For the spherical and cylindrical surface would require to have a negative focal distance of 30″, and the axis of the cylindrical surface would have to be placed horizontally.

2. Compound hypermetropic astigmatism (H + Ah). Hypermetropia exists in both principal meridians, but more in the one than in the other.

In the vertical meridian let $H = \frac{1}{18}$. In the horizontal meridian let $H = \frac{1}{12}$. We have then $H = \frac{1}{18}$ and moreover $Ah = \frac{1}{12} - \frac{1}{18} = \frac{1}{36}$, and we write $H\frac{1}{18} + Ah\ \frac{1}{36}$. Hence a positive spherico-cylindrical lens will be required, and it will be corrected by $\frac{1}{18}$ s $\subset \frac{1}{36}$ c. The axis of the cylindrical surface to be placed vertically.

III. Mixed astigmatism. In this form, in which myopia exists in the one principal meridian and hypermetropia in the other, we must make use of bi-cylindrical glasses. These consist of two cylindrical surfaces of curvature, the axes of which are perpendicular to one another; the one surface is concave, the other convex. In consequence of this, the effect of such lenses is to render parallel incident rays divergent in the plane of one axis,



and convergent in that of the other. The axis of the concave surface must be placed in the direction of the hypermetropic meridian, and the axis of the convex surface in the direction of the myopic meridian. Their action may be expressed by the formula for each of the two planes, united by a sign of a right angle ⌜.

1. Mixed astigmatism with predominant myopia (Amh).

In the vertical meridian let $M = \frac{1}{10}$. In the horizontal meridian let $H = \frac{1}{20}$. Therefore Amh $= M\frac{1}{10} + H\ \frac{1}{20} = \frac{1}{6\frac{2}{3}}$, and is corrected by $\frac{1}{20}$ c ⌜ $-\frac{1}{10}$ c.

The axis of the convex surface to be placed vertically, that of the concave horizontally.

2. Mixed astigmatism, with predominant hypermetropia (Ahm).

In the vertical meridian let $M = \frac{1}{18}$. In the horizontal meridian let $H = \frac{1}{12}$. Therefore Ahm $= H\ \frac{1}{12} + M\ \frac{1}{18} = \frac{1}{7\frac{1}{2}}$, and is corrected by $\frac{1}{12}$ c ⌜ $-\frac{1}{18}$ c.

The axis of the convex surface to be placed vertically, that of the concave surface horizontally.

These examples illustrate the method to be adopted in finding glasses to correct the astigmatism and the ametropia. But in many cases it is not advisable completely to neutralize the anomaly of refraction, both on account of the difference in the size of the retinal images which will occur if the lenses are strong, and also on account of the disturbance in the combined action of the ciliary muscle and the internal recti muscles. It is often desirable that the astigmatism should be wholly corrected, but that only a certain portion of the myopia or hypermetropia should be neutralized.

After the operation of extraction of cataract, the sight is often materially improved by cylindrical lenses, even although before the opacity of the lens, the vision had been perfectly normal. Such cases can only be explained on the supposition, that a certain degree of corneal astigmatism had been neutralized (compensated for) by some lenticular astigmatism, so that when the lens is absent, the ill-effects from the corneal astigmatism make themselves felt. This condition must of course be distinguished from the acquired astigmatism due to a faulty cicatrization of the section. In all cases of extraction, in which the sight is not as good as might be expected from the general appearance of the eye, the presence of astigmatism



should be looked for, and the effect of cylindrical lenses tried.

It is of great consequence that the axes of the surfaces of curvature of the cylindrical glasses should be situated in the principal meridians of the eye, for even a very slight deviation will give rise to considerable indistinctness of vision. In order to insure the exact adaptation of the glasses to the eye, the lenses should be set in round frames, which permit of their being readily rotated in any direction. When the proper position of the axis is found, the screw should be tightened, and the lens thus firmly fixed in the desired position. The clumsy and awkward appearance of the circular frames may be greatly diminished by making them of a smaller diameter, or by having the glasses ground down into oval ones, and then reset into oval frames. But this requires great exactitude and nicety.

*Irregular* astigmatism depends sometimes upon irregularities in the curvature of the cornea, such as occur from thinning of the cornea after corneitis, in conical cornea, and a faulty union of the section in extraction of cataract. Irregularities in the structure of the lens, or displacement of the latter, so that its edge lies partially in the area of the pupil, may also give rise to this form of astigma-

tism. On account of these irregularities in the cornea or lens, the refraction of luminous rays is much distorted, for not only do the rays in a certain diameter undergo irregular refraction, but even perhaps individual rays in the same diameter. The retina, therefore, receives a very confused and blurred image, and hence there is always a considerable impairment of vision, the object looking crooked and distorted. Not unfrequently there is marked monocular diplopia or polyopia. Whilst this irregular astigmatism cannot be corrected by cylindrical glasses, it is often susceptible of improvement by stenopaic spectacles, which, by excluding a large portion of the irregularly refracted rays, render the image less distorted and confused.

## APHAKIA (ABSENCE OF THE CRYSTALLINE LENS).

This condition may be due to an operation for cataract (*e.g.*, extraction, division, or reclination), to absorption of the lens after traumatic cataract, or dislocation of the lens into the vitreous humour, etc. The state of refraction is of course greatly altered by absence of the lens. Thus an emmetropic eye becomes strongly hypermetropic; a hypermetropic eye still more so; whereas a myopic eye will become less short-sighted, or, if the degree of



myopia was very great, it may even become emmetropic. The power of accommodation is completely absent in aphakia. This has been now incontrovertibly proved by Donders' numerous and most exact experiments.

The acuteness of vision, even after the most successful operations for cataract and with the aid of the most suitable glasses, does not usually reach the normal standard. In old persons this is often due to certain senile changes which take place in all eyes, and often deteriorate the sight considerably. Another not unfrequent cause is to be found in the presence of secondary cataract, or even in the wrinkling of the transparent capsule, which may produce considerable distortion and confusion of the retinal image.

Patients who have been operated upon for cataract require very strong convex glasses to neutralize the acquired hypermetropia. The strength of these glasses will vary according to the degree of the hypermetropia, *i.e.*, the length of the optic axis; for the shorter the latter is, the stronger will the lens require to be. Two sets of glasses will be necessary—one for distant objects, and one for reading, sewing, etc. For the former purpose, the number generally ranges from 4 to 5″ focus, for the latter from 2 to 2½″ focus. But

as this varies considerably, different numbers must be tried until the best is found, and it must be remembered that in these lenses of high power, a slight difference may exert a very considerable effect upon the sight. In order to remedy the great spherical and chromatic aberration of light which is produced in these lenses from the difference in their thickness at the centre and at the edges, such spectacles are generally set in a broad horn or tortoise-shell frame, which leaves only the more central portion of the glass exposed.

## CHAPTER IX.

### PARALYSIS, SPASM, AND ATONY OF THE CILIARY MUSCLE.

Considerable diminution, or even complete loss of the power of accommodation is occasionally met with. We have seen that the range of accommodation is often greatly diminished in presbyopia, for the near point may have receded to 16″ or 18″ from the eye, so that the range of accommodation is reduced to $\frac{1}{16}$ or $\frac{1}{18}$, instead of being as in the normal eye, $= \frac{1}{4}$ or $\frac{1}{5}$. The range of accommodation is also frequently considerably diminished in persons who are very short-sighted, and who have worked much at near objects, so that the ciliary muscle has lost some of its elasticity and become somewhat rigid.

Diminution or loss of the power of accommodation, is often due to paralysis, spasm, or atony of the ciliary muscle.

The fact that we frequently meet with loss of accommodative power, together with a general or