under-corrected by its concave glass, the light will appear red, with a broader blue border.

A convex or concave cylindrical spectacle lens elongates or shortens the retinal image in a direction at right angles to its axis, thus giving rise to a change in the apparent shape of the object—a circle appearing elongated or shortened to an

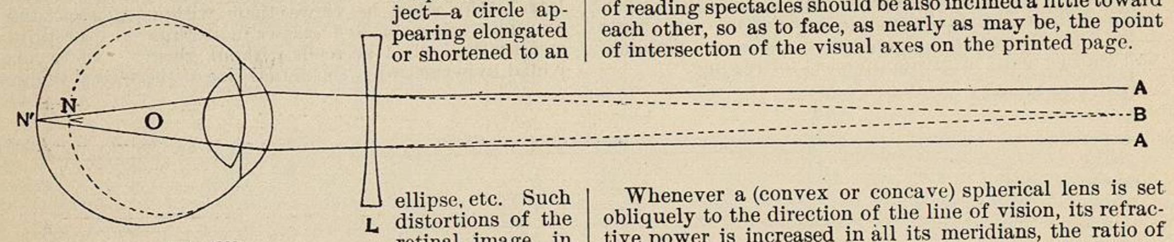

FIG. 4330.

ellipse, etc. Such distortions of the retinal image, in one eye or in both eyes, incident to the correction of astigmatism, or even a difference in the size of the two images caused by unequal spherical glasses, may give rise, in binocular vision, to a great variety of stereoscopical illusions which, until corrected by experience, may be a source of considerable annoyance.

Incidental to the action of convex and concave glasses in modifying the exercise of the accommodation is the effect which they exert upon the associated convergence. Convex glasses, by relieving the accommodation of a part of its burden (in hypermetropia), exert at the same time a positive effect in controlling the correlated convergence; hence, they rank first among the therapeutic agents at our disposal for arresting the development of convergent strabismus, and, in many cases, for its cure. Concave glasses, on the other hand, by increasing the demand made upon the accommodation in near vision, evoke increased action of the recti interni muscles (with correlated relaxation of the recti externi), and thus afford relief in many cases of muscular asthenopia and of crossed diplopia, and even of divergent strabismus (see *Asthenopia*).

Prismatic glasses with plane surfaces (Fig. 4326) may be mounted with their bases toward the nose, in which case they relieve the recti interni muscles of a part of their work in convergence, and are thus of service in certain cases of muscular asthenopia and of crossed diplopia of low grade. Mounted with their bases toward the temples, they are applicable in certain cases of homonymous diplopia dependent on insufficiency of the recti externi muscles. A prismatic glass, mounted with the base of the prism upward or downward, may be used to neutralize the effect of a slight downward or upward deviation of either eye, or the correction may be divided between the two eyes by making use of two prisms, the one mounted with its base upward and the other with its base downward. The deviation which may be thus overcome by a prism is equal to about one-half of the angle included between its two sides—*i.e.*, about 4° with a single prism of 8° angle, or 8° with a prism of 8° angle worn before each eye. Prisms of more than 10° or 12° angle are ordinarily rejected by reason of the conspicuous colored fringes due to chromatic dispersion.

The normal effect of any (convex or concave) spectacle lens is obtained only when the lens is accurately centred in front of the pupil, and the plane of the lens is perpendicular to the direction of the line of vision.* The distance between the centres of the two lenses of a pair of spectacles intended to be worn in distant vision should, therefore, be exactly equal to the interpupillary distance. In the case of reading glasses, the distance between the centres of the two lenses should be a little less than the lesser interpupillary distance when the visual axes are made to converge upon the printed page. In the case of spectacles or eyeglasses to be worn in distant vision, the two lenses should be set in one and the same (vertical) plane, perpendicular to the direction of the (parallel) visual axes, but they should be tipped forward in spectacles which are to be used in reading. In strictness, the lenses of reading spectacles should be also inclined a little toward each other, so as to face, as nearly as may be, the point of intersection of the visual axes on the printed page.

* In a plano-cylindrical lens the centre of the face of the lens is represented by a line, and the condition of accurate centration is fulfilled when this line crosses the centre of the pupil:—a lens with plane surfaces, *e.g.*, a simple prismatic glass (Fig. 4326), has no centre; —in general, the greater the radius of curvature (*i.e.*, the weaker the lens), the less is the error resulting from imperfect centration or from a faulty direction of the plane of the lens.

Whenever a (convex or concave) spherical lens is set obliquely to the direction of the line of vision, its refractive power is increased in all its meridians, the ratio of increase being, however, greatest in the meridian corresponding to the plane of the arc through which the lens is rotated, and least in the meridian corresponding to the axis of rotation. In the case of a (convex or concave) cylindrical lens, rotated about its axis, the increase in refractive power varies from a maximum, in the meridian at right angles to the axis, to zero, in the meridian of the axis. When rotated about a line at right angles to its axis, a (convex or concave) cylindrical lens shows also an increase in refractive power, though in a lesser degree than when it is rotated about its axis. It follows that a tipped spherical lens becomes practically equivalent to a somewhat stronger spherical lens with a cylindrical lens added to it, and that, in the case of a sphero-cylindrical lens, the special effect of the cylindrical surface may be either increased or diminished, according as the compound lens is rotated about one or the other of its principal meridians. A tipped concave spherical lens may be occasionally utilized in distant vision in myopia, with astigmatism of relatively low grade, when the ocular meridian of greatest refraction is vertical or nearly vertical; conversely, a vertically mounted convex spherical lens may be given for reading, when the ocular meridian of greatest refraction is horizontal or approximately horizontal.* Again, in myopia with astigmatism, when the ocular meridian of greatest refraction is approximately horizontal, the wearer of concave spherical glasses may learn the trick of looking obliquely through his glasses, to the right or to the left, in order to improve his acuteness of vision, though at the cost of acquiring an awkward carriage of the head. So, also, a hypermetrope with some measure of astigmatism, when the ocular meridian of greatest refraction is approximately vertical, may get a better correction from his (convex spherical) glasses by looking obliquely through them to one side.

*A familiar instance of such a correction, in myopia, is seen in the not infrequent preference given to a tipped (concave spherical) eyeglass over glasses mounted in a vertical position, in a spectacle frame. So, also, after the extraction of cataract, a spherico-cylindrical lens, with axis horizontal, may be required to raise distant vision to its maximum, although, for reading, a spherical glass may be preferred, by reason of the increased power of the lens in its vertical meridian, incident to the oblique (downward) direction of the visual axes.

If we represent the power of any spherical spectacle lens by D, the angle through which the lens is tilted by ϕ, and the angle whose sine $= \frac{2}{3} \sin \phi$ by ϕ' (assuming the approximate value $\frac{3}{2} = 1.5$ for the refractive index of glass), the effective power of the tilted lens in its horizontal meridian will be represented by—

$$(3 \cos \phi' - 2 \cos \phi)\ D, \ldots\ldots\ldots\ldots [1]$$

and in its vertical meridian by—

$$\frac{1}{\cos^2 \phi}(3 \cos \phi' - 2 \cos \phi)\ D\ ; \ldots\ldots\ldots [2]$$

the difference—

$$\left(\frac{1}{\cos^2 \phi} - 1\right)(3 \cos \phi' - 2 \cos \phi)\ D, \ldots\ldots [3]$$

representing the astigmatism of the tilted lens due to the tilting.

The following table shows the computed values of the several coefficients of D, for differences of 5° in the value of ϕ from zero to 45°.

$\phi =$	$3 \cos \phi' - 2 \cos \phi =$	$\frac{1}{\cos^2 \phi}(3 \cos \phi' - 2 \cos \phi) =$	$\left(\frac{1}{\cos^2 \phi} - 1\right)(3 \cos \phi' - 2 \cos \phi) =$
Zero.	1.000	1.000	0.000
5°	1.002	1.010	.008
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90°	2.236	Infinity.	Infinity.

By inspection of the table it will be seen that for every increase of the angle through which the lens is tilted, the astigmatism of the lens (due to the tilting) increases at a much higher and progressively increasing rate. Thus, for 10° of tilting the increase in the resultant astigmatism of the lens is about four times as great as for 5°; for 20° it is 4.31 times as much as for 10°; for 30° it is 4.94 times as much as for 15°; for 40° it is 6.01 times as much as for 20°; etc. It follows that in any case in which the same spectacles are to be worn both for distant vision and in reading, as in correcting hypermetropic or myopic refraction in persons whose range of accommodation is practically unimpaired, by far the best adjustment is that in which the glasses are tilted forward through an angle equal to one-half of the difference in the direction of the visual line in distant vision and in reading (pantoscopic position).

In the case of a spectacle lens of asymmetrical refraction (sphericocylindrical, toric), with the two principal meridians horizontal and vertical, respectively, the coefficients of increase in the power of the tilted lens are the same as in the case of a spherical lens, noting, however, that D [1], which we may write Dh, now represents the normal power of the lens in its horizontal meridian, and D [2], which we may write Dv, now represents the normal power of the lens in its vertical meridian.

In the case of a plano-cylindrical (or other equivalent) lens with the axis of the cylinder vertical, we have Dv = 0 [2], the effective power of the tilted lens increasing as shown in [1]. Taking the axis of the cylinder horizontal, we have Dh = 0 [1], the effective power of the tilted lens increasing as shown in [2].

For a full discussion of the case of oblique centrical refraction through any spherical lens, see Parkinson's Optics, iv., 68; for an extension of the discussion to principal cases of oblique centrical refraction through plano-cylindrical, spherico-cylindrical, and toric lenses, see two communications, by the writer, in Transactions Am. Ophthalmological Society, 1890 and 1895.

A myope, wearing concave glasses of a power insufficient fully to correct his myopia, may look obliquely to one side, in order to improve his vision for the vertical lines of a distant object, and at the same time contract the opening of the eyelids, in order to improve his vision for horizontal lines; a hypermetrope, wearing convex glasses of insufficient power, is generally able to supplement their effect in distant vision by an exercise of the accommodation.

Spectacle lenses are usually mounted in oval rims, of metal or, in the case of eyeglasses, also of tortoise shell, horn, hard rubber, celluloid, etc. The rims used in mounting convex glasses are generally grooved, so as to grasp the sharp edge of the lens; concave glasses, too, are ground to an edge, and mounted in grooved rims, but it is a not infrequent practice to groove the lens itself, and to sink the rim, which is then made of (steel or gold) wire, in the groove. Convex lenses also are sometimes mounted with the rims sunken, but at the cost of making the lens needlessly thick and heavy. So-called frameless or rimless glasses have the metallic parts attached by means of screws passing through holes drilled in the lenses; concave lenses, with their thick margins, lend themselves better to this construction than do convex lenses.

Caprice has sometimes dictated the wearing of a single eyeglass, carried at the end of a riding-whip, a fan, etc., or worn suspended by a cord; in the latter case the circular glass is held in front of the eye by contracting the orbicularis muscle upon its rim. Binocular glasses may be divided, according to the way in which they are mounted, into three groups—namely, eyeglasses held in the hand (lorgnette—*face à main*); those held in place by means of a spring which pinches the nose (*pince-nez, Kneifer, Zwicker, Klemmer*), and spectacles proper, which are held in place by means of side-pieces passing above and behind the ears (*lunettes à branches, Bügel-brille*). To these three principal types may be added a fourth, still often used in the case of protective goggles, in which the glasses are held in place by means of an elastic band passing around the head.

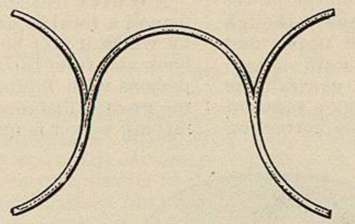

FIG. 4331.

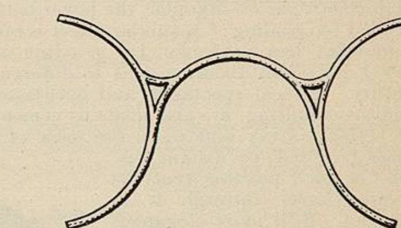

FIG. 4332.

The several parts of a pair of spectacles are (1) the rims (*cercles*), in which the glasses are mounted; (2) the bridge, or nose-piece (*arcade centrale, Bügel*), by which the rims are connected and supported upon the nose; and (3) the side-pieces (temples, bows, *branches laterales*), by which the spectacles are held in place upon the head. The size of the rims and the length of the bridge should be adjusted to the interpupillary distance, in order that the wearer may look through the centres of the glasses, and to the width of the face, so that the side-pieces may touch, but not press against, the sides of the head. In the case of great width of face, larger or longer lenses are required than when the face is narrow.

The bridge should be shaped to fit the nose, and partially to encircle it; noses, however, differ greatly in prominence and in thickness, so that no single type of bridge is suited to all cases. The plain or the braced "hoop" bridge (Figs. 4331 and 4332) is one of the older forms, and is suited to noses of considerable thickness and prominence; the hoop may lie in the same plane with the glasses, or it may be turned forward at any required angle. The so-called "C" bridge (Fig. 4336) is the form most commonly found in the shops and, like the "hoop" bridge, it may be set at any required angle to the plane of the glasses. These forms serve best for reading-spectacles, but for spectacles to be worn in distant vision they often fail to support the glasses at the proper height, or at a sufficient distance from the eyes to avoid contact with the eyelashes. The "saddle" bridge (Fig. 4333), of comparatively recent invention, can be made to fit the greatest variety of noses, and when made of gold can be bent by means of pliers to meet almost any required conditions. The so-called "X" bridge (Fig. 4334), and the "K" bridge (Fig. 4335), are used principally in frames of very light weight; they are, however, of less general applicability than the other forms. The bridge should present a rather broad surface of contact with the nose, and special care should be taken to secure an accurate and comfortable fit. Bridges of the "X" and "K" patterns, when made from very thin wire, are apt to cut the nose. A gold bridge is often to be preferred, even when the other parts of the frame are made of steel, as being more easily moulded to the nose and free from liability to rust. Spectacle frames of tortoise shell were once in common use and have lately reappeared in the shops; when properly fitted to the face they are especially comfortable in reading and sewing.

The side-pieces (temples, bows, *branches*) should be slightly curved to fit the sides of the head, and they should be of a length sufficient to reach somewhat beyond the ears. Best of all, for spectacles to be worn constantly, are the hooked temples (Figs. 4333 to 4335) made of thin, elastic wire bent downward in a curve behind the ears.

The several parts of a spectacle frame should be nicely proportioned to each other. In the case of spectacles with straight sides the bridge should be of sufficient stiffness to maintain its shape unaffected by the lateral spring of the side-pieces. Only when hooked sides are used is it admissible to make all parts of the frame of very light weight.

under-corrected by its concave glass, the light will appear red, with a broader blue border.

A convex or concave cylindrical spectacle lens elongates or shortens the retinal image in a direction at right angles to its axis, thus giving rise to a change in the apparent shape of the object—a circle appearing elongated or shortened to an ellipse, etc. Such distortions of the retinal image, in one eye or in both eyes, incident to the correction of astigmatism, or even a difference in the size of the two images caused by unequal spherical glasses, may give rise, in binocular vision, to a great variety of stereoscopical illusions which, until corrected by experience, may be a source of considerable annoyance.

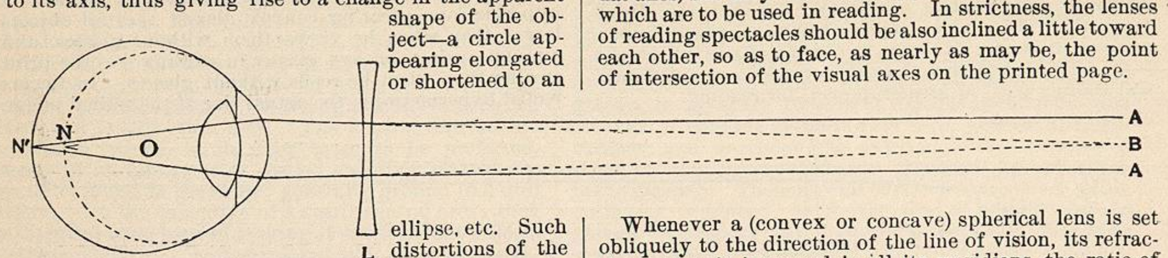

FIG. 4330.

Incidental to the action of convex and concave glasses in modifying the exercise of the accommodation is the effect which they exert upon the associated convergence. Convex glasses, by relieving the accommodation of a part of its burden (in hypermetropia), exert at the same time a positive effect in controlling the correlated convergence; hence, they rank first among the therapeutic agents at our disposal for arresting the development of convergent strabismus, and, in many cases, for its cure. Concave glasses, on the other hand, by increasing the demand made upon the accommodation in near vision, evoke increased action of the recti interni muscles (with correlated relaxation of the recti externi), and thus afford relief in many cases of muscular asthenopia and of crossed diplopia, and even of divergent strabismus (see *Asthenopia*).

Prismatic glasses with plane surfaces (Fig. 4326) may be mounted with their bases toward the nose, in which case they relieve the recti interni muscles of a part of their work in convergence, and are thus of service in certain cases of muscular asthenopia and of crossed diplopia of low grade. Mounted with their bases toward the temples, they are applicable in certain cases of homonymous diplopia dependent on insufficiency of the recti externi muscles. A prismatic glass, mounted with the base of the prism upward or downward, may be used to neutralize the effect of a slight downward or upward deviation of either eye, or the correction may be divided between the two eyes by making use of two prisms, the one mounted with its base upward and the other with its base downward. The deviation which may be thus overcome by a prism is equal to about one-half of the angle included between its two sides—*i.e.*, about 4° with a single prism of 8° angle, or 8° with a prism of 8° angle worn before each eye. Prisms of more than 10° or 12° angle are ordinarily rejected by reason of the conspicuous colored fringes due to chromatic dispersion.

The normal effect of any (convex or concave) spectacle lens is obtained only when the lens is accurately centred in front of the pupil, and the plane of the lens is perpendicular to the direction of the line of vision.* The distance between the centres of the two lenses of a pair of spectacles intended to be worn in distant vision should, therefore, be exactly equal to the interpupillary distance. In the case of reading glasses, the distance between the centres of the two lenses should be a little less than the lesser interpupillary distance when the visual axes are made to converge upon the printed page. In the case of spectacles or eyeglasses to be worn in distant vision, the two lenses should be set in one and the same (vertical) plane, perpendicular to the direction of the (parallel) visual axes, but they should be tipped forward in spectacles which are to be used in reading. In strictness, the lenses of reading spectacles should be also inclined a little toward each other, so as to face, as nearly as may be, the point of intersection of the visual axes on the printed page.

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Whenever a (convex or concave) spherical lens is set obliquely to the direction of the line of vision, its refractive power is increased in all its meridians, the ratio of increase being, however, greatest in the meridian corresponding to the plane of the arc through which the lens is rotated, and least in the meridian corresponding to the axis of rotation. In the case of a (convex or concave) cylindrical lens, rotated about its axis, the increase in refractive power varies from a maximum, in the meridian at right angles to the axis, to zero, in the meridian of the axis. When rotated about a line at right angles to its axis, a (convex or concave) cylindrical lens shows also an increase in refractive power, though in a lesser degree than when it is rotated about its axis. It follows that a tipped spherical lens becomes practically equivalent to a somewhat stronger spherical lens with a cylindrical lens added to it, and that, in the case of a spherico-cylindrical lens, the special effect of the cylindrical surface may be either increased or diminished, according as the compound lens is rotated about one or the other of its principal meridians. A tipped concave spherical lens may be occasionally utilized in distant vision in myopia, with astigmatism of relatively low grade, when the ocular meridian of greatest refraction is vertical or nearly vertical; conversely, a vertically mounted convex spherical lens may be given for reading, when the ocular meridian of greatest refraction is horizontal or approximately horizontal.* Again, in myopia with astigmatism, when the ocular meridian of greatest refraction is approximately horizontal, the wearer of concave spherical glasses may learn the trick of looking obliquely through his glasses, to the right or to the left, in order to improve his acuteness of vision, though at the cost of acquiring an awkward carriage of the head. So, also, a hypermetrope with some measure of astigmatism, when the ocular meridian of greatest refraction is approximately vertical, may get a better correction from his (convex spherical) glasses by looking obliquely through them to one side.

*A familiar instance of such a correction, in myopia, is seen in the not infrequent preference given to a tipped (concave spherical) eyeglass over glasses mounted in a vertical position, in a spectacle frame. So, also, after the extraction of cataract, a spherico-cylindrical lens, with axis horizontal, may be required to raise distant vision to its maximum, although, for reading, a spherical glass may be preferred, by reason of the increased power of the lens in its vertical meridian, incident to the oblique (downward) direction of the visual axes.

If we represent the power of any spherical spectacle lens by D, the angle through which the lens is tilted by ϕ, and the angle whose sine $= \frac{2}{3}\sin\phi$ by ϕ' (assuming the approximate value $\frac{3}{2} = 1.5$ for the refractive index of glass), the effective power of the tilted lens in its horizontal meridian will be represented by—

$$(3\cos\phi' - 2\cos\phi)\ D, \ldots\ldots\ldots\ldots [1]$$

and in its vertical meridian by—

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the difference—

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In the case of a spectacle lens of asymmetrical refraction (sphericocylindrical, toric), with the two principal meridians horizontal and vertical, respectively, the coefficients of increase in the power of the tilted lens are the same as in the case of a spherical lens, noting, however, that D [1], which we may write Dh, now represents the normal power of the lens in its horizontal meridian, and D [2], which we may write Dv, now represents the normal power of the lens in its vertical meridian.

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Caprice has sometimes dictated the wearing of a single eyeglass, carried at the end of a riding-whip, a fan, etc., or worn suspended by a cord; in the latter case the circular glass is held in front of the eye by contracting the orbicularis muscle upon its rim. Binocular glasses may be divided, according to the way in which they are mounted, into three groups—namely, eyeglasses held in the hand (lorgnette—*face à main*); those held in place by means of a spring which pinches the nose (*pince-nez, Kneifer, Zwicker, Klemmer*), and spectacles proper, which are held in place by means of side-pieces passing above and behind the ears (*lunettes à branches, Bügel-brille*). To these three principal types may be added a fourth, still often used in the case of protective goggles, in which the glasses are held in place by means of an elastic band passing around the head.

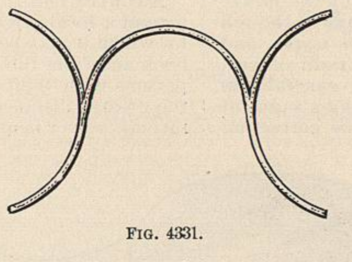
FIG. 4331.

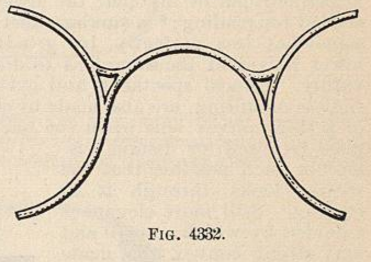
FIG. 4332.

The several parts of a pair of spectacles are (1) the rims (*cercles*), in which the glasses are mounted; (2) the bridge, or nose-piece (*arcade centrale, Bügel*), by which the rims are connected and supported upon the nose; and (3) the side-pieces (temples, bows, *branches laterales*), by which the spectacles are held in place upon the head. The size of the rims and the length of the bridge should be adjusted to the interpupillary distance, in order that the wearer may look through the centres of the glasses, and to the width of the face, so that the side-pieces may touch, but not press against, the sides of the head. In the case of great width of face, larger or longer lenses are required than when the face is narrow.

The bridge should be shaped to fit the nose, and partially to encircle it; noses, however, differ greatly in prominence and in thickness, so that no single type of bridge is suited to all cases. The plain or the braced "hoop" bridge (Figs. 4331 and 4332) is one of the older forms, and is suited to noses of considerable thickness and prominence; the hoop may lie in the same plane with the glasses, or it may be turned forward at any required angle. The so-called "C" bridge (Fig. 4336) is the form most commonly found in the shops and, like the "hoop" bridge, it may be set at any required angle to the plane of the glasses. These forms serve best for reading-spectacles, but for spectacles to be worn in distant vision they often fail to support the glasses at the proper height, or at a sufficient distance from the eyes to avoid contact with the eyelashes. The "saddle" bridge (Fig. 4333), of comparatively recent invention, can be made to fit the greatest variety of noses, and when made of gold can be bent by means of pliers to meet almost any required conditions. The so-called "X" bridge (Fig. 4334), and the "K" bridge (Fig. 4335), are used principally in frames of very light weight; they are, however, of less general applicability than the other forms. The bridge should present a rather broad surface of contact with the nose, and special care should be taken to secure an accurate and comfortable fit. Bridges of the "X" and "K" patterns, when made from very thin wire, are apt to cut the nose. A gold bridge is often to be preferred, even when the other parts of the frame are made of steel, as being more easily moulded to the nose and free from liability to rust. Spectacle frames of tortoise shell were once in common use and have lately reappeared in the shops; when properly fitted to the face they are especially comfortable in reading and sewing.

The side-pieces (temples, bows, *branches*) should be slightly curved to fit the sides of the head, and they should be of a length sufficient to reach somewhat beyond the ears. Best of all, for spectacles to be worn constantly, are the hooked temples (Figs. 4333 to 4335) made of thin, elastic wire bent downward in a curve behind the ears.

The several parts of a spectacle frame should be nicely proportioned to each other. In the case of spectacles with straight sides the bridge should be of sufficient stiffness to maintain its shape unaffected by the lateral spring of the side-pieces. Only when hooked sides are used is it admissible to make all parts of the frame of very light weight.

under-corrected by its concave glass, the light will appear red, with a broader blue border.

A convex or concave cylindrical spectacle lens elongates or shortens the retinal image in a direction at right angles to its axis, thus giving rise to a change in the apparent shape of the object—a circle appearing elongated or shortened to an

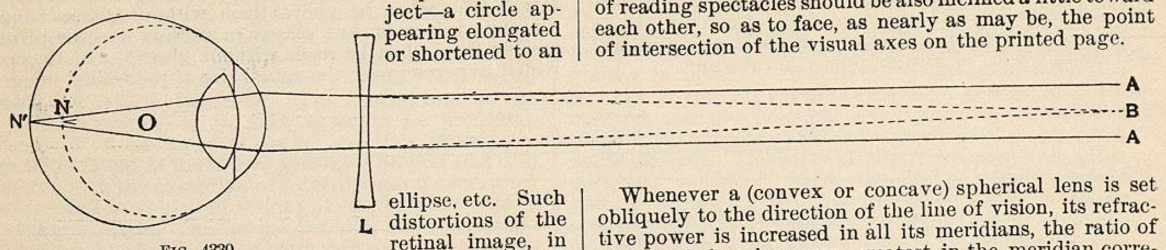

FIG. 4330.

ellipse, etc. Such distortions of the retinal image, in one eye or in both eyes, incident to the correction of astigmatism, or even a difference in the size of the two images caused by unequal spherical glasses, may give rise, in binocular vision, to a great variety of stereoscopical illusions which, until corrected by experience, may be a source of considerable annoyance.

Incidental to the action of convex and concave glasses in modifying the exercise of the accommodation is the effect which they exert upon the associated convergence. Convex glasses, by relieving the accommodation of a part of its burden (in hypermetropia), exert at the same time a positive effect in controlling the correlated convergence; hence, they rank first among the therapeutic agents at our disposal for arresting the development of convergent strabismus, and, in many cases, for its cure. Concave glasses, on the other hand, by increasing the demand made upon the accommodation in near vision, evoke increased action of the recti interni muscles (with correlated relaxation of the recti externi), and thus afford relief in many cases of muscular asthenopia and of crossed diplopia, and even of divergent strabismus (see *Asthenopia*).

Prismatic glasses with plane surfaces (Fig. 4326) may be mounted with their bases toward the nose, in which case they relieve the recti interni muscles of a part of their work in convergence, and are thus of service in certain cases of muscular asthenopia and of crossed diplopia of low grade. Mounted with their bases toward the temples, they are applicable in certain cases of homonymous diplopia dependent on insufficiency of the recti externi muscles. A prismatic glass, mounted with the base of the prism upward or downward, may be used to neutralize the effect of a slight downward or upward deviation of either eye, or the correction may be divided between the two eyes by making use of two prisms, the one mounted with its base upward and the other with its base downward. The deviation which may be thus overcome by a prism is equal to about one-half of the angle included between its two sides—*i.e.*, about 4° with a single prism of 8° angle, or 8° with a prism of 8° angle worn before each eye. Prisms of more than 10° or 12° angle are ordinarily rejected by reason of the conspicuous colored fringes due to chromatic dispersion.

The normal effect of any (convex or concave) spectacle lens is obtained only when the lens is accurately centred in front of the pupil, and the plane of the lens is perpendicular to the direction of the line of vision.* The distance between the centres of the two lenses of a pair of spectacles intended to be worn in distant vision should, therefore, be exactly equal to the interpupillary distance. In the case of reading glasses, the distance between the centres of the two lenses should be a little less than the lesser interpupillary distance when the visual axes are made to converge upon the printed page. In the case of spectacles or eyeglasses to be worn in distant vision, the two lenses should be set in one and the same (vertical) plane, perpendicular to the direction of the (parallel) visual axes, but they should be tipped forward in spectacles which are to be used in reading. In strictness, the lenses of reading spectacles should be also inclined a little toward each other, so as to face, as nearly as may be, the point of intersection of the visual axes on the printed page.

* In a plano-cylindrical lens the centre of the face of the lens is represented by a line, and the condition of accurate centration is fulfilled when this line crosses the centre of the pupil:—a lens with plane surfaces, *e.g.*, a simple prismatic glass (Fig. 4326), has no centre; —in general, the greater the radius of curvature (*i.e.*, the weaker the lens), the less is the error resulting from imperfect centration or from a faulty direction of the plane of the lens.

Whenever a (convex or concave) spherical lens is set obliquely to the direction of the line of vision, its refractive power is increased in all its meridians, the ratio of increase being, however, greatest in the meridian corresponding to the plane of the arc through which the lens is rotated, and least in the meridian corresponding to the axis of rotation. In the case of a (convex or concave) cylindrical lens, rotated about its axis, the increase in refractive power varies from a maximum, in the meridian at right angles to the axis, to zero, in the meridian of the axis. When rotated about a line at right angles to its axis, a (convex or concave) cylindrical lens shows also an increase in refractive power, though in a lesser degree than when it is rotated about its axis. It follows that a tipped spherical lens becomes practically equivalent to a somewhat stronger spherical lens with a cylindrical lens added to it, and that, in the case of a spherico-cylindrical lens, the special effect of the cylindrical surface may be either increased or diminished, according as the compound lens is rotated about one or the other of its principal meridians. A tipped concave spherical lens may be occasionally utilized in distant vision in myopia, with astigmatism of relatively low grade, when the ocular meridian of greatest refraction is vertical or nearly vertical; conversely, a vertically mounted convex spherical lens may be given for reading, when the ocular meridian of greatest refraction is horizontal or approximately horizontal.* Again, in myopia with astigmatism, when the ocular meridian of greatest refraction is approximately horizontal, the wearer of concave spherical glasses may learn the trick of looking obliquely through his glasses, to the right or to the left, in order to improve his acuteness of vision, though at the cost of acquiring an awkward carriage of the head. So, also, a hypermetrope with some measure of astigmatism, when the ocular meridian of greatest refraction is approximately vertical, may get a better correction from his (convex spherical) glasses by looking obliquely through them to one side.

*A familiar instance of such a correction, in myopia, is seen in the not infrequent preference given to a tipped (concave spherical) eyeglass over glasses mounted in a vertical position, in a spectacle frame. So, also, after the extraction of cataract, a spherico-cylindrical lens, with axis horizontal, may be required to raise distant vision to its maximum, although, for reading, a spherical glass may be preferred, by reason of the increased power of the lens in its vertical meridian, incident to the oblique (downward) direction of the visual axes.

If we represent the power of any spherical spectacle lens by D, the angle through which the lens is tilted by ϕ, and the angle whose sine $= \frac{2}{3} \sin \phi$ by ϕ' (assuming the approximate value $\frac{3}{2} = 1.5$ for the refractive index of glass), the effective power of the tilted lens in its horizontal meridian will be represented by—

$$(3 \cos \phi' - 2 \cos \phi)\ D, \ldots\ldots\ldots\ldots [1]$$

and in its vertical meridian by—

$$\frac{1}{\cos^2 \phi}\ (3 \cos \phi' - 2 \cos \phi)\ D; \ldots\ldots\ldots [2]$$

the difference—

$$\left(\frac{1}{\cos^2 \phi} - 1\right)\ (3 \cos \phi' - 2 \cos \phi)\ D, \ldots\ldots [3]$$

representing the astigmatism of the tilted lens due to the tilting.

The following table shows the computed values of the several coefficients of D, for differences of 5° in the value of ϕ from zero to 45°.

$\phi =$	$3 \cos \phi' - 2 \cos \phi =$	$\frac{1}{\cos^2 \phi}(3 \cos \phi' - 2 \cos \phi) =$	$\left(\frac{1}{\cos^2 \phi} - 1\right)(3 \cos \phi' - 2 \cos \phi) =$
Zero.	1.000	1.000	0.000
5°	1.002	1.010	.008
10°	1.010	1.042	.032
15°	1.023	1.097	.074
20°	1.041	1.179	.138
25°	1.066	1.297	.231
30°	1.096	1.462	.366
35°	1.134	1.689	.555
40°	1.178	2.008	.830
45°	1.232	2.464	1.232
..	......	......	......
90°	2.236	Infinity.	Infinity.

By inspection of the table it will be seen that for every increase of the angle through which the lens is tilted, the astigmatism of the lens (due to the tilting) increases at a much higher and progressively increasing rate. Thus, for 10° of tilting the increase in the resultant astigmatism of the lens is about four times as great as for 5°; for 20° it is 4.31 times as much as for 10°; for 30° it is 4.94 times as much as for 15°; for 40° it is 6.01 times as much as for 20°; etc. It follows that in any case in which the same spectacles are to be worn both for distant vision and in reading, as in correcting hypermetropic or myopic refraction in persons whose range of accommodation is practically unimpaired, by far the best adjustment is that in which the glasses are tilted forward through an angle equal to one-half of the difference in the direction of the visual line in distant vision and in reading (pantoscopic position).

In the case of a spectacle lens of asymmetrical refraction (spherico-cylindrical, toric), with the two principal meridians horizontal and vertical, respectively, the coefficients of increase in the power of the tilted lens are the same as in the case of a spherical lens, noting, however, that D [1], which we may write Dh, now represents the normal power of the lens in its horizontal meridian, and D [2], which we may write Dv, now represents the normal power of the lens in its vertical meridian.

In the case of a plano-cylindrical (or other equivalent) lens with the axis of the cylinder vertical, we have Dv = 0 [2], the effective power of the tilted lens increasing as shown in [1]. Taking the axis of the cylinder horizontal, we have Dh = 0 [1], the effective power of the tilted lens increasing as shown in [2].

For a full discussion of the case of oblique centrical refraction through any spherical lens, see Parkinson's Optics, iv., 68; for an extension of the discussion to principal cases of oblique centrical refraction through plano-cylindrical, spherico-cylindrical, and toric lenses, see two communications, by the writer, in Transactions Am. Ophthalmological Society, 1890 and 1895.

A myope, wearing concave glasses of a power insufficient fully to correct his myopia, may look obliquely to one side, in order to improve his vision for the vertical lines of a distant object, and at the same time contract the opening of the eyelids, in order to improve his vision for horizontal lines; a hypermetrope, wearing convex glasses of insufficient power, is generally able to supplement their effect in distant vision by an exercise of the accommodation.

Spectacle lenses are usually mounted in oval rims, of metal or, in the case of eyeglasses, also of tortoise shell, horn, hard rubber, celluloid, etc. The rims used in mounting convex glasses are generally grooved, so as to grasp the sharp edge of the lens; concave glasses, too, are ground to an edge, and mounted in grooved rims, but it is a not infrequent practice to groove the lens itself, and to sink the rim, which is then made of (steel or gold) wire, in the groove. Convex lenses also are sometimes mounted with the rims sunken, but at the cost of making the lens needlessly thick and heavy. So-called frameless or rimless glasses have the metallic parts attached by means of screws passing through holes drilled in the lenses; concave lenses, with their thick margins, lend themselves better to this construction than do convex lenses.

Caprice has sometimes dictated the wearing of a single eyeglass, carried at the end of a riding-whip, a fan, etc., or worn suspended by a cord; in the latter case the circular glass is held in front of the eye by contracting the orbicularis muscle upon its rim. Binocular glasses may be divided, according to the way in which they are mounted, into three groups—namely, eyeglasses held in the hand (lorgnette—*face à main*); those held in place by means of a spring which pinches the nose (*pince-nez*, *Kneifer*, *Zwicker*, *Klemmer*), and spectacles proper, which are held in place by means of side-pieces passing above and behind the ears (*lunettes à branches*, *Bügel-brille*). To these three principal types may be added a fourth, still often used in the case of protective goggles, in which the glasses are held in place by means of an elastic band passing around the head.

The several parts of a pair of spectacles are (1) the rims (*cercles*), in which the glasses are mounted; (2) the bridge, or nose-piece (*arcade centrale*, *Bügel*), by which the rims are connected and supported upon the nose; and (3) the side-pieces (temples, bows, *branches laterales*), by which the spectacles are held in place upon the head. The size of the rims and the length of the bridge should be adjusted to the interpupillary distance, in order that the wearer may look through the centres of the glasses, and to the width of the face, so that the side-pieces may touch, but not press against, the sides of the head. In the case of great width of face, larger or longer lenses are required than when the face is narrow.

The bridge should be shaped to fit the nose, and partially to encircle it; noses, however, differ greatly in prominence and in thickness, so that no single type of bridge is suited to all cases. The plain or the braced "hoop" bridge (Figs. 4331 and 4332) is one of the older forms, and is suited to noses of considerable thickness and prominence; the hoop may lie in the same plane with the glasses, or it may be turned forward at any required angle. The so-called "C" bridge (Fig. 4336) is the form most commonly found in the shops and, like the "hoop" bridge, it may be set at any required angle to the plane of the glasses. These forms serve best for reading-spectacles, but for spectacles to be worn in distant vision they often fail to support the glasses at the proper height, or at a sufficient distance from the eyes to avoid contact with the eyelashes. The "saddle" bridge (Fig. 4333), of comparatively recent invention, can be made to fit the greatest variety of noses, and when made of gold can be bent by means of pliers to meet almost any required conditions. The so-called "X" bridge (Fig. 4334), and the "K" bridge (Fig. 4335), are used principally in frames of very light weight; they are, however, of less general applicability than the other forms.

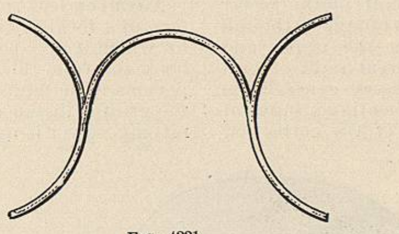

FIG. 4331.

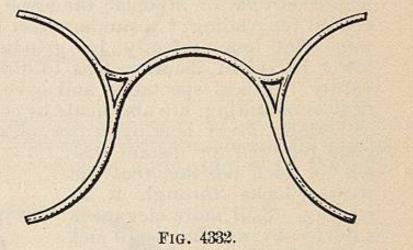

FIG. 4332.

The bridge should present a rather broad surface of contact with the nose, and special care should be taken to secure an accurate and comfortable fit. Bridges of the "X" and "K" patterns, when made from very thin wire, are apt to cut the nose. A gold bridge is often to be preferred, even when the other parts of the frame are made of steel, as being more easily moulded to the nose and free from liability to rust. Spectacle frames of tortoise shell were once in common use and have lately reappeared in the shops; when properly fitted to the face they are especially comfortable in reading and sewing.

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