Saghalin they had not seen anything of the kind. Then I visited the villages Tarankotan and Taraika, where I first fell in with the Ainu. I also visited the Tungus villages Unu, Muiko and Walit, after having passed the famous lake of Taraika. It was impossible to proceed farther eastward, since I received an official letter of warning not to proceed, because a few versts farther east a band of highwaymen consisting of escaped convicts had built a fort and were terrorizing the country. For this reason I returned without making the acquaintance of these gentlemen.

On New Year's Eve I reached Siska. On the following day I took phonographic records of songs, which created the greatest sensation among the Russians as well as among the natives. A young Gilyak woman who sang into the instrument said: "It took me so long to learn this song, and this thing here learned it at once, without making any mistakes. There is surely a man or a devil in this box which imitates me!" And at the same time she was crying and laughing from excitement.

On the second of January I started by dog-sledge for Naiero, where I had the best results in my work with the Ainu. Then I visited all the settlements on the coast as far as Naibuchi, which is 260 versts from Siska. This journey was exceedingly difficult, and sometimes even dangerous. At one time I narrowly escaped drowning when passing the ice at the foot of a steep promontory. I broke through the ice, which was much weakened by the waves. Fortunately, my guide, who was travelling in front of me, happened to capsize on his sledge at the same moment when I broke through. Thus it happened that he saw my situation and extricated me with his staff.

Towards the end of the month I arrived at Korsakovsk, making the distance from Naibuchi, about 100 versts, on horseback. Originally I intended to return from this point along the west coast of the island; but this proved to be impossible, as there is no means of communication in winter. For this reason I had to return northward the same way by which I came, and I had to travel as rapidly as possible in order to reach Nikolaievsk in time. Towards the end of March communication between the island and mainland over the ice is suspended. Therefore, I returned with all possible speed; working and collecting, however, when opportunity offered. The last few days I travelled day and night, camping a few hours, but not more than necessary to give the reindeer time to rest. At nine o'clock this morning I arrived here, having covered, since six o'clock yesterday morning, a distance of 200 versts.

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*ON THE BRIGHTNESS OF PIGMENTS BY OBLIQUE VISION.**

In the formation of any theory of color-vision the phenomena of color-blindness necessarily play an important part. This is especially true, of late years, of total color-blindness, or the absence of all color-sense. Of this phenomena there are three classes, exemplified by the eyes of those rare individuals who lack from birth all power of perceiving color by the normal eye in faint light and by the peripheral vision of the normal retina.

In each of these three cases the spectrum appears as a colorless band of graduated brightness. It was pointed out by Hering, in 1891, that the distribution of brightness in the first two of these three classes is the same, and it has been generally supposed that the color-blindness of the retinal periphery is of similar character. Von Kries showed, however, that this supposition was untrue (*Zeitschr. für Psychologie und Phys-*

*A paper read at the Boston meeting of the American Association for the Advancement of Science, August, 1898

iologie der Sinnesorgane, XV., pp. 247–279, 1897), the maximum brightness for peripheral as for direct vision in bright light being in the yellow, and not, as in the other two classes, in the green.

According to the theory of Von Kries the visual mechanism used in bright light differs entirely from that used in faint light. The former distinguishes colors as colors, and finds the greatest brightness in the yellow of the spectrum, but requires a certain intensity of illumination before it can act at all. The other is insensible to color, seeing the spectrum, as stated above, as a strip of varying brightness, with its maximum in the green. As one who is born totally color-blind sees the spectrum in the same way, von Kries argues that in this case the 'brightness-apparatus' is absent or ineffective, and that vision is due entirely to the 'twilight-apparatus,' which in the normal eye becomes important only in faint light.

On the other hand, he goes on to say, the periphery of the normal eye acts "not (as the totally color-blind eye) by means of an absence of the 'brightness-apparatus,' and an exclusive use, therefore, of the 'darkness-apparatus,' but through a limitation or change in the functions of the 'brightness-apparatus.' In the language of the anatomical hypothesis, we must assume that even in the periphery of the 'brightness-adapted' eye the cones play the most important part, and that the color-blindness arises from a functional modification of the apparatus depending mainly on these elements, the 'brightness-apparatus.' This view is supported by the fact that the periphery values show approximately the same relations in the distribution of brightness as the color-perceiving portions of the eye, with the maximum near the sodium-line."

As this question is of considerable importance in the theory of color-vision, it seemed worth while to re-examine it with the flicker photometer, an instrument which appears excellently adapted to such a purpose. Its value in the study of ordinary color-blindness was pointed out by the writer in a paper read at the Detroit meeting of this Association, and Professor Rood, working with a flicker instrument of an entirely different type, has come to the same conclusion. The flicker photometer is also peculiarly adapted to the study of peripheral vision, since, as is well known, the peripheral regions of the retina are especially sensitive to appearances of motion or of changing brightness.

The instrument used in these experiments was of the revolving-disk type already described by the writer (*Physical Review*, Vol. III., No. 16, Jan.–Feb., 1896). To this instrument the arc of a circle was attached, the center of which was as nearly as possible the place occupied by the eye in front of the observing tube. This was marked in three points, at 30, 50 and 70 degrees from the line of direct vision. When the eye was directed on one of these marks observations with the sight tube could be made at the corresponding obliquity. All observations were made in a horizontal plane on the nasal side of the retina.

The conditions were those of ordinary photometric observation; the room was dark and the eye screened from any light except that under observation. Thus the eye was, without doubt, partially 'adapted for darkness,' though the lights under observation were too bright to allow this adaptation to go very far. The sources of light were kerosene lamps, provided with Methven slits and burning a special high-grade oil. They were found to burn with great uniformity, but were checked by frequent direct observations. The right-hand lamp was used as a standard, was kept always in one place, and used to illuminate the revolving disk. The left-hand lamp illu-

minated the pigments to be studied, and could be moved along the bar. All colors were brought to the same intensity before observations, that is, the photometer, containing the colored card, was set at a definite distance from the right-hand lamp, and the other lamp moved backward or forward until a balance was approximately attained. It was left in this position, and the set of observations on any given color made by moving the photometer head in the usual way. Thus the uncertainties were avoided which arise from working with lights of small intensity.

Six colored papers were selected from the set published by the Milton Bradley Company—red, orange, yellow, green, green-blue, blue. Each of these was examined by direct vision, and at each of the three angles before mentioned. Two concordant series of observations, each involving a large number of readings, were made on different days, and the mean of the two series taken as the final result. It soon became evident that the pigments at the red end of the spectrum decreased in brightness from the center to the periphery of the retina, while those nearer the blue end increased in brightness. It seemed probable that some color must exist for which the brightness would be the same for all parts of the retina, and to locate this color more closely the intermediate pigments yellow-green and green-yellow were added to the set originally selected. The results are exhibited in Table I.

TABLE I.

	0°	30°	50°	70°
R.	.238	.128	.089	.079
O.	.603	.297	.227	.225
Y.	.902	.755	.674	.660
G.Y.	.602	.544	.503	.505
Y.G.	.463	.466	.459	.478
G.	.292	.347	.376	.391
G.B.	.245	.317	.329	.343
B	.107	.151	.175	.193

It is shown by this table that the yellow-green remains nearly at the same brightness for all angles of vision; that, in fact, the brightness curve for the whole set of pigments might almost be said to rotate about this color as an axis, the red falling and the blue rising as the periphery is approached. The character of the change is, perhaps, more clearly shown in Table II., which is derived from Table I. by multiplying each series of figures by a factor which brings the yellow-green value to unity, changing all other results in like proportion. The value for any color at any angle of vision may then be directly read as a percentage of the value for yellow-green.

TABLE II.

	0°	30°	50°	70°
R.	.514	.275	.194	.165
O.	1.303	.637	.495	.471
Y.	2.070	1.620	1.468	1.381
G.Y.	1.300	1.167	1.096	1.057
Y.G.	1.000	1.000	1.000	1.000
G.	.631	.720	.819	.818
G.B.	.529	.680	.717	.717
B.	.231	.324	.381	.404

It is thus seen that while the red falls in peripheral vision to about one-third of its brightness when viewed directly, and blue is nearly doubled in brightness, yellow is reduced in brightness by about one-third, and yellow-green, that portion of the spectrum where we should expect the greatest brightness if the peripheral color-blindness were of the same character as 'twilight' color-blindness, remains practically the same at all angles of vision. Yellow is still the brightest of the colors, and the maximum is shifted but little toward the blue.

It is to be noted, also, that there is comparatively little change from 50° of obliquity outward. At 50° most colors are still distinguishable; at 70°, none of them. At 50° the apparatus which gives us the sensation of color must still contribute its quota to the sensation of brightness, as in

direct vision. It is probable, therefore, from the similarity of the results at the two angles, that it continues to do so in the more peripheral parts of the retina, although it has lost its other function, of color-sensation.

The results at 70° confirm in a general way the measurements of von Kries. His results are given in Table III., with the column for 70° from the flicker experiments, both also reduced to the value unity in the yellow for purposes of comparison.

TABLE III.

	VON KRIES.		WHITMAN.	
	Original Values.	Reduced.	Original Values.	Reduced.
R.	1.35	.199	.079	.130
O.	4.03	.594	.222	.337
Y.	6.78	1.000	.660	1.000
Y.G.	......	......	.478	.724
G.	4.92	.726	.391	.592
B.G.	3.87	.571	......	......
G.B.	......	......	.344	.521
B.	......	......	.193	.292
V.	.86	.127	......	......

The two sets of measurements, though differing considerably in detail, show a progression in brightness of a similar character, especially as to the position of the maximum. An inspection of the table makes it evident that differences in the results might possibly be explained by the assumption of slight differences in the pigments used by the two observers; but it is perhaps more probable that the difference is a real one, caused by the fact that my observations were made in a darkened room, and, therefore, with an eye more 'adapted for darkness' than that of von Kries, who worked in a well-lighted place.

While it appears evident, as von Kries holds, that the color-perceiving apparatus is of importance in determining the brightness of any color peripherally seen, it is plain that—in the language of his theory—the apparatus for twilight vision plays a more important part than in the central portions of the retina. For the diminution of the reds and increase of the blues in brightness are characteristic only of faint illumination by direct vision—illumination fainter than the lowest at which the flicker method can be advantageously used (*Physical Review, loc. cit.*, p. 247), whereas they are shown by these experiments to exist in the outer regions of the retina under conditions of considerable brightness.

It may be said, in conclusion, that the brightness-sensation of the retinal periphery, so far as it differs from that of the central portions, differs from it in the same direction, though not so greatly, as in the other two types of complete color-blindness.

FRANK P. WHITMAN.
ADELBERT COLLEGE.

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*AN EXTENSION OF HELMHOLTZ'S THEORY OF THE HEAT OF THE SUN.**

ON the occasion of the Kant Commemoration at Königsberg, February 7, 1854, Helmholtz delivered an address on the 'Interaction of Natural Forces,' in which he laid the foundation of the modern theory of the sun's heat. The whole address, with the principal formulæ by which the numerical results were obtained, was translated into English and published in the *Philosophical Magazine* for 1856. In this paper the author discusses the conservation of energy, which he had been so instrumental in establishing upon a sound mathematical basis; and ascribes the maintenance of the sun's heat to the potential energy given up by the particles in descending towards the center of his globe. On the hypothesis that the solar sphere is of homogeneous density he subjects the problem to computation, and finds that the heat developed by a very small shrinkage of the mass will be sufficient to

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