image, therefore, is not the *image* of the external object, but the image of the *image*. At a certain distance a figure appears inverted in a concave mirror, but on approaching nearer it becomes erect. What we first see is an image of the image, and not the image of the external figure. Because the image in the mirror appears inverted in the first instance, it is not to be inferred that we always see objects in that position. The mistake is corrected by our going within the range of an angle that suits our eye, the rays from which represent the figure in an erect position.

With the inverted images that *may* be formed on the foramen centrale, the mind, or seeing principle, has nothing to do. The inverted image that falls there might have been on any other concave surface *not* belonging to the eye. A million of eyes could be so placed as to see the inverted images on the surface of a large glass globe of water, and yet no two of them will see the same rays. Images are formed on any convex and concave surface; and it is owing to the unchangeable laws of light, when passing through a globular transparent medium, that globular surfaces vary the position of their images.

A glass globe of water and the eye of an animal are constructed on the same principle; they are, as it regards the formation of images, exactly alike; and our seeing *inverted* images on *their* surface, is no proof that in real vision, when no lens intervenes, it is so too. If we stand out of doors in front of the apothecary's window, the case is reversed, there is no inverted image there; we see the whole panorama of the street there too, on the same glass globes of water, but the images are erect. In this case the rays from the external object converge to a point on the *surface* of the glass globe, and the straight rays from *that* axis enter the axis of our own eye, and the panorama is erect; for the rays do not have to pass through the water, and thus go through several other refractions as they do when we see them inside of the window.

It is true that objects are seen upside down on the wall opposite to the hole in a window shutter; but if there were no other solution to be given than the one now established, of inverted images, to whom, let me ask, *is* the image upside down? Is it inverted to the man whose back is to the wall, or to the one with his back to the shutter? It is well known that the external landscape or objects which the rays from the hole represent, can be intercepted inside of the room at any point between the hole and the wall opposite. If we stand in the middle of the room, *facing* the hole, with a sheet of white paper in our hand held *horizontally*, we shall receive the rays of light on it, and the picture they represent will not be inverted to us! To be sure, if a person, whose *back* is to the window, is also looking at the picture, it must appear inverted to *him*; and so would any picture, or any object that we might have in our hand.

Now, by thus receiving the rays of light horizontally, we do not alter their course, for it was exactly in that direction that the central rays were going. If there were no obstructions, such as a wall or other upright thing like a screen, the rays would diverge to the extent of their limits, and the *central* pencil of rays would elongate to the same limits also, for the wall is certainly not their boundary. We see the whole length of our shadow on the ground when our back is to the setting sun, and although the feet of the shadow touches our own, yet the head is far distant; that shadow, however, is erect to *our* own vision, though it is reversed to some one else. But if we advance towards the wall of a house, we shall perceive that the head of the shadow is rising up, and when we are near the wall the whole figure will be seen there and *seen in an erect position, because the wall is a plane surface. If the wall were a double lens, and we stood on the other side of the lens, the shadow would be seen inverted;* but nature does not require that we should have a double lens between us and the external object.

So if we advance towards the wall, having a gum elastic tube with the funnel part in our hand, the point of the tube will run up the wall, and as we advance the funnel will be the lowest part of the tube as it rests on the wall. It was horizontal at first as we approached, but it met with a resisting medium, and it was bent out of its course. Of one thing we are certain, which is, that the central rays from the hole or lens come in straight lines from every object, and these central or *horizontal* rays carry the image or shadow in a *horizontal* direction until they meet with some vertical obstruction. They not only proceed in this direction till they are thus intercepted, but the shadow of the object always enters through the hole in the same way, the *lower* part first—and why,—because they are the shadows of the *shadow* of external bodies, and not the shadows of the bodies themselves.

But although this be true of images formed on screens and walls proceeding from rays that diverge from a small hole—which hole is nothing more than a double convex lens; yet, from all the foregoing facts, we are sure that we do not see external things in that manner. We seize hold of a phenomenon like this of the inverted image, bordering on the marvellous, and overlook those that are natural and simple. For at the very same time that we see the inverted image, we can also see the erect one if we bring the rays of the angle of light from the hole or lens parallel with the axis of our own eye—which is the only way that we see external objects when no lens intervenes; for if we look *through* the hole of the shutter, we shall see all the external objects erect, small though the angle may be.

We often look at our own picture or shadow on the outside or inside of the wall of a house, and then certainly we see ourselves and others in an erect position. It must not be objected that in this case the shadow is thrown on the wall because the rays proceed from a *wide-spreading* self-luminous body, for the same erect shadow proceeds from a small hole in a window shutter provided we are *inside* of the room. Because the interposition of a double lens produces inverted images, is that to say that there must be inverted images when no lens intervenes? We only interpose a bullock's eye, or lenses—for all small holes through which light passes are lenses—for some optical experiment; and unless we *do* interpose these lens, we shall not see inverted images. Even when a lens is placed between our eye and the light, I trust I have satisfactorily proved that the objects are seen erect when the axis of our own eye encounters the small angle of light proceeding from the lens.

It would be quite another consideration if we could not see external objects unless we held a globe of water, or an animal's eye, or other lenses always in our hand; the inference then would be that such a lens was necessary to vision. But when we perceive that it is only when double convex lenses are between our eyes and the object, and that a very small part of the field of view can be thrown on the outer surface of the lens, we must believe that the rays from a self-luminous body, whether direct or reflected, are all that vision requires. I cannot conceive how it has happened that the whole learned world has resorted to the complicated and unphilosophical theory of refractions and divergencies, distinct from, and in addition to, those of our own eye. If we look through a telescope in which there are a certain number of convex and concave lenses, we shall see objects erect; but if two of these lenses be removed, then the objects seen through the remainder will be inverted.

As to the eye of an animal, or a globe of water, it cannot be too often repeated that we can only see a very small part of the landscape at once. An eye, or a globe of water of the size of an eye, only gives us a very limited portion of the field of view, not more than an angle of 2°; a globe of water, having a foot diameter, gives only an angle of 8 or 10°; but our own eye gives us an angle of 90°. This shows that the condition of things is entirely altered; but even when we hold the animal's eye or the inch globe quite close to our own eye, the erect image, or rather the external object that is to give us an erect image, must be held quite close to the globe or animal's eye, or it cannot be seen.

There is still another question to be raised, and that is, where the precise spot is that the rays of light cross each other? It is asserted that the crossing of the rays takes place in the centre of a lens, and in the centre of the hole in the window shutter. But if this be the case, how does it happen that we cannot see an object that is close to the front of the hole, or close to the back part of the hole outside of the window shutter? If a pin be fastened to the front of the hole in a shutter so that the head shall not rise higher than the middle of the hole—see P in figure 17—there will be no representation of the pin either on the wall, or on the horizontal paper which we hold in our hand to receive the rays. But if we move the pin from the hole, and present it to the rays at the distance of four or five inches from the hole, within the room, it will then cast a shadow on the horizontal paper and on the wall. But in this case the pin will be erect on the wall, and inverted to the person who receives its shadow on the horizontal paper. At a certain distance from the hole in the shutter a different angle of light presents itself, the light then comes under another law, the rays proceed as from a self-luminous body, and *rays from a self-luminous body always throw erect shadows on a plane wall or screen.*

If we fasten the pin *outside* of the hole in the same way as before, it will not throw a shadow on the wall within the room, as the other objects do that are farther removed from the hole. But if we place the pin a foot or two from the hole, it will be represented. When the pin is fastened to the hole, as in figure 17, we can see it with the naked eye; and if we cover the hole with fine letter paper, we shall still see it, and see it erect too; but it will not cast a shadow on the paper if the paper is removed a few inches from the pin, although the shadows of external objects fall on the paper. When the pin is removed from the hole about a foot within the room, it will be represented on the horizontal paper along with the other shadows that come from without the hole, but they will be erect to us while the pin will be inverted—it will be inverted horizontally, and erect on the wall.

If the rays crossed each other in the centre of every lens, as is asserted, then the pin in both situations would come between the angles and be represented. In figure 17, A is the ascending ray and D the descending ray; they are crossed in the hole of the shutter S S, and fall on the wall W. The pin, therefore, should obstruct the rays either when it is in the converging angle without, or when in the diverging angle within; but as this is not the case, we must infer that the rays cross each other differently. If the hole in the shutter were a double *concave* lens, then the rays would necessarily cross each other as is represented in figure 17; but if all small holes are considered to be double *convex* lenses, then the rays would cross, as all other double convex lenses do; the rays from which act at a little distance, as if proceeding from a self-luminous body.

Were it really true that we saw objects in an inverted position, it might then be said that "rays coming from the bottom of an object go to the top of the wall, and those that come from the top of an object go to the bottom of the wall." This is the case, certainly, when a lens intervenes; but when this fact is asserted of common vision, and of those rays of light that come from a self-luminous body, it is absurd; for such rays cast a shadow on all plane surfaces; and when they touch our eye, the impression they make is productive of an erect image also; for it is only the central rays from an angle adapted to our vision that the perceiving faculty receives impressions.

Objects that are seen erect by us were erect at the moment the rays entered our eye; and when inverted images appear on any surface, whether that surface is a convex lens or a plane, depend upon it the mind will see it inverted; for it was in that position the moment we saw it, and so it will remain. If we look at the inverted image on a large or small glass globe of water, and then close our eyes—*provided the images are of a bright colour*—we shall still see the spectrum of this image inverted. Now, if the inverted image *righted* itself as soon as the light from it entered the eye, we should see no inverted image when our eyes are shut. To make this experiment, it should be recollected that the inverted image on the glass globe or lens must be stationary, *for a moving picture leaves no spectrum after the eye is shut.* We cannot, therefore, agree to the theory of first seeing all things in an inverted position—and that "in virtue of the lines of visible direction, being in all cases perpendicular to the impressed part of the retina, an inverted image necessarily produces an erect one." By referring to No. 12, it will be seen what is meant by not seeing a *spectrum* of the object, if the object is a moving one.

When rays of light come to us by reflection from a glass lens, the erect image there seen is larger, brighter, and more distinct than the inverted one ; but if we interpose the lens between the window and our own eye—in both cases holding the lens at arm's length—we only see the inverted image, and that one is clear and distinct. If we stand between the window and the lens, the inverted image will be on the surface, and the erect one will be deeply seated, apparently at a distance from the glass. I mention all this to show that an intervening lens is not connected with *real* vision.

The moment this inverted image was detected on the surface of the hinder part of the dead eye, there was no rest for the mind until all truth was distorted to account for the phenomenon. Every effort was made to reconcile this newly discovered fact with the actual appearance of objects thus seen. In ordinary vision external things were seen erect, yet here was an image inserted! Now, how this image *righted* itself, so that the mind could see it erect, becomes a serious question, and which the lapse of two centuries has not answered. How could such a question be satisfactorily answered, when the fact itself was questionable? Theory after theory bear witness of the absurdity, and now when the error is detected, who shall be honest enough to acknowledge it?

How true it is that the generality of persons never look through a subject, but content themselves with resting their eye on the surface. When we look *through* a glass globe of water, or the eye of an animal, or any other lens, we see the object erect, either at a greater or less distance according to the convexity of the lens; and yet the rays of light, as in the case of the inverted image, have to pass through media of different refractive and divergent powers. When looking *through* the globe, at whatever point of the surface we may, an image there seen is formed in the brain in the same position that it would take if we saw it through a pane of glass, or through any plane transparent surface; for whether the medium be spherical or plane, *it is only through one single interstice that the point of the whole angle of rays comes to meet the cornea of our own eye!* This fact will be contested, but time and repeated experiment will prove that I am correct. Is it not wonderful that so many of these facts have escaped the attention of those whose interest and desire it must have been to get at the truth.

Light falls in every direction from an object, such as the rainbow, in figure 3, where the rays from the whole arch meet at a point on the cornea, and enter the pupil there. It is at that point that they commence acting as stimulants, for it is not the light on the *whole surface of the cornea* that contracts the pupil and the external muscle, but its action on the *retina and optic nerve*; and the optic nerve being somehow connected *internally* with the external muscles of the eyes, those muscles are stimulated likewise. I now allude to those muscles that turn *both* eyes inwards, as I shall explain in No. 15. The dotted and crossed lines B,B in figure 3, are pencils of rays falling *without* the axis of vision, and therefore do not influence the visual apparatus; consequently they do not impress any image of the rainbow on the internal organs of vision. Millions of such pencils of rays as are seen thus dotted and crossed in figure 3, fall on opaque objects and leave no trace. Millions, too, of such cones or angles of light as C C C in figure 9 touch the cornea ; but as their points all merge in the great point belonging to the great angle from the whole field of view, B, B, B, they leave an impression more or less distinct as they are nearer to us or further from us. Such rays always present erect images.

But again I must observe, that this only refers to external objects as we see them *without* the intervention of a globe of water, or an animal's eye, or any other convex lens—for what are these but lenses ? When a convex lens intervenes, we then observe that the circumstances of the case are very materially altered. Two things are to be added to the points under consideration ; first, the field of view that is presented to the convex surface of the glass globe of water, or to any other lens ; second, the field of view under which our own eye ranges. The intervention of an artificial convex lens, such as those specified, shuts out the field of view appertaining to our own eye, and introduces that which passes before the artificial lens. When no lens obstructs the view, we can see an object distinctly, so as to recognize it at the distance of a mile ; but a large object before a lens is not seen at all. An object of small dimensions merges into shadow, and finally disappears at a foot or two beyond the convex surface of the glass globe of water or the bullock's eye, a fact well known to all. Has this never occurred to any one before?

But although the image of the external object—supposing it to be a pin—disappears at a very short distance, yet it appears again under a different aspect, although when the lens is close to *our* eye, we do not see it again until the lens is held farther off. Rays of light are still issuing from it, and the cones they form must touch the convex surface at some point. As the surface is spherical, all the explanation to be given of the inverted image seen on the hinder part of a bullock's eye, and of all transparent lenses or globes of water, is, that there is a double field of view, the one belonging to our own eye—which is very circumscribed when looking at an intervening artificial globe or eye—and the one belonging to the glass globe or the animal's eye. Only those rays, therefore, that proceed from a very short obtuse angle, enter the axis of our own eye for the purpose of conveying an erect image to us; and these we perceive are obtained by looking *through* the globe when it is close to our own eye. All other rays fall at random, and do not belong to our field of view; the very moment the lens is held a little further from us, the angle under which the object appeared is so altered that it no longer comes under the laws of visible direction. A new angle is presented to the outer and inner surface of the globe or eye, and the image of the *image* of the external object being in an inverted position on these surfaces, we *see* it inverted.

From every new fact that presents itself in this investigation, it is plain that we shall be compelled to discard the present theory of light as far as it regards the entering point of the rays. Instead of converging to the *centre* of the crystalline lens, we shall find that those angles or cones of light, which proceed immediately from an external object, and which are to represent erect images, *converge to the first surface that they touch.* In fact, it will be perceived that these rays of light converge to an inappreciable point the moment they touch the surface of any body, whether concave, convex, or plane ; whether these rays proceed obliquely or direct.

To recapitulate. Inverted images are only formed when convex lenses intervene, and every hole or interstice is a convex lens. They are only the images or spectra of images of such objects as are presented to the exterior surface. From all these experiments and deductions, it *must* be conceded that both the erect and inverted images owe nothing more to the retina than they do to the lens or cornea. In the *dead eye the retina is powerless and useless*—utterly so ; which would not be the case if its reflecting or transmitting medium were the seat of vision. If the long established theory were the correct one, then we might say, that "in virtue of the lines of visible direction being, in all cases, perpendicular to the impressed part of the retina, an inverted image necessarily produces an erect one." The oblique cones B, as represented in figure 3, are impressed on the *convex surface* of the globe of water and on the small hole at the back part of the animal's eye. These cones or angles have been reflected three times from the concave surface of the globe, and thus it is that the image appears inverted. As the subject is so new, and I expect much of opposition, I have been perhaps tediously particular.

It being, I trust, satisfactorily proved that the retina is not essential to the rectification of the inverted image, nor to the production of an erect one, it follows that we are still to seek for an efficient power that shall transmit external intelligence to the sensorium. Whatever this power is, it cannot be doubted that its influence extends to the whole apparatus of vision. Every part of the eye, within and without the ball, contributes its proper share towards conveying through the optic nerve all that the eye-ball receives from an external source.

I infer, therefore, from all the experiments I have made, that the first impression which the cerebral ganglion of vision receives, is on its own pulpy, nervous consistence; and the first perception of the impression of which the *thinking* faculty is conscious, is from this concentrated spot. It is here, and no where else, that the mind perceives the figure of the man cut out of black paper, which Sir David Brewster describes in his Treatise on Optics, chap. 35, on Vision. It is here, in fact, that all spectra rest, whether from a longer or shorter impression; and it is from this very spot that spectra are perceived again—though faintly—when the mind has a desire to recall them.

In the living eye, the power of the retina lies in its elasticity; by this power it transmits to the whole of the optic nerve an impulse which is productive of an impression on the receptacle within the brain; that receptacle to which external intelligence is conveyed. Where this reticulated membrane, or expansion, terminates, has never yet been satisfactorily ascertained; but of this I am certain, that the network *thins* off, as it were, into a fine transparent membrane that is attached to the ciliary processes. Some writers imagined that this coat of the eye continued further, and covered the posterior surface of the crystalline lens. Trusting to their representations, for a time, I took this for granted; but of late, on a careful examination with good glasses, I never could detect the membrane, nor was there any thing perceptible but the capsule of the vitreous humour, and the capsule which surrounds the lens.

As to the lens itself, we perceive that in the case of cataract and other diseases, it is taken out of the eye entirely, and yet vision can be effected by the substitution of a glass lens, externally applied. It is a fact likewise, stated by Wenzel and others, that when the pupil of the eye, by some disease, has contracted so as wholly to exclude light, an artful pupil has been made by removing, or making an opening in, the lower part of the iris! It is asserted, that although vision is not so perfect as when the lens is within the eye and the pupil in its natural place, yet that with good spectacles vision to a certain degree could be restored.

I have questioned several persons from whose eyes the lens had been extracted, and I have attentively examined their eyes, but great as was the benefit they received from the operation, yet all the nicer, finer shades and pleasure of vision were lost for ever; and amongst other deficiencies, vision could not be accommodated to long or short distances. But no one can imagine how difficult it is to come at the truth in such investigations, for there are so few who can describe their own sensations, or who can, in fact, comprehend the exact purport of the questions asked. Even the terms used, simplify them as we may, are new to them; and to understand one another fully, both must be conversant in the science under discussion.

When the lens is taken from the living eye, if the operation has been skilfully performed, the iris will not be much injured, it can still perform part of its labour, which is to assist the pupil in its contraction and expansion. Some pupils retain their power, others remains immoveable; and, of course, the whole transmission of external intelligence devolves on the retina. In this case, if the retina did not contract and dilate, the operation of removing the lens would be useless. But when the whole of the optic nerve is paralyzed, as in complete Gutta serena, then vision is gone entirely. It sometimes happens that the retina alone is relaxed; if this proceeds from some local irritation, relief may be obtained, otherwise the eye is unable to rest long on any object.

In connexion with a knowledge of this disease or weakness of the retina and optic nerve, is a knowledge of the variations of the pupil. To a person of nice observation, the slightest change in the diameter of the pupil can be detected, and it will be perceived that this variation in the diameter takes place when the eyes move from long to short distances. If we hold a pencil about a foot from our eye, making the top parallel with some object a little wider than the pencil, this curious fact can be seen by others and felt by ourselves. If the pupil of our eye is examined whilst we are looking at the top of the pencil, it will be perceived that it is of a certain diameter; and when we cast our eyes beyond the pencil, and look at the object which stands at the distance of ten or twenty feet, it will be perceived that the pupil is very sensibly enlarged. This experiment should be performed in a room with our back to the light, otherwise the rays which fall on the eye prevent the one who is examining the pupil from seeing the contraction and dilation.

This is another proof that the mobility of the pupil is necessary to the change from long to short distances ; and it proves also, that in the disease of cataract, when the lens has not been skilfully removed, the pupil will be unable to contract and dilate ; and, consequently, the change from long to short distances cannot be effected. A person with an immoveable pupil can only see objects far off or near when the glasses of the spectacles are more or less adapted to the peculiarity of the vision.

There can be no doubt that the adjustment of the lens to the different distances, which means an adjustment to the different cones or angles of light, is accomplished by the assistance which the retina gives to the iris, the ciliary processes, and the pupil. all these being attached to the capsule of the crystalline lens, impart to the lens the very limited motion required of it. When it is exactly understood what is meant by the *different distances* to which it is supposed the eye accommodates itself, we shall find how very circumscribed the movement of the lens is. But this motion, slight as it is, cannot be imparted to the spectacles or other lens used externally after the crystalline lens has been extracted, and therefore the head itself must be in constant motion to repair this deficiency. The object of this motion is to bring the different rays of light to the axis of the eye. Still the retina, if it be sound, can perform its part, and assist the whole apparatus of the eye, as well as the external lens, in transmitting to the central organ of vision as much information of what is passing without as the imperfect pupil and the artificial lens permits it to do; for one part of the visual machinery is dependent on the other.

It will be perceived, therefore, that the retina has no such power assigned to it as that of presenting foci to refracted rays. Independently of every other objection, where would the foci be? It cannot be that the different nuclei formed by the intersections of the meshes are considered as the foci. I allude to those little double thicknesses, less transparent than the other parts of the meshes, in consequence of the crossing of the lines at these points. Assuredly these cannot be the foci, for amongst the other disqualifications of these interrupted points, it should be recollected that these intersectional lines of the retina form squares, and squares of an irregular shape, in consequence of the spherical shape of the eye-ball. If the theory be confined to one focus—the foramen centrale—then here is the fact, just made apparent, that the inverted and erect image do not depend on that focus at all, for those images are seen just as plainly when the foramen centrale is entirely removed.

M. Mariette conjectures that the choroids may be the seat of vision, because at the base of the optic nerve within the eye-ball, where there is no choroidal tissue, there is no distinct vision. If we accept of the doctrine of interference as a solution of the phenomenon, then this conjecture has no force. But there is a strong, a much stronger reason for disregarding the hypothesis of the choroids than any thing that can be urged in its favour. By a reference to No. 10 of this memoir, it will be perceived that the whole of the vascular tissue of the choroids, which is external to the true seat of vision, can be perceived by the mind or seeing principle in the way there described. The blood-vessels, and the membranous lining of the choroids, are of no more importance to the transmission of light or imagery than the sclerotic coat itself. This vascular tissue is as much an object of perception, internally, as any external object whatever. In fact, the whole eye-ball is external to the central or internal point of vision, for it is nothing but a telescope to the mind.

Every external object *that obstructs the passage of light*, is an object external to the internal *seeing* faculty. *Would objects ever appear to our mental perception, excepting as they obstruct or interrupt the free passage of light?* Even the opaque and transparent circular spots between the laminæ of the cornea and the lens, are but so many obstructions to light; but for this circumstance we should never see these parts of the eye, as I have proved that they can be seen in No. 9, and elsewhere.

When men of science speak of the seat of vision, they certainly are impressed with the belief, that wherever it may be, there is something conveyed by it to the optic nerve. In the first place we may ask, of what the optic nerve consists? and this is a pertinent question, for the optic nerve is the sole channel of communication. There is a continuance of the sclerotic coat that all must acknowledge, and some pretend that they have detected the choroids and the black pigment; but there is no black pigment, excepting that which is seen *outside* of the optic nerve. I should have given a different account from what I now do, if I had listened to the objections of others and to my former limited experience. Of late I have dissected and examined twenty-five nerves—meaning by nerves, the main tube where it leaves the eyeball until it enters the brain; and certainly there was no black colouring matter in any of these, neither was there any trace of the vascular tissue of the choroids; all the black pigment seen, was attached to a thin membrane distinct from the optic nerve.

The optic nerve has no pretensions to transparency after it leaves the eye-ball, and each coat and humour of the eye has a membrane of its own, the extreme fineness of which causes its apparent transparency; but this is not for the purpose of transmitting rays of light. These membranes or capsules are thicker where resistance is necessary, and thinner at the extremities. They completely envelop the coats and humours; and although they touch each other, yet owing to the oleaginous secretions of the eye, they never adhere. There is much yet to learn about the optic nerve and its connexion with the eye-ball—only think of being still undecided about the vanishing point of the retina.

The intelligence of what passes without is therefore conveyed by the optic nerve—not by the sclerotic coat, which is only the sheath or case—nor by the choroids, for neither this tissue nor its membrane are continued through this tube. Still less do the humours transmit any thing to the interior, for they are confined to their own proper sack or capsules; nor do the blood-vessels of the retina perform this part, for we know where they enter the tube and where they terminate within the eye-ball.

If light, *as luminousness*, were transmitted to the visual organ within the brain, there is only one way by which it could pass, which way is through the base of the optic nerve, within the eye-ball and adjoining the foramen centrale. What, again let me ask, do we suppose the nature of the intelligence to be? Certainly an image; of this there is no question. Whatever the optic nerve imparts to the seeing faculty of the mind, can only be the *image* of an eternal object. But the image must be composed of something—for instance—it must, for two of its parts be composed of *light* and shade. Now how is light and shade to be transmitted through the optic nerve to the sensorium when it is opaque itself, and when the entering point (the base) is covered by an opaque membrane, which any one can see that chooses to make the experiment. M. Mariette's discovery of what I call *the dark angle*, has given rise to the conjecture that only a *certain* part of this base is impervious, or insensible to light; whereas the whole is insensible and opaque. The truth is, that light, *as luminousness*, never passes the base, or the periphery of the base, at all.

It follows from this view of the question, that the *dark angle* does not originate in the insensibility of the base, or any part of the periphery of the base, of the optic nerve; for this base is composed of a material that cannot convey luminous particles; there is, therefore, a physical impossibility that this should be the case, and there is likewise a physical impossibility that the choroids should be the seat of vision, for nothing can act where it is not; and certainly there is no trace of the choroids at the base or throughout any part of the optic nerve.

As a transmitting medium, it is as much out of the question as the retina. I have placed the subject in every variety of form, that it may not be subject to misapprehension.

Sir David Brewster states, that according to Bernouilli the part of the optic nerve insensible to distinct impressions, occupies about the seventh part of the diameter of the eye, or the eighth of an inch, which is an appreciable quantity. M. Le Cat comes nearer the truth; he estimates the space to be about the one third or the one fourth *of a line*; but the fact is, the space is inappreciable. The dark angle terminates in a very severe point. I made a black dot of this size ● on a slip of white paper, and it was not lost in the dark angle when at the distance of two inches from the cornea!

Before I conclude this part of the subject, let me ask again, what it is that is impressed on the central focus of vision within the brain after it has passed through the optic nerve, for through the nerve it must come. It could be nothing but light in any event, even if the vesicles of which the nerve is composed were so constructed as to permit light to pass. It could be nothing but *coloured* light; and surely, on a view of the physical capacities of the optic nerve, no philosopher can for a moment believe that this coloured light passes through the nerve itself. But as it is an illuminated image; as all external objects appear to be arranged in different colours; it necessarily follows that the actual *luminousness* and *colouring* of light is *first* elicited at the *interior* extremity of the optic nerve. Light and colour are there set free again by the slight contractions and pressure of the fibrous terminations of the optic nerve.

The inverted image of the schools, and the erect one which I have recently discovered, are therefore phenomena incident to all spherical and convex surfaces, which are either transparent in themselves or contain transparent fluids. Neither the inverted nor erect figure are decisive, if the true mode of seeing further than that we *can* see an erect figure on them, and that this erect figure being in all cases seen when the rays from a short angle are parallel to the axis of our own eye, ensures a probability that we see objects erect at once. We are therefore warranted, from these premises, to believe that the luminousness and colouring of light is first generated, or made perceptible to the seeing faculty, at the interior termination of the optic nerve.

That the result of all these experiments, and those which are to follow, will be to overthrow some of the long-established theories of that branch of optics which relates to vision, there can be no doubt; that there will be great unwillingness to concede any thing contrary to the received opinions of the generation of light, is to be expected; for it is a hard thing to give up theories on which so much of reputation is founded. The truth, however, will ultimately prevail, although many years must elapse before prejudices can be overcome. I trust, however, that the optic nerve, and its final termination in the brain, will now become a subject of deep interest; and that with the aid of good glasses the true seat of vision, and the exact situation of the point of the dark angle, will no longer remain doubtful. Will not Mr. George Combe set the inquiry on foot?

I have made a very curious discovery with respect to prisms and the coloured fringes of transparent bodies, but I must wait till the foregoing hints and facts have made an impression; for unless they are fully comprehended, what I have further to disclose will be useless.

Too little attention has been paid to the investigation of natural phenomena. When certain formula have been established, both the professors and students of universities square all their labours and opinions by these rules, and science does not advance. If any one whose views have been less circumscribed, chance to discover a new principle, which explains some points in natural science more philosophically than the established one, all the learned societies rise up in opposition; and by ridicule or sarcasm prevent its progress. The true theory of the circulation of the blood, when it first made its appearance, was at once rejected; and, in short, nothing but a mathematical problem was ever received and adopted when first ushered in the world. Time will do that for me which it has done for others, and it is therefore to another century that I must address myself.

No. 2.—If we look at the clear sky through a pin hole in a card, directing the eye merely to the pin hole itself and not to the landscape beyond it, we shall see the aqueous humour of the anterior chamber of the eye, with a number of air bubbles floating in it. The air bubbles in the fluid next to the crystalline lens can be distinguished from those nearest the cornea by their greater transparency. The fluid thus seen only occupies the space or area of the pupil, through the opening of which it is seen. The circumference of the pupil is accurately defined, although its contracting and expanding motion is not so plainly visible as in No. 5, No. 7, and No. 9.

No. 3.—On looking through the same pin hole—or rather through a pin hole that suits the eye, for the same sized hole does not suit every eye—we shall see the oblong drops of the viscid fluid that lubricates the conjunctiva. They roll down outside of the cornea, and appear by sun-light demi-transparent, being very different in size and shape from the air bubbles mentioned in No. 2. They are seen in conjunction with the air bubbles, but persons unaccustomed to these experiments had better attend to one object at a time; and for that reason I have mentioned them apart.

No. 4.—Make several sized pin holes, and look through them alternately until one is observed to show the spectra in the eye more plainly than the rest. If a person, subject to that curious disease of the eye caused by the movements of little black specks, will look through one of these holes—bringing the card closely to the eye—their nature and shape will be known. They are called by medical writers muscæ volitantes, and hitherto have been supposed to originate in a diseased state of the retina, which in a short time would produce amaurosis. But that these flying moats are neither the cause nor consequence of that disease, can be plainly ascertained by looking at them through the pin holes.

They can exist in the fluids of the eye to a great extent without endangering or distressing vision in any other way than by casting their dark shadows on white surfaces.

Dr. Abercrombie, in his "Inquiries concerning the Intellectual Powers of Man," calls these *real* objects false perceptions, and Mr. M'Kenzie calls them "false visual sensations;" which is an excusable error, as until now they have never actually been seen but as shadows in the air or on paper. I discovered their character and texture in the way above described, having had two little bunches of them in my right eye for many years. They are as real, as tangible, and as much objects of sight, as any other thing external to the eye; for these muscæ volitantes have substance and form.

Their connected appearance in the fluids of the anterior chamber and in the liquor Morgagni, between the lens and its capsule—for I am certain that they float between those membranes and in the aqueous humour—is owing to an unusual degree of viscidity in the fluid. This viscidity causes these air bubbles, for they are nothing more or less, to adhere closely to one another whenever they come in contact. It is only when they form themselves into a little knot, or bunch, that they appear as dark spots flitting before the eye, and giving the impression that they are outside of the eye. These little opaque objects are of different shapes, sometimes round and of the size of a pea, and frequently two of these large bunches are connected. They appear to be floating in the air, and to fall on every white substance on which the eye rests. It is the cause of great uneasiness to those who are troubled with them, from the apprehension that they will become blind, particularly since these flying specks were attributed to a diseased retina. These obstructions, in reality, only proceed from some derangement in the secretory ducts, and with a reference to this hint a cure might be attempted. When the fluids are completely filled with these viscid bubbles, a slight opening might be made in the cornea, which would relieve the anterior chamber of this viscid mass, and the reaction from change of regimen would purify the fluids. I mention this with all diffidence.

It is the want of transparency, when in their connected form, that causes them to appear as obstructions, and this opacity is owing to their axes not being parallel. When they float about singly, or in the form of a string of beads—a phenomenon which every eye exhibits, whether diseased or not, and which can be ascertained by looking through the pin holes—the want of parallelism in one direction of their axes is not perceived. In different eyes they assume different shapes, and they alter with every motion of the eye. Sometimes they are huddled together irregularly, as in figures 5, darting from side to side, and up and down, either singly or in links, as if they had life, but, in reality, only driven about in the fluid by the quick motion of the eye.

Sometimes the string of beads has a nucleus of bubbles adhering to it, as in figures 6, varying its form whenever the eye-ball moves. It often happens that only one eye is affected by these muscæ volitantes, a fact which can be ascertained by shutting the eyes alternately, and looking through the pin hole.

The experiment by which these air bubbles can be seen, is so simple, that it is surprising no one before this time has discovered the mode of ascertaining of what they were composed. We have only to look through the pin hole in the card, and by moving the eye quickly or slowly either up or down, or from side to side, these air bubbles, with long strings of a smaller size, are seen moving about; and it will be at once ascertained that they are nothing but the common air bubbles seen in all fluids.

In all these experiments with pin holes, we should look through them at the clear sky, without houses or trees to obstruct the sight; and the brighter the sky, the better for the investigation.

Mr. M'Kenzie, in his able treatise on the Diseases of the Eye, observes, that the "muscæ volitantes seldom appear in the optic axis, but are generally to one or other side of it—or above, or below;" but, on examination through the pin hole, it will be found that as they are floating masses of bubbles (not corpuscles), they are not confined to any one part of the fluid, but move over the axis, and dart from side to side, or up and down, just as the eye moves. Mr. M'Kenzie, in common with all the writers on Optics, thinks that the motion which these muscæ volitantes have, is a deception; he expressly states as follows: that "All these motions are merely apparent. In those muscæ, indeed, which present the appearance of globules contained within transparent tubes, there is sometimes perceived a motion which is real, and which is probably that of the blood passing through the vessels of the retina or of the vitreous humour; *but neither these semi-transparent tubes themselves,* nor *any of the filamentous muscæ, or black spots, which are so frequently complained of, possess any real motion independent of the general motion of the eye-ball.* If the cause of the muscæ volitantes, be it in the vitreous humour or in the retina, lies below the optic axis, it will produce an impression as if it were placed above the level of the eye, inducing us to turn our eyes that way, expecting to bring it in the centre of the eye that we may view it more distinctly; and in this case the dark spots fly upwards. Slowly as the eyes descend, the muscæ again come in view. If the cause be placed much above the optic axis, be it above or below, to the right or to the left, it is impossible to gain a deliberate view of the spectrum which it produces. It flies, *as it were*, before us, and as quickly returns again to annoy the eye, equally tired of its presence, and of the ineffectual attempts made to examine it more at leisure. But if the cause be within a few degrees of the optic axis, no difficulty is experienced in obtaining a distinct view of the muscæ."

"*Muscæ volitantes are never seen in the sense that objects out of the eye are seen.* Opaque spots in any part of the eye anterior to the retina, could never produce an image on that membrane sufficiently defined to give rise to such impressions as the generality of muscæ volitantes. Such spots might produce an obscurity in vision by intercepting the rays of light, exactly as specks on the cornea, depositions in the pupil, or incipient cataract does, or as any one may do by holding a piece of wire across and close to his cornea; *but no object within the eye*, (nor indeed without the eye, unless beyond a certain distance from the cornea,) can be brought to a focus on the retina, or produce any other impression than a greater degree of dimness. This, however, is not the kind of impression produced in what we term muscæ volitantes. Even when these appearances are remote from the axis of vision, so that they cannot be dwelt upon, but are only glanced at as if in passing, they are still too much defined to be of the nature of mere shadows or intercepted light.

"I by no means deny that the branches of the arteria centralis retinæ, which ramify through the hyaloid membrane and end on the posterior hemisphere of the crystalline capsule, are capable of becoming varicose; that opaque depositions may take place in the lens; or opaque corpuscles float in the aqueous humour; but as these cannot cause muscæ volitantes, this disease must be referred either to the retina itself, including, of course, the three laminæ of which it is composed, or to the choroid. The probability is that the semi-transparent muscæ of tabular form are owing to a dilatation of the branches of the arteria centralis retinæ; and that the dark muscæ are the effect of certain portions of the retina having become altogether insensible to light, either from the pressure of some irregular projecting point or points of the choroid, or from some other cause. We can conceive the nervous layer of the retina to be in one, or in many minute portions of its extent, so altered by disease, or so pressed upon by the neighbouring parts in a morbid state, as to be no longer stimulated by light at the parts affected, each of which will necessarily give rise to the sensation of a muscæ volitans. Blood effused either by the vessels of the retina or those of the choroid, is a likely cause of partial insensibility of the retina, and consequently of muscæ volitantes."

I have given the whole of the remarks of this author to show the opinion that prevails of this disease called muscæ volitantes, and now that I have proved them to be real, tangible bodies, as far as air bubbles can be called tangible, we cannot but wonder at the suggestions and conjectures in which this author has indulged. When we have no experience to account for a phenomenon, we must resort to such conjectures; but how strange they appear when the real cause is made manifest by experiment.

The eye can be fixed at a certain point or on a particular spot when looking through the pin hole in the card, and we shall then see the air bubbles falling down slowly to the bottom, where they remain till the eye moves, when they float again. As to their opacity, it is entirely owing to the want of parallelism in their axes ; for they are huddled together in a bunch, sometimes by themselves as in figure 6, and sometimes they are attached to a long string of bubbles as in figure 5. Muscæ volitantes *may* accompany amaurosis, but they are neither the precursors nor the necessary appendages of this disease.

The transparent tubes of which Mr. M'Kenzie speaks, are merely elongated filaments of the viscid secretions that the fluids contain. They are precisely of the nature of viscid saliva, the particles of which adhere so closely as to form a long filament, which every one can see by placing a drop of saliva between the thumb and finger, and then opening them slowly. It is to this filament that the air bubbles adhere, changing their form every instant. The liquor Morgagni is likewise viciated in this way, all of which will be perceptible to us as we proceed in the investigation.

No. 5.—When sitting by the candle at night, dip the end of the middle finger in clear water, and rest the hand in such a way as that the drop of water shall be near the centre of the eye, and so close to the eye-lash as just to clear it. Turn the head from the candle, or lower the head far enough to lose sight of the flame, and then cast the eye on the drop of water. The *oblique* rays of light from the candle will illuminate the drop, and display to our vision the whole of that portion of the cornea which comes within the circumference of the pupil. If the other hand is held up behind the drop of water, the image of the cornea will be more plainly seen. By varying the position of the middle finger—moving the drop farther off or closer to the eye—the object will be more or less magnified, and the fixed spots between the laminæ of the cornea and lens will be more or less distinct. The rim of the pupil will be seen contracting and expanding, showing in most instances a villous edge, the filaments of which stand off at right angles to the periphery of the pupil—as seen in figure 7—and appear to rest in the fluid. The viscidity of the fluid is in this experiment and that of No. 6 very perceptible; for if we close the eyelids together slowly, and then open them, looking at the drop of water, a ridge, or gathering of the fluid in one line, is plainly seen for a second or two before it gravitates.

Whilst looking steadily at this drop, if we cast the eyes down towards our bosom *without bending or moving the head*, and then raise the eye again, looking at the drop of water as before, we shall see the fluid that lubricates the conjunctiva, the fluid of the aqueous chamber, and the fluid between the lens and its capsule, in quick motion. When the eye thus falls down and is raised again to the drop, the dimmest air bubbles will be seen to rise first; and when at the top, they will fall again, part over the lower edge of the pupil or iris, and part over the lens. The bubbles in the liquor Morgagni are brighter and larger than the others, rising up on the front side and falling over behind, in the forms of strings of beads or loose air bubbles of a large size. When a person becomes accustomed to experiments of this kind, all that I have described will appear in order; whilst to a beginner all the minutiæ will be lost. The act of holding the hand steady whilst viewing the motion of the air bubbles, will be soon acquired.

No. 6.—The same phenomenon may be observed by looking through the interstices of a piece of coarse black muslin *folded double.* When the sun shines brightly, if we hold this small piece of double black muslin close to the eye, directing it to the window, every one of the interstices will become a good lens; and, what is very extraordinary, they will show all the phenomena described in No. 5, with the addition of a much clearer view of the fluids as they rise. The muslin should not be too thick, but experience will guide us as to the proper quality of the muslin. By moving it along the eye, it will be perceived that some of the interstices present better lenses than others. This is a beautiful experiment.

No. 7.—Make a hole, of the size of one of the balls C, in figure 9, or one of a little larger size will do, either in a piece of thick paste-board or thin wood, such as is used for veneering, and pass the tongue over the hole so that an air bubble of saliva shall fill it up. On looking through this hole at a bright candle at night, *all* the fluids of the eye can be seen, and with some eyes even better than in the other experiments; and when the eye moves, the different fluids are set in motion as before. It is here, too, that the rim of the pupil can be seen in the most perfect manner contracting and expanding. Whilst looking at this spectrum, if we open the eye that is closed, the pupil of the other eye will contract suddenly, so as to be compressed one third. As I have proved elsewhere that the light which enters one eye cannot pass through the optic nerve of the other eye, the contraction of that pupil, which is directed to the spectrum in the hole, must be attributed to some other cause.

I threw a strong light on the eye of a person who had an immoveable pupil, but I could not perceive that it contracted; that is, it did not contract in the ordinary way, neither did it give pain; but when I threw the same light on the other pupil, which was a healthy one, there was a perceptible motion in both. I perceived that the motion in the diseased eye was of a different kind from the other. It appeared like a *sinking* or depression of one side of the iris, a tremulous motion rather than a contraction. I cannot but infer from this, that though nothing can pass from one optic nerve to another, yet that there may be contact between them by some cerebral ligament, which is connected with the muscles and blood vessels of the eye. If the light thrown on the sound pupil depresses the ligament at the base of the optic nerves which rest on the cerebral mass, then a depression of the lens and retina of both eyes may take place, and produce all the motion that I have described. In addition to this motion, there may be the contracting one in the pupil of the *sound* eye, such as always takes place when light falls on it suddenly. As to the question of the assistance of the external muscles of the eye, all my experience leads to the conclusion, that although they do not act on the cornea so as to depress it, they are connected in such a manner with the blood vessels and other ligaments of the eye at the internal cerebral point of vision, as to influence their movements at the extremities within the eye-ball.

When the air bubble of saliva covers the hole in the thin piece of wood, and one eye is shut whilst we are looking with the other at a bright candle, we shall perceive that the pupil contracts, and expands, as we advance and recede from the light ; but the variation is not so great as when the other eye opens. At the instant the eye opens, the pupil of the one that has been directed to the hole, will suddenly contract ; but it recovers its former dimensions instantly, although the eye that was first closed still remains open. Now, if it were true that the light which falls on the newly opened eye entered the base of the optic nerve of the other eye, then the pupil would remain contracted; for the light being of the same intensity, would fall on both eyes constantly, and the pupils in both eyes having attained their maximum, would remain of the same diameter.

It follows, therefore, that the *light* which falls on the eye just opened, does not enter the base of the optic nerve of the other eye, and cause the pupil to contract by passing up the nerve, and acting on the retina and iris.

All that we know of light proves that in no event can it be so bent or modified as to pass through the curve of one optic nerve, enter a connecting section of the two nerves, and then pass up the other nerve till it reaches the pupil of the eye that did not receive the impression. I have ventured at one solution of the phenomenon, but there is still another, which may, perhaps, be more satisfactory.

It was Mr. M'Kenzie's observation on an immoveable pupil which led me to make the experiment that he describes. On throwing the light of a concave mirror on the immoveable pupil, it did not contract, but a tremor of the eye-ball, and a wavy motion of the iris took place, which was only, however, of momentary duration. When I threw the light on both eyes, then the pupil of the sound eye contracted to half of its ordinary size; and the pupil of the diseased eye, as far as a momentary glance allowed me to see it, likewise contracted; but it appeared of an oblong form. I made the experiments on this person's eyes twice, but could not prevail on him to allow me to repeat them. The first time I was intent on the variation of the pupil, and the second time I observed that when the light fell on both eyes, *they were both turned inwards towards the nose*, the unsound eye not quite so much so as the sound one.

We know that both eyes see better than one, and by referring to No. 14, it will be perceived that I have ventured on a solution of the phenomenon. To produce a double intensity of light and shade on the cerebral organ of vision, it is necessary to draw the axis of the two corneas nearer together, so that the centre of the luminous or other external object shall enter the axis of each eye. It may be that the open eye which is looking through the hole in the pasteboard or thin wood, as described in No. 7, is contracted to the size that is apparent to us by the light which it receives from its own apparatus; but that when the other eye opens, and the light falls on it likewise, then both the eye-balls turn towards the nose, and a double quantity of light falls on the cerebral organ of vision, and the diminution of the diameter of each pupil is produced by the contraction of its own cerebral apparatus.

No. 8.—Touch the tongue to the outside of the upper part of the rim of a pair of spectacles, so that an air bubble, or one small drop of the saliva, shall adhere. When the spectacles are on, turn the head a little away from the flame of a candle, and then look at the air bubble. All the fluids of the eye will be seen in motion as the eye moves from side to side, or up and down. In this experiment those eyes that are troubled with the muscæ volitantes can see them plainly. I need not observe that in these experiments one eye must always be kept shut, and in *this* case the eye nearest the candle must be closed.

The rays from the bottom of the candle are the best, as they show the image in a perfectly round form and very distinct. A little practice will enable us to see this spectrum to great advantage, and as it is a beautiful sight, great pains should be taken to observe the directions. Many persons are so awkward in these matters as never to be able to get the light to fall on the air bubbles in the right place, and others are unable to keep one eye shut without holding the lids with the finger.

No. 9.—If we look at a bright spermaceti candle, closing one eye and only admitting a single ray of light in the other, the same image is seen as in numbers 7 and 8. This discovery I made known in Sir David Brewster's magazine. In addition to what was then stated, I have ascertained that the pupil of the eye is not truly circular like a ring, but that it has a wavy outline, as described in figure 7. The rim of this wavy outline is in constant motion, contracting and expanding with every tremor of the lid or turn of the eye, both of which it is difficult to prevent. The brilliant spectacle which this transparent surface exhibits is seldom seen at once by those who first make the experiment, being very difficult to accomplish on account of the extreme sensibility of the eye. No one at first sees the whole surface, for, owing to the tremor of the lid, the rays are let into the pupil by sudden glances, and, of course, only show a small section of the circle, spreading out like a fan or peacock's tail, which the spots and brilliancy makes it greatly resemble.

By degrees, as the eye becomes accustomed to the sight, and is able to remain a second or two in one position, a larger portion of the circle will be seen, until, at length, the whole will appear at a glance, and we shall not only see the fluids rising and falling in the anterior chamber, but in the capsule of the lens. All the fixed spots of different densities and texture between the laminæ of the cornea and lens are more distinctly seen than any thing else. That the fixed spots of the cornea and the lens are seen in conjunction will be plainly discernible to those who are in the habit of making nice and accurate experiments. This is the only case that requires time to see the whole circle. I did not see it fully until I had made a number of attempts; but, having by accident caught a glimpse of the whole figure, I persevered until I was able to keep the eye steady enough to see this figure at pleasure. There is no fear of injuring the eyesight in any of these experiments, I have never known even weak eyes to suffer. Those who have accustomed themselves to observe optical phenomena are never apprehensive of injuring their sight, unless they allow too much light to fall on the eye.

No. 10.—The whole of the vascular tissue of the choroids can be seen by observing the following directions. Make a hole of this size O, in a card, and stand with the *back* to a very bright window when the sun shines, and hold a sheet of white paper in your hand; rest the card on the eyebrow of the open eye, and whilst looking through the hole on the white paper, move the card horizontally—from side to side—without taking it from the eyebrow. In a second or two the whole vascular tissue of the choroids will be seen on the sheet of white paper; that is, they will *appear* to be on the paper, but in reality they are perceived by the thinking principle in the same place where all spectra are seen, as described in No. 1 of this memoir.

Nothing can be more beautifully delineated than these blood vessels as they are called, with all their delicate ramifications and terminations. They are transparent and colourless, no red particles being seen at all, nor does the red colour appear to any eye that has made the experiment. W. G. Horner Esq. in speaking of his discovery of the blood vessels of the retina, does not say whether they were colourless; but as dissection shows them without red blood, I presume he saw them without any red colour.

The nearer the card approaches the eye, so that it does not touch the eyelash, the more the vesicles are magnified, and the greater number of terminating branches will be seen on the paper. But can these vessels, or those called the blood vessels of the retina, be considered blood vessels, when we comprehend by that term something filled with a red fluid? Vessels that only contain a white transparent fluid are merely to replenish the humours.

A short-sighted eye can see these vessels in much greater perfection than one that is long sighted, but it requires a bright day to see them well. There are several ways by which we can see this spectrum, and ingenious persons will soon be able to invent new modes by which they will be still more distinctly seen. If we sit in a dark room when strong rays of light are coming through the hole of a window shutter, and catch the rays obliquely on a small pocket lens, we shall see the vascular tissue of the choroids if we shake the glass as we did the card. In this pocket magnifier we can see the *air bubbles* in the different fluids, but we must have more direct rays on the glass, for this experiment of the bubbles and of course the lens must not be shaken as when we are to see the blood vessels. By putting a thin slip of pale yellow or pink paper behind the hole in the card, and then shaking the card whilst looking at the sun, we shall see the same vessels; but not so distinctly as when the back is to the sun, and we are looking through the open hole on white paper.

At candle-light, if we shake the piece of wood or pasteboard, the hole of which is filled with an air bubble of transparent saliva, as described in No. 7, we shall see this beautiful spectrum of the choroids likewise, and, of course, brilliantly illuminated.

If we pass the tongue over the hole in a spool of cotton, so that a transparent air bubble fills it up, and if we shake the spool whilst looking at the clear sky, the same spectrum can be seen. The spool should be black, and the hole of the same size as those already described. It sometimes happens that a few smaller air bubbles will adhere to the rim of the large bubble, and in these the fluid of the conjunctiva are seen falling down in demi-transparent drops.

The vessels seen when these holes are shaken, are certainly different from those described by Mr. W. G. Horner in the London and Edinburgh Journal of Science. Their configuration is very dissimilar, as will be seen in the neat diagrams which that gentleman has given of them. Here, therefore, are two distinct sets of vessels seen—those that I presume are the vascular tissue of the choroids, and those which Mr. Horner calls the blood vessels of the retina. At first I concluded that the image I saw was the same that Mr. Horner so accurately described, but on close inspection I was compelled to change my opinion, for it is very unlike those in the diagram. On shaking the card vertically, or, in other words, up and down, there is a confusion and blending of the whole figure; it is therefore necessary that the card should be moved horizontally. I have no doubt that we shall soon discover a mode by which we shall see the blood vessels of the conjunctiva; and the time is not far distant when we shall call the vessels that ramify through the vitreous humour by some other name than *blood vessels;* for they carry no blood, but are filled with a thin transparent fluid resembling the vitreous humour itself.

In the centre of the spectrum, seen when the card is moving, there appears in one of my eyes, which is shorter sighted than the other, two round transparent spots, one above the other, rather representing two globules of water than any thing else. In the long-sighted eye this central spot is dim like a shadow, but never appearing double like the globules in the other eye; neither are the terminal ramifications so plainly seen as in the short-sighted eye. This is the case with all eyes that have made the experiment; I allude to eyes having different focal lengths.

As I give the first motion to the card when it is resting on the brow of the long-sighted eye, a section of a vein appears, but only for a second or two, for it vanishes, and does not show itself until I renew the experiment at some other time. It may be a section of the trunk of the blood vessel of the retina; but be it what it may, it seems to have no connexion with any of the vessels then under observation. It is in the lower part of the right eye, near the nose, and is described in figure 8. Several persons have seen this section of a vessel, and always in the right eye.

No. 11.—If we hold up a very small black figure, such as an arrow, or a cross, or a pair of tongs—cut out of black pasteboard—letting it rest on the clear sky, at arm's length from us—or if we look at the window sash with a bright light behind it, *shaking the open eye in all these cases with the thumb and finger at the very instant that we cast our eye on it*—we shall find that when we shut the eye, no spectrum, either of the black figures or of the window sash, is seen! The same absence of spectrum is seen when we wink the eyelids in quick succession whilst looking at the object, or when we shake the head quickly No spectrum is perceptible to the mind when the head, eyelids, or eye-balls, are shaken quickly whilst we are looking at an object that is highly illuminated. Nothing is perceptible but an undefined mass of pale light.

Now, it is well known that if we look at the window sash, or at the black figure, *without* shaking the head, or the eye-lids, or the eye-balls; the spectrum of the sash or of the small black figure—after looking at them attentively when illuminated by a bright light—will be seen, *internally*, as soon as we shut the eye and cover the eyelids, so as to exclude all light. Those phenomena give rise to a curious question. When the card resting on the eyebrow, is shaken—as explained in No. 10—the vascular tissue of the choroids is seen as a spectrum, or as the image of an object external to the seeing principle. In this case the light from the hole in the card cannot subtend an angle of more than a quarter of an inch, for the card is always held closely to the eye. When the angle is of greater dimensions, such as proceeds from a window-sash at the distance of ten or twelve feet, or from the black figure held up against the clear sky, then the shaking process prevents the formation of spectra from objects external to the eye-ball.

From a number of carefully conducted experiments, which I hope to make known at some future time, and all of which have a strong bearing on this agitation of light and density of light, I have discovered that rays of light converge to a point *on the surface* of every object that they touch; see figure 9, where A is the cornea, B B B the angle of light coming from the whole field of view, and C C C the smaller angles coming from objects within the large angle. Instead of converging to the centre of the lens, as in figure 10, which is the received opinion, I find that *the convergence takes place on the surface of every medium capable of admitting or reflecting light.*

There are within the field of view numerous cones or angles of light touching every part of the surface of the cornea, none of which enter the pupil, for they fall without the sphere of vision. But what would not enter one eye may at the same moment of time be parallel with the axis of another. If a million of eyes were looking at the same object, they would find millions of cones to correspond with the axis of each vision. The rays, therefore, which are to give us correct delineations, enter the axis of the eye; go in one straight course through that axis, and give an erect image of the object; whilst those which *cross* this axis—see figure 9, D—present the image upside down, because they undergo three refractions. They touch the cornea, but obliquely, and therefore cross the axis obliquely, and are of no importance to vision, for they are not impressed on the internal organs. Every cone of light, coming from objects that are placed in the field of view, converges to the same point, and enters the pupil in the same direction. Whatever cone or angle of light—such as D D in figure 9—falls *without* this central point or axis, makes no impression on the optic nerve, and therefore imparts nothing to the internal organs of vision.

No. 12.—It is a fact well known, that after looking steadily at an object—and for experiments like these a window-sash with a bright light behind it is the most suitable—if the eyes are then closed and the lids are covered, the image or spectrum of the sash will remain for some time visible to the mind. I have discovered that this spectrum, and in fact all spectra, are situated beyond the eye, and that none are ever formed within the eye-ball.

To ascertain this, let us look at the window-sash when there is a bright light on it, and after fixing the eye there for a minute, shut it, and cover the lid. I am presuming that the other eye is closed, and for beginners it is better in this experiment to tie a handkerchief over one eye, as both hands are wanted for the occasion; for although we may be able to keep one eye shut, yet, as the *lid* must be kept from the light as well as the eye, it had better be bandaged. When the impression has been made on the open eye, and the lid is covered by the hand, the spectrum of the sash will be plainly seen. As soon as it is exactly defined, push the eye-ball about with the thumb and finger, and it will be perceived *that the spectrum of the window-sash does not move at all—it stands perfectly still, although the eye is in violent motion!*

Now this does not proceed from the smallness of the point within the eye, on which it has hitherto been supposed that images are formed, for I shall presently show that it is not within the eye at all. In the article on Optics, in the Library of Useful Knowledge, page 48, it is asserted that these spectra move; but if it be meant that those spectra move which are produced by the experiments I describe, then the writer of that article is in an error. No one who has observed these spectra could perceive the least motion in them whilst the eye was pushed from side to side, either quickly or slowly. When inexperienced persons let the light fall on the closed lid during the examination of the spectrum, whilst the eye is being moved, the fluctuations of light give the appearance of motion to the spectrum, but in reality the spectrum does *not* move.

We cannot, by the most patient attention, perceive that the spectrum moves when the eye-ball is moved by an external effort—such as pushing it from side to side with the thumb and finger; but when we perceive that the spectrum is formed, and the seeing principle is taking cognizance of it, if the *will* prompts the eye-balls to move, then the spectrum follows the motion of the eye-ball. This takes place let the spectrum be what it may, whether an illuminated window-sash, or the figure of a man cut out of black paper, as described by Sir David Brewster in his Treatise on Optics, chapter 35.

It is possible, that in consequence of performing the experiment inaccurately, the spectrum has been made to move even while pushing the eye-ball with the finger; for the *will* may prompt the ball to move at the same moment that we are pushing the eye-ball about. The circular flashes of light are seen in motion when the eye is shaken, and they glance from side to side; but this is different from the spectra of external objects. Even whilst these circular flashes of light are glancing about, the spectra stand still; for they can be seen at the same time. Unfortunately, there are very few persons who can distinguish all the minutiæ of a new experiment; if they do not therefore comprehend the whole at once, they refuse to give any further attention to it, and pronounce it an illusion. But those who persevere, will find in this instance that no external power, shake the eye-ball as we may, can compel the spectrum to move. Yet if the *will* prompts the eye-ball to turn from side to side, then the spectrum follows the movement; but if we prevent the *will* from acting, then the spectrum is motionless.

The motion of the spectrum by an effort of the *will*, is the natural consequence of the position of the internal organ, or ganglion of vision, and its adherence to the muscles and optic nerve. The terminations of the *external* muscles of the eye-ball as well as the optic nerve itself, being attached to this ganglion, or what not, of the true seat of vision—lying in the cerebral space allotted to vision—it follows that the central point, or axis of visible direction, must be parallel throughout. Therefore, which ever way the mind or *will* directs the eye-ball to move, the spectrum must be seen in a line parallel to this axis. Whilst the whole apparatus of vision labours under the same restraint or tension, the axes of the whole line throughout—from the point of the cornea to the centre of the visible direction on the internal nucleus—moves, as it were, on a pivot. But if the tension is removed from part of the machinery, then one portion of it acts independently of the other.

I shall endeavour to explain myself in this way. If we lift a pair of scales which are attached to the counter, holding up one of the scales in each hand, the chains that are fastened to them relax, and do not move the lever or walking beam, to the ends of which the chains are suspended; nor is any part of the apparatus moved by shaking the scales about in our hands. But if we tell the men behind the counter to pull the string, then the pulley, lever, chains, and scales move simultaneously. If we push against the flanks of a horse, as he stands harnessed to a chaise, the hinder feet can be made to move without disturbing the fore feet, or the chaise, or the reins, or the driver. But if the *driver* pull the reins, then the horse, chaise, and all move.

Therefore, if the *will*, like the driver, directs the motion of the muscles of the eye-ball, which are the reins of the eye-ball, then both the external and internal apparatus move. But if we only move the eye-ball by some *external* operation, then the muscles or *reins* of the eye-ball relax. They are thus relieved from tension, and, of course, no motion is imparted to the fibrous expansion at the internal termination of the optic nerve, and in consequence of this relaxation of the muscles, the spectrum does not move.

In figure 1, there is an eye with two of its muscles and optic nerve; I have added an arrow, as I suppose it to be imprinted on the central ganglion of vision by the fibrous terminations of the optic nerve. Now, whilst the two long muscles E and F are in a state of tension, they obey the impulse or direction of the *will;* and as the contraction of the muscle E moves the eye-ball to the right—the line of visible direction being the same—the arrow will be seen in the same axis. When the muscle F contracts, moving the eye through the whole field of view, from B to C and from C to D, the spectrum of the arrow must always be in the same direction. When the eye is pushed about externally, then these long muscles are not called upon to act; they are relieved from duty, as it were, and the spectrum, or arrow A A, remains immoveable.

No. 13.—If we sleep in a dark room till after sunrise, and the window shutter is thrown open suddenly *before the eyes have been opened or rubbed with the fingers*, the whole of the retina can be seen, the retinæ of both eyes appearing as one. On some occasions, when the light thus suddenly thrown on the *closed* lids has been stronger or weaker, the intersectional lines appear nearer together or wider apart. This proves that the retina contracts and expands. On close examination it will be perceived that the aperture of the pupil is simultaneously affected; for when the meshes or crossed lines of the retina are nearer together, the diameter of the pupil is larger; and when they are wider apart, the pupil is smaller. This is another of the many proofs that the retina is not the seat of vision, for at such times it becomes *itself* an image or spectrum to the *seeing* faculty.

I must not omit to observe that these experiments should be often repeated to ensure the above results, for the mind at first, unprepared for the kind of spectrum thus made visible, does not perceive all the peculiarities at once. I did not know that the retina contracted and expanded until the experiment was several times repeated, and then I only saw the fact by itself, not taking the pupil in connexion with it.

If we sit in a dark room at noon, when the sun is very bright, at the zenith, or at three o'clock, and the eyes have been closed for an hour, with a dark covering over the lids, and the shutter is then thrown open suddenly as we remove the cover from the lids, the blaze of light then thrown on the closed lids will produce a beautiful spectacle. Instead of the net-work first described, there will be a brilliant display of coloured squares. The colours are those of the solar spectrum, and sometimes, when there is a transition from these bright colours to dark ones, there will be a bright star in the centre of every square, just as if the light were brought to a focus there.

At one time I imagined these squares to be the interstices of the retina, but the brilliancy of the colours took me so by surprise that I could not, although I saw them a number of times, decide whether they were really the interstices between the meshes of the retina, or whether they belonged to the compartments of the vitreous humour. On reflection, I think they are too distinctly square for the spherical shape of the retina. The meshes of the network never appear in regular squares, nor could they ever show regular squares let them be seen in any position. I am persuaded that the vitreous humour, and *one* other part of the internal apparatus of the eye-ball, have intersectional compartments formed of squares and hexagons. Every one accustomed to close and minute observation, must, at times, under peculiar circumstances, have had glimpses of certain spectral squares and hexagons—a momentary perception of them in the eye. Sometimes a sudden turn of the eye-ball, on removing it from a glare of light to a dark corner, will show a faint tracery of some of the phenomena I mention.

No. 14.*—The whole operation of seeing objects single with two eyes—so long the subject of perplexity—can be seen internally in the following manner. Sit facing a window-sash that is strongly illuminated, *with one eye shut and the lid covered before looking at the sash.* Hold a pen, or ruler, or any thin stick, at arm's length, in such a manner that it shall make a diagonal line across the sash, or across a particular pane of glass—see figure 11. After looking earnestly at the *centre* of the pen or

* I have made a tangible diagram illustrating this phenomenon.

or ruler, shut this eye, which I shall call the right eye, and open the other, which thus far has been kept shut and covered. Shift the pencil or ruler so as to make a diagonal line across the pane or sash, but in a contrary direction—see figure 12—and look earnestly at the sash for the same length of time that the right eye saw it, eight or ten seconds will suffice. Now shut and cover both eyes with the hands, and as soon as the fluctuations of light have subsided, the spectrum of the window-sash will be plainly seen.

With the generality of those eyes that have come under my observation, the window-sash seen by the left eye will flush up first, because, being the last that took the impression, it will be the most vivid. The diagonal line will of course appear as in No. 12. *Remembering to keep the eye shut during the whole experiment*, now uncover the *lid* of the right eye, and let the strong light fall on the *closed* lid. This light will illuminate the *spectrum* of the sash seen by this eye, it will slowly emerge through the other spectrum, and the sash, with its diagonal line, will appear as in figure 11. Cover this eye-lid again, and take the hand from the left eye-lid, and the light which falls on the closed lid will illuminate the spectrum formed by this eye, and it will slowly emerge through the other, which appears to fade away. This spectrum will be crossed, as in figure 12. Keeping the eyes still shut, for on this the success of the experiment depends, remove both hands from the lids. If the light falls strongly on the lids, and they are covered again in a moment, *the sash seen by each eye will be seen, and appear as one*, the spectra lying so accurately one over the other that but one object will be seen, excepting that there will be *two* diagonal lines, and crossed as in figure 13.

It is truly wonderful to see the fluctuations and shadings off of the light and spectrum ; and it is well enough to remark that the impetus given by the optic nerve penetrates beyond the spectrum that is formed by the first eye. For instance, when both eye-lids are covered, if we raise the hand from one lid and then cover it again, we shall perceive that the light has penetrated through the spectrum formed by the other eye, thus bringing forward the spectrum that was formed by the eye whose lid was last uncovered. The light illuminates this spectrum, and then it works up through the other; and whilst this spectrum is still visible, if the other lid is uncovered and then instantly covered again, the light which penetrated through the closed lid will illuminate the spectrum formed by *this* eye, and it will rise up through the other. When the hands are taken from *both* lids, then the two spectra merge into one, and the lines are crossed as in figure 13. The light thrown on one eye-lid never illuminates the spectrum of the other eye.

Now, by illumination I do not mean that light itself (light as luminousness) enters the optic nerve and illuminates the different spectra, for that would be inadmissible. But I believe, that as latent light pervades all space, it can be elicited by friction, pressure, or concussion; which, in fact, are all but different degrees of pressure. Whenever two bodies come together capable of setting light free, the laws of the universe apply equally to them, whether they are masses of air bubbles, or masses of stone and iron. The slightest motion produces light in the fire-fly and glow-worm, and the least pressure renders it perceptible in our own eye; for, cavil as we may about the nature of the light, whether phosphorescent or not, still it is light—luminousness—that we see. I allude to the circular flashes that appear when we press the eye-ball from side to side. Besides this, there is a spontaneous emission of light from the eyes of those persons who use them a great deal at night. After fifty years of age there are many people who see two or three flashes of light darting from the eye at the moment the candle is put out late at night.

In the darkest dungeon where a ray of light has never penetrated, concussion between flint and steel can elicit light, but no one pretends that it is disengaged from the flint and steel, or that it is held in greater abundance in those two substances than in the atmosphere of the dungeon. *Latent* light may pass through some bodies with greater ease, and it is probably owing to this circumstance that it is more readily set free in them when they come in contact. The sudden and violent approximation of the flint and steel may bring up (so to say) the particles of latent light suddenly, and condense them to a focus.

Perhaps it may be the sudden collision of two *gases* that elicits light in this instance as it does in others, and why may not the same operation be going on internally, for it is not *always* necessary to use force in bringing substances together. The disengagement of light, as I have before observed, can be effected by the gentlest of all pressures; if this were not the case, how could there be that constant emission in the glow-worm, a soft pulpy grub, with but little muscularity, moist throughout, and coming nearer in consistency to the material of the brain than any other thing? The eye is filled with fluid secretions, and yet it can disengage light, for luminousness is light, whether it be accompanied with heat or not. Perhaps one reason of our refusing to consider the flashes in our own eyes as light, is, that it emanates from an apparatus filled with fluids. If it can be set free in the eye-ball and in glow-worms, why may it not be set free in the brain by the pressure of the optic nerve? This is not begging the question, for I shall prove in the course of these memoirs that light, as luminousness merely, cannot pass through the tube of the optic nerve to the point of vision in the brain where spectra are formed. That spectra are in the interior of the brain, beyond the eye-ball itself, I have abundantly proved.

The production of light in space is quite as extraordinary as the production of it in so small a space as the cavities under the wings of the lampyrus, and under the convolutions of the glow-worm—and in the slow combustion among the particles of rotten wood, cotton fibre, and oil. Yet it is pardonable to doubt its generation in the cavities of the visual ganglion, because our attention has never been directed to it. As to fluids, we know that light can pass through them with the greatest ease; we see it through heavy showers, through glass globes of water, and under water. A fluid therefore is no objection to the theory, neither is the darkness of the interior of the brain any hindrance—*combustion* cannot be effected in water, but combustion is a distinct thing.

There are not wanting many persons—even those calling themselves philosophers—who will at once condemn these opinions, particularly the one that is to follow, and will also neglect the facts; but this should not deter me from proceeding. I have lived to see the day when the merits of the great inductive system of Lord Bacon have been called in question. But science has advanced so rapidly since that valuable work was given to the world, so many distinguished men have risen to eminence by pursuing the course there laid down, that we cannot stop to give more than a look of surprise at the man—himself a teacher of rules by induction—who thus boldly and gratuitously maintains that the Novum Organum has been of no particular benefit to science.

In a recent work, entitled the "Life and Character of Lord Bacon, by Mr. Thomas Martin," this ungenerous attack on that great man has been ably answered. When it was asked by Sir David Brewster, in a late life of Sir Isaac Newton, whether or not the philosophers who succeeded Lord Bacon acknowledged any obligation to his system, or derived the slightest advantage from his precepts, he answers quickly, "no such testimony is found." But Mr. Martin brings forward a host of names to prove that an acknowledgment *was* made, and that great benefits were derived from them. If Newton never even mentioned the name of Bacon or his system, it is only another proof—as in the case of Flamsteed—that unworthy motives sometimes influenced him. The testy letter which he wrote to poor Flamsteed, and which by some strange mistake the author of the before mentioned Life of Sir Isaac Newton has attributed to Flamsteed, proves that even so great a man as Newton could be ungenerous, even to one to whom he knew he was under obligations, and who was then living and rendering him favours.

Lord Bacon has justly been called the father of experimental philosophy; but for him, but for the vigorous yet simple method he advises, many of the beautiful discoveries in natural science would never have been made. If such, therefore, can be the language held towards so illustrious a name — if such contempt can be expressed and tolerated towards one whose fame is imperishable, surely one of the most humble of his followers should not regard either ridicule or neglect. It was by long observation and minute experiment that I discovered the facts which I have here made known in these memoirs. They are facts that cannot be disproved, and the theories in which I have indulged are but the natural results of phenomena so curious and novel. The consciousness of their importance to science will more than sustain me either through neglect or sarcasm; I shall therefore proceed fearlessly.

We perceive that the system of the universe is replete with gases—that they fill all the interstices of space, and that the animal system is abundantly supplied with them. It is the gases, from without, which transmit all the nutriment that is to sustain the body; and it is through their agency *within*, that alimentary and secretory matter are equally distributed. Muscular and nervous motion are effected by their agency also; in short, they are the prime agents that propel all matter, and only that system is well balanced where their power is equably diffused.

The gases, like every other agent in the physical and moral world, are constantly acting adversely, or in opposition to one another; the one with an elastic, the other with a contractile power; the one depresses and follows the motions of *gravity*, and the other elevates and is attached to levity. The one condenses bodies and causes the presence of cold, the other expands bodies and causes the sensation of heat; for I cannot allow that "cold is the lowest degree of heat," or that "blackness is the lowest degree of light." We might as well say that vice is the lowest degree of virtue, that acids are the lowest degree of alkalies, and that gravity is the lowest degree of levity.

As to *gravity*, we cannot but perceive that it acts on the *surface* of bodies, whether in atoms or in masses; and that *levity* acts by occupying the *interstices* of bodies, whether large or small, likewise. Both these great powers—Levity and Gravity—employ gases as their agents; and every motion in the physical world, and every emotion of mind, is effected by their active presence. The power which expels all matter from the centrifugal point of our earth, employs gases to assist in the expulsion; and the power which forces all matter to gravitate towards this centre, has likewise to make use of the same agency. Different though these agents may be in their nature, the one having a contractile and the other an expansive power, their character, as elastic bodies, are the same.

When gaseous compounds are thrown off from the sun as it revolves, and other gaseous compounds are thrown off from the earth in her quicker revolutions, there must be some point in space where these gaseous bodies will come in contact;—now, if there is collision, what would be the consequence? Where does this point of contact exist? If we can show where this precise spot is, we shall know exactly where the focus of illumination is. In figure 14, if S is the sun and E the earth, then the point of illumination must be at G.

From such data a new theory of light might be formed—I mean that light which illuminates the earth. If light can be set free by the sudden collision of two gases, as is familiarly illustrated in chemical experiment, a perpetual fountain of it can be generated at a point where this collision is constantly taking place between vast masses of gaseous matter thrown off by the sun and earth.

At any rate, however reluctant philosophers may be to admit this new doctrine, to one conclusion they must all submit :—there is a certain focus where the ultimate powers of the sun and the earth meet, otherwise all lesser bodies would fall in the sun. If light, or luminousness, really did emanate from the sun, it follows, as a certainty, that when it converges to this focus—and converge the rays must to some point—they would be there arrested, and partake of the rotary motion incident to the conflict existing at this point. That a rotary motion is created amongst the particles in the space between two bodies having a rotary motion themselves, can be easily proved ; this rotary motion must necessarily be imparted to the gaseous particles that are thrown off from these bodies as they revolve. This produces friction, and, as there are abundance of gases present, this friction disengages light.

It follows, therefore, as a consequence, that *our* light, wherever it may be set free, if it is not actually generated at the focus G, in figure 14, must be *arrested* at this point; and that there is such a point, no law of physics or mathematics can disprove. When the light is there arrested or generated, it has to undergo a rotary probation before its rays can illuminate our earth; and this being the case, the luminousness of light must, in any event, proceed from that point. It is from this rotary focus that we see it, and call it our sun; it is there that the great nucleus of light exists, and from which the rays are projected. The axis of the dense body, called the sun, throwing off the gaseous compound to oppose those that are expelled from our surface, is so immediately on a line with the axis of the earth, that it is entirely hidden by the mass of light that is interposed.

I shall not dwell any further on this part of the subject, nor trace the connexion between the sun and planets; but only observe again, that, view this conjecture as we may, it must be conceded by all, that the light which illuminates the earth *is not immediately projected from the sun*, but that it is arrested and made to revolve at a definite point in space, whence a portion of its rays diverges, from the centre of that focus to our earth.

Such being my opinion of light or luminousness, it may be inferred that I cannot perceive any difficulty in its sudden and constant extrication, either at an ultimate point in space, where there is material enough to set a great mass free, or at a certain point in the brain where only a very small portion is wanted—a quantity just sufficient to illuminate spectra. We must likewise take into consideration that these spectra, small though they appear compared to the external object that they represent, and having a definite size to our perception, may, notwithstanding, occupy no more than the millionth part of a line.

That one eye sees the whole object without the least assistance from the other, is clearly demonstrated from the experiment made on the eye-lids for the illumination of spectra. The optic nerves never communicate with each other, nor is it necessary that they should. The outer surfaces of the external muscles, in case of disease, may depress the cornea, and so give a tremor to the iris or pupil, but nothing else ; the optic nerve, at some particular point, may touch, and perhaps adhere, but it is only for the purpose of preserving a regularity of motion when the eye-balls are acted upon by the muscles. The contact is not for the purpose of assisting each other in the transmission of intelligence to the central ganglion, for each eye-ball, with its own optic nerve and its retinous and fibrous terminations, is *entirely independent*. All the organs of sense are double, and independent of one another ; even the tongue, which is the principal organ of taste, is divided in the centre, so that if one half is injured, the other can perform the duties assigned to it. This is a benevolent plan of the Deity, which would be frustrated if one of the same set of organs was dependent on the others.

We perceive that when both eyes are shut and the lids covered, if we raise the hand from one eye-lid, the light which falls on it does not illuminate the internal apparatus of the other eye. It only illuminates that part of the internal ganglion of vision on which the spectrum rests that belongs to the eye whose lid has just received the light on it. I covered the left eye, and looked very earnestly with the right eye at a very bright lamp as long as I could bear the pain, holding a pen, diagonally, at arm's length from me. Shutting this eye and putting my hand over the lid, I looked at the lamp in the same earnest manner with the left eye, holding the pen diagonally, in a contrary direction. The lamp was removed suddenly, and when left in darkness I cast my left eye to a part of the wall where I had previously fastened a black cloth. I distinctly saw the spectrum of light with this eye, and it had the diagonal mark of the pen. In an instant the spectrum of the right eye worked up through this one, and as the diagonal line was reversed, they appeared together as a regular cross—thus ×. Both eyes were open, yet I saw the same spectrum on the black cloth just as plainly as if they were shut. Covering my eyes closely with my hands, the lamp was brought in again, and I let the light fall on the lid of my right eye for an instant, and on covering it again the spectrum was thrown back as it were, and the one just illuminated from the lid became more distinct. I know it was the spectrum formed by the right eye, for I recollected the position of the diagonal line. When I let the light fall on the closed lid of the other eye, and covered it again, the spectrum of the right eye was thrown back, and the one recently illuminated appeared.

The next evening I tied up one eye very closely, so that no ray of light could enter, and looking earnestly at the lamp with the open eye, I crossed the lamp with a pen as before, and when the lamp was removed from the room I saw the spectrum on the black curtain as before; that is, I saw a mass of light with a dark line intersecting it obliquely. I then shut this eye, and taking the bandage from the other, directing it to the curtain, I saw the spectrum, with its oblique dark line just as well with this eye as the other; *and so I should if both eyes had been suddenly removed from the sockets.*

If this spectrum had been formed within the eye-ball, and was there perceived by the mind, so intense was the light in both instances, that a person looking at my eyes when the lamp was removed could certainly have seen the corruscations or radiations of light just as well as before the light was taken away, for we can always see the spent light as it is leaving the eye. If it were in the eye-ball, the black pigment of the choroids could not decompose all the light suddenly, nor could the foramen centrale reflect the whole at once. It remained perceptible to myself, *internally*, for half an hour; and surely, as light it was, *if it were in the eye-*

ball, there ought to be some external appearance of it *before* the lamp was taken out of the room, and *after* it was removed; yet no one could see the light in my eye-ball.

By this excess of light the choroids were as useless as those in the albinos, for their eyes reflect light, visible to those who are examining them. The spectra of the two eyes formed by the light of the lamp and by the shade or obstruction of the oblique pen, were not only formed, but remained at the extremity of the fibrous termination of the optic nerve *internally*. I could not perceive them to move whilst shaking the eye-ball, although I paid the closest attention to them,—I say *them*, because I knew there were *two* on the first night that I made the experiment, only that one lay closely over the other. That all the internal spectra have the appearance of moving when the *will* directs their motion, I have already shown, and I hope satisfactorily.

The images or spectra of external objects being therefore impressed on the internal organ of vision, beyond the ball of the eye, the mind, or *seeing* faculty, inspects them without reference to the eye at all; and, as I said before, if the eye-ball could be removed without disturbing that part of the optic nerve which is attached to the internal ganglion of vision, the image or spectrum would be as perceptible to the mind as before the eye was taken out.

When the light has been faint, there is a weak impression, and the light is soon absorbed, but when the light is intense, then there is a corresponding intensity of light, and the spectrum remains perceptible for some time—nay, can be recalled—as has been recorded by Sir Isaac Newton, Epinus, and others, as well as by Sir David Brewster. I brought back the spectrum of a window-sash that had been strongly illuminated, and at which I had gazed earnestly for about a minute. By an exertion of the *will*—if I may say so—I renewed the spectrum two or three times during the day, when I shut and covered my eyes, although each time it grew fainter.

When the window-sash is very strongly illuminated by the sun, and we receive the impression on one eye whilst the other is closely bandaged, it will be perceived when both eyes are shut that there is a bright spectrum of it. On uncovering the eye and covering the one that took the impression, and looking in the hollow of our hand when a black cloth has been thrown over the head so as wholly to exclude external light, we shall see a faint spectrum of the window-sash, even when this eye which did not see the sash is looking in the palm of the hand.

Now, it is plainly understood from all that has been said, that the spectrum thus seen is not, in reality, seen through this eye. The fact is, the mind is contemplating, or taking cognizance of, the spectrum *at the precise point where it was first impressed, which point is at the internal extremity of the optic nerve.* The eye-balls are only a telescope to the mind, they have nothing to do with images or spectra; they are to the seeing faculty a perfect blank, and might as well be out at that moment for all the service that they render vision as the makers and retainers of images.

It is unfortunate that the operations of the mind, as it regards its physical movements, have been so little scrutinized. All phenomena of the above kind, particularly those that relate to vision, have gone under the name of fancy or imagination; as if that were a solution of the difficulty. When Sir Isaac Newton, after a lapse of several weeks, brought back the spectrum of the sun, he attributed it to "fancy;" whereas it was an effort of the *will* on the same part of the internal organs of vision that were at first excited by the direct action of the solar rays. Sir Isaac Newton observed that he saw the spectrum when he opened his left eye quite as well as he did with the one that received the image at first. Did he suppose that the image or spectrum of the sun left the eye that first received it, and then moved round internally through the optic nerve of the other eye, and so into the eye-ball of the left eye? If the spectrum did really get in the eye-ball, then certainly there was no other way of its getting there but by passing out of the end of the optic nerve in the brain and entering the end of the other tube, moving along this tube till it reached the eye-ball. Can any one *now* believe this? Had Sir Isaac Newton made further experiments in vision, he would have detected this error.

It will be a long time before these facts and conjectures can obtain that consideration which they deserve, for the common sense of mankind, of which Dr. Reid so frequently boasts, being accustomed to think that all of seeing is in the eye-ball itself, will not be able to go deeper into the subject. As to philosophers themselves, they will be still more averse to receive them kindly, for they have written volumes on those subjects which these memoirs are to disprove. I must therefore wait patiently till the science of the mind is more fully investigated, as at present I cannot hope to be understood. The overthrow of the theory of the inverted image is, however, one great step in advance, and I depend very much upon the consideration which that will receive ; but I must proceed.

That the two eyes, conjointly, see better than one by itself, arises from two causes ; in the first place the focal distance of no pair of eyes is exactly the same—the one being farther removed than the other. Separately, therefore, the eyes of most persons see objects smaller or larger, dimmer or clearer, but, conjointly, the one modifies the excess of the other. There are very few persons that have arrived at the age of fifty, who can read a line of print or writing as well at night as in the day, with either eye separately, and yet can read it easily with both eyes. Nor do glasses of different magnifying powers, when placed in the same spectacles to suit the focal distance of each eye, enable us to see as distinctly as if both glasses were alike ; for by the time we find out the defect, the eyes have accommodated themselves to the difference. In young people, when this defect of vision occurs, glasses of different magnifying powers may be of service.

That the lens of the eye advances and recedes, is fully demonstrable by carefully attending to the following circumstance. Look at the round figure O ; whilst both eyes are directed to it, close, or wink one eye slowly, yet firmly and tightly, keeping the other open and looking exactly at the figure. It will be seen that whilst this eye is intently fixed on it—not having moved a hair's breadth—the other eye, as it opens slowly from winking, has to make a little effort to adjust itself to the focal length of the eye that has not winked. The mere closing the eye tightly for half a minute releases the lens and external muscle from that constrained position which they are compelled to take when acting in concert. The adjustment of the lens is always an effort, and every one knows how agreeable the sensation is when the eyes relax from that tension which seems necessary to the adjustment of both eyes.

The oftener the above experiment is made, the more obvious it will appear that the external muscles of the eye-ball are also necessary to the adjustment of the eyes to the different distances, a fact which I have only lately discovered. These muscles not only regulate the movement of the eye-balls themselves, either from side to side, or up and down, through the whole range of vision, but draw both eyes towards the nose, not only to look at near objects, but to see objects single with two eyes. When directing our attention to the round figure ○, we shall perceive that a very considerable relaxation takes place during the closing of one eye—*remembering that the open eye never wanders from the figure.* As the eye slowly opens again, it will be perceived that the lens, and something *without* the eye, has been drawn from its usual position; for there is a perceptible effort made by the lens and the external muscles, to be restored, as it were, to the previous adjustment with the other eye.

If the eyes have different focal lengths, then the lens in the near-sighted eye will have to make but a very slight effort to arrange itself with the long-sighted eye. The difference in the focal lengths can be estimated by holding the point of a pen or pencil over the round figure, exactly in the centre, when the head is about eighteen inches from the paper. Both eyes must be directed to the point of the pen, which must be about an inch from the paper. If both eyes perceive that the point of the pen is exactly in the centre, then by slowly closing one eye, it will be ascertained which is the short or which is the long-sighted eye. When the long-sighted eye closes, and the other is intent on the figure, on opening it again it will be perceived that the round figure has been thrown out of the centre; or rather that the lens of this long-sighted eye has been moved from the centre of visible direction about a quarter of an inch. Whereas the short-sighted eye, when it opens again and looks at the figure under the pen, will have scarcely moved from the centre of vision, although the letters around it appear to move.

That the lens moves, we can therefore both *see* and *feel;* for it will be allowed by all capable of making the experiment correctly, that there is a *sensation* accompanying the motion as the eye opens and looks at the round figure. I must again remind those who are investigating this fact, that they should not move the open eye from the object under examination. A person who is deprived of the crystalline lens cannot make this experiment, neither can they if the muscles of the eye do not contract.

One cause, therefore, why two eyes see better than one, is the simultaneous adjustment by which one modifies the excess of the other; and the second cause is this:—although light does not illuminate the spectra of both eyes at once when it only penetrates the closed lids of one, as in the foregoing experiments, yet it certainly illuminates the spectrum of the *interior* of that eye on whose closed lid the light falls. This spectrum, therefore, is made the brighter by this accession of light. When the light penetrates the lid of the other eye, then the spectrum of that eye is made brighter, and thus a double portion of light is thrown on the cerebral seat of vision, where alone light is ever seen by the perceiving power. The light from two candles makes every thing more conspicuous, although one may be placed exactly behind the other, and only one flame is seen ; that is—with regard to the vision of the person who is either before or behind the candles.

The light, therefore, in the interior is of double intensity when it proceeds from the light which follows two spectra or images, thus enabling the seeing faculty to perceive them with greater distinctness. Not that I suppose the thinking principle *sees*, or perceives in the usual sense of these words ; but that the double intensity of light makes a stronger impression on the visual ganglion, and is thus made apparent with greater distinctness.

I observed in another part of this memoir, that of the composition of images or spectra seen by us when the eyes are closed, we only know two of its parts—light and shade. I might likewise have alluded to the colour of external bodies, for certainly in common vision the images appear to us coloured; but I did not want to perplex the subject with any additional suggestion, as I am only speaking of simple spectra. I hope to dwell on this point more fully at some future time, but must now merely observe, that, vivid as these colours are, they fade away entirely when the external impression of them fades away. They then only leave their spectra or shadow behind, for colour seems an evanescent quality altogether. The shadows or spectra are rarely of any other colour than a faint yellow and a gray black, with a slight tinge at times of pale violet and white; the yellow tinge represents light itself, and it is the only colour which can represent light.

Spectra are therefore the mere outlines, as it were, of the images of external objects, for in spectra nothing is discernible but outline. The coloured images are all that the mind can ever know of bodies, or substances external to the eye-balls; and it is entirely owing to this colouring matter that their exact proportions and texture can be known. When I look at a window-sash, the information previously conveyed by the other senses assures me that the sash, the image of which is now under contemplation by the mind, is composed of wood, paint, and glass; not that the real wood, paint, and glass of the external sash is transferred to the internal ganglion of vision, but only the picture of them. Colour does all this; colour represents the paint and *light*, and represents the glass; whilst the *obstruction* of the rays of light represent the outlines of all the parts of the sash. This rounding of the different parts of the image is entirely, therefore, caused by light and colour.

All paintings or pictures formed by art, are composed in the same way; and there is no more bone and flesh in the picture of the horse which the eye conveys to the seeing faculty within the brain, than there is in the horse painted on canvas. *If there were any other thing or substance necessary to our seeing external objects than outline and colour*, a painter could *never make an exact representation of them.* Whether this colouring matter belong to the external object, whether it be a component part of light, or whether it be first elicited on the internal ganglion of vision, is a question not now to be discussed, but a question might very fairly be raised about it ;—all I shall further observe is, that when we recall objects that have long faded away, we only excite again the *colour* which belonged to them and the *light* which accompanied them ; and the impression is exactly similar, only that the light and colour are fainter.

We perceive that the filling up of the squares of the window-sash, as we are looking at it externally, is composed of a transparent substance admitting light very freely ; but it can only in reality be known to us as a resisting medium by the little flaws and irregularities common to glass. Some glass, however, is so perfectly free from speck or blemish, that we could not tell, but by inference, that it was a resisting medium at all. Such a substance, therefore, cannot leave a spectrum in any other way than as a mass of light; and painters, when portraying window-glass, can only succeed by drawing dark outlines and forming lights and shades, with light and dark colouring matter.

Therefore, when the eyes are closed, thus shutting out the external rays of light, then the colouring matter which designated the proportion and qualities of the outward object, disappears, and the mere outline formed by simple light remains, and this outline is what we denominate a spectrum. It is when in this skeleton state that we can examine the curious process of seeing objects single with two eyes. The spectrum remains quite long enough to comprehend the method, and it will be perceived that the picture which one eye forms is not blended with the other, but lies exactly before it or on it.* Now, it follows, that though there is only one spectrum seen, yet as all spectra or images are only composed of light and shade, or light and colour, a double portion, a deeper tinge—if I may say so—must fall on the ganglion of vision. Thus it happens that the mind perceives objects more distinctly with two eyes than with one. It is well known that the more intense the light, the deeper the shadows will be.

No. 15.—There has long been a dispute as to the share that the external muscles of the eye-ball have in producing those motions of the eye which give information of long and short distances. Whilst investigating this fact, I made the following very curious discovery.

If we shut both eyes, we shall find that it is utterly impossible to bring the extremities of the axes of the cornea nearer together; that is, the

* I have made a small brass machine fully illustrating this.

muscles of the eye cannot contract so that the eyes can move in *contrary* directions. Nor can there be any motion in the pupil and lens of either eye when they are both shut!

This does not arise from any supposed con finement of the eye-lids, because both eyes, when the lids are closed, can move with ease in the *same* direction. They can move vertically, circularly, and horizontally, but always in one direction. Nor, what is quite as singular, can any contraction take place in those muscles that move the eye-balls in *contrary* directions, *when in the dark, although the eyes may be open.*

To understand this thoroughly, let us first hold up our finger to that focus which gives us a single image of it without pain to the eye-ball. At a foot from the eye, only one finger is seen, and there is no strain or uneasiness felt; but as the finger approaches the nose, the difficulty of keeping it at the point of distinct vision of *both* eyes, so that only one finger can be seen, is very plainly felt; and it amounts to absolute pain when the finger is within four inches of the nose. I have made the experiment on many persons, and all have found the greatest difficulty in keeping the object single. All eyes are very much distorted when endeavouring to keep the object single, and the effort is never made without pain. When the eyes are shut, or even when open, in a dark room, and the object touches the nose, although we make every effort to contract the eye-balls, it cannot be done; nor can any sensation be perceived either in the lens and pupil when in the dark.

It is therefore certain that the stimulus of light is necessary to produce contraction in the external muscles, and in the lens and pupil of the eye, when this contraction is for the purpose of enabling both eyes to see one object so that it shall appear single; and for the purpose also of enabling the pupil and lens of both or one eye to move in concert.

Now there are other movements of the eye-balls, which can take place when the eyes are shut as well as open, but they are not at all connected with that part of *seeing* which relates to *distinct* vision either with one or both eyes. We can, as I observed, turn the eyes to the right and left, up and down, or circularly, and as one eye moves the other will follow; for in all these movements the eyes are parallel, and they turn without pain or effort. The truth is, that all this is for a two-fold purpose; the first is *to present the axes of the eyes to different cones of light*, or, in other words, to present the axes to the different scenery and objects that are external to the eye-ball. The second purpose is to enable the will to change our thoughts, of which I shall say more in the course of this work.

There is no illusion of judgment in this phenomenon, for we have only to make the experiment to test its reality. We know, for instance, that it is very painful to turn *both* eyes towards the nose; and even those who cannot by any effort produce this crossing of the eyes as it is called, or squinting with *both* eyes, can do it the moment an object is held up within a few inches of the nose. When we have succeeded in seeing but one finger, or one pencil, finding that the effort has been accompanied by uneasiness or actual pain, we shall certainly infer that this pain is the effect of turning *both* eyes in one direction. Being assured, therefore, that no crossing of the eyes *can* take place unless there be actual pain, we shall know whether we *can* turn both eyes inward when we close our eyes, or when they are open in the dark. I am compelled to be thus particular, because there are many who have not ingenuity enough to comprehend every point of a new subject, and so give up the fact as a fallacy.

It is therefore an indisputable truth, that light is an indispensable stimulus to the contraction of those muscles which are to assist in our seeing but one object when both eyes are directed to it, whether the object be near the nose or a mile from us. And light is likewise a necessary stimulus to produce contraction in the pupil, and a depression in the position of the lens.

The focus of the eye varies with the advance of years; but whatever the age may be, there is always a focal point to each person wherein an object is seen with more distinctness and ease. If we lengthen the angle, or in other words, if we move the pencil or other object *beyond* that focus, it will not be seen as *distinctly* as it was before, although the receding of the object gives greater ease to the eye. If the pencil is brought *within* the focus, it will appear double, unless both eyes are directed to it; and if both eyes are directed to it, there *must* be an unnatural contraction of the muscles, and this contraction *cannot* take place unless light be present. If we are sitting in a dark room, and we are ever so desirous of contracting the eye-balls, or in other words, squinting with *both* eyes, we cannot do it.

The eyes can only see objects by direct vision, through a range of 90° instead of 110 or 120°. Eyes that are prominent, when there is no defect of cornea or lens, have a more extensive range than those that were deeply set in the head, particularly when they are very close together, for then the projection of the nose takes off at least 20° ; but the average is 90° for direct vision with both eyes, and 135° for oblique vision with *both* eyes. A man having but one eye, has only a range of 90 for direct vision and about 116 for oblique vision. There must be some mistake, therefore, in stating that the range of vision is 110 or 120, for with the greatest care and nicety I could not produce such a result. To prove that 90° is the range of double vision, let any one place himself in the centre of a graduated circle, and he will find that 90° is the utmost at which an object can by direct vision be seen, without pain, by *both* eyes, and that 135° is all that both eyes can see by oblique vision. He will find when one eye is shut and the head still, that 90° is all the one eye can see by direct vision, and 116 by oblique vision, without pain.

I observed that although we could not make the muscles contract in contrary directions, either in the dark or when the eyes were shut, yet that neither darkness nor closing the eyes prevented those muscles from contracting that allow the eye to move in the *same* direction; that is, with the axes parallel. When we want to change our thoughts, the eye-balls *must* move, or the *will* has no power to enable us to do so. This part of the investigation will not be comprehended by many persons, for the cause of the change from one thought to another, or I should say with more propriety, from one scene or image to another, has never been the subject of inquiry. Every one has wondered what thought *is*, but what produces a *change* of thought has never been questioned; but now that the fact is stated, it will be ascertained that no change of thought can take place unless the eye-balls move. In strictness, it should be said, unless the *internal* organs of vision move, there can be no change from one object, or one subject, to another.

It may then be asked, how it happens that a blind person thinks, one who has lost both eye-balls? The answer is plain; the extremities of the optic nerve all centre in the internal ganglion of vision, and when we look at the construction of a nerve, we shall perceive at once that to separate the optic nerve at any particular section, is not to destroy the vitality of the true organ of vision.

Let us stop to examine the nerve itself; of what is it composed? When the eye of an ox is taken out, it will be perceived, if the bones have been carefully separated, that there is about four inches of nerve attached to the eye-ball. If this nerve is cut transversely at any section, the appearance is always the same; and on examining it with good glasses, a surface resembling the transverse cut of a plant will be seen. If it be cut, or rather *torn*, longitudinally, still the same condition of things presents itself as is perceived in a longitudinal cut of the stem of a plant. The fibres, or, more properly speaking, the vesicles, lie in regular rows in one direction, but they are all of irregular lengths, some being about an inch, and others half an inch long. Some lie evenly, and others dip a little one under the other, but they all terminate abruptly; they are hermetically sealed, yet they touch at their extremities and at their sides, lying compactly. That we may see them to advantage, the sclerotic coat should be cut down each side, and then the nerve can easily be pulled asunder.

When I began these experiments, it was repugnant to my taste to engage even in such simple dissections as the eye and optic nerve. The only nerve that I had ever examined must have been diseased, for on making a transverse cut, a glutinous ring was seen, which at that time I thought was the true nerve—see figure 4. Having examined a number of eyes since that period, I am of opinion that the nerve I first saw was diseased. So it is that mistakes are made and perpetuated.

I was nearly making another mistake by taking a thing upon trust. In the 8th volume of the philosophical works of the Rev. Mr.

Jones, F. R. S. 1801, I met with a paragraph which seemed to confirm what is stated in all the works on the phenomenon of vision. It was that light (luminous particles) passed from the eyes through the optic nerve to the brain. In page 398 Mr. Jones says—"The nerves do not appear as if they were designed to admit within them any animal fluid or liquor, unless it be an indolent lymph, which is necessary to keep them moist. But their pellucidity indicates that they are properly adapted to give a direct passage to the fluid of light, for they are transparent, not transverrsely but longitudinally, or in the direction of their fibres. I once observed this accidentally, as some eyes of sheep and oxen were lying on my table for experiment. One of these eyes shone in the day-time much in the manner as the eyes of some animals do in the dark. Not being able to account for this, I endeavoured to examine the fact as narrowly as I could; and at length perceived that if my hand were interposed between the nearest window and the extremity of the optic nerve (a part of which, nearly an inch long, remained with the eye and was accidentally pointed toward the window), the light immediately disappeared."

With a view to test this, I conquered my dislike to touch the dead eyes, and made a number of experiments; for it struck me that if the light went through one inch, or even half an inch, of the nerve, it might pass the whole length. I succeeded in making it pass through a thin slice of the nerve, about the eighth of an inch, cut transversely; but when I presented only half an inch, either attached to the eye or separate from it, no light was perceptible. These experiments are easily made, and the secretions of the vesicles are of such a glutinous nature that the cut part of the nerve adheres very strongly to glass or any other dry transparent substance. Of course I took the precaution to cover my head with black cloth to keep out all external light, and only admitted the end of the nerve in a hole adapted to its size. Sometimes I brought the eye inside and pointed, the nerve to the strong light of a lamp or the sun, and sometimes I kept the eye outside; but even in this complete darkness within the cover, I could not discern the smallest ray of light in any case. Supposing that the secretions were congealed by coming in contact with the air, I kept the eye and nerve in a cloth wet with hot water, only exposing the cornea to the light, and the extremity of the nerve to the air within the black cover, but still I saw no light.

It may be urged, that a spermaceti candle allows of the transmission of rays. This is true to a certain extent, but light does not penetrate the opaque particles, it only passes through the *interstices* between the opaque matter, which contains nothing but air. By referring to No. 6 of this memoir, it will be there seen that every small interstice is a lens —even the hole in a window-shutter may be considered as a lens; and it is in this way that light is propagated through the intersticial media of the candle. The light is transmitted at short distances from lens to lens, until the rays become extinct. If the candle is broken within the range of illumination, we perceive that the light breaks off suddenly, because the connecting medium is separated, and it is then absorbed in the *darkness* which exists between the broken edges of the candle.

The vesicles of the nerves almost preclude the idea of their being lenses, for the length is so disproportionate to their breadth, and the lymph or whatever the secretion is that fills them, is of too opaque a nature to act as a transmitting medium. In fact, all nerves are composed of vesicles, or, as they are called, fibres, running in a longitudinal direction, and they lie precisely in the same manner as in plants. The interstices between these connected vesicles are very differently arranged from those of spermaceti, snow, or ice, for the adhesion of the sides of all the parts of the vesicles of the nerve is so firm, and the contact is so close, that they appear almost like a compact body, and in tearing them apart they all separate in the same way. Yet still, as light is capable of such minute attenuation, it might be transmitted even through this thin stratum of glutinous secretion, if the vesicles were of a continued length, and were always opposite to each other. But this not being the case, and the nerve passing from the eye to the interior, being so *curved,* there seems no probability that it is designed to transmit light; and where would be the necessity, when light is so easy of generation? —I mean the *luminousness* of light.

There are many persons who can comprehend what is meant by latent *heat*, but they cannot imagine that there is latent *light* also. Others, again, do not know that light is cold, and that the rays would always reach us as cold rays, did not some combustible matter intervene. The rays that are brought to a focus in a lens when at a great height in a balloon would be cold was there not a dark paper, or our hand, or some combustible matter, presented to them. It is when light and *heat* come in contact that *flame* is produced; but there cannot be *flame* unless there is combustible matter present. There is but little evaporation going on in winter, consequently there is not much of combustible matter in the clouds; and light, therefore, encounters but a small quantity of heat.

These remarks may appear irrelevant in this place, but I wish to bring as many of the phenomena of light together as possible, to prove that light may be independent of the optic nerve, which is not a conductor of it to the brain; and that light, as luminousness—which is light in its free state—can be elicited, and exist, just as well in the moist, pulpy substance of the brain, or rather can be elicited and exist in a *transparent* medium belonging to the internal organ of vision, as it can in the glow-worm.

The optic nerve, therefore, is not composed of a continued length of fibres or vessels, but of interrupted links; so that the destruction of *one* of these links, either by concussion of the brain or by disease, does not prevent the *others* from conveying stimulus to the internal organ, although that stimulus may not be light. To cut off any particular section of the nerve between the eye-ball and the internal ganglion or organ of vision, does not therefore destroy the vitality of that portion which adheres to the internal organ, nor would the nerve lose its vitality if all the humours of the eye-ball were discharged. To go still further—if the whole nerve were destroyed, it would not paralyze the ganglion of vision on which the extremity of the optic nerve rests. It is exactly similar when the fibres or vesicles of a plant are separated; the inspissated secretion, which each vessel contains, runs out, if that particular vesicle is ruptured; but the injury is confined to the wounded part. If some of the secretive and absorbent vessels of a plant are injured, they do not impede the action of the others; and if these only are wounded, the general health of the plant does not suffer; but if the passage of the ascending *sap* is intersected, then no fresh nutriment can be carried to the different vessels. The case is strictly analogous with the human system, although the fashion of the present day is to deny that any analogy exists. If an artery is separated, and the orifice is closed, the upper part is not incapacitated from acting; if a nerve is separated, the part which is attached to the ganglion whence it originated is not dead.

We should ask, on what the extremity of the *optic* nerve rests, for this nerve is not part of the pulpy mass on which the fibrous terminations extend. The eye-ball and the optic nerve is but an optical instrument through which the internal organ of vision receives the impression of external things. When the instrument has made the impression, its business, for the time being, is over. These impressions, then, belong to the organ within the cerebral mass, and this organ is the receptacle on which the thinking principle immediately operates. Whether the optic nerve be *now* destroyed or not, is of no consequence to the internal organ, for there the impressions remain; so that a blind man *that has once seen*, is in possession of a series of pictures that he can look at for ever. The *will* has only to direct the movement of the fibres that spread over the organ—the terminating fibres of the optic nerve—and each picture will turn up in succession as it is wanted.

Light, therefore, appears to be of no further use to the eye, *after it enters the eye*, than to produce *contraction* in the external and internal muscles of the eye-ball itself; and it is this contractile power in the external muscles, and in the retinous expansion, which propels the whole machinery of the eye. Light is necessary to produce this motion, but not necessary to illuminate spectra in the interior of the cerebral organs of vision.

No. 16.—If we cast our eye over a field in a very hot afternoon, or over a small cooking furnace lighted with charcoal and standing out of doors, we shall perceive that there is a quick, wavy, upright motion, either of air or heated air. Whilst looking at it, if we shake the head quickly, or wink quickly, or shake one eye-ball whilst the other is shut, we can no longer see this upright, wavy, tremulous motion.

If we observe all these motions whilst looking at the leaves of an aspen tree when they are agitated by a light breeze, they will appear to be perfectly still, although the leaves are as plainly seen as when the eyes are quiet. This takes place with every thing that has a quivering motion, or with any object, in fact, that does not move more than a quarter or half an inch either way. This only happens when the large moving body is at a little distance from us, for when near, the angle under which it is seen is more obtuse, and the motion is magnified. If the object is very small, and within two or three feet from us, then the motion is not perceptible. When the wind is high enough to move the limbs, this movement is perceived, although that of the leaves is not. A very near object appears still if we look at it without regarding those that are beyond it.

For instance, if we hold a thread of two or three inches in length, by a slender filament at the end, so that the tremor of the hand shall impart to it a slight motion, this motion will be imperceptible if we wink very quickly, and do not cast our eyes beyond it. The thread should be held at arm's length, suspended by one of the fine fibres at the end.

We know that two pencils of rays, two musical sounds, and two waves meeting adversely, neutralize each other; here, therefore, is another phenomenon coming under the same law. The motion which the eye makes in winking produces a wave in the air; the motion which tremulous bodies make in the air will likewise produce a wave. Do these waves meet at some intermediate point and neutralize each other? We perceive that sound, light, and water, are subject to the law of interference; why may not air—or perhaps I might say why may not motion, come under the same law? Motion is neutralized when two tangible objects of equal force come in contact; and why may not motion be annihilated when aërial undulations meet in opposition.

Certain it is, that light can be annihilated when the rays meet at some point, which point is nicely reduced to a rule, as will be seen in Dr. Young's experiments. In the experiments that I have shown in this memoir, it will be perceived that there is a possibility of altering the course of light. This will give rise to a curious question respecting the blending of all the colours of the solar spectrum so as to produce a pure white colour.

A rotary movement in the particles of light that emanate from an object, will prevent that object from being seen by us. Even a black surface, when made to revolve rapidly, will hide much of its colouring matter; but divided colours, like those of the solar spectrum, will be lost to view entirely. This does not arise from the blending of the colours on the *retina*, as is stated, but from the fact that the particles of light issuing from this rotary wheel, do not come to us in straight lines, but converge to a focus and reach us from that focus. The light thus closes, as it were, over the wheel, and the rays, therefore, give no impression of the object behind them.

When walking in the street with the horizontal sun in our eyes, the pupil is so filled with light that the feeble rays coming from objects that are in front of us cannot enter. The strong light of the sun is so deeply impressed on the visual organs, that fainter light is not represented. When the strong rays of a bright sun fall on a dark-coloured or a white cloth, there is such an accumulation of light that it entirely occupies the space on which it rests, particularly if it comes through a small hole. At this moment, whilst writing, the light is shining strongly on the hearth-rug, part of the spectrum lies on the black fringe, and part on the blue ground work of the rug. Now the gray colour seen through the dense body of light is not produced by the blending of the black and blue colours of the rays. It is the density, the accumulation of light at that spot, which prevents the more attenuated rays that proceed from the coloured body from being seen. It is owing to the same cause that the rays from a faint flame are not so visible when the full blaze of the sun shines on the fire. An accumulation of light, therefore, on any particular spot, prevents our seeing the object on which it rests. If we receive the light that falls on a picture at a certain angle, the colouring matter will be hidden from our view.

As to the compounding or blending of all the primary colours so as to produce a pure white, I could never succeed in it, nor could any one do it that ever made the experiment under my direction, although we observed all the rules prescribed. To be sure, if I mixed all the colours together, or if I took black and green only, and let the strong light of the sun fall on it from a lens, nothing but the light was seen, the black and green appeared through the light as a dirty white or ash colour: so did black and orange, or any other dark colour.

Light becomes just as opaque when it is accu-

mulated at a focus, as any other dense body. We cannot see through the flame of a candle, neither can we see through a spectrum of the sun on the floor; but if the hole through which the light comes is made larger, so that the rays can spread wider, then the colouring matter under the light can be seen.

No. 17.—If we look at the moon through a large and then through a small pin hole made in a card when the moon is full and at the horizon, we shall see it under different angles, and of course of different size. It will appear much larger through the large pin hole than through the small one. On examining the pupil of an eye thus engaged, it will be seen that in one case the pupil is more dilated than in the other. The mobility of the eye makes it necessary that we should use both nicety and despatch in investigations of this kind, for the moment the rays of light have access to the pupil it contracts. The card should therefore be moved gently, yet quickly.

There are, therefore, several causes combined, to produce the phenomenon of the increased magnitude of the moon when it rises and sets, which causes operate on the whole of the solar system; but I select the moon in particular, as experiments are carried on with much more certainty and ease on account of the fainter light. These causes are four in number.

1st. The greater distance that the moon is from us at two periods of the day—being nearly four thousand miles further from us when at the horizon than when at the zenith.

2d. The enlargement of the pupil of the eye when the moon is at the horizon, enabling it to admit a greater number of rays of light.

3d. The increased density of the atmosphere of the surface of the earth, which has the effect of increasing the horizontal diameter of the moon.

4th. The greater angle which subtends at the eye in consequence of the above combination of causes.*

* I have made a brass machine illustrating this.

Sir John Herschel, in his admirable Treatise on Astronomy, says, that the increased diameter of the sun and moon, when at the horizon, "is owing to an illusion of judgment arising from the terrestrial objects interposed, or placed in close comparison with them. In that situation we view and judge of them as we do of terrestrial objects —in detail, and with acquired habits of attention to parts. When they are aloft we have no associations to guide us, and their isolation in the expanse of the sky leads us rather to undervalue than to overrate their apparent magnitude. Actual measurement, with proper instruments, corrects this error, without however dispelling the illusion. By this we learn that the sun, when just on the horizon, subtends at our eyes almost the same, and the moon a materially less angle than when at great altitude in the sky, owing to what is called parallax."

This distinguished philosopher, whose remarks I have given at length, has overlooked several important facts which would tend to disprove his assertions. He forgets that the same increase of magnitude in the sun and moon is apparent on the ocean when they rise and set, where there are no more associations to guide us than whilst they are isolated among the clouds in the expanse of the sky. He overlooks, too, that they present the same large disks when we see them over the top of a wall, which excludes every object but the luminary itself. As to the decrease of the moon's angle when at the horizon, under what condition is the measurement to be effected?

I have observed in the beginning of No. 17, that the angle which the moon subtends is arbitrary, increasing and decreasing according to the diameter of the aperture through which we view it, whether it be the pin hole in a card or the aperture of the pupil. This additional remark may be offered in refutation of Sir John Herschel's observation of an illusion of judgment; that when looking through the large and the small pin hole, wherein the moon is larger in the former hole than in the latter, *nothing else is seen but the moon*—every other object being excluded. This does not, as might be suggested, arise from the smallness of the pin holes, for there is a sufficient space to allow of our seeing other objects if they were near, as the disk of the moon does not fill the aperture either of the large or the small pin hole.

Surely there can be no other illusion in this case than there is in viewing the moon with a large or a small pupil, and in looking at it through a smoked glass. If we smoke a strip of glass unequally, letting the smoke fall more densely as we draw the glass over the candle, and at intervals make little dots or marks with a pin's point, we shall find that the moon increases in diameter as the smoke decreases in density. Surely this is no illusion of judgment, for in this case as in the other, the size of the moon depends on the size of the angle under which we view it, let the aperture be of what size it may. Neither is there an illusion of judgment when we look at it through a telescope; for still in this case the increased diameter of the moon is owing to the larger angle which is presented to us. There is an illusion of *vision* in these cases, but not of judgment; and there is likewise an illusion of vision when we see the spherical shading of light in the new moon; it is called "the old moon in the new moon's arms." To prove that it is an illusion, let us shut one eye and look at the moon when two or three days old, with the thin blade of a penknife intervening, at arm's length. The blade is only to cover the luminous part of the moon, and the hand to be kept steady. It will be seen that this shadow of the old moon is not confined to the curve of the new moon, but extends all around the enlightened part at the convex side, and it appears as a cloud, or as a part of the moon's atmosphere.

A variation of the diameter of the pupil of the eye necessarily accompanies every variation of the aperture through which the moon is seen. I have made a number of experiments to test this fact. Only let us examine the pupil of an eye that is engaged in looking through holes and tubes of different diameter, and we shall then see how great a difference there is in the diameter of the pupil. Amongst a number of persons who are looking at the moon when at the horizon, not one of them can be supposed to see it precisely under the same angle, for the diameter of each pupil is different and variable.

How, therefore, shall a correct measurement be effected? for what would be true and definite with regard to one man's vision, would be false to another. One thing, however, is self-evident, and about which there can be no difence of opinion, it is this—be the diameter of the pupil what it may, whether we see the full moon on the horizon with houses and trees intervening, or see it through tubes and holes of different size, or on the ocean "alone in its glory," the diameter always appears greater, either at rising and setting, than when over head at the zenith. Every eye that looks at it sees and acknowledges that it is larger under every circumstance; and to true philosophy the cause of this increased diameter *is the larger angle that subtends at the eye.*

It is known to *many* persons of science, *but not to all,* that the sun and moon, when at the horizon, are nearly four thousand miles further from us than when at the zenith. Now a general rule is, that the object diminishes as the distance increases; and this rule would apply to the moon did not causes intervene to make an exception in its favour. I must endeavour to explain what these causes are, and how it happens, that though the moon is actually four thousand miles further removed every morning and evening, yet, instead of appearing smaller, it shows a larger disk to every eye that looks at it.

Four thousand miles, or half the diameter of the earth, to be sure is of small importance when compared to the whole distance of the moon, which at the horizon is computed to be 241,000 miles. But what has this to do with vision? The eye has nothing to do with space, with mere length of distance. Does any one imagine that the eye itself looks as far into space as 237,000 miles, or 4000, or one mile, or one inch even? When the moon is present to our sight, do we suppose that we are looking *through* space, or *in* space—at distance, per se?

To give a clear idea of the incorrectness of the present theory of *visible distance*, I shall mention one fact. Let us shut one eye and look at the full moon. Whilst the face is turned to the moon, let us move the *open* eye from it in a direction towards the nose, remembering to keep the eye a little *above* the moon—not *exactly* on a line with it. When the eye has moved over a short space, the whole moon will merge in the dark angle and suddenly disappear, *at the same apparent distance at which an object of the same apparent size disappears near us on earth;* and in both cases it will re-appear as soon as the eye gets beyond the prescribed point. Now, if such a distant object, which appears to the eye to be only of a foot diameter, is lost in the dark angle at the precise point where a near, tangible object of that size disappears, what becomes of the theory of visible distance as it now stands?

Here we perceive is an object stated to be 237,000 miles distant from us, and upwards of 2000 miles diameter, a distance and breadth which is of no more consequence to vision than if it were only of a foot diameter and but thirty feet from us. It proves that pure, unmixed, unobstructed light, gives us no intimation of real size and distance—of distance in the abstract. The atmosphere, or space, is nothing more to the eye than a flat surface; and no part of the dark angle can ever occupy more than a limited portion of this surface, although in reality the base, in comparison with the moon, is far more than 2180 miles in diameter. That is to say—when the orbit in which the moon moves is divided into 360 parts, the dark angle will occupy *four* and the moon but the *half of one* of these parts, or half a degree. A circular piece of paper, whether black, white, or gold colour, of a foot diameter, will be lost to vision in the dark angle at the distance of twenty or thirty feet, although light or flame of that circumference requires a greater distance, as the rays extend themselves widely. What is very singular, the eye apparently in both cases, passes over the same space *before* the object merges in the dark angle, and *after* the object is in the dark angle.

Looking at the moon with the window-sash down, we shall perceive that if it occupies one pane of glass twelve inches wide, the eye will have to pass over a pane and a half—18 inches—before the moon is lost in the dark angle. I am presuming that we are sitting closely to the window. A street lamp at the distance of thirty feet, the light of which occupies one of these panes, will be lost at the same point.

It follows, therefore, that the pupil is only capable of admitting a certain portion of light, and that objects at ever so great a distance must be narrowed down to a very limited field of view before the seeing principle can take cognizance of them. The range of vision with two eye sis about 90° ; this, in reality, is of no greater extent of surface than that very minute, circumscribed one *which actually* touches the cornea—that narrow arc on which the eye traverses ! By direct or oblique vision, therefore, whether the eye is fixed, looking at a particular object, or moving from one point to another, it only catches on its surface—the surface of the cornea ; the points of the different cones of light that meet there from direct and reflected rays. What, therefore, is the theory of visible distance, perceiving that nothing can be communicated beyond what touches the transparent part of the eye itself?

Let us suppose, that from the two extremities of the moon's disk lines are drawn, the points of which meet and touch the cornea, and a number of moons, illuminated exactly as ours is, were placed a mile apart throughout the whole of the angle, decreasing in size as the angle decreased, till the last one is of a foot diameter and about thirty feet from us, what would be the result ?—why, we should only see *one* moon, and that of a twelve inch disk. If these lines were drawn from the circumference of the moon when in the dark angle, and the same number of moons were similarly placed, *not one of them would be seen !* There is not, therefore, any such thing as visible distance in the way and manner explained to us ; shorter and longer rays of light, of stronger or weaker density, constitute the true theory of *seeing*, both as it comprehends visible distance and direct or oblique vision.

Perhaps this unlimited extent, or rather power, of the dark angle will enable astronomers to measure size and distance with greater accuracy and with less complex instruments ; cross bars and a good time-piece would perhaps be all that is necessary.

He, therefore, that thinks he sees further into space than another, has no greater superiority of vision than what arises from a pupil capable of being differently adjusted. Near and far, are therefore terms which mean nothing more than certain adjustments of the machinery of the eye, by which the pupil can admit a greater or less quantity of light; and this power in the pupil depends, in some measure, likewise, on the convexity of the cornea.

Let us examine the eyes of a person that is looking at the top of a pencil held at the distance of a foot from him. When his eyes are fixed on the pencil, let him look at a knob or other object at the distance of eight or ten feet, which object is at the same height of the pencil. Although the light is equably diffused throughout the room, *and the back is to the light*, yet it is plainly to be seen, that when the eye rests on the top of the pencil the pupils contract, and that they dilate when the eyes are directed to the distant object.

It is in this experiment that we learn how far the external muscles of the eye assist us in looking at different distances as explained in No. 15. When the object is six inches from the eye, the eye-balls are both drawn together towards the nose, and produce such a distortion as to amount to a squint; but the distortion is with *both* eyes. When the object is at a distance, then the muscles relax, the lens recedes, and the pupil dilates; thus restoring the axes to a position nearly parallel.

Sir David Brewster, in his Treatise on Optics, observes, "That to discover the cause of the adjustment, he made a series of experiments from which the following inferences may be drawn:—

"1st. The construction of the pupil, which necessarily takes place when the eye is adjusted to near objects, does not produce distinct vision by the diminution of the aperture, but by some other action which necessarily accompanies it.

"2d. That the eye adjusts itself to near objects by two actions; the one of which is *voluntary*, depending wholly on the will, and the other *involuntary*, depending on the stimulus of light falling on the retina.

"Reasoning from these inferences and other results of experiments, it seems difficult to avoid the conclusion that the power of adjustment depends on the mechanism which contracts and dilates the pupil; and as this adjustment is independent of the variation of its aperture, it must be effected by the parts immediately in contact with the base of the iris. By considering the various ways in which the mechanism at the base of the iris may produce the adjustment, it appears almost certain that the lens is removed from the retina by the contraction of the pupil."

There is no doubt that the contraction of the pupil removes the lens from its quiescent state; but this is not the only fact to be considered, for, in connexion with it, is the contraction of the external muscles of the eye-ball, by which the two eyes are made to move inwards. In figure 18, if A is the object, or point on which both eyes are looking, then B B will be the position of the two eyes. But in figure 19, if A is the point of distinct vision, then B B will be the position. In the latter figure it is perceived that the point of distinct vision being more distant, there is an elongation of the rays of light from the object to the eyes; and this length of the cone or angle allows the axes of the eyes to be more parallel. In figure 18, the point of distinct vision being nearer, the axes are removed very far from parallelism; and there is therefore a very strong effort in the external muscles of the eye-balls to maintain the constrained position of the eyes. We are all conscious that the greatest relief to the eyes is to remove them from a short focus to a longer one. We obtain this relief by two modes, one of which is to let the muscle of *one* eye relax, and the other is to shut the eyes.

Looking at the top of a pencil *when one eye is shut,* puts the open eye to no torture, although the pencil may be within two inches of it. Neither does the muscle appear at all strained; yet an acute observer, *after repeated experiment,* will perceive that there is a slight sensation in the interior of the eye when the pencil approaches or recedes from a certain point—the focal point that suits the eye. The pencil being only presented to the axis of *one* eye, the other eye is not called upon to act; and therefore, having no effort to make either in long or short distance, it now remains nearly parallel with the open eye.

The power of adjustment, therefore, *with one eye*, depends on the ability of the pupil to contract and dilate, and also on the ability of the lens to advance and recede; for the lens and pupil move at the same instant of time. This simultaneous movement of all the parts in each eye is for the purpose of accommodating it to long and short distance, or rather to long and short cones or angles of light. But the adjustment of *both* eyes to the same point—the point of distinct vision—is an operation entirely independent of that which affects *one* eye. That the apex of each cone of light, issuing from the point of distinct vision, may enter the axis of each eye, the eye-balls, which move in a curve, are drawn towards each other; that is, the central point of the axis of each cornea are made to approach nearer to one another, The axes, therefore, are *not* parallel, nor can they ever be altogether parallel, excepting when the eyes are shut or the mind is inattentive to external impressions. When the muscles draw the central points of the cornea together, the eye-balls themselves do not approach nearer, they merely have a circular motion.

There are, therefore, two simultaneous movements in single vision, and three in double vision; all, however, voluntary, yet depending on external stimulus; and without this harmony the eyes could not accommodate themselves to long and short distances. The third inference of Sir David Brewster is, that when the voluntary power of adjustment fails, it still may be effected by the involuntary stimulus of light. This cannot be; for when the *voluntary* power, which is the *will*, fails—when the *will* ceases to have power over the muscularity of the body, or of any part of the body, then that body, or that part of the body, must be paralyzed, or life itself must be extinct. The *will* never rests, never sleeps; it commences its activity at our birth, and continues through life; acting when in health or in delirium, in the vacant mind of childhood, in the intelligence of manhood, and in the imbecility of old age. It is as active in idiots and lunatics as it is in the sane and wise; and it is to the never quiet power of the *will*, when the judgment and other analytical faculties are in repose, that the other excitable faculties are operated upon, as they are in dreams, infancy, and cerebral derangement.

We should therefore hesitate in saying that there are *involuntary* motions, for let our judgment be ever so much at fault, the *will* is active, and ever on the alert to produce or prevent motion. We perceive, therefore, that though the *will* is thus for ever active, or if I may use the term, for ever willing to act, it must always have a material on which to act; and this material must be stimulated by an active principle, such as life itself, or the *will* cannot act on the whole body, or on any part of the body. The *will* must be assisted by the stimulus called life, the nature of which we do not know, or it cannot act on *particular parts*, such as the nerves and muscles in general; and it must be assisted by a stimulus *that we do know*, or the eye cannot be accommodated to long and short distances, to single or double vision. As to the involuntary stimulus of light, that cannot affect the pupil without the simultaneous co-operation of the *will*.

The stimulating principle that we do know is light, for by a reference to No. 15 it will be fully understood that by no effort of the *will*, either *when the eyes are closed or when in the dark, can we produce any contraction of those muscles that draw the extremities of the axes of the two eyes nearer together, nor can the pupil contract, or the lens recede, unless light assist the motions of the will.* Therefore, whilst the muscles of the interior of the eye (for what are the ciliary processes and the retina but elastic media) are in a healthy state, the *will* is ready to act; and unless it is thus active, the stimulus of light will fall powerless on the lens and pupil. Although the muscles that draw the axes of the two eyes together might be in a perfectly sound state, yet the most powerful condensation of light could not make them contract for the purpose of producing single vision with two eyes if the *will* did not direct their motion.

I have observed that the will, at all times, without the stimulus of light, can move the external muscles of both eyes, or one eye when they are to move *in one direction*—either circularly, horizontally, or vertically. These movements can be effected in the dark, or with the eyes shut, quite as well as when the light is on them; for they are for other purposes than distinct vision, or for the admission of shorter or longer rays of light. In the case of distinct direct vision the two eyes move in *contrary* directions, both turning towards the nose; but when the eyes move horizontally or vertically, it is in the same direction; and these movements, in the first place, are for the purpose of changing the external scenery or objects, and in the second place for the purpose of changing our thoughts.

When the eyes are moving from side to side either in the dark or with the lids closed, or even in the light, it is only to shift their position. They do not *rest* on any object; this motion is given to them solely for the purpose of seeing a particular object single and by distinct vision. They are therefore parallel, or nearly so, until the attention is to be fixed on one object. Then, that both eyes may see the same thing, they are no longer parallel, but their axes approach each other at the outer surface of the cornea. I find these repetitions necessary as the subject is so new.

I shall endeavour to prove in the succeeding memoir, that our thoughts, or the *change* of thought, is dependent on this very movement of the eyes. *For, as all* our thoughts are founded on, or rather pass through the medium of language, and language has arisen from signs, and signs are but representatives of external things; the organs of vision are consulted both in the external impression of these objects, and in the internal or mental revival of them. In consequence of this the apparatus that is to revive images and things in the mind must be the same that gives us intelligence of what is passing externally.

Therefore, *external* light is the stimulus which animates the eye either to produce long or short distance, or single vision, with two eyes. But whether the contraction of the pupil, lens, and muscles, takes place from the equable flow of light which is emanating from the sun, or from the sudden flash of a great accumulation of it, certain it is, the *will* is never off of its guard. Mental impulse is quite as efficient and as quick in acting, as a flash of light, and suddenly as the contraction follows the flash, the will is on the alert to direct its motions. When no contraction of the pupil takes place, the parts are paralyzed; for though there may be an appearance of motion in the pupil when the sound eye is excited, yet that proceeds from the action of the external muscles which action depresses the cornea.

All, therefore, that we know of seeing, is what is impressed on the eye from without ; and visible distance consists in the different densities of those rays of light which enter the pupil. The fact is, that by no law can it be proved that the eye looks into space, or that any thing is admitted within the pupil but light. It admits the large cone coming from the whole field of view, and all the smaller ones which emanate from the transparent and reflecting surfaces of those bodies that are within the range of vision. Light, therefore, fills our eye, and by the different densities and length of its rays gives us notice of distance, and of the forms of all the objects that are within that distance, and likewise of the qualities of those objects—*that* is what is meant by *seeing*. The pituitary membrane of the nose is excited, and *that* is all that we know of smelling. The vibrations of the air, jar the tympanum of the ear, and *that* is all we comprehend of sound. The flavour of a substance must come in contact with the tongue before it can be recognized. An external body must touch our fingers before we can judge of its softness, or roughness, or hardness. And cones of light must meet in a point on the cornea before we can judge of the height, length, breadth, colour, and distance of external bodies.

The eye, therefore, imparts no other signification of distance than what is comprehended in the angle, or, more properly speaking, in the cones of light which fill the pupil. To the *seeing* principle, the base of one of these cones of light in the pupil, one coming from the moon for instance, is the only representation of the moon; and it is to this diminutive aperture of the pupil that the mind refers for the diameter of any object, whether it be at a great distance or near the eye. In a very short time science will instruct us that we owe all our knowledge of external objects entirely to the circumstance of their obstructing rays of light.

The light which illuminates the whole field of view when we are looking at the sun, would converge to a point, and form on the interior organs of vision a circular mass of pale light, without giving us any intimation of distance, provided the rays converged without obstruction. If the sun were square, the spectrum would be square also; but being round, the spectrum is round. This is supposing we are looking at the sun, a thing we can scarcely do for a second of time. If the eye merely takes in reflected light—such as the light which enters the pupil when our back is to the sun—then there is no spherical spectrum of light, as there always is after looking at the *direct* rays of the sun, but a simple luminous suffusion, as it were, of momentary duration, which the mind perceives after the eyes are shut.

But whilst looking at the clear sky with our back to the sun, if an opaque object should place itself in the field of view, then that object would obstruct some of the rays of light which were converging to the eye. What would be the consequence? would any thing occur by thus preventing some of the rays from touching the cornea at the same time with those from the whole field? If the object that appeared in the field of view were black, without any transparent particles on its surface, then nothing but the mere outline of this figure would be represented, as the rays which are to represent the inequalities of its surface would all be absorbed. The object, therefore, obstructs as many rays of this field of view as the size of its body is capable of intercepting. Inasmuch as it does intercept these rays, there is a vacancy or blank where these rays should be. And this vacancy—what is it? why, simply an outline and flat surface; whereas the surface, if it could have *reflected* the rays instead of *absorbing* them, would have shown great indentations and variety of form. It is owing to the mere absence of light, therefore, that this body shows a flat surface.

A black object, therefore, having no transparent particles, stands between us and the light, as if it were cut out of black pasteboard, without apparent thickness; and it forms no other cone of light than the one which proceeds from its own outline, and from the circumference of which outline the rays from the field of view converge, so as to meet in the same point with the great cone that touches the cornea and enters the pupil.

But if the object have transparent particles, then each elevation and depression is represented by longer and shorter rays of light, all of which converge to the point of the great cone that touches the cornea; for although these rays have been interrupted in their course by the opaque body, yet they join the rays from the great cone, and all meet at the point again. It should be recollected that this white object intercepts as many of those rays that are falling on the cornea as the black one does; but as the white object gives out all the light that falls on its own front surface, and the black figure decomposes it, the former makes all its dimensions perceptible by the means of long and short, dense and attenuated rays; whilst the black object shows nothing but a flat, black surface in front, because it has decomposed all the rays that would have represented its inequalities.

To *see* an object and all its proportions is, therefore, to see nothing but rays of light conveying to a point—the short rays giving us notice, or a knowledge of the prominent parts of a figure, and the long ones those portions that are depressed. All these rays have indicia on the internal organs of vision, and enable the mind to comprehend the whole exterior and quality of a body. By this simple yet beautiful arrangement, light, as luminousness, gives us notice of the outward form, quality, and distance of all bodies; and, as I before observed, these external bodies can only be made perceptible to us so far as they are obstructions to the rays of light from the whole field of view.

Having thus premised, in as short a way as possible, what I think is the true theory of seeing distant and near objects, I shall proceed to the next point, which is, the increase of the moon's horizontal diameter.

The prevailing theory is no doubt the true one as far as it goes; it is that rays of light, coming from the moon when at the horizon, have to travel through a much denser medium than when at the zenith; that all objects, and in fact, all matter, in consequence of passing through this dense medium, have their horizontal diameter greatly magnified. All the rays that come to the eye being horizontal, it follows, therefore, that the whole of the horizontal diameter of the moon must be larger than its vertical diameter.

Rays of light, however, have not only to travel through a denser medium at the horizon, *but that medium is nearly* 4000 *miles longer* *than the distance they have to travel when at the zenith.* What is the result of this to the eye? The farther a ray of light has to travel, the more it is attenuated; of course the impression that it makes on the eye is much weaker. But if the medium is much more dense when such rays are horizontal, then, in addition to the 4000 miles of length that they have to travel, their *breadth* is attenuated likewise.

This spreading out of the horizontal diameter of the rays of light during their passage through a dense medium, continues through the whole distance, 4000 miles. A thread of gold, one foot in length, can be drawn to four or five times the length, and by a mechanical process can still have its horizontal diameter wider than it was before. It certainly appears wider to the eye, and it is so in realty; although, as to quantity, it possesses no more than at first. An Indian rubber ball, of a foot diameter, is certainly possessed of that size, and it is really of a foot diameter to the eye, although before it was attenuated by inflation it was only of half that size. It is the same with a ray of light as with a thread of gold or an inflated elastic ball, only that with the ray of light and the thread of gold the length is attenuated and the breadth magnified or made wider.

In consequence of this loss of density—this attenuation of both length and breadth of the rays—the pupil of the eye is enabled to dilate, and of course it can admit a wider cone or angle of light, or, as it is termed, a wider angle subtends at the eye. The apex of every cone of light must either touch the surface of the cornea or the centre of the lens—philosophers have decided that all rays conveys to the centre of the lens; be this as it may, it is certain that the whole of the pupil is filled with these rays of light. The larger, therefore, that the aperture of the pupil is, the larger the diameter of the cone of light will be; consequently the light within the pupil being the representative of the moon, the horizontal diameter of the moon will be larger, as we see it is in reality.

We only judge of the dimensions of an object by the extent of surface that we see. I will once more mention the gum elastic ball, it can be inflated till it is a foot in diameter. It is no illusion, no error of judgment; for the fact is so—the ball may be of four times the size it was at first, although no more of the material has been added to it. It is so with the moon; the rays have been attenuated during their progress over a very dense medium of 4000 miles, and have not only to be made weaker by the additional length to which they are drawn, but this weakness is greatly increased by the stretching out of their horizontal diameter likewise. A large space is therefore covered by the rays of the sun and moon at two periods of the day; and those periods are when these luminaries are 4000 miles further from us than at mid-day.

It is nonsense to say that the difference between 4000 miles and 237,000 is so great, that the small amount of the first number mentioned is not worth consideration; and that the difference is still greater between 4000 and 90,000,000, no one understands this objection better than myself; but it is not *distance* that we look at, or that touches the cornea—it is *light*. The whole space of 90,000,000 of miles is filled by luminous matter from the sun—that is, if the distance be so great; and we understand that rays from the sun are 90,000,000 of miles long, the upper extremities touching or emanating from the sun, and the lower parts touching the cornea and going through the axis of the eye.

The eye, therefore, need not look so far as 90,000,000 of miles to see the sun—to see the whole length of these rays; nor need it stop short at the distance of one mile, or at any point of what is called visible distance; for the thing is differently arranged. The eye has not to travel out into space for information, as every thing necessary for it to know comes *to* the pupil, and it is on what that pupil contains that we depend for our knowledge of all those external objects that relate to vision.

The rays of light may be 237,000 or 90,000,000 of miles long, yet the seeing faculty only busies itself with that portion of the rays which fills the pupil. I take it for granted, therefore, that when light is present the pupil of the eye is always filled with it. The following diagram will more fully convey my meaning. In figure 15 of A is the apex of the cone of light, and B is the diameter of the pupil, then C C will be the diameter of the moon; but in figure 16, if A is the apex of the cone and B the diameter of the pupil, then O O will be the diameter of the moon. To a pupil of such a small aperture as No. 16, fewer rays will come, and of course a more acute angle will be formed; for whether the pupil be of large or small diameter, the point of the angle or cone of light *must* always touch the same spot on the lens. In short, it is the light *which fills the pupil* that gives the seeing faculty a conception of the dimensions of every external object. We must recollect, also, that though it may be true that light alone fills the pupil, yet if the rays come in straight lines from the whole circumference of the moon to the eye, or from every part of the field of view, we should never be able to see an external object. But these rays being interrupted in their passage to the eye by some objects they are turned off, as it were, and shorter ones proceed from that part of the object which is in front of the eye.

Within the broad cone throughout the whole angle of vision, there are innumerable smaller ones, all emanating from the surface of opaque bodies. In figure 9, C C C are three of these small cones within the whole field of view. But whether there are only three, like the three balls C C C in figure 9, or a countless number of objects, just in proportion to the quantity of light they intercept, will be the distinctness with which they are seen.

No one can for a moment suppose that *all* the light from the whole broad diameter of the moon falls on the cornea. If the whole does not touch it, then what part does? We may as well suppose the whole to fall as one foot of it. Even were we to allow that the point of the cone touched the centre of the lens, still only the breadth of the pupil would be filled with the light which falls on the cornea. The fact is, *that only just so much light touches the cornea as the pupil can receive within its aperture. We judge of the whole and entire magnitude of the moon by the size of that part only of the large angle which subtends at the eye from the whole field of view; which part touches the cornea, fills the pupil, and goes in a straight line through the lens.*

Let us imagine that one man has a pupil that, when fully dilated, is just half an inch in diameter, and that when a cone of light converged to a point on the crystalline lens, it formed an equilateral triangle. The two sides of this angle when extended to the moon at the horizon, would be 241,000 miles in length, and of course the base of this angle would be 241,000 miles in breadth. To this man's eye, therefore, the true diameter of the moon would be 241,000 miles. But if the pupil of another man be only one half of that diameter, then the sides of the angle being always the same, the moon to *his* eye would only have a diameter of half the size. See figures 15 and 16.

All these causes, combined, sufficiently account for the increased magnitude of the moon when at the horizon. There is no illusion of judgment, becanse a ray of light coming from the moon at that time is longer and broader, and consequently makes a weaker impression on the optic nerve. This enables the pupil to enlarge its own aperture so that it can admit a greater number of rays, and thus a larger angle subtends at the eye; and as a large angle subtends at the eye, the moon, in reality, is larger than when at the zenith.

Having brought this memoir to a close, and presuming that the experiments will be accurately tested by the curious, I feel it incumbent on me to subjoin certain remarks which, for prudential reasons, at the time could not be introduced in the body of the work. The truth is, there was so much of novelty, both in the facts and theory, that I feared the mind of a beginner could not embrace the whole at once; I was compelled therefore to reserve some part of the testimony until the strangeness of the phenomena had worn off. Throughout the memoir, when speaking of lenses near the eye, I have observed that the fluid drops which lubricate the conjunctiva "roll down;" that the aqueous humour "rises up;" that the air bubbles "fall to the bottom." Now these are actually the appearances which these objects make when in motion; but as beginners have so much to unlearn and so much to surprise them, it would look too much like legerdemain to say that this was a deception. Had I then stated, what is really the case, that the aqueous humour *falls down*—that what I called the fluid drops of the conjunctiva are *large air bubbles which rise up*—and that the connected strings and bunches of air bubbles *rise* instead of fall, very few persons would have ventured to proceed.

The truth is, that spectra *produced in this way* are always inverted, and the mind, or seeing faculty, *always sees them inverted.* When an external object is seen through a lens that is at a certain distance from the eye, it is inverted on the surface of the lens. When the lens—let it be a small hole, a drop of water, or an air bubble—is brought close to the eye so as to touch the lid or come within a quarter of an inch of it, then the objects are also inverted.

If we only consult the surface of the external lens, it is nothing more than a mirror. The rays from the candle touch the drop of water at a certain angle, whence they proceed to the cornea of our own eye. They bring no external image with them, but before they reach the crystalline lens they are partially intercepted by certain tangible objects, such as the aqueous humour, the air bubbles, and the spots between the laminæ of the cornea and lens.

It may be asked why I suppose that the spectrum thus formed is inverted, since nothing is seen but air bubbles and certain fixed spots, all of which may be erect. To prove that we do not see them in their true place whilst looking through the hole described in No. 7, or on a drop of water resting either on the finger nail or hanging from the finger, let us push up the lower eye-lid, and we shall see that on the spectrum the upper part is obscured by the *coming down* of the lid. If we push the upper eye-lid down, then it appears to rise up from the lower part of the spectrum.

Here is another proof that images once inverted on the visual organs always remain inverted, and that they are never reversed in the cerebral point of vision. In this particular case the crystalline lens acts as an external lens ; and the *spent light*, as it leaves the eye in passing through the crystalline, gives intimation of the obstructions that intercepted its rays as it entered—the question is, whether these irregular rays act immediately on the optic nerve, or fall on the drop of water that lies on the finger nail, and thus pass back again to the eye. In a mirror, the rays that are to represent an external figure are first reflected from that to the glass, and then pass back again to the figure. That the image we see is erect, is owing to the *plane* surface of the mirror ; at a certain angle we find that our figure is inverted on a *concave* mirror, but this is rectified when the central rays reach our eye.

At this point I shall leave the inquiry, reserving what I have further to say till another opportunity.

MENTAL PHENOMENA.

METAPHYSICAL speculations have grown out of an investigation of the conduct of the body—they have resulted from an observance of external action, and not from an analysis of the mind in conjunction with the body. It is this mistake which has caused the science to fall into neglect. Philosophers has so separated external from mental influences, that very few original thinkers will take the trouble to comprehend their meaning.

The truth is, that the subject has been taken up at the highest point; a clock has been constructed without the main spring—all the parts are well adjusted, but the work is useless for the want of that on which its whole value depends.

Let us suppose that in a labyrinth there is an organ concealed, and of such curious and ingenious mechanism that it can emit sounds and produce all the combinations of which music is susceptible. It would be very desirable to discover the secret by which this is effected. If there is nothing to hinder us from unravelling the mystery, what course should we pursue to gratify our curiosity?

No knowledge could be gained by speculating on the outward movements of the machine, nor by comparing the sounds with those that issue from other bodies. We should gain nothing by hearing that it can modify or create new sounds when acted upon by pressure or high winds, or that the machine has no such power; that it performs all its parts unresistingly, it being the intention of the Creator of it, from the first, that it should play so many tunes in such a way. Can knowledge ever be obtained by such vague reasonings? Surely there ought to be some way of coming at the truth; there must be some certain clue to guide us through the labyrinth. When it is known that there are no less than five avenues, all leading to the interior of the machine, and that in this way all the tubes, valves, and wires connecting and moving the whole can be accurately examined; is it not rational that the inquiry should commence this way?

To obtain a clear knowledge of the operations of the mind, we must investigate the phenomena which grow out of a connexion with them; we must begin with the avenues—the external senses; and not only trace their dependence on one another, but on the spirit or mind which animates the body. Before stating the result of such a mode of inquiry the following question proposes itself, and which must be clearly understood before we can proceed to advantage. Does the *will* enable us to act? On what does its power to do so depend?

As to what the *will* is, excepting that it is one of the faculties or constituent parts of the mind, or that it is the whole mind acting on a particular part of the nervous organization, is a question that in this life can never be answered. But there is nothing so self-evident as that we have this power, and that in some way or other it enables us to think and act. It is useless, also, to go into a disquisition as to what an animal would be without this power; for, excepting in suspended animation, every thing that has life owes its mental and bodily activity to the *will*. I mean all action, whether in cerebral derangement or otherwise—whether directed to some definite purpose or at random. Of course I do not allude to subsultus tendinum, or any other twitching of the nerves; for the connecting link between the *will* and the nerves is relaxed or broken in these cases. Neither do I allude to the *will* as it influences our religious or moral impulses; for these are speculations too much in advance. The view I shall take of the subject is preparatory to a closer investigation, but it is now simple and elementary, and is to be kept clear and distinct—by itself. It is my intention to show, if adequate terms can be found to convey the meaning, what it is that gives the *will* the power over our thoughts and actions; and how we are enabled to call the *will* to our assistance when we desire to think and act.

The *will* is one of the first faculties brought into action, and it accompanies us throughout life; it is the *will* which enables us *to be—to do*—and *to suffer*.

The *will* not only enables us to move our limbs and bodies at pleasure, but it allows us to speculate on these movements. By means of this power we compare and combine, enlarge and simplify, create and destroy! To ask how this magnificent power originates, is absurd; it may be, as I said before, the whole force of the mind, or only a distinct portion of it; and if at any future time I go deeper into the speculation, it will be solely with the view to mark the connexion between mind and matter. At present I shall only take up one single branch of the subject—I shall speak of the *will* abstractedly, and not as it may be connected with any psychological question.

Until the present moment we have not known by what means the *will* acts when we desire that it should. It has never been doubted that the will could *not* act, or enable us to act, when mental and bodily organization are perfect. To comprehend fully the extraordinary and beautiful phenomena, and the facts connected with them, all of which I am about to disclose; it should be kept in mind, *constantly*, that the freedom of the action of the body depends on the free action of the mind; that although the mental faculties may be perfect, they are useless unless the external organs be perfect and active too. Throughout the exposition, it is to be understood that I am only connecting it with perfect organization of mind and matter. I shall now once more propose the question. What is it that enables the *will* to act?

Can we put out one hand, and touch or raise up any thing because we have a desire to do so?

Can we, by the mere act of the *will*, bring a flower to our nose and smell it, perceiving that it has a pleasant or unpleasant odour?

Can we, by the simple power of the *will*, recall to our mind the sensations which the odour produced when it was actually present? I am now confining the subject to the organs of *smell*, and to a mental perception or recurrence of it.

Undoubtedly we can; by the mere act of the *will* there is not alone the ability to see, touch, and smell of a plant or substance; but, more wonderful still, we can recall to the mind the same sensations which objects of sight, touch, taste, hearing, and smell, produce in reality. I confine my remarks to those who can recall to their mind the sensations which the appearance and qualities of bodies produce, including odours in the term quality. There are a few, who, with the external senses perfect, either have no *mental* perception of odours, or else have not the capacity to comprehend the question. The mental senses or faculties are as much capable of cultivation in this respect as if the subject were numbers or music; and we all know how easy it is to trace the thoughts to a comprehension of these difficult sciences.

All persons take pleasure in cultivating, or, in more familiar terms, in exercising the *mental* faculty of *vision;* this is done unconsciously. It commenced so early, and is at all times so pleasant, that it is not considered as a thing that was ever learned. We can recollect, however, how long it is before a child acquires a just knowledge of proportions and distance, yet the child itself never remembers it. As the mind advances to maturity, that particular part of the brain which receives the impressions of *light* by a simple operation of the mind—the mere *willing* it—can be again excited so as to produce the same spectrum or image. Certain faculties can be so trained, and vision, for instance, has been so highly cultivated, *mentally*, that we can please ourselves with the same objects and scenes that afforded us so much pleasure in reality.

Next to vision, the *mental* perception of *touch* is cultivated; then hearing, and to a great degree we encourage the thoughts to dwell on flavours. Perhaps it may be said that the *mental* perception of flavours is more the subject of thought than any other, excepting *objects*. With many persons the mental perception of *touch* is, to be sure, very exquisite. For instance, the bare recollection of the sensations produced by rubbing a piece of woollen cloth across the teeth after eating a lemon, will make many a one shiver, set the teeth on edge, and make their flesh crawl and creep as in reality. There are many, too, who have the salivary glands strongly excited at the mere *recollection* of a slice of pine-apple, or of some savory or highly flavoured dish.

But I grieve to say that very few, hitherto, have a keen *mental* perception of perfumes; it is to be regretted, because the enjoyment is more refined and intellectual. In prison or other solitary confinement, it would be a great pleasure if our memory were as tenacious of the recollection of perfumes as it is of the other qualities of bodies. The *mental* sight of the poor prisoner—such, for instance, as those virtuous sufferers, Silvio Pellico and Marincelli—is always painfully acute; if a quick perception of perfumes and flavours had been added to their intellectual gifts, there might have been a few moments now and then of some pleasurable sensations. M. Marincelli told me, that through the whole course of his imprisonment he was only *twice* able to bring to his *mental* perception the fragrance of the rose and the aroma of coffee, often as he desired to recollect them. That twice, and twice only, the true and real perfume of the rose, and twice the aroma of coffee, came over his benighted mind, affording him for a second or two exquisite pleasure; but he could never bring them back again.

Those who have not cultivated that internal faculty, which enables us to recall sweet odours, can attach no importance to a fact of this kind. It is a subject, however, worth their attention. Such facts as these, from their very nature, must throw great light on metaphysical science; facts which afford proof, available proof, *of the intimate, the inseparable connexion, the entire dependence of the will on the organs of sense.*

I find it necessary to subjoin a few additional remarks to this preamble, that those who take an interest in such investigations may recall to mind the difference between the perception of internal and external sensations—sensations which are produced by the contact of external bodies, or those which are produced by an effort of the mind. I wish them to recollect the difference between the perfume of a flower when the mind recalls it, and when the perfume is actually present.

Some persons have their sense of smell so highly cultivated by long practice—I mean their *mental* sense—that they have almost as vivid a perception of perfumes when the flower is not present, as those persons already described have of the mental sense of *touch.* The perfume of flowers when they are near to us, seems to diffuse itself through the mind as it were, and produces the most grateful, pleasant, and I may say, for I have experienced it, the most subdued and hallowed feelings. A mental perception of perfumes is almost as agreeable to a sensitive, non-exacting, simple mind, as the reality ; and yet so little is this understood, that few can appreciate it—more particularly as so very few cultivate or are passionately fond of flowers.

Even the wicked and unprincipled, some of them at least, take great delight in cultivating shrubs and flowers, and their perverse nature is all the better for it ; but for this their brutal propensities would be still more brutal ; it is a beneficent gift, let it be given to whom it may. If those infatuated wretches who destroyed the beautiful gardens of the nunnery near Boston, had been early taught to love and cultivate flowers, they never would have raised their hand to assist in that work of destruction. The only moments that a brutal mind abstains from acts of violence—as religious impulses do not influence him—is when the recollections of flowers and their perfumes occupy his mind. Dirck Hattairack associated freedom from guilt with a "bloomen garden," and surely, whilst this vision was present to his mind, sinful thoughts were shut out. When the face is buried amongst flowering shrubs and their pleasant fragrance, all the evil passions that assail us are chased away. It is the peculiar property of agreeable odours to keep *exclusive* possession of the thoughts; if we will only deign to look closely into the matter, we shall find that a calmness comes over the mental senses, which prevents the admission of angry, or unruly, or unholy thoughts. It is like throwing oil on the troubled waters; and it is to assist in the perfection of our nature that our good and Heavenly Father has so profusely scattered plants and flowers around. As there is truth in these remarks, of how much importance is it so to train the mind, as that the recollection of flowers and their perfumes can be as pleasant, and produce the same innocent feelings, that they did when they were present in reality.

The fragrance of a flower can be recalled to the mind a thousand times, and each time there will be a distinct perception of it. Not so vivid, certainly, as when the perfume is present, but vivid enough to render it apparent that it is the exact resemblance of that which was inhaled from the flower. When the system is in perfect health, so that the mind can be refreshed after hard study, with simple pleasures, we can regale ourselves, mentally, with the perfume of any flower that we choose. At any moment, the fresh, spring-like, tender fragrance of the lilac can be enjoyed as fully by the mental sense of those trained to the love of sweet odours, as if the lilac were really present.

Being confident, therefore, that there is a power connected with animal life which allows of the free action of the *will*, so that any agreeable or disagreeable perfume or odour can be *recalled* to the mind, the conclusion must follow that there is no obstacle to prevent a recurrence of this mental ability, and that we can oblige the *will* to recall the perception of odours whenever we choose it—there never has been a doubt of this before.

After stating thus much, in order that the mind might be a little prepared for what is to follow, I shall produce the proof to the contrary; it will be seen that the faculties of the mind are wholly dependent on *external* influences. This discovery, if rightly appreciated, will go far to throw new light on the inquiry of the freedom of the *will* in other questions than those that relate to objects of sense.

Let any one who possesses the power of recalling odours to the mind think of the perfume of a cigar, or mint, or coffee, or burnt feathers, or of any other perfume that is more frequently present. The person will perceive—

provided there be no other perfume really near him externally—that he has a very vivid perception of the aroma of the cigar, the mint, the coffee, or the burnt feathers; and that in quality these mental perfumes exactly resemble the real ones.

When he is thus sure that he *has* the power of recalling perfumes, *let him stop breathing through the nose*, and then endeavour to recall the perception of odours. It will be perceived immediately, that by no effort of the *will* can these or any perfume be recalled to the mind. He can, mentally, see the cigar, the mint, the burnt coffee; he can recollect that they each have a separate perfume; but much as he desires it—and the *will* make strong efforts—he cannot, *whilst he stops breathing*, recall their peculiar fragrance.

The will has no power to act, or to enable us to bring the mental perception of odours to the mind or consciousness, unless the external membrane over which the same odours passed in reality, be again excited! We must actually breathe through the nose, or the perception of the perfume of flowers, or the odour of any substance whatever, cannot be recalled to our mental sense. Nor, what is quite as extraordinary, can there be a *mental* perception of these, or of any perfumes, *even when breathing through the nose, if there be a strong perfume of a different nature near us!* In other words, if we are *in reality* inhaling the fragrance of a cigar, or a lemon, or a rose, or are smelling an onion, or rhubarb, or laudanum, we cannot recall to our mind the perfume of any other odorous body, however earnestly the effort is made. *We must remember to keep the odorous substance close to the nose, whilst we are endeavouring to recall the perfume of a different one.* Is not this a fact of vital importance to the metaphysican? If by keeping an external organ in a quiescent state the *will* can be prevented from acting, or if the actual presence of a strong perfume can prevent our calling to mind the perfume of a different substance, may not a clue be found that will unravel a mystery very closely allied to this one—the freedom of the *will* as it regards religious and moral impulse? Is there not a simplicity throughout the laws of nature, nothing can be more economical; for all the variety and combinations proceed from a limited number of fixed principles. The kaleidescope, that has but a dozen differently shaped objects in it, produces an endless variety. The principles of *Form* appear to be settled by the great Creator as an *innate* principle, and is diffused throughout the whole economy of nature. Inanimate matter resolves itself into definite proportions, crystals from different residua settle into different shapes, the forms of squares, hexagons, octagons, triangles, and circles are inherent to matter; for insects, at the *moment* of their birth, make them all with unerring precision and regularity.

There is scarcely a marine shell that has not some species of imagery on its surface that resembles the work of art. There are shells, on whose surfaces are regular bars of music; others have various specimens of architecture, such as bridges, towers, columns, and arches. Others have beautiful landscapes, in which are seen trees, shrubs, fountains, and temples ; and the forms of animals can be traced in many. Does any one suppose that this is the result of chance? there is no such thing as chance in the physical works of nature.

Man, therefore, only makes use of that which is at hand—that which may be considered as a fixed principle. He has within him the *organ of form*, and he cultivates it ; but when he chisels out the animal from marble or transfers this animal to canvas ; when he discovers, by a laborious calculation—by an extensive series of numbers, that the hexagon is the best form for durability and economy of space ; he does no more than work out a natural problem, the principle of which exists already. In this respect he is less gifted than insects and crystals, for their labours, *mechanically*, resolve themselves into particular forms which never vary. The bee makes its hexagon cells, and the butterfly its green and gold chrysalis; not by chance nor yet by design on their part, but from an *innate fixed principle*, instituted from the beginning of all things by the great Creator of all things. Man, therefore, is a kaleidescope, in which there is but a limited number of organs and faculties, all of which correspond to such of the fixed principles in nature as are useful to his existence. God, in his wisdom and benevolence, has endowed him with *mind*, with the liberty of combining and comparing; and this mind, or thinking principle, enables him to make use of every combination of which the united organs and faculties are capable.

If flour and water were not present, we could not make bread; if the organ of form and the faculty of perceiving and conceiving were not innate, we could neither comprehend particular nor general species; we could not from a variety make *one whole*. We have therefore organs of body and faculties of mind intimately blended one with the other, and all capable of ringing so many changes. If, therefore, we bestow more labour in the cultivation of *one* organ and faculty than another, *that* faculty and organ will excel the others; and, to return to the point whence I digressed, as the organ of *smell* is as capable of being improved as the organs of sight and touch, we can enjoy perfumes at those times when they are not present.

But, as I remarked before, this sense is the least cultivated, for the inhabitants of cities, the majority at least, scarcely see a flower or ever smell pleasant perfumes. Their aim is to deaden this sense as much as possible, for in cities there is a compound of disgusting and deleterious effluvia which it is necessary to exclude. Those who *labour* in the country are likewise compelled to shut out the sense of smelling, for they have to come in contact with vegetable and animal substances in every stage of decay. But happy is he who, having leisure and wealth, can move from what is offensive and hurtful to what is pleasant and healthful. He has then a new sense, and if he will only cultivate it, he shall find that it is as exquisite as that of sight or taste. He will find that he can *mentally* perceive the fragrance of a flower quite as vividly as he can, *mentally*, see the flower itself; for that we can, in our mind, see the full, elegantly shaped, cool, moist, tender coloured, sweetly perfumed lilac, no one doubts for a moment. In our silent chamber, even in winter—and let me add *particularly* in winter, for then there are no *external* odours present—we can recall any agreeable perfume that we choose, keeping always in mind that no other perfume is to be near us. What is quite as pleasant, by not breathing we can prevent the nausea which often arises when a disgusting perfume is passing in review before our *mental* sense, or, as it is called, our imagination—which perception will sometimes intrude in spite of our desire to repel it.

When this extraordinary fact first presented itself, I was filled with wonder and admiration; admiration at the simplicity of the mechanism of mind and matter, and wonder, that truths, so singular and important—pointing so clearly to the source whence an inquiry into the nature and powers of the mental faculties should commence—had so long escaped observation. Is it going to stimulate us to farther action ; or because the envious, the vulgar, or the dull, may profess to view it as a joke, shall men of true science refuse to examine it ?

And here let it be observed in the outset, that I have experienced a very great difficulty—that of making myself understood by those who are really desirous of comprehending this curious phenomenon. So unaccustomed are the generality of men to view the mind otherwise than as an essence existing separately from the body—considering it as a distinct illumination, and floating about loosely in the brain—that when this singular fact was first made known to them they were incapable of comprehending it. There are very few that can believe with Drew, and other distinguished writers, that the spiritual essence called *mind*, and vivified matter, must in this life be intimately interwoven. Nay, that organized matter must accompany the soul or spirit in a future state, if identity is to be preserved.

Even when convinced of the fact that the *will* was useless to our mentally perceiving an absent perfume, unless the external organ were again excited as it was in reality, they could not understand it, for they considered the *will* as absolute and quite independent of bodily organization. How, said another person, can we expect to smell when we close the organs of smell? The question was not in connexion with the phenomenon; for here, the real and the imaginary perfume—for so I must call it now—were blended together. Few, therefore, can comprehend that the *will* is as powerless to recall the perception of the qualities of bodies, unless the external senses are in full activity, as it would be to allow us to perceive them in reality if the external organ were destroyed.

As soon as I discovered that the *will* had no power to bring back the perception of perfumes to the internal sense when the external organ was closed, then I suspected at once that the *will* had no power to enable us to revive, *mentally*, any appearance or quality of a body—sounds, flavours, and odours being included in the term quality—without the joint effort of the external senses. These suspicions become realities, for by patient experiment I have found, that unless the internal, physical organs of Sight, Hearing, Taste, Smell, and Touch were agitated, as they necessarily are when any outward object presents itself, there can be no *mental* perception of the same sensations—no recalling them again to the mind!

I then made a series of experiments on the organs of Taste, and its intimate connexion with Smell was apparent at the first glance; a fact of which we are generally well aware. So little are we in the habit of analyzing our sensations, that this inability to taste the flavour or smell the aroma of any sapid or fragrant body, was merely attributed to a cold, and there the question rested. No one reasons so closely as to allow that *Taste* is entirely dependent on smell—that flavours and odours are insepa-rably combined—that the delicious flavour of a strawberry could not be imparted to the sense of taste, unless the organ of smell gave us leave to perceive the aroma of its flavour at the same time.

Smell is perfect without the aid of taste, but taste has no individuality; it is not a distinct sense, unless in conjunction with smell. Even then, being dependent on smell, it is questiona-ble to call it a simple sense, because its charac-ter of imparting a perception of flavours is en-tirely in consequence of its intimate union with smell. Those who come newly to this curious and important investigation, have a difficulty in comprehending all this.

The sense of taste lies wholly in the tongue, but every part, indiscriminately, does not con-vey a perception of flavour. The strongest perception is *near the tip and on each side of the tongue as far as the root.* The roof of the mouth only serves as a resisting medium to the fulcrum of the tongue, for the purpose of deglutition. The mere contact of the sapid body with the tip and sides of the tongue conveys an impression of flavour to the internal organ of taste. But what is very extraordinary and important—*unless the saliva overflow the tongue and fauces, and we breathe through the nose, we not only cannot have a perception of flavour in reality, but we cannot recall the perception of flavours mentally!*

This singular fact forms a strong link to the chain of reasoning to prove that the mental faculties are as entirely dependent on the healthy and continued action of the corporeal powers as the latter are on the faculties of the mind.

It was conjectured by Dr. Reid that the saliva was somehow connected with the development of taste. "It is possible," says he, "that every thing which affects the taste is in *some degree* soluble in the saliva. It is not conceivable how any thing should enter readily, and of its own accord as it were, into the pores of the tongue, palate, and fauces, unless it had some chemical affinity to the liquor with which their pores are always replete."

It is surprising when experiment was so easy, and the conjecture had crossed his mind, that he did not ascertain the truth of it. He would have found that the tongue and fauces, *when perfectly dry*, cannot, by any effort that the *will* makes, impart to us the taste, or rather the flavour, of any sapid body. A fluid menstruum is absolutely necessary to the conveyance of flavours—just as necessary as a fluid is to the movement or conveyance of a boat. Even odours require a moist atmosphere, a fact which every one knows; for the fragrance of flowers is more perceptible at night, and in the morning when dews are present, than when the sun has absorbed the moisture.

If careful experiment be made, it will be found that the saliva—as a distinct secretion—is not of vital importance to the transmission of flavour. Water is almost as good a medium for simple experiment. The saliva, independently of its fluidity, is possessed of a certain viscidity, which may concentrate the particles composing flavour, and in this way confine the sapidity of a substance to one spot—to the tongue and fauces. But there is a state of the system when too much of this viscidity is imparted to the fluid secretions, and in consequence the aroma of a sapid body cannot be admitted into the pores of the fluid. By turning to No. 4 of the preceding memoir, it will be observed that too great a viscidity in the fluid secretions of the eye-ball causes the air-bubbles, with which it is charged, to adhere, and brings on the disease called Muscæ volitantes. Every one is aware of the fact that the saliva is clammy and thick during fever, and that no perception of flavour is conveyed by the tongue at that time.

But if all this is extraordinary, is it not more so when we find that we must breathe through the nose, and that the saliva must overflow the tongue, or we cannot recall to the mind the perception of flavours? It is a fact, that *if we stop breathing through the nose, and keep the* *tongue, the roof of the mouth and fauces from coming in contact—covering the tongue and all the adjacent parts with dry linen, taking care not to imitate the action of swallowing—we cannot recollect the flavour of any sapid body!*

When speaking of flavours, I do not allude to those peculiar qualities which always accompany certain bodies, and are distinct from their sapidity—such as cold, heat, bitter, or other pungent, stimulating qualities. The sensation which they impart can be felt just as sensibly when these pungent substances are applied to the skin of the arms and legs as to the tongue. Rubifacients are applied to every part of the skin, but the *aroma* of the cayenne, turpentine, mustard, brandy, &c., is not perceived through the pores. The skin of the tongue, *when thoroughly dry*, is no more than the skin of the cheek, and has no power to convey a perception of flavour to the mind.

It is not, therefore, of the *burning* sensations which the above substances, or cloves, cinnamon, pepper, alcohol, and vinegar have independently of their aroma or flavour that I speak, but simply that which applies exclusively to taste—flavour itself. I repeat again, *that unless the essence which constitutes flavour is conveyed through the saliva, and unless the sense of smell is externally active, and also, unless we imitate the action of swallowing, the will has no power to convey to the mind the perception of that quality which sapid bodies have, and which quality is quite distinct from pungency.*

There is scarcely any one *with the external organs perfect,* who has not a mental perception of pleasant or unpleasant flavours. We can at any moment—when no strong perfume is near us—*recall* to our mind the *flavour* of fried oysters, ham, beef a-la-mode, musk-melons, apples, strawberries, wine, assafœtida, bilge-water, garlick, &c. But if the tongue and roof of the mouth are quite dry—linen being covered over the inside of the mouth—it will be perceived, as in the above case, when flavours were applied to the tongue in reality, that if the nose be kept shut, the mouth dry, and the action of swallowing prevented during the experiment, we can no more *recall* the perception of flavours than we could in reality under such circumstances if the flavoured substances were present.

If we closely attend to the impressions which the external senses make on the mind, and observe how the mind operates on the external senses, the whole evidence of their dependence is made out, and other phenomena grow out of the investigation demanding attention.

Thus, on pursuing the subject farther, I was induced to believe that *utterance*, or the power of embodying and uttering words, with or without *sounds*, was a distinct sense. What first gave rise to the conjecture was the remarkable observation of Condillac—" That we think through the medium of language." After reaching this happy thought, why did he not proceed? Had he advanced one step further, he would have made the extraordinary discovery that we not only *think* through the medium of words or language, but that when in *imagination* we are speaking to another, and go over a conversation which had previously occurred, or which might have occurred, *the same internal organs and muscles must be excited which were used in talking aloud in reality!* Unless these organs and muscles are thus acted upon, we cannot, even in mental thought, go over any conversation or pursue any train of reasoning.

It is evident, from a close analysis, that the internal organs are more strongly excited when in imagination we are speaking aloud than in a whisper; and further, that this only applies to our own share of the conversation. We cannot in our *thoughts* go over the words spoken aloud without being conscious that the same nerves and muscles are operated upon that were excited when we uttered sounds and words in reality. But this is not the case when *recalling* the sounds and words spoken or emitted by another person. We are then sensible that a very different set of organs and muscles are in action, for in the imaginary emission of sounds by others, as in reality, the organs of *hearing* are excited.

The louder, in our imagination, that we are uttering sounds or words, the more apparent is the fact that the *will* has no power to allow us to do this unless the same apparatus which assisted in real utterance is again in motion. To prove this, let us fancy that we are *repeating* the word Lismehago, not looking at it merely, but repeating it in a low whisper, without allowing the outward organs of speech to have the least motion, keeping the tongue still and the mouth shut. Is it not perceived immediately, that a slight impression has been made on the brain, accompanied by a perceptible motion of the respiratory organs—a motion very distinct from that of breathing?

Now let us, still in imagination, for so we must express ourselves, fancy that we are uttering the same word, Lismehago, louder, and then louder still, and finally that we are shout-it aloud, Lismehago, to the full extent of the voice; is it not perceived that a certain part of the brain, as well as the breast, and even the stomach and lungs, have been strongly excited? Is it not apparent that we are operating on the same internal organs which were called into action when we uttered the word aloud? But it should be kept in view that *we ourselves* are the persons calling or shouting; otherwise, so rapid is thought, that we may imagine it is some one else. In case that another person is calling, the organs of *hearing* are only excited, and no internal motion will be perceived; we must identify ourselves with the sound, or we shall make a mistake.

Repeated experiments, by myself and others, induces the belief that utterance has stronger claims to rank as another sense than Taste, which is not perfect unless in connexion with Smell. Utterance, like the other senses, depends upon muscular action; in fact, muscular action accompanies the movements of every sense; and if, as Dr. Brown suggests, *muscular contraction* should be considered as another sense, so peculiar and extensive is its range, it would have to take precedence of all others. It not only accompanies the movement, or, rather, causes the movements of all the senses, but it likewise assists the motion of every organ in the body. Utterance is exclusive and confined to one operation; it is, besides, very strongly marked in its character. Like Sight, Smell, and Hearing, it only depends on one set of organs and muscles; and this is simply for the emission of sounds or words.

There is therefore the organ of Utterance for the projection of sounds, and the organ of Hearing for the admission of sounds. If that can be called a sense which receives sounds from without, another organ should be called a sense when it projects sounds from within, for the operations require different apparatus. Taste, on the contrary, is dependent on Smell for its capacity to impart the perception of flavours. The tongue, which is the external organ of Taste, has likewise the power of distinguishing substances by touch, quite as accurately, nay, with greater nicety, than the finger, which is the principal organ of Touch. Taste, then, or rather the organ of Taste, is of a threefold compound; it is indebted to Smell for the flavour which gives it the character it bears, and it performs the office of touch. Sight, Hearing, Smell, and Utterance, are simple and exclusive.

I despair, in this early stage of the inquiry, to convey to others a knowledge of the mode of pursuing the experiments to the sense of Hearing; I shall, however, make the attempt. Let us imagine that we are listening to the sound of a trumpet, to a song, to loud laughter from others; is it not perceived that these imaginary sounds fall on a different part of the brain; that they do not produce any of those faint catches in the breathing to which we are sensible when in *imagination* we are blowing the trumpet, singing, or laughing loud ourselves?

Only let us suppose that we are calling aloud to a man who is standing on the edge of a rock, far above ordinary hearing. To make him hear *our* voice, the muscles, *as in reality*, must be exerted to the utmost. It will at once be perceived that the same set of muscles must come in play which are used when the voice is raised to such a height in reality. And when in imagination we go through the notes of a song, can we avoid moving the same muscles that we do when really singing aloud? In this way, and no other, can we account for the great fatigue that the mind undergoes when the thoughts are hard at work. If a person is exhausted by haranguing or conversing for a long time, he will become doubly so should he go over the same discussion again, mentally. For, *as we think through the medium of language*, and the organs of Utterance have been greatly exercised in reality, they must receive additional fatigue when again called upon to perform the same labour.

To prove, in another way, that the same muscles must move as in reality, let us call aloud to the man on the rock. Whilst we merely prevent the external organs of speech from moving, we perceive that the internal organs and muscles are excited, and we are able to articulate *mentally*. But whilst we thus shut the mouth, let us also *stop breathing;* and we shall find to our astonishment that we have no power to revive in our mind the words which we intend shall reach the man's ear, so entirely are we *mentally* dumb that we absolutely catch ourselves beckoning to him! This experiment can easily be made if we fill and empty the lungs with a long breath—we can then stop breathing for nearly a minute.

But at the same time that we are thus incapable of uttering sounds mentally, it can be distinctly perceived that another set of organs have been operated upon, when we fancy that we hear the voice of the man calling down to us. The voice, as we listen, falls on the *ear,* the *mental* ear as it were; for there is no effort of the organ of utterance to receive or make use of the sound.

The same mental agents employed to cause motion in the organs and muscles of the internal senses in reality, can also agitate the auditory nerves so as to bring to our perception, mentally, the same sounds that they are capable of exciting in reality. External sounds only jar or agitate certain nerves, which agitation, in fact, constitutes all the knowledge that the external world can give us of sound. No music or sound can issue from any instrument externally. It is not music or sound, *as* music or sound, that causes us to know it as such. It is only as different degrees of vibrations, which agitate the tympanum or auditory nerve, that sounds strike us as harmonious or otherwise—either soft or harsh, low or loud. *It is in our own ear, in short, that sounds are first created!*

If we touch the strings of a harp or violin, neither the strings themselves, nor their contact with the air that their motion separates, impart the sensation of sweet or harsh sounds. The air is agitated, and the tremulous motion disturbs the contiguous particles, and they proceed swiftly from the point of contact to all surrounding space. Whatever is within the range of this disturbance or vibration, is sensibly affected by it ; the delicate chords of

Hearing, when within the influence of this tremulous commotion, are agitated likewise; and it is only from these internal chords that we have any knowledge of sounds at all; there is no music in mere vibration—it is only when the tremulous air jars the *internal* chords, where the true and only musical sounding board ever exists, that there is any real music or sound.

If the air without have the power of agitating the nerves of Hearing, and if the *will* have the power of allowing us to comprehend these external vibrations when sounds are to be communicated, why can it not make use of the *same agent* to propel sounds from the mouth as in singing and speaking? It can do so—it does do so—by the mere act of the *will;* the internal chords are agitated, and the external air vibrates; the ear of the person near us is then a sounding board, against which our voice rebounds; not only that ear, but hundreds of others, and our own ear likewise; all become sensible to the vibrations. Education has taught us to attach precise meaning to the different intonations and modulations, and thus *sound becomes the interpreter of thought !*

There is, therefore, an agent at the command of the *will* always ready to act ; this agent is air or gas. The system is replete with gases, and the *will* or mind has the ability of operating on the different nerves and muscles of the brain by their means. It can thus excite the system throughout ; we perceive that it can produce, or cause to be produced, *external* sounds ; and it can also produce, though in a fainter degree, but strong enough for recognition, all those sounds which the jarring or concussion of external bodies has the power to do on the same cerebral organs. Whilst the external senses are perfect, the *will* can draw in, as it were, through those inlets the five senses, the lungs, and the pores, all external matter, such as heat, light, cold, effluvia ; and this it is enabled *to do by making use of the elastic gases as a medium of communication !*

The *will* of man, surely, has this power, as well as the *will* of a toad. Whoever observed the habits of toads, must have seen them catch flies or other small insects that unwarily approach within a foot of them. A toad opens his mouth as the fly is passing, and closes it again suddenly with a perceptible noise; he draws in a stream of air by this motion, and into this current the insect is drawn. It is an instantaneous operation; for he draws in the fly just as quickly as we can draw in a feather when near our mouth.

Now if the will have the power of drawing in external gases to its aid, and if it have the power also of allowing of the easy admission of gases charged with common atmospheric matter—such as is constantly drawn in through the nose and mouth—it can surely do a *less* difficult thing. Because tangible, perceptible effects proceed from external operations, and to which we are hourly witness, are we to refuse belief to that which is not so apparently perceptible? The mind, or *will*, has as much command over the *centre* of intelligence as it has over the extremities. If the *will* can allow us to draw in breath, and throw out breath, and stop the breath for a certain length of time; why can we not believe that it may use *part* of this breath or air for other purposes? Why need it employ other means, when the one so constantly at command is all-sufficient? If the *will* can direct the extremity of the nerves—those, for instance, at the end of the fingers—to strike or jar the chord of a harp for the purpose of creating a loud sound that shall *appear* as a loud sound to the centre of intelligence, surely that same centre can be acted upon by the same agent in a fainter degree.

The man who has the power to direct his agents to obtain supplies from the frontiers, can certainly make use of their services and supplies at the seat of government. There are but few laws in force to govern the moral and physical world; and the reason is, that matter and mind are so intimately blended. The further we advance in the investigations of natural science, the more forcibly shall we be struck with the simplicity and regularity of those principles in nature, which, although they comprehend all things appertaining to animate and inanimate creation, yet if we trace them to their source, are found to be few in number and of simple construction. From a few figures what extensive combinations can be made, yet ramified as they are when we go to the root, the original powers are few indeed.

The internal operations of the mind have never been examined in the right way; we expect wonders, and great complication as well as mystification, when all there is as simple as external motion. We look at *thought* in the abstract, and never view it as part and parcel of life, flesh, blood, bones, and nerves. We consider the power which regulates and conducts *thought* as an independent essence, which *hovers around* the nucleus where sensation originates, but which never touches it; like a dew-drop on a cabbage leaf, which rolls over it as free from all contact of the leaf as the balloon over head. Let those who have such limited notions read "Drew on the Resurrection."

They will gather from his argument that the *spirit*, the life, and the body are but arbitrary distinctions ; and that neither Scripture nor philosophy warrant us in assigning them separate existences. They will there see the matter fairly argued, proving that the soul and body are so intimately interwoven, so identified, that they cannot exist for any useful purpose, either here or hereafter, unless they are connected; that the spirit, the life, and the body are three and one, neither separated nor divided.

Taking it for granted, therefore, that the spirit, which directs the motives and actions of organized beings, is completely identified with it, it is strictly philosophical to infer that that there is but one mode of operating—not one set of apparatus to excite thought and another to excite action. We must conclude that there is but one seat of sensation, whence all bodily and mental action is perceived. That all painful sensations originate at one point, is clearly proved by the fact that a nerve which was injured in the toe and gave great pain, is still subject to spasms at its source. For although the whole leg may be amputated, yet whenever the pain returns, which it frequently does, it appears to the sufferer to be in the toe still ; not at the end of the amputated part, where we should naturally suppose the pain would be felt, but where the toe was when connected with the body.

That pleasurable sensations are likewise referable to the same central apparatus, our own experience will show. The actual presence of near and dear friends produces the most agreeable and lively emotions. When they are absent, the anticipation of their return awakens the same feelings ; we are conscious that they must flow from the same source, and that they are the same that were felt when the reality was before us.

After all, to what does it amount? Why only this—that our perceptions of sensations which originate from some external impulse, and our perception of those that have their origin in the mind when there is *no external* impulse, are precisely of the same nature. The only difference is, that the former make a greater impression, because they are much stronger than those which owe their existence to the *will* without the intervention of an external object. But the mere fact of perceiving more or less vividly does not affect the question, for the same nucleus or ganglion, or whatever it may be called, is excited, whether the impulse proceeds from within or without. Is it not in mercy that the revival of sounds, internally, should be accomplished without loudness? Would not the organs soon wear out if loud sounds were constant?

If a door slam, or is pushed shut with violence, the concussion jars the air, and every thing within the range of the shock trembles as the vibrations reach it. The organ of Hearing being one of the things moved, is also rendered tremulous by the vibrations; and if the sound has been very loud and harsh, the pain will be severe. The organ, being impressed, as it were, with the particular kind of motion which the slamming of a door gives to the internal organ, it is ever after capable of being excited in the same way. If the *loudness* of the sound could be as readily revived as the *peculiarity* of the sound is, we should be miserable indeed. There are some persons who suffer torture from loud sounds which are constantly perceptible in the head.

When we wish to refer, mentally, to the sound which the slamming of a door makes, the *will* enables us to perceive it, because the same chords or nerves are agitated as in reality—only in a fainter degree ; for of what use, as I observed before, but to wear out the organ, would it be to subject the nerves to the same violence which the strong vibrations from without inflict on the ear. We all know the pain that sharp, loud noises cause ; and certainly when the *will* enables us to recall the kind of noise required, it is mercifully ordained that we should be able to revive them without the pain originally felt. The principal agents, therefore, for both the reality of sound and the revival of it, are the elastic gases; they are the agents, too, of universal nature, and are present every where; capable of causing pain when collected with force, and pleasure when gently used. They fill all the interstices of space; even the brain has its share; and, in short, it is through the medium of this elastic power that the slight and simple motions requisite for mental purposes are effected.

Having thus hinted at the probable mode of producing motion in the brain, I shall follow up one fact. Let any one who is sitting quietly by himself, watch the progress of one sound as it falls on the ear. If he strike the table with a hard instrument, the sound will grate harshly on the tympanum; he listens steadily, it continues; there has been no perceptible break or cessation. If the attention were rivetted on this sound from the commencement, it will be acknowledged that no other has intervened to displace this particular one. It is identified with the noise produced by striking the table, and the sensations and perceptions of them appear to be the same, and no *revival* ; yet the external vibrations of the air must long since have ceased. He still listens—the sound is yet ringing, but it has become fainter and fainter ; it is attenuated, yet he perceives that it is the same. If that is called a sound which he heard when the table was struck, is it not the very same that he is hearing during this interval of ten or fifteen minutes? It is undoubtedly the same sound contemplated from the first to the last. If he had the power of abstracting his attention for one hour, and it was strictly confined to this one sound, he would perceive that there was, apparently, no interruption of it ; so quickly are the changes rung, so rapid is mental action, so smoothly are the transitions made on the delicate machinery of the internal organs!

If this be true, as it certainly is, what becomes of the theory of mental perception as a distinct and separate operation of the mind independent of the organs of sense ? Wherein lies the difficulty of comprehending that we can have no mental perception of sounds, or of any other quality of bodies, unless there be some internal effort to agitate, or render tremulous, the same chords, nerves, or other apparatus which were operated upon by external agency.

The laws of the universe are not complicated; the complexity lies more in our erroneous mode of philosophising, than in reality. The brain, by its organization is not only fitted to receive all the impressions which the outward senses convey, but it is capable of having these impressions revived or renewed on a more contracted scale by the same effort of the *will*. The revival or renewal is made on the same organs—the mind or *will* employs no others.

There are in the brain, convolutions, sinuosities, and secretive matter enough to warrant the belief that around and through this pulpy, plastic region the *will* may operate. The mind or *will* is intimately incorporated with every part of the body; its strong hold, or seat of government, being in some part, or throughout the cerebral mass. The other principle also, *life*, is diffused throughout the whole system, and renders every part capable of being put in motion by the *will*; but it is the judgment *that directs this motion to definite purposes.* It is not the *life* in the finger that impels it to touch the chord; it is the judgment that directs, and the *will* which allows of the movement. The commencement of the movement is at the central or cerebral point of *touch*, and it is at this point, on the same ganglion, that we perceive a renewal of the same sensations. The centre of intelligence may be compared to a book with many leaves. The will directs the external organs to imprint what passes without on these leaves, and according to the goodness of the impression will be our perception of the matter there registered. When we have a desire to recall some particular object, the *will* has only to turn over the leaves and bring the precise thing to our mental perception. I have varied these remarks, that their exact meaning may be easily understood.

That the brain has a double set of organs, shows the wisdom and benevolence of the Great Author of our being. The nerves and all the apparatus of sense, are all double; even the tongue is divided into two parts, although joined in the centre; and the necessity is apparent, for if one organ is injured, then its fellow can perform its part alone. There are cases on record wherein there appeared no want of mental capacity after the loss of one half of the brain. No one, however, can believe that even brute instinct can remain when the brain has been wholly removed. A man might as well be expected to see *external* things without eyes, as to think or reason without brains; and yet there are those who would fain make us believe the contrary.

By paying strict attention to those slight motions which every thinking person must have perceived in the brain, evidence will be obtained to corroborate what I am still further to disclose. The habit of attending to mental operations is much more easily acquired than is imagined, and instead of throwing these remarks aside as puerile and unworthy of investigation, let those who value truth make the experiments at once and with care; a little patience will soon put them in the right train of thought. When it is considered that this is the only mode of gaining a knowledge of what is passing within, all the powers of the mind should be held in requisition to pursue the subject as far as it will go.

It is a fact, well established, that if the word is a long one, either written or printed, the whole cannot be seen at once so as to be comprehended fully. On looking at the word Lismehago, as it is here seen on the paper, the eye *appears* to take in the whole word at once, provided the eye is quiet and directed somewhere near the middle. But if we only look at the first, or last letter, then the eye can only comprehend the letter adjoining it. By direct distinct vision, the eye is not capable of conveying more than a very small portion of an object. The eye *appears* to take in the whole word, Lismehago; but by close observation we perceive that it only rests on one letter at a time. When the object is *near*, the point of distinct vision is very minute; but when at a great distance, the point or centre on which the eye rests, *appears* much larger, though in reality it is not.

The same thing applies to the *mental* revival of the appearance of objects. To comprehend this, let us look earnestly at the word LISMEHAGO, and after shutting our eyes take a *mental* look at it. If we pay strict attention to our sensations whilst we are examining it, we shall perceive that the eye slides along the word, just as it does in reality, that we may comprehend the whole. The mind's eye, therefore, *which in fact is the only vision*, cannot, unlimited as its power has hitherto been considered, take in the whole word at a glance. To me this is no cause of wonder, as I am fully persuaded that the same organs which are operated upon when external objects present themselves, serve also for a revival of them in the mind.

That a slight motion takes place whenever we experience any of these sensations which the outward senses have caused, can readily be inferred, for our attention need only be directed to the eye-ball itself. It will be perceived at once that we cannot change our thoughts; we cannot wander from one thought to another, unless the eye-balls, or, strictly speaking, the internal apparatus attached to the eye-balls, move something far into the interior, something far deeper than the eye-ball itself. Even the blind, when deprived of the eye-balls, have still the power of moving the interior part of the muscles, and the extremity also of the optic nerve which rests on that part of the organ or apparatus that gives us a perception of external objects.

It will be perceived, therefore, that our thoughts cannot change unless the eye-ball moves—*precisely on the same principle that the* *spectrum of any image whatever cannot be moved when fixed on the internal ganglion of vision, without the permission of the will.* If we desire to recall any object—such as an apple, a child, a tree, a horse, a river—we *cannot, even in thought,* look from the apple to the child, thence to the tree, the river, the horse, unless the eye moves from one to the other, exactly as it would in reality when these objects were externally present. *The* same unknown power operates in real and imaginary vision, on the same organs and with the same movements.

If the eye-ball is held by the thumb and finger perfectly quiet, which any patient, ready handed person can do for a few seconds at a time, *but no longer*, we shall find that we cannot recall to our thoughts the image of any thing whatever, be the will ever so ready to assist us. To prove this, let any one recall to his memory the appearance of a lemon tree full of fruit. Being certain that he has the power of seeing the image of the tree, let him press his finger against the ball of the eye near the nose.

Whilst for the few seconds that the eye is kept perfectly still, he will find that he cannot recall the image of the lemon tree, or of any other thing. The *will* has no power to enable him to see objects, unless the organs attached to external vision are again excited or moved.

If we revive in the mind the relative position of houses as they stand in a row, just as they are joined to one another in a street, the eye-ball is obliged to move as it does when the eyes are open in real vision if the houses are externally present. The eye, when directed by the *will*, must, of necessity, assist in moving the *internal* organ of vision, so that each object can be contemplated as in reality. The internal extremity of the optic nerve *must* move, that we may be enabled to contemplate each object separately. Even if there are no eye-balls, this extremity of the optic nerve must move, or our thoughts cannot pass from house to house, if we want to look, mentally, from one to another. It is the same with books on the shelf, or with different articles in a room.

Let us imagine that we are looking at a ship sailing up the river, and whilst we are thus mentally following it with our eye to the head of the river, let us endeavour to look at another ship coming up from below, which is taking the same course. We shall find that we cannot place our attention on the second ship down the river, unless the eye-balls move as they would do in reality. If we imagine that we see two rivers, one on each side of an island, like the Hudson and East rivers that lie on each side of New-York, we shall perceive that if our mental eye is directed to the centre of the island, that the two rivers will be seen by oblique vision, for they then occupy the same field of view; but if the mental eye is directed to one river, we cannot see the opposite one without the eye-balls move. Nor need we move the head or body in this mental operation, for in reality the eye only moves through the same arc as when they are open.

In organic life, whether it be animal or vegetable, every operation of nature is effected through the medium of a fluid. All organic matter moves through a moist or liquid medium, whether this matter be inert or capable of voluntary motion. Even gases, the sole agents employed to effect all the changes in matter, are not able to traverse with ease, unless moisture of some kind be present. Whether they act in globular individuality among loose particles of matter, in the connected and undetachable particles of organic matter accompanying the vitality of animals, or in the vast, adhesive concretions of the interior of the globe, these elastic gases can only maintain their position and act with definite purpose when their globules have the aid of a fluid menstruum. This fluidity may often be only the insensible perspiration of the soil, of the human body, or the insensible, invisible moisture of the atmosphere.

All the muscles, nerves, fibres, and articulations of the human body, act through the media of muculent, oleaginous, gelatinous, and salivous secretions; and according as these are present, and according as they are equably diffused, is the effective action of the whole system impeded or advanced. Every part of the system is lubricated by this secretive matter, all more or less in a fluid state. A soft, gelatinous substance protects the spinal marrow, the nervous expansions, in short, every part of the brain; and its use is not only to repair waste and assist in the extension of the parts, but to render all the muscles, nerves, fibres, and joints, flexible and ready for constant action.

The eye loses its perfect vision, the tongue its power to taste, the pituitary membrane its ability to transmit odours, the auditory nerve its capacity to vibrate so as to induce the sensation of sound; in short, no organ or faculty can move without causing pain, or can perform its destined labour, unless the secretions are abundantly present and ready for action in a pure and healthy state.

The organs of sight are obviously and entirely dependent on these secretions. The eye floats, as it were, in a translucid liquid, elicited from the glands by the perpetual motion of the eye-ball; and the conjunctiva and cornea are lubricated with this fluid by the action of the eye-lid. These movements of the eye-ball not only fill the aqueous chamber of the eye itself, but preserve to the pigmentum nigrum its peculiar consistence, and give to the eye that brilliancy so much admired.

In sickness and old age, the absence of this secretive matter is soon made manifest by a prostration of strength; for these secretions deposite nutriment throughout the system. The eyes become dim, the joints grow stiff, the external senses are less acute, sometimes failing altogether; and, to sum up all, there is often an obtusity of apprehension; and all this in the strongest mind. *Without these secretions the will could not enable us to move a finger or even change our thoughts.*

The constant motion of the eye is neither accidental nor the force of habit; it belongs to the constitution of the organs of vision. The eye must of necessity move perpetually, whether asleep or awake. The object of this perpetual motion, in the first place, is to direct the axis to the centre of the object under inspection ; in the second place to excite the secretory glands ; and third, to disperse these fluids, so that they can lubricate every part of the apparatus of the eye ; thus rendering it always flexible. It is only by being thus kept pliant as it were, that this organ of sight, whether operating on external or internal vision, are able to shift the scenes which are externally passing, or which the mind is contemplating within.

The eye-balls, therefore, and the nerves and muscles connected with vision, can never be in a state of absolute rest. Their very existence as organs of sight depends on the motion and flexibility of all the parts. The objects of vision are vast indeed, for the eye gives us a knowledge of all external and internal movements ; it allows us to think and to vary our thoughts at pleasure. The excitation and lubrication of the whole apparatus must be as incessant and copious as the perpetual variety of the shifting and changing scenes require; the great mystery is, that all this and more should be effected by the simple motion of the organs of sight.

The apparatus of vision, simple as is the impulse which sets it in motion, must be very delicate and complicated; necessarily so from the nature of its office. It is the business of this curious instrument to admit into the eye those rays of light, the action of which is to convey to the mind the impression of external objects. It has to absorb, or render latent, the same rays as fast as the mind takes cognizance of their effects; it has likewise to discard, or return into space such particles of light as the dark colouring matter of the choroids cannot absorb or decompose!

That there is not in every eye a sufficiency of this black pigment to absorb or decompose all the light which falls on the eye, can be readily imagined when we see the vivid flashes which often dart from our own eyes as we advance in life; a circumstance which I have mentioned in the preceding memoir. On blowing out the candle late at night, after reading and writing, three or four bright flashes, apparently about an inch in length, become perceptible to our mental vision. But this redundancy of light is scarcely ever seen in young eyes that have a due share of the black pigment. The Albinos suffer extremely in consequence of the absence of this black colouring matter in the choroids; and to get relief from the painful action of light, their eyes are in a constant state of vacillation, to prevent, as it were, the admission of too much light.

This tremulous motion is sometimes changed in others for quick winking, both of which are productive of the same result. Those persons who have the habit of winking rapidly, when looking at a bright object or a highly illuminated window sash, will never see the spectrum of the sash when their eyes are closed. I have shown also, in the preceding memoir, that by agitating the rays of light, an external object is not strongly represented on the internal organ of vision when the eyes are shut. In a very short time many things now obscure will be satisfactorily explained by this very agitation of the rays of light.

To those who can acquire the expertness necessary to keep the eye-ball quiet for a few seconds, so that at the same time they can reflect upon what is *just then* passing in the mind, these remarks will give great pleasure. They will find that this theory is correct, and that without the movement of the internal apparatus of vision, to all of which the eye-ball is attached, they cannot, *mentally*, see any object, nor can they change their thoughts ; nor, what is quite as extraordinary, can the same part of the internal apparatus enable us to comprehend the meaning of each word in more than one way.

The mutes, or the deaf and dumb, comprehend every thing by signs of action. The organs of utterance have either been denied them, or have become useless for want of exercise. Signs pass as rapidly through the mind as the motions of the muscles do when the organs of utterance are excited. The meaning of the word *yesterday* is comprehended by a mute when we point our finger over the shoulder backwards, and *to-morrow* by pointing the finger straight forwards. Signs pass very quickly, also, to those who have the power of speech. Even while reading a sentence, the objects and things which these signs are to represent pass along with the signs themselves—with the words. When we see the sentence, "he beckoned to me," in an instant, though dimly, a person is seen beckoning with his head or finger. We should not feel half the horror, perhaps no horror at all, on reading this sentence—the child's clothes took fire and he was burnt to death—unless the whole awful, shocking scene was represented in the mind at the same time. These *words*, combined, originally represented the action of a child being burnt.

It was by *signs* that the deaf were taught the meaning of words and sentences, and it is by signs that they refer to them mentally. When speech and writing are denied us, we naturally return to the primitive mode of communication; nature never fails us. We recollect what was said in a preceding paragraph, that *if we stop breathing, and do not allow any of the internal apparatus of speech to move*, we cannot call, mentally, to the imaginary man on the rock by speech, but we do the next best thing—we beckon to him. The difference between us and the deaf and dumb is this: they learn by signs—for words are but arbitrary signs—and they can convey their desires and thoughts in *two* ways, by signs of *action* and by signs of writing. We have *three* modes of communication—signs of action, signs of writing, and signs of utterance. The deaf can utter *sounds*, but they have not the ability to modulate them, or form them into signs of words. It was by being taught to modulate, or form words, and then attach sounds to them, that a child learned to convey to us his wants; but of the mode of doing this he was unconscious. When he said, *give me a cake*, the image of the cake was represented in his mind; but so rapid is thought, that very few persons, still less a child, have ever been able to detain it long enough to analyze the process by which it operates.

After repeated trials we shall discover that there is a vast difference between the sensations of *looking* at a word merely to see the letters, and the sensations when we look at the word and its *meaning* together. Let us take a line of this page, and ascertain whether we can, by any effort that the *will* makes, comprehend the meaning of each word in the line, unless we, mentally, move the same internal muscles that would be moved if we were to repeat them aloud. It is impossible to do it if we stop the internal organ of utterance; for although inexperienced or obtuse persons may fancy that they can comprehend the meaning without employing the organ of utterance, yet those who are capable of making delicate experiments will perceive at once, that, faint and rapid as is the motion of the organs of utterance, yet this motion is fully perceived. That it requires great nicety of apprehension to perceive this, does not disprove the fact.

The Chinese or Hebrew characters, as also the Greek and Black letter, can only be viewed by those ignorant of the languages, as pictures or signs, because the meaning is unknown; they are therefore mere objects of sight or pictorial attention. We cannot pronounce the letters and words, because we do not know their sound nor what they signify. We may be ignorant of Spanish and Latin, yet the letters are objects of sight and utterance, although we do not comprehend the meaning of the words that these letters compose. There are, therefore, three operations going on within the jurisdiction of the ganglion of vision—one motion of the muscles by which the signs of the letters and words are explained—another muscular movement by which the word is connected with the adjoining ones, thus allowing us to comprehend the meaning of that word and the bearing it has with the sentence—and a third movement, by which the word and those connected with it are *uttered* or formed into a peculiar shape so as to be clear to the mental perception. All this is effected by the perpetual changing and motion of the internal organs of vision!

When it is considered, therefore, how much depends on the action of the extremity of the optic nerve, it is not surprising that the eye-ball, while it is connected with the extremity of the nerve, is never at rest. If it were to stop one moment, some derangement of the scenic or reflective apparatus would take place. Whilst the finger is pressing the eye-ball that its motion may be stopped, and we are trying to recollect the image of a ship or a lemon tree, it will be perceived, that before the image is well defined, a dimness comes over it and blurs it out. When the eye-ball moves, as move it will, a glimpse of the ship or tree can be caught again, but the instant the eye is *fixed* the image is gone. Every time the organ of vision makes the slightest of all movements—movements scarcely perceptible but to those in the habit of attending strictly to minute experiment—the image of the ship, or any other object, is again visible to the mind. This motion of the eye-ball, the lens, and the pupil, is perpetual.

We may be assured, by delicate and close observation, that this inability to renew, mentally, the image of a ship or any other object, does not arise from the novel position of the eye, nor from the constraint under which the *will* labours on attempting to recall objects when it has to perform another operation at the same time—that of directing the action of the finger which is on the eye-ball. Those who are acute and expert will soon be convinced that it is entirely owing to the motions of the organ of vision that we owe the phenomena of mental vision as well as that which is called *real* vision ; and that we are indebted to these motions for our ability to change from one thought to another, and from one object to another.

With a view to assist those still further who have a desire to become acquainted with this beautiful theory, I shall give one more illustration. If we look steadily at a small speck—one of the dots on this page—we shall perceive how difficult it is, even with the strongest endeavours, to prevent the eye from moving ; and while it is fixed there, there can be no consecutive reasoning; we can *repeat*, but not reason. It becomes absolutely painful to stop the motion of the eye, either by the *will* or by external pressure. It is not a motion such as we can see in the eye of another, but a little jerking motion, such as is felt when our attention is fixed on it, a motion quite distinct from winking, for the shutting the lids has nothing to do with it; but it is, as I said, only perceptible to the minute observer. While the eye is thus intent on this little dot, it will be perceived that there is no consecutive thought going on, but the thoughts seem free again the moment the eye moves.

It may be urged, that in a reverie, or brown study as it is called, the eye *appears* to be fixed and without motion; but this is not the case. When falling into this reverie one eye rolls gently inwards, and a suspension of all mental effort takes place; the thoughts do not follow each other regularly, but the eye is not motionless. The rest which is thus given to the organs of vision by this crossing of the eye arises from that relief of tension under which the eye always labours when directing both eyes to one object. We not only relieve the whole apparatus of sight by this relaxation, but those also of the other senses. They throw aside their vigilance; and odours, sounds, flavours, and images, pass in review unconnected and unheeded. Even intense and consecutive thought is suspended, and there exists only a dim consciousness that a pleasing lassitude has thrown its gentle influence over us, and from which there is no inclination to be roused.

It is only during one of these reveries, which are shorter or longer as the state of the system happens to be, that sleep overtakes us. Whoever has watched the commencement of an infant's slumber, will recollect the fixedness of the little eye, and its gentle rolling as entire unconsciousness takes place. The same gentle, yet prolonged rolling of the eye takes place when the child awakens from an undisturbed slumber. Even in old persons sleep can be induced by gently rolling one eye inward and fixing it on a point. Drowsiness always accompanies this motion; for, as I have observed, change, or suspension of thought is the consequence of it. It is mental excitement, it is the exercising the muscles of utterance over and over again, the dwelling too long on exciting subjects, which so often causes wakefulness.

From a knowledge of the foregoing facts, it is therefore fair to conclude, that even in the efforts of the mind the *will* has no power to act, unless each internal organ or apparatus of sense is excited in the same way as when outward objects were presented to it; and that mental and real Sight, Touch, Smell, Taste, Hearing, and Utterance, are one and the same thing.

Before I conclude, let me explain that by utterance I mean that internal, aspirated movement which is divided and modulated so that it appears in the form of letters and words. It is a movement without any external sound, although the process is effected by the aid of external air; for we are sensible that it is a gaseous movement. There is yet no name for these internal impulses, nor for the nerves on which they operate. They do not belong to the organs of speech, for these organs are confined to the throat and mouth; but they are capable of having sound attached to them when the organs of speech receives them. It is in their soundless state that the mind uses them; when they are accompanied by sound, they are for the use of others.

My greatest fear is that I shall not be able to make others sensible of my exact meaning; yet it is well for those who are anxious to comprehend this curious subject to recollect that truth may lie hidden under an unintelligible phrase or an inapplicable word. This difficulty arises in the first instance from the imperfection of language, which, thus far, has been constructed for the use of our physical wants; and, in the second place, from the inaptness of those who are to perform the most simple experiment with a reference to its ultimate bearing on the question. Besides these two impediments, there is the novelty of the theory. Its simplicity will deter some from entering into the investigation; and many obtuse, perverted minds will reject it with examination. But there are a few who will see at once that what is capable of proof is worthy of attention; if I err in supposing that these memoirs will draw the attention of these few, and none of the present day care to pursue the inquiry, then I must assign my work to posterity. I know that an investigation of natural phenomena is not the fashion of the day, but I know also, that unless it do become the fashion, science must decline. One of the distinguished philosophers of England has most ably proved that the neglect of natural science has caused the present decline of science in England.

This is the first proof that science has ever received of the entire dependence of the mental and bodily faculties on one another; for although their dependence was always allowed to exist, yet the *manner* in which the union or dependence took place was never before brought to experimental proof.

THE END.

ERRATA.

Page 19—5 lines from the bottom, instead of, *this dimness, if it did not*, read *if this dimness did not.*

34—3 from bottom, for *there*, read *thence.*

50—4 from bottom, for *from which*, read *from the centre of which.*

63—5 from top, for *artful*, read *artificial.*

75—2 from bottom, for *if the true mode*, read *of the true mode.*

194—13 from top, for *construction*, read *contraction.*

212—7 from bottom, for *conveys*, read *converge.*

213—6 from bottom, for *large*, read *larger.*

223—11 from bottom, for *Philosophers*, read *Philosophy.*

300—1st line, for *with*, read *without.*