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ART. XXIX.—*On some controverted points in Geological Climatology; a reply to Professor Newcomb, Mr. Hill and others*; by JAMES CROLL, LL.D., F.R.S.

NINETEEN years ago the theory was advanced that the Glacial epoch was the result of a combination of physical agents brought into operation by an increase in the eccentricity of the earth's orbit. Few or no objections have been urged against what may be called the astronomical part of the theory. But the portions relating to these physical agencies, which is by far the most important part, have from time to time met with considerable opposition. Considering the newness of the subject, and the complex nature of many of these combinations of physical agencies, it would not be surprising if some of the original deductions in regard to them proved erroneous. But after long and careful re-consideration of the whole matter I have not found reason to abandon any of them or alter them to any material extent.

The only class of objections urged against the theory which I have as yet considered at length are those relating to the cause of ocean currents, and their influence on the distribution of heat over the globe; and I think, it will be admitted that the views which I have advocated on these points are now being pretty generally accepted.

But it is in reference to the influence of aqueous vapor, fogs and clouds on the production and preservation of snow that the greatest diversity of opinion has prevailed. The object of the present article is to examine at some length the principal

ART. XXXII.—*On the Sensitiveness of the Eye to Slight Differences of Color*; by BENJAMIN OSGOOD PEIRCE, JR.

AUBERT has shown* by his experiments with revolving discs that the eye is able to detect the change produced by the addition of 1 part of white light to 360 parts of colored light, and that perceptible changes in hue can be brought about by adding to light of any color less than 1 per cent of light of a different color. He infers from this that a normal eye could distinguish at least one thousand different hues in the solar spectrum.

At the suggestion of Professor Wolcott Gibbs, I have made a few experiments to test the sensitiveness of the eyes of different people to slight changes of wave-length in different parts of the spectrum.

For this purpose, a long, thin sheet of vulcanite was inserted lengthwise into the collimator of a large spectroscope so as to divide the tube into an upper and a lower half. The lower part of the tube received light from a fixed slit, the upper part from a movable slit of the same width, which could be set exactly over the other, or displaced to the right or to the left. The amount of displacement was determined by means of a steel scale fastened to the upper slit and moving with it past a fixed zero point. The light from the collimator fell upon a Rutherfurd diffraction-grating of about 17,000 lines to the inch, and the resulting spectra were then thrown, one above the other, into the observing telescope. A blackened, metallic diaphragm, out of which two narrow slits had been cut in the same vertical line, was placed in the eye-piece of the telescope, so that when the two collimator slits were even the observer saw merely two narrow strips (one over the other) of the same colored light on a black field. When the movable collimator slit was displaced, the *color* of the observer's lower strip was changed without changing its *position in the field*, and the object of the experiments was to see how small a displacement could be infallibly *detected* and *named in direction* by the observer.

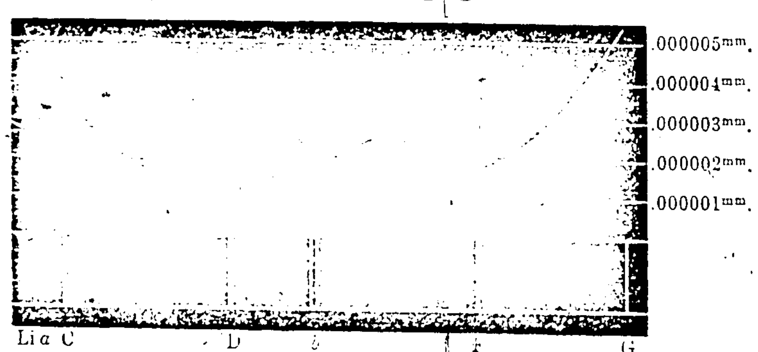
The width of the collimator slit was about $\cdot 25^{mm}$, and the slit in the eye-piece diaphragm was nearly of the apparent size of the collimator slits as seen through the telescope. The length of that part of the spectrum which was so bright as to be easily studied (say from Li α to G) extended over more than 12 degrees of arc as measured in the instrument, and the width of the strip seen by the observer was about 5 minutes of arc, so that not more than the $\frac{1}{150}$ part of this brighter part of the spectrum was in the field at the same time.

* "Physiologie der Netzhaut," Breslau, 1865, pp. 132-154; Rood, "Modern Chromatics," pp. 39-41.

libly detect corresponded to a difference in wave-length of only ·0000005mm. This last is rather remarkable, for although no one could see any difference between the colors of the edges of either of the strips, a displacement which made the color of the middle of one strip the same as that of an edge of the other sometimes made the two strips distinguishable.

There was a singular uniformity in the performance of different eyes as judged by the average of these displacements for the whole visible spectrum. Perhaps smaller differences might have been detected if the strips had been narrower, but the work proved to be so trying to the eyes that I thought it best not to experiment further.

From a series of observations made by a number of different persons and extending over several months, two or three general conclusions may be drawn. To make these evident, I have plotted a curve by laying off over different places in the spectrum ordinates obtained by averaging in each case the least



displacements distinguishable by the different observers at that point. The general features of this curve appeared in the results of every observer.

In all cases the eye was most sensitive to changes in a color slightly less refrangible than that of the sodium line, though this color varied somewhat with different persons, being in some cases more orange and in others more yellow. In all cases the eye was more sensitive to changes in the color corresponding to the F line than to changes in colors lying half-way between *b* and F.

In many cases, though not in all, the eye was less sensitive to changes in a red near the C line than to a somewhat darker red beyond the Lithium line. In the darker colors at the ends of the spectrum it was, of course, very hard to distinguish small differences.

In addition to these general features there were in most of the curves obtained by plotting the results of the different observers lesser maxima and minima which showed peculiarities

in the different eyes. These peculiarities appeared unchanged in every set of observations taken by the same person.

I wish to express my obligations to Professor Gibbs for his advice and for the loan of apparatus, to Professor J. P. Cooke, who kindly placed at my service the magnificent spectroscope made for him by the Clarks, and, among others, to Professor W. E. Byerly, Professor C. R. Lanman and Messrs. F. B. Knapp, E. B. Lefavour and E. S. Sheldon for their kindness in helping me with their observations.

Cambridge, Aug., 1883.

ART. XXXIII.—*Injury sustained by the Eye of a Trilobite at the time of the Moulting of the Shell;* by CHARLES D. WALCOTT.

MR. WILLIAM P. RUST, of Trenton Falls, N. Y., called my attention some time since to the eyes of a small but very perfect specimen of *Illænus crassicauda*, from the Trenton limestone, that he has in his beautiful collection of Trenton fossils.

The left eye is perfect; the visual surface is clearly defined, and in the sunlight almost translucent between the darker base and the curve of the facial suture above. The right eye at first sight appears to have been broken in working away the matrix, but a close examination shows, as Mr. Rust expressed it, that the eye had been put out while the animal was living. This is shown by the peculiar growth of the shell about the aperture formerly occupied by the visual surface of the eye. The margins are turned in, rounded and contracted, and the size of the palpebral lobe materially lessened. An injury to the visual surface would scarcely produce this effect if the shell was hard. If slightly injured before the moulting of the shell, the separation would be imperfect and the visual surface carried away with the old shell would leave a cavity around which the new shell would form as in the eye before us. If injured before the new shell had hardened, that effect might be produced, but the probabilities are that the loss of the visual surface occurred at the time of the moulting of the old shell.

Among the thousands of trilobites that have passed through my hands in which the eyes were preserved, I have never noticed any distortion or injury that occurred during the life of the animal. In a few instances, the shell of the pygidium of *Asaphus platycephalus* has shown evidence of local fracture that appears to have occurred during the life of the animal, but these were very unsatisfactory. To Mr. Rust's skill in working out the specimen described and also in detecting the character of the injured eye, we are indebted for some positive information of an injury sustained during the moulting of the shell of a trilobite.