are pierced with holes which represent the stems of upright plants, thickets of which were buried by the descending showers or rapidly accumulating sediment of volcanic ash. Here the source of the materials is to be sought in the line of great volcanic vents which crown the summit of the Cascade Mountains, and from which, at intervals, were emitted either floods of lava, poured down on to the plain along the eastern border of the range, or showers of ashes which, borne inland by the prevailing westerly winds, fell on forest, savannah and lake, temporarily destroying animal and vegetable life and forming, when falling or washed into water basins, strata which alternate with fossil beds, the accumulations of quieter times. In other places these tufaceous deposits were washed from all the highlands into the valleys, forming local masses of considerable thickness without the intercalated beds mentioned above.

The accompanying section, copied from my report on the Geology of Northern California and Oregon (Pacific R. R. Report, Vol VI, Geology, p. 47), will illustrate the deposition of these tufaceous rocks in the lake basins where they are inters'ratified with the fossiliferous beds.

THE SCIENTIFIC SOCIETIES OF WASHINGTON, D. C.

THE PHILOSOPHICAL SOCIETY.—During the month of November three very important papers were read: on the Anomalies of Sound Signals, by President James C. Welling; on the Storage of Electric Energy, by Mr. J. C. Koyl; and on Baiometric Hypsometry, by Mr. G. K. Gilbert.

The first named paper was a comprehensive review of the vexed discussion concerning the anomalies observed in the transmission of sound, and the summation of the result in a series of twelve aphorisms. The second paper was by a fellow of Johns Hopkins College, with reference to a series of experiments lately made by him in company with some Washington gentlemen upon an invention for the storage of electricity. Mr. Gilbert's communication had reference to a scheme of measuring altitudes by means of two barometric stations in the same vicinity, the one quite elevated, the other as low as convenient. By this means the influence of the thousand and one local causes affecting the barometer would be more thoroughly brought under the knowledge of the observer.

THE BIOLOGICAL SOCIETY.—The following communications have been made during the past month: on the Philosophy of the Retardation of Development Among the Lower Animals, by Prof. C. V. Riley; Antiquity of Certain Types of North American Non-Marine Mollusca, and the Extinction of Others, by Dr. C. A. White; Recent Explorations of the U. S. Fish Commission, by Mr. Richard Rathbun.

Professor Riley drew the attention of the society to a number of instances where the development of insects had been retarded in the embryo stage for a very long time. This did not refer to the well known retardations of whole broods, but to wholly exceptional cases. The speaker attributed the phenomena to evolutionary causes, and showed how a species might be saved from the wholesale destruction of a very severe winter or other disaster by this means.

Professor White's paper had reference to the survival from very high antiquity of many of the fresh water and brackish water forms, and to the total disappearance of others, for which events no adequate causes can be assigned.

Mr. Rathbun's communication was a review of the work of the Fish Commission from its foundation, illustrated by a map locating every dredging station; by a papier maché model of the Atlantic bottom as far out as the deep soundings, from the mouth of the St. Lawrence southward, and by specimens of the apparatus employed as well as the fauna discovered. The address was necessarily very comprehensive, but exceedingly interesting. At the same time the attention of the society was called to a pamphlet by Prof. G. Brown Goode, entitled "The First Decade of the United States Fish Commission, its Plan of Work and Accomplished Results, Scientific and Economical, Salem, Mass.: Salem Press, 1881."

THE ANTHROPOLOGICAL SOCIETY.—Three papers were also read before this society in November, to wit: How Shall the Deaf be Educated? by President E. M. Gallaudet; a Navajo Myth, by Mr. R. L. Packard; the Regulative System of the Zunis, by Prof. J. Howard Gore. The education of the deaf must be preceded by a proper classification of the heterogeneous group commonly called deaf mutes. The question of the relative superiority of the sign language and of visible speech was discussed with great minuteness. The author also treated the problem of heredity, of relative intelligence, and of the power of abstraction, with great ability.

Mr. Packard's myth was one taken by him last summer from one of the Navajo tribe and related to the origin of the Navajos.

Mr. Gore has spent some years upon the evolution of deliberative assemblies and the conduct of such bodies. Last summer, being in charge of a surveying party in New Mexico for the government, he availed himself of his opportunities to become familiar with the customs of the Pueblo Indians in such matters. These papers will be published in the proceedings of the Society.

DIAGRAMMATIC REPRESENTATION OF STEREOSCOPIC PHENOMENA.

(*Continued from p. 548, Nov. 19th, 1881, in Transactions of N. Y. Academy of Sciences*).

In a previous article (8) it has been shown that no reliance can be placed upon the theory of apparent distance in the stereoscope, elaborated by Wheatstone and Brewster, and applied in the diagrammatic explanation of stereoscopic phenomena in all our text books on Physics. We may well ask, therefore, to what extent it is possible, by any diagram, to represent the position of objects as they should appear in the stereoscopic field of view. So far as this is determined by the relation between the visual lines we may secure an approximation only by the following method, in which it must be assumed that we know also the relation between the camera axes at the time the photograph was taken. Since the visual lines may be practically regarded as special secondary axes to the crystalline lenses, it will be found convenient to call them visual axes, and their possible relations, axial convergence, parallelism, and divergence. It may be well also to restate two principles that have been sufficiently demonstrated elsewhere.

I. A point farther or nearer than the point of sight is necessarily seen double (9) and with imperfect focalization. If farther, the internal rectus muscles of the eyeballs must be slightly relaxed to make it the point of sight; if nearer, they must be contracted. Such relaxation is habitually associated with remoteness, such contraction with nearness, of the point fixed.

II. If an external point is imaged upon corresponding retinal points, the subjective effect is that of union of the two eyes into a central binocular eye, the nodal point of which is the point of origin in all estimates of direction and distance. (10)

A brief preliminary proof of a geometrical principle to be applied is also necessary. Let C and C′, fig. 1, be two fixed points, and E midpoint between them on a horizontal plane. Let this plane be cut by four vertical planes, parallel to each other, their traces being marked I, II, III, and IV. Let B and Q be any points of plane I, from which straight lines are drawn to E, piercing plane II at A and P respectively. Through C and C′ let projecting lines be drawn from A, B, P and Q to plane IV. It is required to find what relation exists between the horizontal displacements of the projections, a from b, p from q, a′ from b′, p′ from q′.

Since CC′ is horizontal, the projected horizontal displacements will be the same for all elevations of B and Q; these may hence be taken as points on the horizontal trace of plane I.

Since EC=EC′, we have

$Pq_2=Pq'_2=Ab_2=Ab'_2$

$\therefore\ pq=p'q'=ab=a'b'$.

This equality will not exist if E be not midpoint between C and C′. It is true for all points in planes I and II respectively, through which straight lines can be drawn to E.

Let now C C′, fig. 2, be the distance between two camera lenses, for example 10^{cm}; A and B, objects in the foreground and background of a landscape, on the median line from E; Aa, Aa′, Bb, Bb′ secondary axes extending to the sensitized plate. The stereoscopic displacements on the photographic negative, a b and a′ b′, are equal to each other and to those of any other points, P and Q, related to the midpoint E, as they are in Fig. 1.

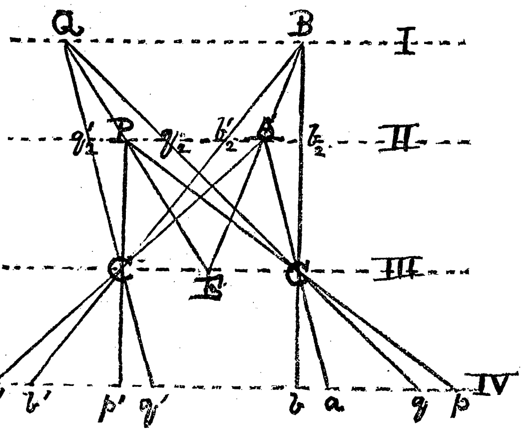

Fig 1.

The camera axes to A make a known angle, θ, with each other. Let E be midpoint also between a pair of eyes, R and L. If proofs from the negative be inverted and placed in front of R and L in such manner that the visual axes through a_1 and a'_1 shall form with each other an angle, α, equal to θ, then A_1 and B_1 are, as nearly as possible, the apparent positions of foreground and background respectively. If α exceed θ, A_1 will be nearer, if α be less than θ, A_1 will be farther; and this will be true if $\alpha = 0$, or $\alpha < 0$. Either of these last conditions is attained by simply increasing the distance $a_1a'_1$. Whether the visual axes are convergent, parallel, or divergent, the *subjective* effect is that of the union of R and L into a binocular eye which, for the geometrical reasons just given, can be nowhere else than at the midpoint, E. In this the dissimilar retinal images are superposed. If those of the points a_1 and a'_1 coincide, b_1 appears to the right eye projected outward on the right, to the left eye an equal distance outward on the left; to the combined eye it is a homonymous double image. Let A_2 be the external projection of the combined images of a_1 and a'_1, as seen by the binocular eye at E_2; if $\alpha = \theta$, the distance E_2A_2 is equal to RA_1 or LA_1, which differs but little from EA_1 unless α be large; it has been drawn equal to EA_1. Then B_2 and B'_2 will be the external projections of the uncombined images of b_2 and b'_2. If the attention be transferred to the background, the angle between the visual axes must be diminished by relaxing the internal rectus muscles, and this instantly suggests greater remoteness of the point of sight. The retinal images of b_2 and b'_2 coalesce and are projected to the more distant external point between B_2 and B'_2, while those of a_2 and a'_2 cross slightly to opposite sides and are projected as a heteronymous double image at its proper distance. The ratio of E_2A_2 to EA_1 must depend upon the variation in muscular tension due to the difference between the angles θ and α. The duplication of the images of the background points when the foreground is regarded, and *vice versa*, is easily perceived if a properly constructed diagram is viewed in the stereoscope, provided the observer be attentive to his own sensations, examining each point of the combined picture separately instead of regarding

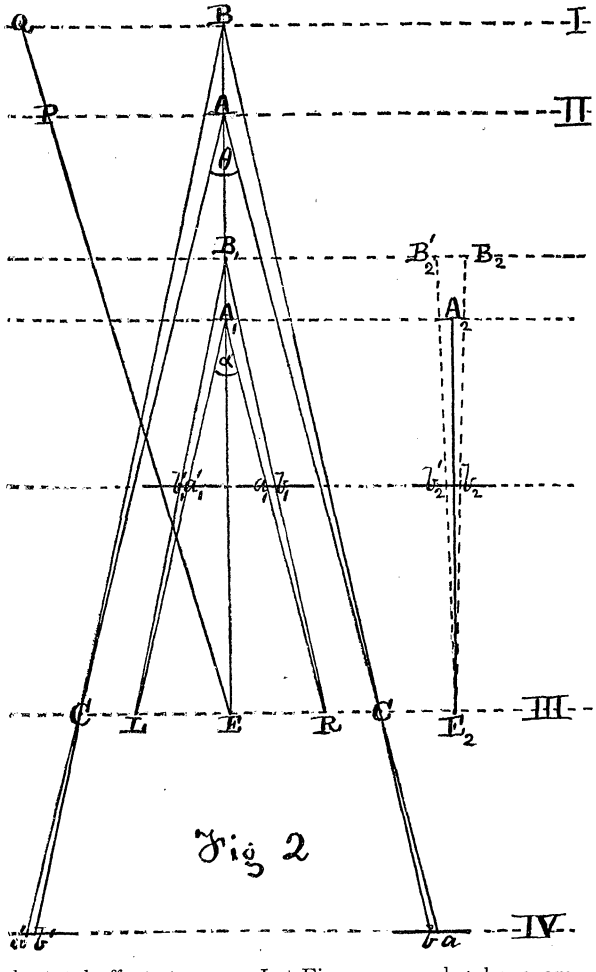

Fig 2

the total effect at once. Let Figures 3 and 4 be examined in the stereoscope, by resting the edge of the page on the cross-bar of the instrument at the proper distance in front of the semi-lenses. In each case, when the foreground circle is seen single, the background dot is seen double, and *vice versa*. When the background circles of one figure are combined binocularly, those of the other are seen separately by monocular vision. Axial convergence is necessary to combine the circles of Fig. 4. The combined image appears nearer, smaller, and less tall in proportion to its base than the combined image of Fig. 3, which requires axial divergence. The stereoscopic displacement is the same in both figures, and is measured by the distance between the centre of the large circle and that of the small one within it. The stereographic interval for the background is 90 mm. in

Fig. 3, and 50 mm. in Fig. 4. An average lenticular stereoscope will fail to produce axial convergence when Fig. 3 is viewed by a pair of eyes whose centres are 64 mm. apart. These variations in visual effect can be rendered still more striking by using the reflecting stereoscope, after cutting apart the right and left halves of the stereograph.

It must be remarked that although the perception of binocular relief is intensified by alternate examination of foreground, and background it is quite possible to attain it by momentary illumination with the electric spark, at least with convergence of visual axes, as has been done by Dove ([11]) and others. During such brief illumination, no variation of convergence is possible, and, if the foreground be distinctly focalized, the background must be slightly doubled homonymously. The position of the point of sight is found thus to be almost as nearly determinate as when the illumination is prolonged. Whether binocular relief, and the position of the binocular image, be perceptible with equal distinctness when the visual lines diverge, has not thus far been ascertained by experiment, so far as I am aware. I hope to test this, and to study certain other points of interest connected with it, at some future time.

Since the apparent distance of the point of sight continues to increase in a positive direction after axial parallelism passes into divergence, it becomes necessary to investigate the physiological conditions that interfere with the results of the mathematical theory hitherto generally applied.

In looking at any picture constructed in accordance with the rules of perspective applied by all artists, the illusion of distance is quickly attained by forming a conception of the reality in space to which the different parts of the picture are supposed to correspond, or of the object as the observer has been accustomed to view things of its kind. With the same degree of axial convergence a mountain and a piece of statuary will never be judged equally distant. It is unnecessary here to enumerate the elements that combine to produce the illusion. If these be excluded to the utmost, as in mere skeleton diagrams, there will still be left three to consider in judging the distance, size, and form of what is represented. These are—

I. The optic angle between the observer's visual axes.
II. The focal adjustment of the crystalline lens.
III. The visual angle subtended by the picture.

Of these the first is the only one usually considered as *distinctive* of binocular vision. It can never be dissociated entirely from the others, and its effect may be so overpowered by them, when distance is to be estimated, that calculations based upon its value, like those of Brewster, lose all claim even as approximations to the truth. Its true importance is dependent upon the extent to which the individual, in natural binocular vision, has been accustomed to associate the sensation of muscular contraction in the rectus muscles of the eyeballs with the true distance of objects as learned by other means. Doubtless this varies with different individuals. For distances of more than 240 m. the optic angle becomes inappreciable, and hence theoretically valueless; its importance is greatest near the lower limit of distinct vision. In every case its effect is appreciated mainly through the muscular sense and through the retinal perception of double images from objects farther or nearer than the point upon which attention is fixed. We are safe in disregarding the mere fact that a pair of imaginary lines *would* make a measurable angle with each other *if constructed*, though the use of this angle may be convenient in analyzing the phenomena of vision. It is well to remember, however, that its variations imply simply changes of muscular tension, and these constitute the most appreciable effects that influence the estimate of limited distance.

The judgment due to focal adjustment is also an interpretation, based upon personal experience, and suggested by the sense of contraction in the ciliary muscle, while adapting the crystalline lens to produce a distinct image. Variations in this are hence inappreciable for distances of more than 6 m., and are most noticeable near the lower limit of distinct vision. It is near this limit that the stereograph is held in most cases when regarded.

The visual angle is important as chiefly determining the size of the binocular retinal image. Since two eyes receive more of the light reflected from a given surface than either eye alone, the binocular image appears brighter than one that is monocular; and this is apt to produce the illusion of slight decrease of distance, if the focalization is perfect. But variation due to this cause is not important in comparison with that due to change in the visual angle.

The relative importance attached to the separate elements enumerated depends most frequently upon the unconscious experience of the individual. The results which they combine to produce cannot be referred to any one mathematical formula until the physiology of sensation is completely brought within the domain of mathematical law.

In testing the effects of these elements it will be best to apply a formula for the distance of the optic vertex from each eye, in terms of the interocular distance, i, and optic angle, α. Assuming the optic triangle to be isosceles, and calling D the required distance, we have, as the formula to be tested by experiment,

$$D = \tfrac{1}{2}\, i \ \text{cosec.}\ \tfrac{1}{2}\, \alpha.$$

Considering angles of convergence positive, the possible values of α, between which I find myself limited, are + 80°

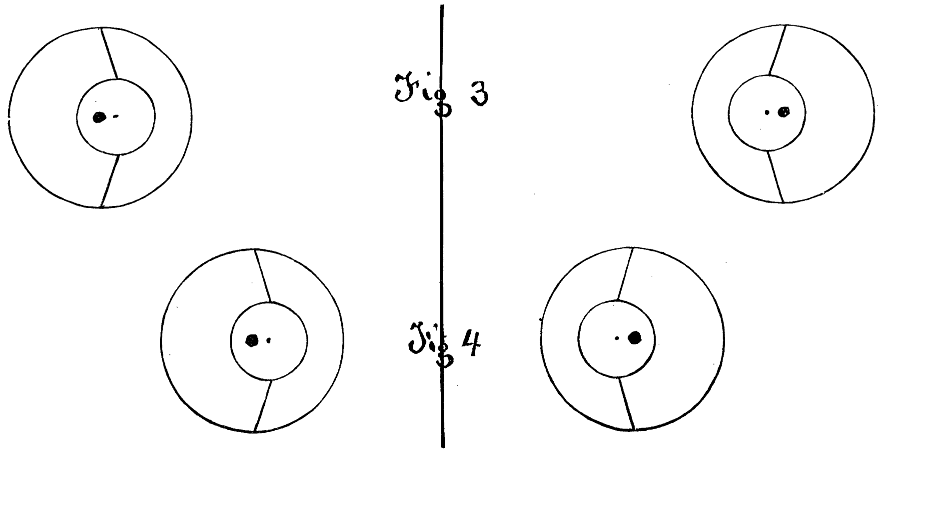

Fig 3

Fig 4

and $-7\frac{1}{2}^{\circ}$, my eyes being perfectly healthy. If a curve be constructed from the formula, the values of a being taken as abscissas and those of D as ordinates, for parallelism of visual lines we have $a = 0$, $D = \infty$, and the axis of ordinates is hence an asymptote. A vanishing point should therefore be reached by the external binocular image. Its apparent distance, however, is still finite, and vision very easy. In passing to negative values of a by increasing the stereographic interval, the distance estimated continues to grow in a positive direction. This is undoubtedly due to the sense of increasing relaxation of the internal rectus muscles and contraction of the external rectus; but the rate of growth bears no recognizable relation to any succession of values given by the formula.

The explanation just given is based upon experiments, the description and discussion of which must be withheld for the present. It may be simply stated that with binocular fusion of images from the same pair of conjugate pictures, I have tested the visual effect of varying the optic angle from -5° to $+45^{\circ}$, vision becoming indistinct after the last named limit is passed. The value of the optic angle has been found to be largely, but by no means exclusively, effective in determining apparent distance in the stereoscope, especially for convergence of visual axes. Its effect is antagonized by the difficulty of focal adjustment and by the constancy of the visual angle, the latter element being particularly important when the axes diverge.

The variation in apparent magnitude of the combined image, dependent upon the value of the optic angle, has been noticed by Wheatstone (12), Helmholtz (13), and Meyer (14). Helmholtz constructed his telestereoscope (15) for producing exaggeration of perspective when distant objects are viewed, but no reference is made, in this connection, to divergence of visual lines. The possibility of fusion by optic divergence seems to have been first noticed about 1860, by Burckhardt (16); and Helmholtz notices the exaggeration of apparent distance thus produced, but explains it by saying (13), "Infinity does not, in our visual conceptions, present an impassable limit. When our eyes occupy a position which is never presented in the normal observation of real objects, all that we can do, conforming ourselves to the rule which we ordinarily follow for the interpretation of abnormal sensations, is to compare the sensation produced with that which resembles it most, and which is distinguished from it only by more feeble convergence, that is, with what is given us by real objects very remote." Vision in the stereoscope is always to some extent abnormal. The error into which Brewster fell, and in which he has been generally followed, was in supposing that under such conditions no modifications would be imposed upon the mathematical law found applicable to normal vision, in which there is perfect coincidence between the impressions traceable to the optic angle, focal adjustment, and visual angle respectively.

W. LE CONTE STEVENS.

THE German government is considering the participation of German men of science in the plan of International Polar Research. The Reichstag has been asked to grant the necessary funds $75,000.

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FOREIGN NOTES ON THE SOURCE OF COMETS' LIGHT.

Numerous observations have been made abroad upon comet *b*, 1881, to settle the question as to the origin of the light of these bodies. Messrs. Thury and Mayer at Geneva compared the brightness of the comet's head, as ascertained by photometric measurements, with the brightness it would have had if its light had been derived solely from the sun, by reflection. It was found that the intensity of the light of the nucleus, as it withdrew from the sun, diminished at first faster, and after a time slower than would have been the case, had it shone solely by reflected light. The decrease in intensity took place, in fact, as if the nucleus, during its approach to perihelion, had acquired through the force of the sun's rays an intrinsic light, which accompanied violent action of some character; this violent action ceasing after the comet had measured some distance on its return track, its light decreased speedily in conformity therewith, but the nucleus continued to glow as if in a state of incandescence, and remained visible, according to the above observers, longer than could have been expected.

This method seems to be well adapted to an independent determination of this interesting question. In the data it is a question, not of absolute, but of relative quantities. Ignorance of the physical condition and nature of a comet's reflecting surface renders it impossible to compute the intensity of its light under reflection alone, with any degree of certainty. As not the absolute light, however, but the increase or decrease under the circumstances, is required, the necessity for such knowledge is eliminated.

Another conclusion as to the origin of the comet's light has been reached by Respighi, from spectroscopic evidence. According to him there is no doubt that the light in part is reflected, as is proved by the appearance of the Fraunhofer lines in the photographs of the comet's spectrum. As to the bright lines or bands, they also may be caused by reflected light, as will be seen when it is taken into consideration what changes this light must have undergone after it has passed through the gases and vapors which form the whole mass of the comet. "It is certain," he continues, "that the largest part of the light emitted by the comet comes from its interior, and that it has passed through thick strata of gases and vapors. It is there subject to the selective absorption which is peculiar to these vapors and their combinations. It is accordingly natural that dark lines and bands should thence arise, which are different from the Fraunhofer lines; and with the weak, but complete, spectrum of the light that is reflected from the exterior substance of the comet, another spectrum must appear, which is considerably modified through powerful absorption."

"The limits of a simple notice do not permit me to enter in detail into my numerous spectroscopic observations of the Comet *b*, 1881. But I can affirm that it does not require the supposition of an intrinsic light to explain the phenomena which they exhibit. For the discontinuity of the spectrum might arise from the same cause as the broad, dark bands in the spectrum of the sun near the horizon, or in those of the planets. In the case of comets, however, the phenomenon is greatly exaggerated by the immense thickness of the absorbing strata, the rich character of their chemical constitution and the weakness of the light which they reflect to us. One must therefore proceed as in the case of the spectrum of our atmosphere, and not consider so much the bright bands as those dark through absorption."

A COMMITTEE has been formed at Reggio, (Emilia) to collect funds for establishing a fitting monument to the memory of the Padre Secchi, in the form of a fine refractor, of which the objective is to have 70 centimetres diameter. Reggio thus follows the example of Arcetri, where a fitting scientific monument has been erected to the memory of Galileo.