OCULAR ROTATIONS.

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(Illustrated.)

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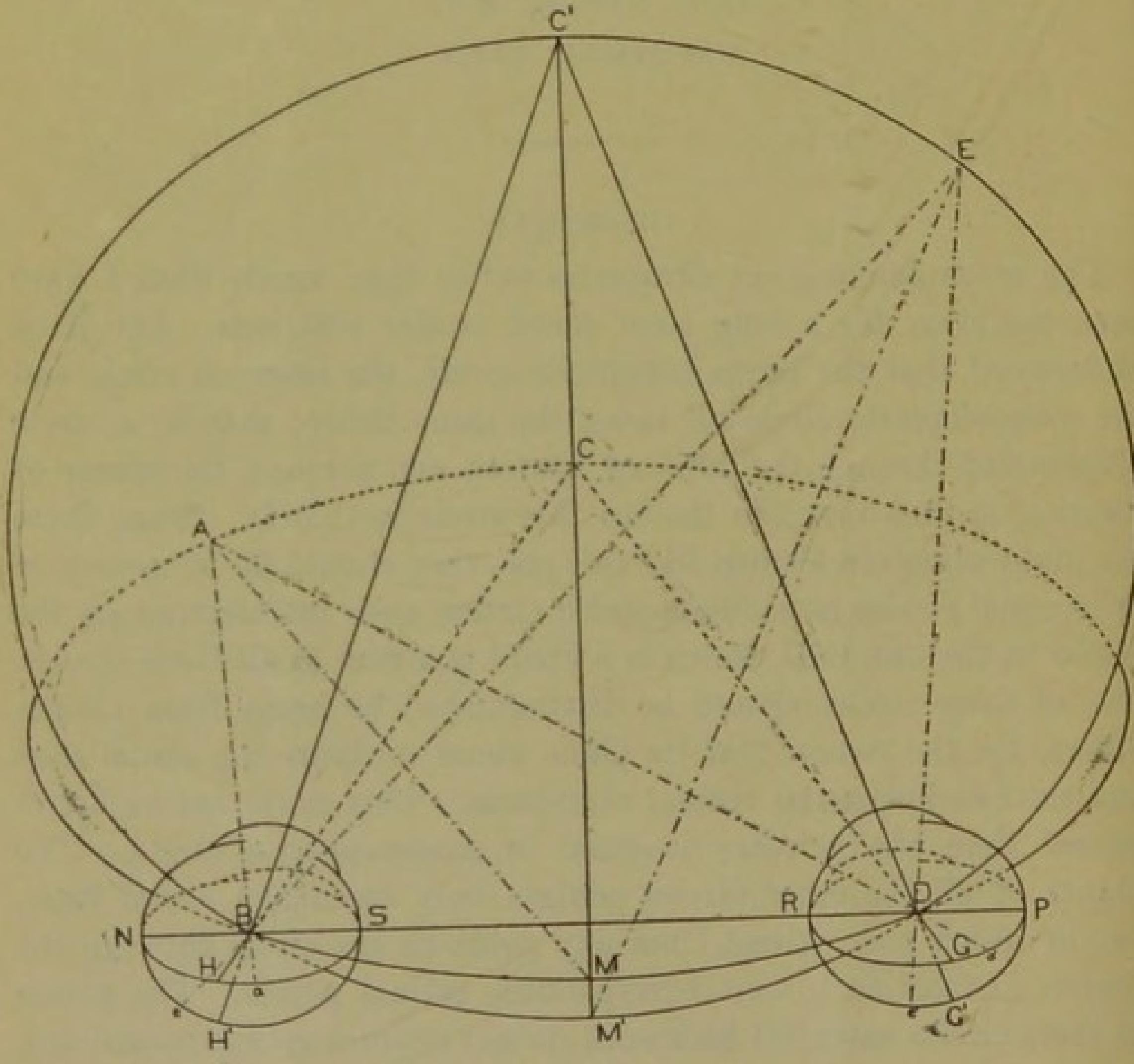
The accompanying cut illustrates better than words what I have been teaching, for a long time, about ocular rotations. Let it be understood that the terms horopteric circle, the isogonal circle and the monoscopteric circle all mean the same thing; that is, a circle constructed through the point of fixation and through the center of rotation in each eye. In the cut this circle is C-B-D. Since there are many other circles just like this one, they should all be spoken of as isogonal circles or monoscopteric circles, each intersecting all the others in the line B-D, which is a chord common to all these circles. One of these circles should be distinguished by name from all the others, for the reason that its plane alone contains the visual axes and the two horizontal retinal meridians. This could not be better named than the primary isogonal or monoscopteric circle. The planes of all the other circles contain only secondary visual lines, two of which may extend from any point on the circle through the centers of rotation to two corresponding retinal points. The planes of these circles extended backward do not contain retinal meridians, but they cross, at different points, every meridian. These should be called secondary isogonal or monoscopteric circles. The primary circle is not a truer mathematical figure than are the secondary circles. The one is precisely like the other, and in ocular rotations the one displaces the other. In the figure, B-C-D is the primary isogonal circle, in the horizontal position, C being the point of fixation, B the center of retinal curvature in the left eye, and D the center of retinal curvature in the right eye. The plane of this circle extended backward to H in the left eye and to G in right eye contains the two visual axes H-B-C and G-D-C, and also contains the two horizontal retinal meridians N-H-S and R-G-P. If the point of view is to be changed from C to A on the same circle, the two eyes will be turned to the left through the arc A-C, so that the visual axis H-C shall take the place of the indirect visual line A-*a*, and the visual axis G-C shall take the place of the indirect visual line A-*a*′. It appears evident that in changing the point of view from C to A



the visual axes and the two horizontal retinal meridians have remained in the unmoved plane, B-C-D.

In the figure the circle C′-D-B is a secondary isogonal circle, forming a definite angle with the primary circle C-D-B. The lines C′-B-H′ and C′-D-G′ are indirect visual lines. That the point C′ is in a vertical plane with C is shown by the fact that the line M-C, bisecting the angle B-C-D, is in a vertical plane with the line M′-C′, the line bisecting the angle B-C′-D. Therefore, H′ must be in a vertical plane with H and G′ must be in a vertical plane with G. G′ and H′ are, therefore, in the vertical retinal meridians of their respective eyes. In changing the point of view from C to C′ the extended plane of the circle C-B-D must be rotated on the chord B-D until it occupies the position of the secondary isogonal circle C′-D-B. In doing this the visual axes H-C and G-C are made to take the places of the indirect visual lines H′-C′ and G′-C′. In this rotation the visual axes and the two horizontal retinal meridians have remained in the plane of the primary isogonal circle; nor in this rotation have either the visual axes or horizontal retinal meridians changed their positions in this plane. Since C′ is directly above C, the visual axis H-C has moved to C′ in the extended plane of the vertical meridian of the left eye, and the visual axis G-C has moved to C′ in the extended plane of the vertical meridian of the right eye. The visual axis moves from one point of view to another point of view in a plane common to these two points of view and the center of rotation. C′ is just as high above C, in degrees of arc, as H′ is below H, for the angle C-B-C′ is equal to the angle H-B-H′, since they are opposite angles, and each is measured by that arc of the vertical meridian between H and H′. By the same reasoning we find that the angle formed by the planes of the primary retinal curve N-H-S and the secondary retinal curve N-H′-S along the line N-B-S is the same as the angle formed by the planes of the primary isogonal circle C-B-D and the secondary isogonal circle C′-B-D, along the chord B-D, for they are opposite.

If the point of view is to be changed from C on the primary isogonal circle on E on the secondary isogonal circle, the plane of the primary circle would be rotated upward on its chord B-D until it reaches E, replacing the plane of the secondary circle C′-B-D, just as it did when the second point of view was C′, and in the new position would still contain the two visual axes and the two horizontal retinal meridians. But from the beginning to the end of this rising of the primary plane the visual axes and the horizontal retinal meridians would be shifting in it toward the right, and at the moment the plane reaches the point E the visual axes would be converged on it. The visual axis H-C in going from C to E has not only shifted its position in the primary isogonal plane, but has moved in a plane common to C, the primary point of view, F, the secondary point of view, and B, the center of rotation. Since a plane that includes the visual axis must cut the poles, it can be none other than a meridianal plane; hence E must lie in an oblique meridianal plane. Since E on the secondary isogonal circle is connected by a straight line, through the center of retinal curvature, with *e* on the secondary retinal curve N-H′-S, then *e* must be on that retinal meridian whose plane extended includes E. It is plain that *e* is just as far below and to the left of the macula H, in degrees of arc, as E is above and to the right of C, for the angle H-B-*e* is equal to the angle C-B-E, for they are opposite angles, and each is measured by the arc of the oblique meridian intervening between the point H of the macula and the point *e* on the secondary circle. In the oblique rotation from C to E the visual axis H-C simply takes the position of the indirect visual line E-*e*, connecting the point E with the image *e*, the latter now being on the macula. The horizontal retinal meridian has been made to take the place of the secondary retinal curve N-H′-S. The former has shifted in the plane of the primary isogonal circle as it rotated upward, but has not been tilted out of it.

Any number of points on the primary isogonal circle B-C-D will have their images on the primary retinal curve N-H-S; likewise any number of points on the secondary isogonal circle B-C′-D will have their images on the secondary retinal curve N-H′-S. When the primary isogonal circle takes the place of a secondary isogonal circle all the special points that were on the latter will be on the former; likewise when the primary retinal curve takes the place of a secondary retinal curve all the image points that were on the latter will be on the former; hence there is no tortioning, declination or cyclotropia of any retinal meridian under normal conditions.

Thus is demonstrated with mathematical precision the following law of binocular rest and motion: Whether in rest or in motion, the superior and inferior recti muscles must keep the visual axes in the plane of the primary isogonal circle, the interni must converge them to some point of fixation on this circle, and the lateral recti (both the interni and the externi) must move the visual axes in this plane when the point of view is to be changed either to the right or left of the extended median plane of the head, all in the interest of binocular single vision; and the obliques must keep the two horizontal retinal meridians in this plane extended backward, in the interest of both binocular single vision and correct orientation.

What has been said about the secondary isogonal circle B-C′-D and its plane, and the secondary retinal curve N-H′-S, is equally true of all other secondary special circles and retinal curves, whether above or below the primary isogonal circle when in the horizontal position; and the latter, by being rotated on the common chord B-D, can be made to take the place of any one of these.

When one eye is in an orbit lower than that of its fellow-eye, the plane of the primary isogonal circle is inclined toward the side of the lower eye, and to the same extent the horizontal retinal meridians must be inclined by action of the superior oblique of the high eye and the inferior oblique of the low eye. All secondary isogonal circles are inclined to the same extent as is the primary circle, and so are all secondary retinal curves. In non-parallel oblique astigmatism, binocular single vision, at the expense of correct orientation, demands that the horizontal retinal meridians shall not lie in the plane of the primary, or any other, isogonal circle. In such uncorrected cases there must be either a plus or minus cyclotropia.