Remarks
on
Photography and the Stereoscope
in their
Scientific & Practical
Relations to the Subjects
of the
Medical Curriculum.

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Introducing the subject of this paper to the notice of the Medical Faculty, I shall do no more than indicate the way in which I propose to treat it.

The divisions to be adopted are as follows:

Part I

Photography in its Scientific Relations to Chemistry

Part II

The Stereoscope in its Scientific Relations to the Physiology of Vision

Part III

Photography and the Stereoscope in their Practical Relations to the Subjects of the Medical Curriculum
Chemical Society's Journal, Vol. VII, page 201 (Mr. Hadow.)
Part I.
Remarks on Photography
in its
Scientific Relations to Chemistry.

Not having devoted any special attention to the chemistry of Photography, I can give only a very general view of the subject, in the hope of being able to supply, though poorly, the deficiency which otherwise might be held to exist in this paper. Of the many chemicals employed in Photography, Collodion is the only substance so purely photographic as to demand an account of its constitution and preparation, and to that I shall immediately proceed. After which, the subjects of the influence of light on bodies as illustrating or modifying, chemical action, the production of latent images, the composition of the photographic image, &c., will be considered.

Collodion is a solution of gum-cotton or pyroxyline, in ether, which, on being exposed to the air by the evaporation of the solvent, is left as a firm, transparent, almost structureless membrane. From this property it is much used by photographers as a convenient method of attaching to a plate of glass,
Hardwick's Photographic Chemistry, p. 100, 6th ed.

a delicate film of iodide of silver, and of rendering it extremely smooth and uniform.

Pyroxylone is now considered as a substitution compound of lignine, in which, by the action of nitric acid, concentrated by the addition of sulphuric acid, peroxide of nitrogen takes the place of hydrogen. The change is exhibited by the following general formula:

\[ \text{C}_n \text{H}_m \text{O} + \text{N}_2 \text{O}_5 = \text{C}_n \text{H}_m \text{O} + \text{NO}_3 + \text{H}_2 \text{O} \]

There was at first after the discovery of pyroxylone much diversity of opinion regarding it. Some of the specimens obtained were highly explosive, others not so, some dissolved in ether while others did not. The analyses published by various chemists also differed widely.

In a paper published in the Chemical Society's Journal Mrs. E. A. Hadow of King's College, London, explains these remarkable discrepancies by pointing out that there are several varieties of pyroxylone consequent on the strength of the nitro-sulphuric acid with which it is prepared. Mrs. Hadow distinguishes four of these varieties.

A. Produced by action of strongest acids and probably by repeated immersion in any mixture not weaker than \(2\text{H}_2\text{O},\text{NO}_3\text{S}_3\) + 3 \(\text{H}_2\text{O}\) soluble only in acetic ether and highly explosive.
C_3 H_2 0_3 N_4 27.5
gave 49.86 by
three hour immersion.

B. Produced by acids of composition between
2(HO, N_2 O_5) + 3 H_2 O and 2(HO, N_2 O_5)_3 + 4 H_2 O
soluble in ether + 5 alcohol and explosive.

C_3 H_2 0_3 N_4 27.6 gave first immersion 46.2,
in second 47.1, in third 47.31.

C. Produced by 2(HO, N_2 O_5)_3 + 4 H_2 O
highly combustible rather than explosive. Very soluble
more as in the case of B, but also soluble in glacial
acetic acid.

C_3 H_2 0_3 N_4 24.1 gave 38.26, after 3 immersion
39.26, after 32, 39.53.

D. Mr. Stadoy infers that this compound is identical
with pholidine.

Of these compounds B, C, and D are alone suitable for
making such a collodion as would fulfill the condi-
tions required by the photographer, and agree with
the description given before. In the preparation of
pyroplasticine, the proportion which the nitric acid bears
to the sulphurous is a point of very considerable im-
portance; as a slight variation will alter the charac-
ter of the collodion. It is found that although a
formula for the mixture is readily obtained deter-
mined, yet owing to the varying strength of nitric acid it is
difficult to assign the exact amount of sulphuric acid which should be added to it. To obviate this difficulty, some, in place of nitric acid, employ nitrate of potash, as its composition may be more safely depended upon, and although on addition of excess of sulphuric acid, there is produced a soluble bisulphate of potash, that does not interfere with the action of the mixed acid. When the nitric & sulphuric acids are used, the formula for the strength of the mixture as given by Mr. Hadow is 140 N, 2(140 S) + 3. The pyroplume is made by soaking cotton in the acid so prepared for a shorter or longer time, corresponding to the heat employed, varying from a few minutes at a high temperature (120°), up to hours at the ordinary one. It is then removed from the acid and very carefully washed in running water, so as to take away every trace of acidity, and afterwards dried with a very moderate heat. The use of the colloision being to attach an even film of iodide of silver to the glass plates, there is dissolved in it an iodide not readily acted upon by light, but which has for silver a stronger affinity than for the substance already in combination with it. When the colloision is poured over the glass plates, the particles of the iodide are also distributed uniformly over it; the plate then
being placed in a solution of nitrate of silver, a double decomposition takes place, resulting in the formation of a regular, even layer of the iodide of silver. As the sensitiveness of the Collodion film and the intensity of the photograph depend to some extent upon the iodide employed to iodize the Collodion, it becomes an important point which is to be used. The chief favourites are the iodides of Potassium, Ammonium and Cadmium; the last making the Collodion keep better, but not being so good in other respects as the two former.

Chloral remarkable changes take place in the Collodion after it is iodized. At first colourless, it quickly assumes a lemon yellow tinge, which gradually passes to a deep red. At the same time it becomes less sensitive but for a time gives a more intense picture. When these changes have advanced to a considerable extent the Collodion becomes almost useless. The alteration of colour, it is thought, depends upon the decomposition of the ether causing liberation of iodine which becomes dissolved in the fluid. Dr. Hill Norris suggests as a reason for the increased intensity of old Collodion, the greater porosity of the film which it leaves, as in that way the developing and silver solution may be allowed
more free action. Mr. Woodworth drew the following conclusion from experiments made by him upon the subject: "She diminished sensitiveness and increased intensity of a collodion which has been long mixed, are due in part to the generation in minute quantity of an organic compound containing some of the elements of pyroxylin in union with a base, and possessing properties analogous to those of the albumin in forming an organic combination with the product of the reduction of silver salts by light." When a photograph is to be taken, a glass plate is covered with a thin layer of the iodized collodion and is then immersed in a bath of nitrate of silver, by which means, as has been already stated, a double decomposition takes place, resulting in the formation of the desired iodide of silver. The collodion for positives generally contains less pyroxylin and is not so highly iodized as that for negatives.

Action of light upon Bodies and formation of Latent Images. The action of light in producing change in the condition of bodies is one of the most interesting in physical chemistry. Professor Ludwig Nier seems to have been one of the first to direct attention to the subject. He experiments which he
made may be divided into two acts on the first of which he grounded the following proposition: 'If a surface has been touched in any particular parts by any body it acquires the property of precipitating all vapours, which adheres to or combines chemically with it, on those spots differently to what it does on the other untouched parts.' The other experiments were intended to show that light acts in the same way as contact. For example, if the shadow of a perforated metal plate be thrown for some time upon glass which is afterwards treated upon, a representation of the plate will be developed exactly as it would have been had the glass been touched by the plate. The proposition founded up on these latter experiments is that, 'light acts on all bodies and its influence may be tested by all vapours that adhere to the substance or act chemically upon it.' Prof. Moser also wrote an interesting paper upon latent light, but as his experiments are rather out of date I will proceed to the consideration of some recent researches upon the same subject conducted by M. Siefre de S. Victor. In the Photographic Journal for Dec. 1857 may be seen a communication in reference to a, "Memoire upon a new
Action of Light" by M. Niepce which begins with the following question: "Will a body which has been subjected to the action of light or insolation preserve in darkness any effects (impressions) of this light?" How far this has been answered may be judged by the following experiments. "An engraving which had been kept for several days in darkness was exposed during quarter of an hour to the action of direct solar rays, one half being covered with an opaque screen. The engraving which was then laid upon a sheet of very sensitive photographic paper and put in a dark place for twenty-four hours and on being examined, it was found that the white portions of the engraving which had not been protected by the screen during its exposure to the sun had been reproduced in black. When the engraving was kept in profound darkness for several days it then applied to the paper without being previously exposed to the sun, no result was produced. "In exposing an engraving to the solar rays for a very long time it becomes, if one may use the term, saturated with light." M. Niepce then goes on to state that although certain substances, such as a layer of colloid or
gelatine, are interposed between the engraving and the sensitized paper; the impression will still take place; but if, on the other hand, a plate of glass, a sheet of mica, or of rock crystal, or a yellow glass colored with oxide of uranium, or if the engraving be covered with picture varnish or gum, the impression will not take place. The engraving as may be seen, does not require to be in immediate contact with the paper. "If it be a bold design it is reproduced at the distance of one centimetre." "The production therefore is not the result of contact, I desire it chemical action." Different colours produce different effects depending upon the chemical composition of the colour, as illustrated in the cases of coloured engravings and of dyed cottons. Perhaps the most interesting experiment is the following: M. Niepce says he took a metal tube (any other opaque substance in the form of a tube answers the same purpose) closed at one of its extremities, and lined with white paper or cotton, and exposed the open end to the direct solar rays for about an hour. After the insolation he applied the same end to a sheet of prepared paper, and found after the lapse of twenty
four hours that the area covered by the tube had been darkened. More than that, an engraving on Chinese paper interposed between the tube and the prepared paper was itself reproduced. If the tube be hermetically closed immediately on being withdrawn from the light, it will preserve for an indefinite period the power of radiation communicated to it by insolation.

Mr. Papée communicated another memoir upon the subject to the Photographic Journal, in which he gives another expeiment and states the practical purposes to which his discoveries may be turned. If a sheet of paper is taken from a place where it has been till'd them in total darkness and a photographic slide or glass or paper laid upon it and then exposed in this condition to the solar rays for a certain time, it will on being treated with a solution of nitrate of silver exhibit an image corresponding to that upon the photographic slide. By interposing the paper with a substance which has a still greater power than it of storing up the light with persistance of the luminous activity (as M. H. expresses it) a picture more rapid in its development and more luminous may be obtained. Amongst the best substances for this purpose are
nitrate of uranous and tartaric acid.

These experiments naturally led to the proposal to print by this means from the negative plate. It was at first thought that not only would much trouble be saved in doing so, but that the photographic prints so obtained would be more certain of being permanent than those produced by the ordinary methods. These hopes, however, do not seem as yet to have been realised. Mr. Niepce's discoveries then lead to the inference, "that light communicated to certain substances it has fallen upon a real activity, or better, that certain bodies have the property of storing up light in a state of persistent activity." The quantity of persistent activity is found to vary with the nature of the substance, the duration of exposure and the atmospheric circumstances under which it takes place. It gives to each substance a maximum of activity beyond which prolonged insolation adds nothing.

Mr. Niepce's researches, though of great interest, must be considered as illustrating rather than explaining the formation of the latent image in the Camera. It might indeed be asserted that in the Camera a certain amount of light is absorbed not capable in itself of altering the iodide or contiguous par-
icles of nitrate, but which can do so when assisted by chemicals tending to produce the same effect. A more general view of the case is that a molecular change takes place in the particles of iodide of silver, which, without altering its composition, makes it amenable to the action of chemicals otherwise possessed of no power over it.

Development of the latent Image. Mr. Hardwich justly remarks that: "The advancement and indeed the very origin of the Photographic Art may be dated from the first discovery of a process for bringing out its view an invisible image by means of a developer." M. Claudet found that in the Daguerreotype process, "with a sensitive layer of bromo-codide of silver, an intensity of light three thousand times greater was required, if the use of the developer was omitted and the exposure continued until the picture became visible upon the plate." The process of development consists in covering the Collodion film with a chemical, which in those parts where the light has acted, possesses the power of reducing the iodide of silver or through it the contiguous particles of nitrate of silver. It is found that no picture can be developed without the presence of the lastnamed salt; some have therefore suspected that the decom-
position takes place in it, not in the iodide. Nitrate of silver and the other salts containing oxygen are reduced by the developer directly removing oxygen but in the case of those which do not contain oxygen water enters into the change, thus with iodide of silver the developer removes the oxygen of the water, the hydrogen unites with iodine to form hydriodic acid which passes off and the silver is left.

The developers generally used are proto-celulphate of iron, gallic acid & pyrogallie acid. The proto-celulphate being considered as the most powerful, will probably be the best for microphotography. The next step is to dissolve away from the glass all the iodide of silver unacted upon, so that no further change may take place. All that is necessary is that the chemical used shall not otherwise act upon the picture. Hyposulphite of soda and cyanide of potassium are the substances generally employed. A picture produced by development is formed by a larger quantity of metallic silver than one where the long continuance action of light alone is employed.
Part II.
Remarks on the Stereoscope in its Scientific Relations to the Physiology of Vision.

When we consider how striking are some of the phenomena of binocular vision and how continually we are reminded of them in the ever varying changes which occur in the visible position of objects as we converge our optic axes at nearer or more distant points, we need not wonder that at an early period the laws of binocular vision were examined, and the difference in the appearance of objects as viewed by the right or left eye was demonstrated. Sir J. Brewster has pointed out that Euclid, Galen, Baptista Porta, Galenius, Aquilonius, Smith, Harris, Portefield, as well as Leonardo da Vinci knew more or less perfectly the essential principles of the stereoscope. The recent discovery of a Stereoscopic picture in the Wicar Gallery at Lille, painted by Jacopo Chimenti, confirms the opinion that the fact of our recognising the solidity of an object by the combination of its two dissimilar pictures, however that is effected, was known long before the invention of the stereoscope. I may here refer to the work entitled "La Vision Parfaite ou le Concours
Published at Paris in 1677.
and why ages de la Vision en un seul point de l'objet; in which Cherubin D'Orleans, a Capuchin friar, besides describing the construction of his binocular telescope, proposed a form of binocular microscope, believing as he did that, "les deux yeux étant joints, et bien conformés, voyant toujours conjointement l'objet plus grand, plus clairement, et plus fortement qu'un seul".

We may now consider the following problem. Receiving, as we do, through the medium of our two eyes a double impression of every point of the objects within our view, how are these impressions combined. That we may have the sensation of unity connected with their source? Gaspardus, Baptista Porta, Tacquet, and Gall in answer to the above problem maintained the now obsolete theory that only one eye is employed at a time in vision. Aquilinius, Dechales, Porterfield, Smith, Reid and others considered that the position of bodies with regard to certain lines or planes determined their appearing as single or double. Galen, Alhazen, Briggs, Newton, Rehault, Hartley, Wallston, Müller and others have answered the problem by referring the combination of the two impressions ultimately to the organization of the deeper or cerebral portion of the visual apparatus. It hardly seems necessary to do more than refer to the
*Read June 21st, 1838

Treatise on Optics, page 414.

In adopting the law that a point is seen in a line at right angles to the surface of the retina at the spot where the impression is made, nothing more is meant than that the simple fact involved is true. How this is done does not fail to be considered here, whether it is by the mind being unable to recognize the picture on the retina as inverted. Simply projecting the impressions there produced into space or not, it still remains true that a point is seen in a line at right angles to the surface of the retina at the point on which the impression is made.

The picture on the retina is considered as indicating the relation in which the different parts of the retina are affected by light.
Inception of Aquilonius or the modifications of the theory by Dr. Wells and others are more or less incorrect. Professor Wheatstone in his paper, presented to the Royal Society of London, truly remarks: "It is obvious, that the result of any attempt to explain the single appearance of objects to both eyes, or, in other words, the law of visible direction for binocular vision, ought to contain nothing inconsistent with the law of visible direction for monocular vision." It will be necessary therefore, before considering the apparent line of visible direction of binocular vision, to ascertain the line of visible direction in monocular vision. Sir D. Brewster has ascertained, by adopting a more correct form of the globe of the eye and using more accurate measures of the refractive powers of its coats and humours, that the mechanical law of visible direction is true and that at an inclination of twenty or thirty degrees the line of visible direction which it gives does not deviate more than half a degree from the true line joining the point and the retina and the corresponding point of the object, a quantity too small to be recognised in oblique vision. It will therefore be necessary to ascertain that the law of apparent visible direction in binocular vision con-
tains nothing inconsistent with the law of visible directions in monocular vision, as ascertained by
Sir J. Brewer. Professor Wheatstone in his paper already referred to, can hardly be said
to offer any explanation of the sensation of unity produced in binocular vision by the duality of
impression, and merely shows what are the reasons which lead him to distrust the sufficiency of any of
the more obvious theories to explain the phenomena be investigated. The first of these theories Con-
sidered is that we only see that point of the field of view distinctly to which the optic axes are directed,
all other points being double and indistinct until the optic axes are in turn converged upon them.
Against this theory he gives the following experiment which I shall state in his own words: "Draw two lines
about two inches long and inclined towards each other, as in fig. 3, on a sheet of paper, and having caused
them to coincide by converging the optic axes to a point nearer than the paper, look intently on
the upper end of the resultant line, without allowing the eyes to wander from it for a moment.
The entire line will appear single and in its proper relief, and a pin or a piece of straight
wire may without the least difficulty be made to
By saying that the combined figure appears like the letter X and in very striking relief, is meant that when the combination is effected by converging the optic axes to a nearer point, the upper end of the X recedes very much; in the other case it is the lower end which does so. In the same way in fig. 8 the two broad lines seem to cast not to be combined throughout their entire length as Prof. Whately maintains.
Coincide exactly in position with it; or, if while the optic axes continue to be directed to the upper and nearer end, the points of a pin be made to coincide with the lower and further end or with any intermediate point of the resultant line, the coincidence will remain exactly the same when the optic axes are moved and meet there. The eyes sometimes become fatigued, which causes the line to appear double at those parts to which the optic axes are not fixed, but in such case all appearance of relief vanishes. Dr. David Brewster has very clearly refuted the errors in this statement. It is, in the first place, most difficult to look intently on the upper part of the line without allowing the eyes to wander from it for a moment and yet ascertain whether the other parts are combined or not. But if one succeeds in doing so, the line appears double with the exception of the points on which the eyes are fixed. When the eyes are not fixed on any one part the combined picture presents to myself the appearance of the letter X in very striking relief, the point of intersection continually changing with the movements of the optic axes. Even although the eyes be for a while fixed on one point, all the other parts of the resulting figure thus appearing double,
In some cases the two halves of the x do not seem to be quite so much inclined to each other as the lenses in the figure are, leading one to believe that a rotation of the eyes each pound its often age may take place so that the impressions may the more readily fall on corresponding points of the retina. I do not state this with very much confidence as one is perhaps apt to be deceived regarding such a fact, still the impression in some cases certainly is in correspondence with such a statement. This change as depending on the muscles would also indicate the varying distance of the different points.

the stereoscopic effect remains, at least for a time, as striking as when the point of convergence of the optic axes is continually changed so as to combine the different parts of the two lines in rapid succession. This circumstance very naturally suggested the idea that through education the mind may receive from the mere difference between the two pictures, where that difference is perceived, such a knowledge of the distance or solidity of objects as it does from perspective. In regard to this Professor Tyndall says, "Every change in nature carries other changes along with it; it is the disturbance of a limb which makes itself felt throughout a chain. When the optic axes are converged upon a certain point of an object, the other points produce a certain determinate effect upon the retina, and are in some measure objects of our attention. There is thus established an association between a certain convergence of the optic axes and certain incidental impressions, and this association may I think become so refined by habit, as to enable us to infer the solidity of a body, or the relative distance of objects while the optic axes are kept immovably fixed upon a single point." I introduce this here as forming a very good explanation of the next experiment of Professor Wheatstone which is as follows. If the drawings of the
time I find it impossible to fix my eyes on any one point of a simple
geometric figure even for a few seconds, without perceiving the double
character of the rest of the figure, even for a few seconds without per-
ceiving the double character of the rest of the figure. I am, of course,
unable to succeed in this experiment, as I believe every one will
be, whose mind is directed to the impressions the object makes
rather than to what is associated by the mind with these
impressions.

No idea could be more fixed than that we are each pro-
duced but of a single sense; still if a mark be made
on each side of the nose about the line of junction of
the bone with the cartilage and close to the ridge, it
will not only be found impossible by most to combine
these marks or place them in their proper relative po-
sition, but when the right eye is shut the mark made
to the left will disappear, that is, the right side of the
nose really appears nearer the left side of the body than
does the left side of the nose. Some very readily admit
that the mere impressions of vision were they not known in this
case to be utterly false, would lead to the very absurd conclusion
that the nose is seen in two directions, but others seem to have lost their
sensation of the double character of these impressions in the con-
sciousness of the unity of the organ with which they are associated so
thoroughly that it is almost impossible to persuade them that with re-
duction to the nose, vision unassisted by a mirror, does not confirm the sensations of

This note
less to lines.
page 22.
component figures of a stereoscopic slide formed, Prof.
Whistler recommends, of broad coloured lines on a
ground of the complementary colour be combined in
the stereoscope as the ordinary figures are; the eyes being
fixed to a single point of the compound figure till a
sufficient time has elapsed to impress the spectra on
the retina and the eyes be carefully covered to exclude all
external light, a spectrum of the object in relief will
appear before the closed eyes. If the source of stere-
ocopic effect first pointed out by Prof. Lyndall be a
correct one, as I was led to believe it to be even before
becoming acquainted with his papers, an easy explana-
tion is given of the results of such experiments as
that now considered. The points on which Profes-
sor Whistler fixed his eyes during the time he was in-
pressing the impressions of the ocular spectra on his
retina, would appear the most strongly marked
in the combined picture and consequently attract
his attention most powerfully, while the other parts
at greater or less distances from the eye and also
from the part of the eye in which vision is most
accurate, would appear more or less indistinct in
the same proportion, and only be regarded with that
amount of attention which is bestowed on objects re-
moved from the line of direct vision. It is there.
See second note last page

*In the one case we never imagine that of two equal sized men the one who is at the greater distance is less than the other, because education has taught us to compensate for the smaller retinal magnitude actually perceived by considering him as at a greater distance. In the other case education again teaches us to compensate for the double impression of an object (when made under those conditions in which a double impression is produced by a single body of three dimensions) by considering its component parts as at varying distances.
for not difficult to conceive that with the attention specially directed to points which necessarily appear combine the double character of the rest of the image would not be recognised otherwise than indeed it is, in the usual effect produced by a solid object when the eyes are fixed for some time on any other single point of it. It may be asserted that it is impossible so powerful an idea of unity can originate from two distinct impressions actually exerting their influence on the mind that the individual believes only one impression was made. The outlines of such solid objects as cubes, except in the parts to which the eyes are specially directed, do produce two impressions on the mind save when one of them is ignored by the rays which fall on the corresponding parts of the other eye, being recognised instead. So wonderful then that the natural education of life should teach us to forget the duality of the impressions in the unity and solidity of the object with which they are continually associated by the mind, which produces them. Any more than that two objects which have different retinal magnitudes may still have the same objective? Owing to the mechanism of our eyes it is indeed as necessary a consequence of a solid object that its various points should appear double when they are not specially
The mind may therefore consider the object single and in relief not less because the impressions of the several points of it—not specially regarded, fall on non-corresponding points of the retina than because those which proceed from the points to which the optic axes are directed do fall on corresponding points. If this theory be true a ready explanation is given of those cases where the relief of a body can be appreciated though it be only seen for a period so short that it seems almost impossible the optic axes can by their movements have united its several parts in however rapid succession. It is not urged for a moment that the mind is incapable of recognising the parts of the object not specially regarded as appearing double. When the attention is directed to the impressions received instead of to the object which produces them the two dissimilar representations of the object may be perceived but even then the power of association is so great that they partake to a wonderful extent of the appearance of the relief which the combined pictures would have.

It must be allowed however, that in the knowledge of distance thus obtained is yet solely from education it does not matter what relation these subjects at first—between the different parts of the double impressions of the object—
regarded, as single when they are*. These opinions are to some extent a revival of those held by Aquilonius with this difference, that natural education, not common sense, is, if I may say so, the combining power and that it is not the principal but only a subordinate means of ascertaining the solidity or relative distance of objects, of the same importance perhaps as the criteria of distance furnished by perspective. In connection with this source of knowledge of distance or solidity the principles of the stereoscope seem rather to support the theory of erect vision maintained by Sir J. Brewer. If a stereoscopic picture be cut in two and each half be turned round an axis within itself, the impression caused by combining the two single pictures would be pseudoscopic. Such is the case with the eye; the two pictures, therefore, as formed on the retina, if combined in the stereoscope would exhibit a pseudoscopic effect and it is manifest the theory adopted by Sir J. Brewer would restore the pictures to their proper relations, while that of Berkeley, Müller, and others would not.*

Sir J. Brewer says, "A visible point is seen single with two eyes only when it is at the intersection of its lines of visible direction as given by each eye"
If that relation be constant, it certainly does seem very difficult to believe that the mind should recognize objects as inverted when all are equally inverted.

According to this law, the point m, fig. 7, is regarded as single because the eye R sees it in the direction B m, while the eye L, seeing it in the direction a m, refers it to the same position in space, but in the same way it should be seen single because from R it is seen in the direction d m and from L in the direction c m, unless indeed from any cause the mind infers that the impression coming from m does not come from so great a distance when by this theory it should be considered double, be seen as it were, both at n' and at n".

†Philosophical Transactions, 1838, page 393
separately. I have not been able clearly to understand how Sir David vents the application of this law. It cannot be that "a visible point is seen single with two eyes always" because according to that it is most clearly evident a point should never appear double. It might be indistinct if out of the line of the optic axes but it would not appear double. Prof. Wheatstone in speaking of this point says: "the determination of the points which shall appear single seems to depend in no small degree on previous knowledge of the form we are regarding." Certainly not a very satisfactory explanation. If it be held that only when the optic axes are directed on an object it is considered single this of course, admits the theory of corresponding points to be true as regards the centres of the retina. It seems therefore impossible not at least to believe that there are points on the retina of the one eye which do not correspond with those on the retina of the other eye, that should two rays proceed from an object and fall, the one on a certain point of the retina of the right eye the other on a non-corresponding point of the retina of the left, they will be considered as proceeding from distinct sources. The next point is to
From Sir D. Brewster's paper in the 15th Vol. of the Edin. Transactions on the Law of Visible Position in singles & Binocular Vision. I find that D'Alembert gave a somewhat similar experiment and came to the conclusion that objects seen in answer which are at a considerable distance from the eye are not seen equally in the optical axis, even when we look at them directly. Sir D. Brewster in answer says, "It is almost impossible to believe that D'Alembert is as good as maintaining these doctrines. The major proposition of his sophism is absolutely incorrect. It is not true that we see the stars nearer than it is. The eye does not see distances directly; the mind only estimates them, and, according to its means of judging, it forms a right or a wrong opinion. The second proposition is equally incorrect. We do not see the stars along the line Pe, Sr. We see it along the N, β, β, at the very place where it is, whether we consider it nearer or more remote than it is; whether we think that it touches our eye, or exists at the remotest verge of space, the position of the optical axis of each eye remains as before, and our vision of the stars is not affected by the truth or falsehood of our judgment." It seems difficult to reconcile this explanation given by Sir D. Brewster either with his own theory or with what he says in his works on the Stereoscope, pag 37. "The most important advantage which we derive from the use of two eyes is to enable us to see distance or a third dimension in space." Again at pag 51. "That this vision of distance is not the result of experience is obvious.
inquire, "Are impressions only considered to proceed from a single point when they are believed to originate with an object at the point of intersection of the optic axes? When the two pictures of a stereoscopic slide are combined by directing the eyes to a point beyond, the resulting picture being of the same retinal magnitude as the others should if referred to the point of intersection of the optic axes, have a perceived magnitude much larger than the single pictures; but it has not been in very favourable circumstances sometimes it seems even smaller than they.* To explain this fact one or other of the following propositions must be admitted.

1st That the perceived magnitude of an object is not connected in any way with its apparent distance.

2nd That Dr. Davie's Bowles's law of visible direction is not correct.

3rd That the optic axes are supposed to converge on a nearer point than they actually do.

4th That the object is not referred to the point of intersection of the optic axes.

The first proposition can hardly be adopted so contrary is it to all experience. Change in the per-
from the fact, that distance is seen as perfectly by children as by adults; and it has been proved by naturalists that animals newly born appreciate distance with the greatest correctness. The star might certainly appear nearer than it really is if yet does so perfectly in accordance with Sir David's view; so long as it is still held to be at a great distance, but if it is actually considered to touch the eye it must surely be regarded as double if there be no corresponding points, unless the law of visible direction in monocular vision be not true or it is believed that the optic axes are converged to a point immensely nearer than they really are.
priced magnitude of an object seen attends change of real or apparent distance. Prof. Wheatstone as
the result of his experiments says, "Variation of retinal magnitude suggests change of distance". If there
there is no change in the perceived magnitude of
the object, the mind must have failed to recognise
any alteration in the inclination of the optic axes
or each eye must see the object in a line different
with respect to the axis of the eye
not only from what it would if Sir D. Brewster's law
of visible direction be true, but from what it did but
a second before, or finally, must not recognise that
it is at the point of union of the optic axes.
3. The law of visible direction in monocular vision
seems to have been proved to satisfactorily by Sir D.
Brewster that this proposition is not tenable.
For will be considered after the following question
is answered. Can the two pictures of a stereoscopic slide
be combined if their centres be so distant as to re-
quire the divergence of the united eyes to do so?
Dr. Wells in discussing a similar point came to
the conclusion by experiment that they did not. Prof.
Syndall says, "It is also possible, as shown by Wheat-
stone to unite objects by converging the optic axes be-
yond them. In this case, however, the distance
between the points to be united must be less than
that want between the two eyes? The same opinion seems to be implied in the language of all the writers on the stereoscope. Being very frequently in the habit of combining stereoscopic pictures by directing the axis of each eye towards the picture of its own side, I was led to observe how very wide apart were the points to which the question might be answered in the affirmation, I frequently combined, but not having paid much attention at the time to the theories of stereoscopic vision and knowing the very positive opinions of Prof. Lydall and others above referred to, I did not measure the distance of separation of the points combined and concluded that they had only been at the utmost limits at which they could be combined according to the views of Wheatstone and others, which they were in reality a fourth of an inch or more beyond. Having remarked, however, to Mr. Cumberbatch, Esq., that I supposed it was impossible to combine points further apart than the distance between the eyes, he immediately showed me that it was not impossible to do so, and proved it by combining two windows in a house at a distance. Though I believe Mr. Brown's method of proving this observation is perfectly satisfactory, it may perhaps be alleged that the windows appeared to combine by one disappearing. Both Mr. Brown and I are
This was done without any great effort and without the least assistance or even the insertion of cardboard to confine each eye to its own picture.
however, in the habit of combining stereoscopic views, the component pictures of which have their centres farther apart than the usual distance between the centres of the human eyes; the true stereoscopic effect is thus produced, or if the slide be cut in two and the parts transplaced a pseudo-stereopic effect is then most evident. It may be right to state that the centres of my own eyes are hardly 2 3/4 inches apart, so that I have combined pictures placed at a distance of ten inches, the centres of which were 3 1/2 inches apart. The question proposed must therefore be answered in the affirmative.

We are now in a position to resume consideration of propositions 30th and 43th, either of which might be applied to give an explanation of the combination of two impressions where these cannot be believed to originate at the union of the optic axes, as in such union ever takes place. Have we then a perverted idea of the direction of the optic axes? It is extremely difficult to believe that this is the true solution of the problem. The mere fact that to believe it true we must set aside the sensations of muscular sense is enough to lead us to inquire whether the mind refers those objects which appear single to the intersection of the optic axes,
Müller's Physiology, page 1197.
whether indeed it has knowledge of any such interaction at all. If it is true that the mind does not refer the course of impressions which are judged to proceed from a single object, to the union of the optic axes, we are forced to adopt more or less fully the theory of corresponding points, but at the same time it has to be shown that the apparent line of visible direction in binocular vision thus obtained, does not disagree with the line of visible direction in monocular vision.

The existence of corresponding points seems almost as certainly ascertained as is the law of visible direction supported by Sir J. Brewster. The very fact that if an impression be made on a point of the one eye so long as it is recognized by the mind, there is a point on the other as good as blind to every impression save one, identical in its nature with the first, proves a very intimate nervous union between the two, while the peculiar structure of the optic nerve furnishes strong presumption that, the eyes may be compared to two branches of a single root, of which every minute portion bifurcates so as to send a twig to each eye. It has already been shown that if Sir J. Brewster's law of visible direction be true, the theory that there are points of the two
It seems to be allowed by all that there are similar parts of the retina.
retinae which do not correspond offers a very ready solution of the fact that we see objects double when the eyes are not fixed on them, perhaps the only satisfactory explanation of this circumstance. If therefore, there be points which do not correspond the presumption here again is that there are those which do. The fact that, Observations made upon persons affected with strabismus do not show that the original relation of the identical parts of the two retinae is disturbed; but that the squinting eye in general does not co-operate in vision, tends to confirm the belief in the theory of corresponding points.

Another fact which proves the existence of something very peculiar in the nervous confirmation of the eyes, is that against general analogy, the inner part of the one eye corresponds with the outer, not the inner, part of the other. Perhaps this theory which explains most satisfactorily the peculiar relation between the eyes, is that given by Prof. Müller. The fibres a and a', coming from identical points of the two retinae, are in the chiasma brought into one optic nerve, and in the brain either are united by a loop, or spring from the same point of the sensory nucleus, or the same ganglionic corpuscle in the cerebral substance.
The same disposition prevails in the case of the i-
dental fibres b'& b'. According to this theory the
left half of each retina would be represented in
the left hemisphere of the brain, and the right
half of each hemisphere retina in the right
hemisphere. If the theory of corresponding points
be true, the two eyes must be regarded by the
mind as one organ and the changes which take
place in the relative positions of objects as they
are viewed from the right or left eye will be as-
ferred to changes taking place among the objects
themselves, not to our viewing them from a dif-
ferent point.

Although more sensations are of no very great im-
portance, still whatever testimony they do bear seems
to be in favour of the opinion that we do not re-
cognize ourselves as seeing from two separate points.
And if we do not recognize ourselves as seeing from
two distinct points, that is, if we have not an ap-
preciation and a very just one of the size of our "base
line", we will, as has been shown by Prof. Müeller,
appear to see single objects in two directions, that
is to see them double, or at least will refer them to
a wrong position in space, unless the theory concerning points be true.
Is the theory of corresponding points inconsistent with the
Law of Visible Direction in Monocular Vision? The only way in which it seems possible that the law and the theory just referred to could be inconsistent with each other, would be if the law of Visible direction were such that owing to ocular parallax or any other cause, rays coming from the same object and falling on corresponding points were seen to come in different directions for each eye. Such, however, cannot be the case as an object is always seen in the direction perpendicular to the surface of the retina at the point on which the resultant ray from it falls. Sir D. Brewster states that the law of Visible direction is inconsistent with the binocular circle of the Germans but it may be so without affecting the general question of corresponding points it only proves the true horopter is yet to be found and that when it is found it will lie, as one would expect it should, without the binocular circle of the Germans.

I have now attempted to show 1st. That the movement of the eyes from point to point of an object is necessary that its several parts be combined and that it may appear single, not merely from association of ideas but because it is actually seen to be so. In this opinion I have the good fortune to be a disciple of Sir David Brewster; in the others I am compelled to differ more.
or less from him and therefore desire to express myself with very great diffidence. 2. That objects cannot be considered single merely because they are referred to the point of union of the lines of visible direction, else every object should be seen single. 3. That two points may appear to be but one though not referred to the point of union of their lines of visible direction, since in some cases the perceived magnitude does not agree with such a supposed distance of the resultant point, while in other cases, points are seen as single though really double and though the lines of visible direction do not diverge.

4. That the theory of corresponding points consistent with all that is known of the very peculiar anatomical structure of the optic nerve consistent with Sir D. Brewster's line of visible direction supported by many of the most eminent philosophers who have ever lived, gives a satisfactory and apparently the only satisfactory explanation of the facts mentioned under the 5 & 8. If then not only Sir D. Brewster's law of visible direction be true but also the theory of corresponding points it may be deduced that—If an impression be made on a certain point in the retina of one eye, and also another identical in its nature, on the corresponding point of the other
they will be referred to the same source in virtue of
the laws of visible direction and of corresponding points.
If the impressions be not identical in their nature it is
well known they are only recognised alternately. If it
were possible that the object by which the impression
on the right eye is caused should be seen not accord-
ing to the law of visible direction, in a line at right-
angles to the surface of the retina at the point on
which it impinges, but say at one degree less to the
left, while the impression on the left eye makes the
object which produces it, whether the same or not,
appear also one degree less, but to the right, very
possibly the effect would be the same as when the
impressions are non-identical, the object or objects
would appear alternately in the one direction and
in the other. If in the Implications the impressions are
made on points which can be distinguished by the
mind, that is, on non-identical points, the object
will appear double.

Having now attempted to ascertain what is the direction
in which an object is seen in binocular vision with re-
ference to the eyes or rather the combined eye, it must
not be considered what knowledge muscular sense will
give us of the apparent changes of the apparent changes
in the combined eye, so that the line of apparent visible
directions be ascertained with regard to ourselves. Whenever we look at any point which is in the pro-
longation of our own visual plane or at two points equally removed from it, as in combining a stereo-
scopic picture, the muscles tending to produce rotation inwards of the eyes, are each exerting the same amount of force and is with those tending to produce rotation outwards. Now the internal rectus of the right eye acts directly, as it were, on the half of the eye corresponding so far as regards vision to that half of the left eye acted on by the external rectus, while the internal rectus of the left eye is in the same way more immediately connected with the external rectus of the right. There is thus connected with the organ of vision as it is recognised by the mind, a kind of balance of muscular sense which is a perfect balance when the object is at infinite distance or when the points combined are the same distance apart as are the centres of the eye. The nearer an object is, the greater becomes the con-
traction of one muscle connected with each side of the combined eye, the less becomes the contraction of the other on each side, but still there is a balance of the muscular sensation. The com-
 pound eye is therefore regarded as looking straight
When one eye is shut, if the eye on which no impression falls moves in exact correspondence to that on which one does the object will be recognized still in the same direction with reference to the body as before, that seems to be the case. If however, the movements do not quite correspond, the impression made may become more connected with the condition of the set of muscles belonging to the eye on which it is made and the object will in consequence become apparently deviated to the side of the shut eye in accordance with the opinion of Harton, since that the object is thus deviated.
fowards. When the attention is directed to a point somewhat to one side this relation is, of course, disturbed and the compound eye becomes regarded as looking to the one side; if to the right, it will not appear to have turned so much as the left eye singly has done, but more than the right singly, since the total amount of muscular effort supposed to be connected with the right side of the compound eye is to the total amount connected with the left, in a greater proportion than it is in the right eye, but less than in the left.

Sir D. Brewster has stated that an intaglio may appear converted into a cameo even when both eyes are open, and every one who has been in the habit of combining stereoscopic pictures by converging the eyes to a nearer point than the pictures, or where the pictures are reversed, must have made a somewhat similar observation. viz., that the whole effect of solidity of the picture is not reversed. A house, for instance, will often still present its wonted appearance while a tree placed in front of it seems cut into two, the lower part being retained near the spectator by its position in front of the house but almost producing a sensation as if it were pressing powerfully against the house, earnestly endeavouring
* I mean a less emergence than the house has required.
to become again the support of its upper part, which has fled far away in obedience to the impression it has produced on the spectator, in consequence of having required a less convergence of his eyes and being free from the disturbing influence of the house behind it. In the same way parts of statues, where the shading is well marked, retain their natural appearance.

It is difficult to understand how this should be so long as it is held that to be seen single the various objects must be referred to where the optic axes meet, since a point which has actually required a less convergence of the optic axes than another appears nearer than it, seems in consequence to have required a more near convergence of the optic axes, leads one to infer that there has been rotation of the eye balls inwards while it was really outwards, reverses in short the impressions obtained from muscular sense. Adopting the theory that an object is considered single though not referred to the point of union of its optic axes, it is seen at once that the sensations derived from the state of contraction or relaxation of the muscles is in no way connected with the apparent unity of the object and that whether the
point seem nearer or more distant than others, must depend entirely on the means we have of judging of its distance.

Believing then, that muscular sense has nothing to do with whether an object appears single or double, as it canly would, near objects seen single only when at the intersection of the optic axes, what connection has it with our knowledge of distance? It can only be considered as one of many ways by which a knowledge of distance is obtained, but for near objects the change in the condition of the muscles are so great that it must be considered a most powerful means. In viewing stereoscopic pictures where to combine them the optic axes must be nearly parallel or even divergent, muscular sense does not inform us of the distance of the combined picture, only of the relative distance of its several parts.
Ocular Stereoscope.

Having now considered the subject of binocular vision it may be right to make a few remarks with regard to what Sir D. Brewster has happily named the Ocular Stereoscope. The three forms of stereoscope in which the pictures are made to overlap by means of lenses or mirrors, the eyes being thus greatly greatly aided in their combination of the several parts of the picture, need not be considered.

The Ocular Stereoscope is of two kinds. In the first the pictures are combined by the optic axes crossing. In the second, by their meeting at a point much beyond the picture, or never meeting at all.

If an ordinary stereoscopic slide be combined as in the first form the effect produced will of course be pseudoscopic. This plane is therefore useful when photographing with a binocular camera in enabling one to judge of the stereoscopic appearance of the object he is about to take as it is seen on the ground glass. Some allowance must however be made, since objects appear necessarily more stereoscopic in this way than when viewed in the stereoscope or by the second form of ocular stereoscope. In some persons the eyes cannot without assistance be turned so far inwards as is necessary. In such cases the simplest means is to keep
the eyes fixed say on the point of a pencil while it is made to approach the face till the prolongation of the optic axes directed to it will fall on corresponding points of the two pictures, the eyes then in most persons readily adapt themselves to the change of focus required.

The second plan of combining the pictures of the stereoscopic slide is of much wider application than the first. Were the power of doing it general a great objection which at present exists to the illustration of works by stereoscopic pictures would be removed.

It seems however, very rare. Sir D. Brewster in his work on the stereoscope says he has found only one who possessed it. Without making any special inquiries I know of four or five persons besides myself, who can more or less readily combine the pictures in this way. It seems generally to be believed that the power is acquired by habit; it was not so in my own case. Reading some years ago the article on the stereoscope in Sir D. Brewster's work on Optics, I endeavoured to combine the pictures there given according to his directions, but found that the effect produced was exactly the reverse of what he stated. I was thus first led to know that pictures could be combined by the second method, only from having actually done it. The merit of the original dis.
loony of this as well as of the other form of ocular stereoscope, belongs to Professor Elliot. It is very difficult to give directions how to acquire the power of combining pictures, by directing the optic axes to a point or points more distant than the stereoscopic slide. Besides, the plan often adopted of preventing the right eye from seeing the picture presented to the left, and the left, from seeing that which should only be seen by the right, there is no other that greatly aids the power of combination. No one who is in the habit of using the ocular stereoscope with which nature has provided him, can fail to observe the relation existing between movements of the eye-ball and changes in the adjustment of the eye to distance. It seems impossible to make the rays which come from an object at first seem single, fall on non-corresponding points without the necessary movements of the muscles being at first accompanied by a change in the focal adjustment of the eye. In the same way the person who resolutely keeps his eye focused on a stereoscopic slide, need probably never expect to see the combination of the two pictures. On the other hand, when the stereoscopic slide is disregarded or put out of focus, there seems almost to be a reflex action set up by the
Longsighted is hardly employed with the usual signification. It is rather intended to mean the power of seeing objects distinctly at a distance, or a tendency to view them when in that position than the mere want of power to see them near at hand.
series of identical impressions falling on non-corresponding parts of the retinae, which makes the muscles rotate the retinae, so that these impressions may fall on corresponding points. During the progress of these movements the eyes become again adjusted to the proper distance of the object. If the centres are not more than two and a half inches apart the combination of the two is not an effort, at least not at first. It is simply disregarding the slide held before the eyes and allowing the eyes to become adapted for viewing distant objects, both as regards the inclination of the optic axes and the adjustment for a distinct focus. The action thus far, exists rather in the negation of any effort than in putting it forth. Whenever the tendency to adapt the eyes for great distances is strong both as regards the amount of convergence of the optic axes and the focal adjustment, there will be more or less difficulty in keeping the eyes converged on near points and seeing them in focus with corresponding ease in combining pictures by the second method. The reverse will of course be the case with regard to the first method. From these circumstances it may be deduced, that a long-sighted person will have the advantage in combining pictures by
the second method, Dr., that a short-sighted person will more readily combine pictures by the first. As I believe I may reckon myself rather long-sighted, I gave what was otherwise undue prominence to the fact of having the power of combining pictures by the second method. Naturally, on the other hand, it was only after long practice I was able to obtain the stereoscopic effect by the first method without assistance. Other circumstances also affect the ease or difficulty with which stereoscopic pictures are combined. If the slide is held near the eyes the difficulty of converging the optic axes or points is near, renders the ease of combining the pictures much greater. If, on the other hand, the slide is held at a greater distance than twelve feet or so, the optic axes being so nearly parallel, have very little tendency to diverge, so as to fall on corresponding points of the two pictures, and this renders it almost impossible (at least for myself) to combine pictures so placed, without the assistance of the eyes being limited to seeing each the picture of its own side. Where great power exists in converging or diverging the optic axes, the stereoscopic combination may of course be readily seen, on the other hand, when a very strong connection
A stereoscope might thus be formed by merely using a pair of spectacles adapted for those who can only see objects at great distances. With such a pair of spectacles, a stereoscopic slide held about ten inches from the eye would be entirely out of focus. There would therefore be a disposition in the eyes to adapt themselves for viewing distant objects both as regards the divergence of the optic axes and the focal adjustment of the eye. Thus the pictures would be combined.
subsists between the adjustment of the eye to distance and the corresponding convergence or divergence of the optic axes, it will be very difficult to combine the pictures. I may here mention an experiment bearing on the connection existing between the adjustment of the focal distance of the eye and the convergence or divergence of the optic axes. Place a stereoscopic picture about ten inches from the eyes and by a piece of card board, or otherwise, let each eye see only the picture of its own side (in such circumstances I find it almost impossible to keep the pictures from rapidly combining). If a pencil be held before one eye and gradually brought nearer to it, the eye being steadily focussed on the pencil, the two pictures of the stereoscopic slide though at first combined will separate further and further from each other. As the card board prevents the pencil being seen save by one eye, the apparent separation of the pictures can only be caused indirectly, through the influence of the change of adjustment of the eye to distance, causing a corresponding change in the convergence of the optic axes.

I had intended to dwell at some length on the relative value of the different means by which a
knowledge of distance is obtained. As however a great part of my subject still remains to be treated I will only describe two experiments bearing on the relative value of the convergence of the optic axes as a means for determining the distance of bodies, contrasted in the one case, with the adjustment of the eye to distance and in the other, with parallel as means to the same end. The first is performed by combining such a figure as No. 5 through convergence of the optic axes on a nearer point. The eyes being adjusted for viewing distinctly objects at the distance of the paper, the combined figure should appear to be at that level, were this the superior means of acquiring a knowledge of distance. It does not seem, however, to be at least in the great majority of cases, but is considered as being at the point of intersection of the optic axes and has thus a smaller perceived magnitude than the uncombined figures. The other experiment is extremely simple. It consists in merely moving about the head when fig. 5 is combined either by convergence or divergence of the optic axes. It will then be seen that although the apparent increase and diminution in the sides of the truncated pyramid is exactly the opposite of what
it is in nature, the apparent relief of the object is in no way affected.
Part III.
Remarks on Photography and the Stereoscope in Their Practical Relations to the Subjects of the Medical Curriculum.

Under the present division of this paper will be considered 1st. The means by which the various kinds of photographs are taken, viz., Prints, Photographs with the ordinary camera, Stereoscopic Photographs, Microscopic, and Micro-stereoscopic. Along with an explanation of the several points the photographs presented with this thesis are intended to illustrate an attempt will be made to show to what extent photography may be successfully employed in connection with the various branches of the Medical Curriculum. (Only such forms of instruments will be described as are not generally known or have been specially adapted for the purposes of this paper.)

Photographic Printing may be generally regarded merely as an adjunct to the other processes, as the means by which the positive proof is obtained from the negative plate. Since, however, printing may sometimes be directly employed to obtain life-size representations of thin flat objects, especially if they be somewhat transparent, it may be considered here. The process
generally employed, and which seems on the whole to be the best, is that known as the albumen process. The apparatus required is merely the printing frame employed to keep the object to be copied in accurate contact with the sensitive paper, so that in proportion to its opacity or transparency in its several parts, it may protect those portions of the sensitive paper from light which are to remain white in the finished photograph, while it freely exposes the chemical rays those other portions which will appear dark. I may shortly describe a very simple form of printing frame which answers well enough any purpose and although not quite so convenient as some others possesses the advantage of cheapness, and being readily extemporised is peculiarly suitable for printing ferns of a size larger than can be admitted into the frames usually employed. Take a box with some flat boards or a box with an even top (for small sizes such a one as is used with Hatchett's microscope answers well), lay along the top of it a strip of black velvet or an old newspaper which will project either beyond the ends of the box or of a piece of plate glass afterwards to be laid above. On the velvet, or whatever may be employed in its place, lay the sensitive paper, silvered side upwards, from the glass negative, collodion side downwards, or what
over object is to be printed, above all the plate glass already spoken of, which should be heavy and considerably larger than the object to be photographed. The print may be examined when desirable by pulling along the sheet or newspaper and, of course, with the sensitive paper, negative and plate glass, so that a good part but not all of the sensitive paper may project over the edge of the book or box, when it may be turned down and examined with facility. If the sheet or newspaper is pulled back to its former position no change will have taken place in the relative positions of the negative and print. It may either be printed light upon a dark ground as in photograph No. 68, which is taken directly from a fern, or using such a photograph merely as a negative, results similar to those obtained in photograph No. 67 may of course be had, where the fern is represented as dark upon a light ground.

Photography with the ordinary Camera. The ordinary camera has been most successfully employed in connection with medical science. It is scarcely necessary to give any description of the various instruments required. Although such photographs are inferior in many respects to those which are stereoscopic, yet where a large picture is desired or where the object to be depicted is
tolerably flat in proportion to its size, the ordinary camera may be used. For illustrations of the almost wonderful power of photography in the hands of a first-class artist, I may refer to the work now publishing in Germany illustrating photographically the finer nerves of the human body.

Stereoscopic Photography. The stereoscope, although many of its applications to the delineation of objects of Natural History were so clearly pointed out by Sir David Brewster, has been by far too great an extent regarded merely as a toy and has found its place more in the drawing room than in the study. The power it affords us of recognising on a flat surface the third dimension of space must make it, or rather the practical application by the unaided eye of the principles on which it is constructed, a most valuable means of obtaining a just idea of the appearance of solid tumours &c. &c., though only represented by the two flat pictures. The camera employed should be of the binocular form invented by Sir D. Brewster, as it is often desirable to obtain the photographs in the shortest time possible, while it can never be desirable, nor even allowable to take the pictures with a greater angle than that permitted by such an instrument. In some respects,
however, the camera required for medical purposes differs from the ordinary form. I will now describe the instrument I have employed. It consists in the first place of an ordinary binocular camera—about which nothing need be said save that it is a very convenient form planned by M'Coyson, Prince of it, in which the front of the camera is removable so that the lenses attached to it may be reversed and packed inside. Such a camera is complete so far as regards photographing comparatively large objects, but adapters are required to enable it to take a considerable proportion of those objects in which the medical or scientific man is interested. The adapters are employed merely to lengthen the camera to obtain a focus when, in consequence of the small size of the object, it must be taken nearer to the natural size than is usual, and they consist of wooden frames similar in shape to the camera, one or more of which is inserted between the lenses and the body of the camera thus increasing the length of the instrument, see photo No. 66. The smallest adapter should be of the same length as the extent of movement possessed by the lenses; the second double that length; the third may be formed of these two united; the fourth, if a fourth is desired, should be double the length
of the second, and others may be formed from combinations of these. By the adapters along with the movement possessed by the lenses an infinite gradation of power is obtained, from the smallest size up to about two diameters or even higher. The coarse adjustment is made by sliding nearer or farther from the object to be taken, and the fine, by slight turns of the ordinary focussing apparatus. It is unfortunate that the camera thus lengthened no longer takes both views at once, or rather that if both lenses are employed, two entirely different pictures are taken, not two different views of the same object. I have always taken one of the pictures and then moved the camera round an imaginary axis passing vertically between the focus of the two pictures on the focussing plate, till the object came in view on the other lens, when the second picture was taken. There are many disadvantages, however, connected with this plan, even when the subject of the photograph is not living. The light with which one works in a museum is often not good, requiring, especially if a small stop is used, an exposure of several minutes. In hot summer weather the plate is apt to become dry even during such an exposure, but since that time is occupied merely in taking
the first view of the object, while the dark frame requires to be removed to adjust and focus the second picture before it is taken, twenty or twenty-five minutes will often elapse between removing the plate from the nitrate bath and bringing it again to the dark room to be developed. The plate is thus apt to become very dry and with a dry plate it is extremely difficult to get a clean picture. One remedy is to take the two pictures on separate plates, another and much better to adopt the "dry process." In the latter case the saving of time is no object so far as sensitiveness of the plate is concerned, but notwithstanding the camera would be more convenient were it made to revolve a few degrees on a pivot the vertical prolongation of which should pass between the pictures on the ground-glass plate. If this lateral motion be limited to the amount required for the particular photograph both views may be focused and adjusted before the first half of the plate is exposed, requiring thus between the exposures of the first and second parts of the plate only the time requisite to change the camera between the positions in which these parts are taken. Where a living object is the subject of the photograph the lens should be small and mounted
When pictures of the ordinary breadth are desired, the lenses would merely require to be pulled separate, the centres are two and a half inches apart.
so that they may slide towards each other. By this means the double picture will be taken as in the ordinary binocular camera. Sir J. Beverley has shown that photographs are more or less incorrect in proportion to the degree that the lenses are larger than the average size of the pupil, or that, if larger, a diaphragm of a corresponding size should be inserted. But as even he has in some cases allowed departure from this rule to a certain extent, it may be hoped that he would not object to a little latitude being permitted when photographing in a comparatively dark ward or when taking the portrait of a sickly patient, if the photographer arranges his camera so that there be no perceptible distortion. Since, so far as my own very limited experience goes, if sufficient care be taken there is nothing to prevent his doing so with lenses of one inch, or, if necessary, one inch and a half, the camera might be conveniently constructed with lenses of such a size. If the traps were in which the lenses are mounted be light the distance between their centres need not exceed one inch and three quarters. The pictures thus obtained would be narrow, but, as already stated, both might be taken at once. In arranging the camera where the aperture of the diaphragm was
One can easily understand how the effect in the stereoscope could be much improved by this plan, at least as far as regards the focus of the combined picture. For so long as the impressions coming from the two pictures are identical in their nature a weak one will not lessen the effect of a strong. Should they become non-identical they will not both be recognised at once and the strong impressions coming from the pictures in focus will almost always, if not always, be that recognised. If the plan were pushed too far the proper stereoscopic effect of the details might suffer.
is greater than one quarter of an inch, the photographer should by squinting combine the pictures on the ground glass and thus ascertain that there is no distortion and that the subject of the photograph is placed at the best distance from the lens. The lenses should be capable of adjustment to different foci as some objects, even when the aperture of the stop used is small, cannot be placed altogether in focus. In such cases the focus of each picture should be slightly different, see photograph No. 27.

Photographs of Microscopic Objects. Sir Humphry Davy appears to have been the first who took photographs from microscopic objects. In 1802, that distinguished chemist, apparently by substituting a sheet of paper or leather soaked in nitrate of silver for the screen of the solar microscope, obtained impressions of the images formed by that instrument. He, however, in common with the other photographers of the time, was unable to fix the picture. There are three arrangements for the combination of the camera and microscope. The first is effected as follows. The lenses are removed from an ordinary camera and the eye piece from a microscope which is then placed in front of the camera, in such a way
section that a line prolonged from the axis of the compound body shall pass through the circular aperture left in the camera by the removal of the lens, and fall at a right angle upon the ground focusing glass. By yellow cloth or some other means, the microscope and camera are united so as to prevent the access of light except through the object glass. This, however, does not seem to be a good plan. In the second arrangement we have a camera similar to that represented in the diagram, but made so that a microscope may rest upon a metal plate projecting from the front, thus doing away with the necessity for the stage, focusing apparatus. The compound body of the microscope is in this case attached to the camera by a screw. Some prefer thus to retain the frame work of the microscope as well as the lenses, especially if the stage is provided of adjusting screws. The third plan seems, however, undoubtedly the best, as there is no trouble mounting or dismounting the microscope, nor consequent risk of injury to it. Besides as only one set of lenses is required for the camera, the microscope may be still found useful in preparing the specimen to be taken, or in comparing the
photograph with it. I shall therefore describe an instrument of this kind constructed by Mr. Bryan of this city. The camera consists of a wooden box, A. D., see diagram, a few feet in length, two inches in breadth, and the same number in depth. At A. B. C. are places for the insertion of the focusing glass or the frame which holds the sensitive plate. At the end D. in front, are attached the tube for the microscope lens, the focusing apparatus and the stage. A coarse adjustment is obtained by the thick tube E. F. on which the stage G. is fixed, sliding upon the rod H. I., at any point of which it may be made fast by the screw at G. Attached to the centre of the rod D. (see also diag. F) is a brass tube, K. L. in which slides a smaller one M. N. (coloured red) having connected with it the adapter O. and the lens P. There is a spiral spring coiled up in K. L. which presses upon M. N. tending to move it, and consequently the lens O. towards the object on the stage G. This motion is permitted or reversed by the screw 2. which, since it passes through the fixed nut R, can be made to press upon 1. Connected with the smaller tube M. N. or to yield before it according to the direction in which the wheel T. is turned.
As it is desirable to have some means of working this wheel, I from the other end of the camera, the rod \( V \) is provided, terminating at \( U \), in a milled head and at \( I \), in a wheel with a grooved margin. The connection between \( V \) and \( I \) is completed by an elastic band, or still better by a waxed ligature, so that when the rod \( U \) is turned, motion is communicated to \( I \) and consequently to the fine adjustment. This arrangement works very well and is probably simple and less expensive than any other. The camera might be still further simplified. The rod \( V \), though most certainly useful, is by no means indispensable, neither indeed is the focusing stage. An adjustment similar to that in Ratchet or Oberhäuser's microscopes and which answers every purpose required, is provided without screws or springs by the tube \( M N \), simply sliding within the larger tube \( K L \). The light may be obtained by pointing the camera directly to the sun or to a white cloud, or otherwise indirectly, from the sun by a mirror. Mr. Bryson proposes having the instrument mounted upon the stand of an equatorial moved by clockwork, so that when the camera is once directed to the sun
it may continue to be so, and thus the operator be saved all further trouble regarding the light. Either this plan or the using of a mirror, mounted and moved as those employed by the Ordnance Survey, in such a manner that the sun's rays as reflected from it always fall upon the same point, is certainly the best, but is also very expensive and consequently not suited for general use. On the whole the most convenient method therefore is to have a mirror either attached to a prolongation of St. I., or mounted upon a small separate stand and arranged so that it may be freely moved about. When the sun's rays are directed on the object, if a piece of ground glass be interposed it diffuses the rays and produces a most agreeable white light. When sunlight can be obtained it is best, but I have sometimes got comparatively good photographs with ten minutes exposure, when the light was so bad as to render it very difficult, even to focus. If the source of light is changeable the exposure must be correspondingly short or a blurred picture will be the result. The lime ball light has been highly praised as an ar-
Official source of light, and rendering one, as it does, independent of weather and of darkness, has many advantages. I should also suppose that in one of the ways of taking microscopographs, presently to be described, it must be very useful.

Regarding the lenses to be used. Having only employed Rachett's, which certainly appear to answer well, I am unable to do more than state what seems to be the opinion of the most successful microphotographers, that the best lenses for ordinary purposes do not give the most pleasing photographs, as in them the angle of aperture is so large, that the slightest inequalities of the specimen appear out of focus, but that this defect may be, to some extent, remedied by the insertion of a diaphragm with a very small aperture. There is another point which should be referred to. In microscope lenses the actinic or chemical focus does not always coincide with the visual, but a few trials will enable one to find the difference in his own lenses as no general rule can be given. In Mr. Rachett's lenses I have not found this defect to exist. The construction of the frame
for holding the prepared plates is the same as in an ordinary camera.

Steroscopic Photography of Microscopic Objects. The increasing estimation in which the binocular microscope is now held, induces me to believe that it is desirable to devote a small portion of this paper to the consideration of the means by which stereoscopic representations of microscopic objects may be photographed. The practice of this branch of the art seems to have been as yet almost, if not entirely, neglected. It is not mentioned in the last edition of Mr. Handworth's Photographic Chemistry published this year, nor have I been able to get any definite information as to such photographs having been done. The suggestion however to take these photographs is by no means new. Sir J. Brewster in his work on the Stereoscope says: "With the binocular microscope of Professor Riddell, and the same instrument as improved by M. Hachet, binocular pictures are obtained directly by having them drawn, as Prof. Riddell suggests, by the Camera lucida, but it would be preferable to take them photographically." Others also have pointed out means by which such photographs may be taken. The chief, if not the only difficulty in the way of microstereophotography, lies in the
fact that these microscopic objects which owing to their depth can alone be represented stereoscopically are for the same reason the worst adapted for photography. There are therefore only a certain class of objects suitable, viz. those which possess depth and yet not so much as to render it impossible to obtain a tolerably good general focus. The application of the fact pointed out in reference to focusing each of the two pictures for the stereoscopic combination on a different point of the object, is important here, indeed if this is properly done the combined picture should not only possess the advantage of being stereoscopic but should also be clearer and in better focus than either of the single ones.

I have adopted two plans in taking the photographs. In both of them the ordinary microscopic camera is used, slightly modified in the one but without the least alteration in the other. In both the two views are taken separately, either on different plates or on the same, if a dark frame be used similar to that of the ordinary stereoscopic camera. The first occurred to me about three years ago but I afterwards found it had been previously proposed by another, though I am not aware that he ever employed it. All that is required is to give the stage a movement
Sir D. Brewster on the Stereoscope, page 100.
round an axis the prolongation of which would pass through the centre of the object to be taken, or as nearly through the centre as possible. When the stereoscopic representation of an object is to be taken according to this plan, the first of the two pictures is photographed with the stage in the position indicated in the diagram 2 by the dotted line $G^\prime G^\prime$. The stage must then be turned round a few degrees till it would nearly coincide with the line $G^\prime G^\prime$ when the object, in consequence of the axis of rotation not passing exactly through its centre, may require to be moved so as to occupy the same place in the field of the microscope it did previously. After the camera is focused on a point of the object at a slightly different distance from what it was in taking the first picture, the second photograph is taken. The stage should be moved through the angle which at the distance of the lens from the object is subtended by a line equal to the distance between the eyes, divided by the magnifying power employed. That is, twice the angle the sine of which is to the cosine as $D_0$ is to the distance of the object from the lens, where $D$ is the distance between the eyes, $a$, the magnifying power.

The second way in which I have taken micro-stereo-
It is hardly necessary to state that the rays of light in passing through the object are sensibly parallel.
graphs presents the anomaly of a stereoscopic picture being photographed by a single camera without the slightest alteration in the relative positions of the lens and the object. I was led to attempt it by observing that when the reflected rays of the sun were employed as the source of the illumination, the change in the appearance of the object, as prepared for taking the first and second views, depended rather on the angle at which the rays of light were directed, than on the alteration in the position of the stage. This not only showed that great care must be taken that the light, if not diffused, be directed towards the object at a constant angle, if the first plan be adopted, but also suggested the idea of taking such stereoscopic pictures by merely altering the angle at which the light is directed on the object. If the camera be horizontal, the rays of light must also be horizontal, or the change in the object will not take place, as it does in that case merely laterally, but also vertically. According to the first plan if the object fills the field of the microscope, only a vertical stripe of it can be in focus and if, as with a high power, the object glass approaches very near the slide, the proper amount of rotation of the stage cannot be effected. The second appear
to be free from these defects. With both, unless the picture be taken in a few seconds, a fixed source of light, as that given by the line ball light would be desirable. Before concluding the first division of this part of the paper I would wish to urge the advantages of what is usually known as the Dry process, in several of the branches of photography in which medical men are interested. Especially in taking stereoscopic representations of preparations & nearly life size, where the two pictures cannot be photographed at the same time, the operator with the wet process, if I may judge by my own experience, will have many disappointments and will lose much time owing to the difficulty of working with a wet plate which is not developed till a long time after it is removed from the nitrate bath.

2. I shall now endeavour to explain the several points which the photographs presented with this paper are intended to illustrate. It is hardly necessary to request that the powers of photography in the several departments illustrated, be not judged by my efforts. I have endeavoured to do my best but it cannot be expected that photographs produced by a comparatively young amateur should possess the merits of those which a professional photographer skilled in
his art might easily execute were sufficient encouragement offered. Had I been able to devote more time to the subject of this paper, several of the plates from which the prints are taken would have been rejected and others photographed in their room. So much time, however, was lost in carrying the apparatus from one place to another, in setting up dark rooms &c., in selecting specimens and in encountering the numerous disappointments which almost invariably attend the efforts of amateurs that I was compelled to present photographs, which, though faulty, will still, if it be remembered that the discredit of the faults lies with the artist not with the art, enable me to illustrate the applications of Photography less imperfectly than I could do without them. Two or three of the binocular pictures are, if I may say so, too stereoscopic, any other faults of importance will be pointed out where necessary. My desire has been to indicate what pure Photography can do and what it cannot. Acting on this principle I have neither coloured any of the photographs nor even touched them further than in one or two cases to hide a slight flaw in the print. Several of the photographs attached to the paper would be vastly improved even
by a few touches just to render the more important
points bolder, so as readily to attract the attention.
It would not only be performing an unnecessary piece of labour
but would prove excessively tedious, were I even to indicate
all the ways in which photography may be usefully em-
ployed in connection with every branch of medical
studies, as self-evident are its applications. The medical
man who has devoted a few spare hours to the practice
of the art has in his Camera a power of delineating a
large proportion of those objects which interest him
with a truthfulness and beauty which exceed the
efforts of the most skilful artist. In Botany and
Natural History few objects exist which may not be
readily photographed. The student of Chemistry would
find stereoscopic representations of complex apparatus
often most useful and would receive from similar
photographs most vivid ideas of intricate crystalline
forms whether microscopic or otherwise. Carefully ex-
ecuted stereoscopic photographs of deflections of the
principal triangles and spaces of the human body
would not fail greatly to aid the student in acquiring
a correct knowledge of anatomy, or in recalling to his
memory the relative position and depth of parts when he
can no longer enjoy the advantage of dissecting. I re-
gret I am not able to present such photographs. No. 60
is however, taken from a cast of the perineum. The
depth colour and light shades given to the muscles
in the cast along with the circumstance of its being
under a glass frame made it, I believe, more difficult
to take than an ordinary dissection would. But al-
though faulty in presenting an appearance as if
fat had been left between the bundles of muscular
fibres, it still shows, I hope, in the ischiococcygeal area,
the advantage of delineating such subjects stereoscopically.
Nos. 24 to 34 and 34 1/2 are the results of an attempt to
prove that anatomical and other preparations may
be readily photographed without distortion, though
suspended in spirits within spherical glass jars.
Photographs of the varying shape of different parts of
the body, as now one, and then another, group of muscles
is brought into action, may be well seen in the stereo-
scope. Where it is desired to exhibit the relations
of parts at various depths, such as different layers of
muscles, it might not unfrequently be done by re-
moving the more superficial, during a short interval
in the exposure of the sensitive plate, which would
thus appear transparent, permitting the deeper parts
to be seen. The applications to Physiology, Pathology
and Midwifery, though equally useful and important
as those to any other branches of medical studies, do
not call for special remark. Many objects of the
Materia Medica being characterised by their external apparence, independent of colour, would be well shown by stereoscopic photographs. In surgery a very rich field is open up to the photographers for the practice of his art, and although in the clinical Medical wards comparatively few cases occur suitable for representation by photography, still, from time to time, such cases do present themselves. I need hardly refer to the delineation of the external characteristics of mental diseases by photography, as such applications of the art are well known and appreciated to require comment.

It seems strange that photography should have been employed so little in connection with Medical jurisprudence. At trials by the production of the stereoscopic camera, right in some cases, not only be made faithful impartial witnesses to the character and severity of wounds, but might assist the medical man in enlightening the minds of a jury on their verity or points of importance connected with them.

In conclusion an important question arises. How may stereoscopic photographs be made generally available? For many purposes they are much too expensive. A work on anatomy could not be illustrated with stereoptics of bones or face at a very great expense, yet, even with such works, it might be useful
to publish stereographs of difficult parts as the base of the skull. Great hopes may be entertained that at no very distant date through the labours of Mr. Salbot and others we will be in possession of means by which stereographs may be published cheaply and in the meantime the large amount which is spent by the public on stereoscopic pictures leads one to believe, that were the rich treasures of some of our museums photographed, not only might it be done profitably, but facilities would be given to those in remote parts to become acquainted with the true appearance of the objects in a way they might never otherwise have been able to do. It does not even seem absurd to suggest that a knowledge of Anatomy, Natural History, Botany &c. might be more generally diffused were there in connection with the libraries of Country towns, museums of Photographs of such objects as would most fully illustrate these sciences. For these purposes stereoscopic prints on glass would be peculiarly suitable as they can be magnified so that a human skull, for instance, might not only stand out in all its natural relief but appear also of the natural size. Such stereoscopic photographs would be very conveniently arranged similar-
the same way the unique specimens of one museum might be correctly and vividly represented in every other. Again, stereoscopic photographs might often usefully illustrate the subjects of a lecture. With these remarks I would conclude this very imperfect attempt to show the advantages of photography, and more especially of stereoscopic photography as a means of obtaining illustrations of those objects in which the medical man, as such, is likely to be interested.