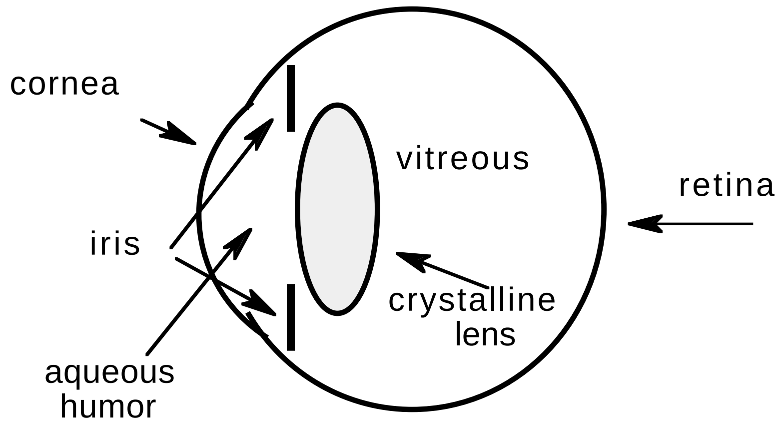
Clinical Refraction

Refractive Components of the Eye

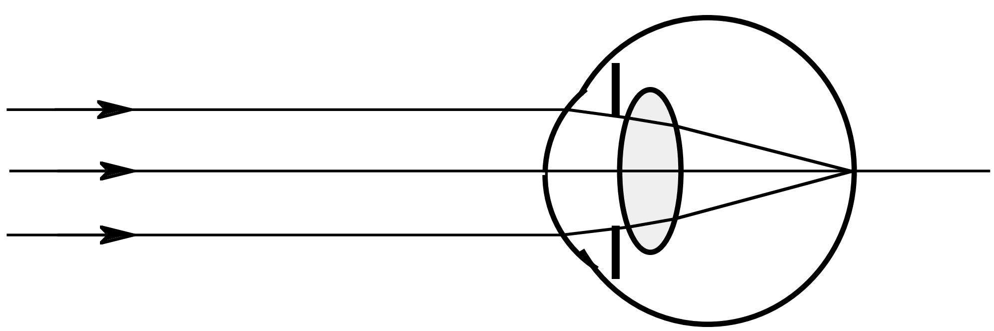
The function of the eye is to form a retinal image which can be processed by the brain. Key optical components are the cornea, the front surface of the eye which does about two thirds of the light bending necessary to form the image. The rest of the bending is done by the crystalline lens, a somewhat flexible structure which sits behind the iris. (*Cataract* is the clouding of the crystalline lens.) The iris is a roughly circular aperture.



Refractive errors are classified according to the way light from a remote object is focused. Each of the following diagrams shows light from a remote source focused in a given refractive state.

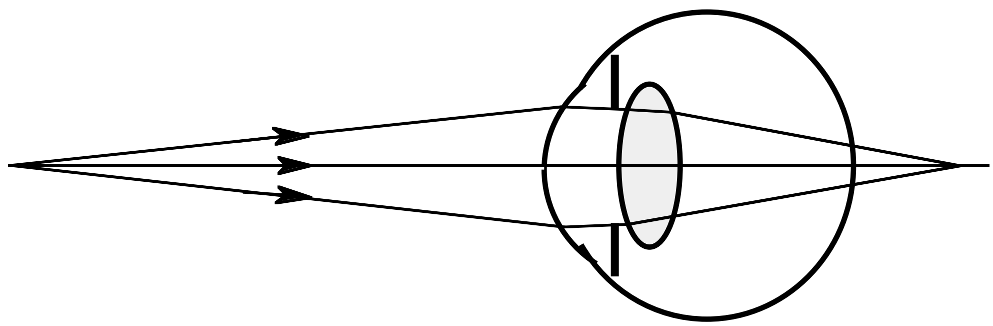
Emmetropia

The *emmetropic* eye focusses light from a remote object perfectly. An *emmetrope* needs no glasses, at least for distance.

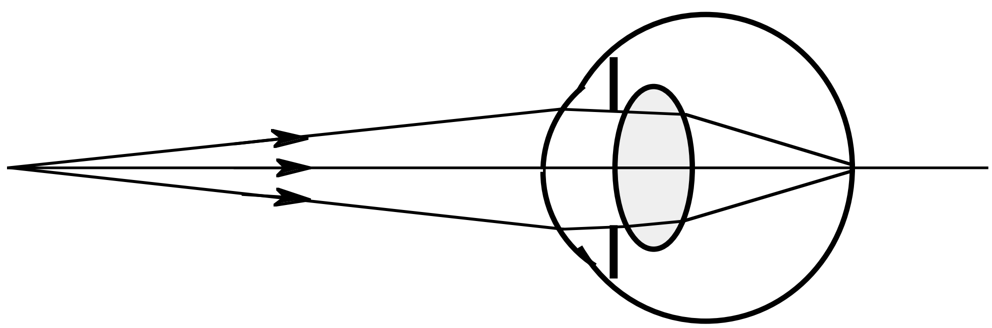


Accommodation and Presbyopia

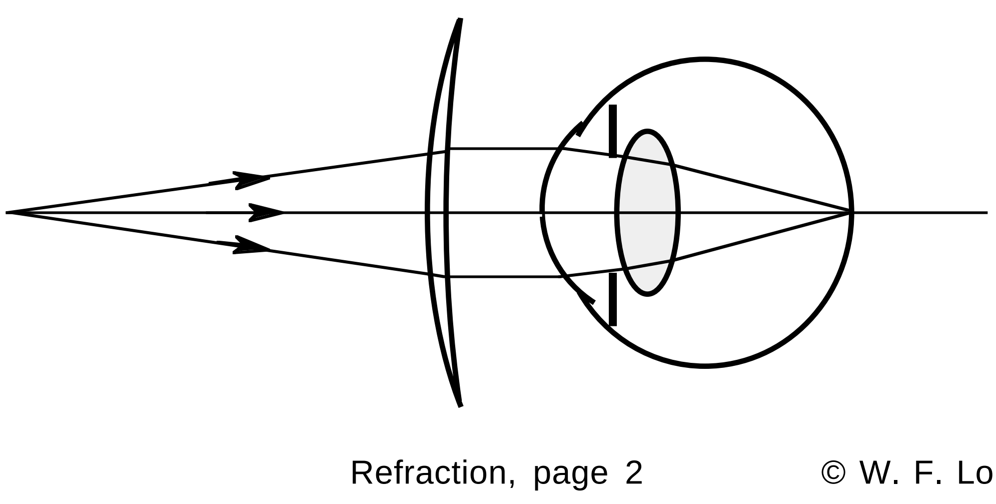
For near objects, an emmetropic eye will produce a blurred retinal image.



In accommodation, a sphincter around the crystalline lens constricts allowing the lens to bulge which focusses the image of a near object.

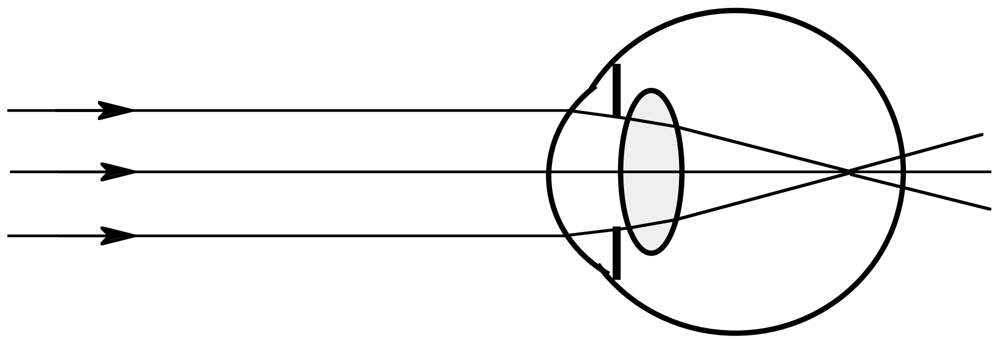


With age, the crystalline lens becomes more rigid, making accommodation more and more difficult and finally impossible.

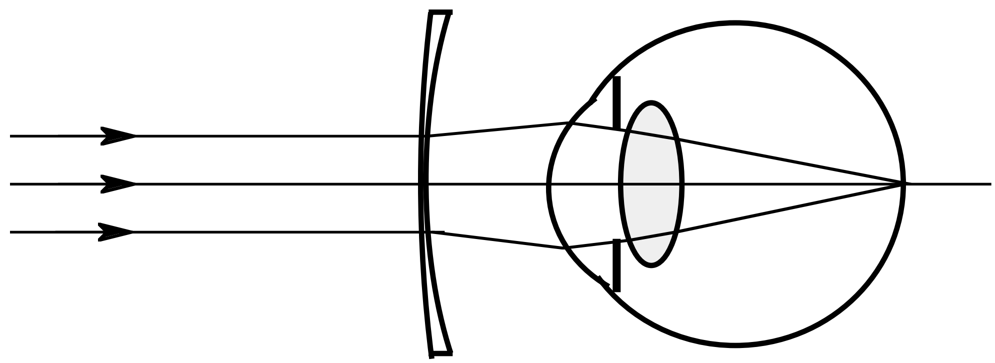


Myopia (near sightedness)

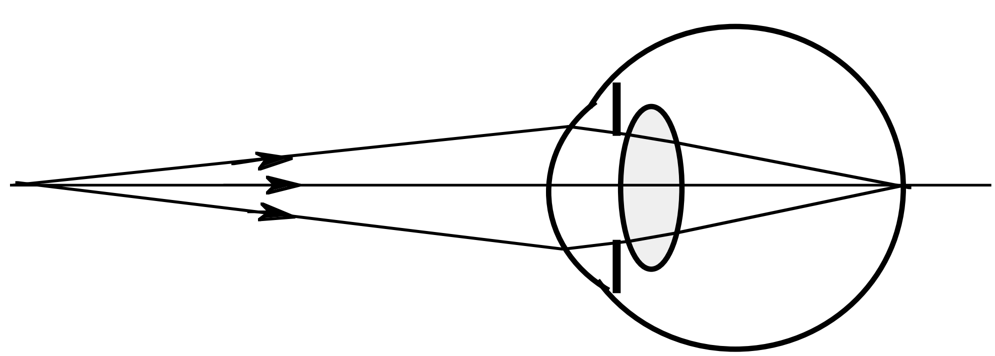
In myopia collimated light focusses in front of the retina, resulting in a blurred retinal image.



The myopic eye is a "large" eye. Myopia is corrected by placing a diverging lens, a minus lens, before the eye.



Without lenses, myopes <u>can</u> focus near objects if they're close enough.



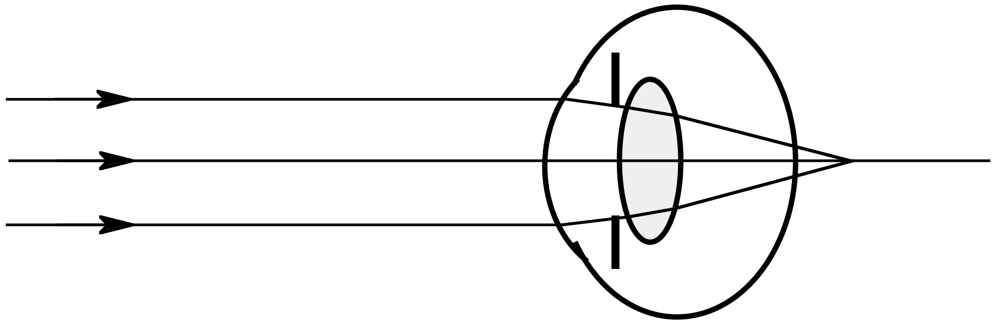
The degree to which light is bent is determined by the *power* of the correcting lens in *diopters* (abbreviated *D*). The greater the power the more the lens bends light. Each diopter of spectacle correction corresponds to about an axial length of the eye about 1/3 millimeters longer than it should be for the optics.

The following table gives some idea of the impairment corresponding to given amounts of myopia.

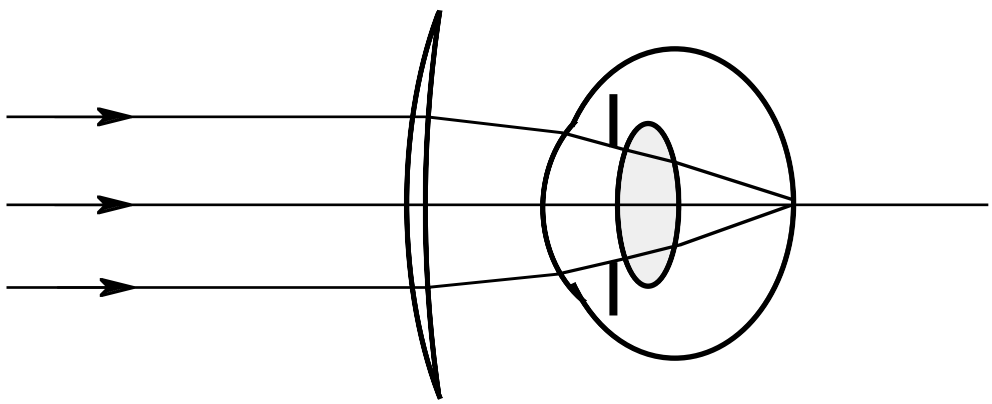
±0.00D to -3.00D	low myopia. Most common optometric patients. Fairly thin lenses, can use just about any eyewear. Patient can read without prescription.
-3.00D to -6.00D	moderate myopia. Common. Somewhat thick lenses require care in selecting eyeware which minimizes weight and thickness. Patient wears glasses full time.
-6.00D to -9.00D	high myopia. Relatively uncommon. Lenses are quite thick and it's worthwhile considering high index plastic lenses or polycarbonate lenses which may be made with a thinner center thickness. The power of the corrective lens depends somewhat on the distance from lens to eye. Contact lenses are recommended.
-9.00D to -12.00D	extreme high myopia. Quite rare. Lenses are very thick and great care must be taken in choosing eyeware and lens design. Contact lenses are strongly recommended. The exact power of the corrective lens depends strongly on the distance from lens to eye. Patients often have "stretched" retinas with lowered visual acuities. They are at risk of retinal detachment.
<-12.00D	pathologically high myopia. Extremely rare.

Hyperopia (far sightedness)

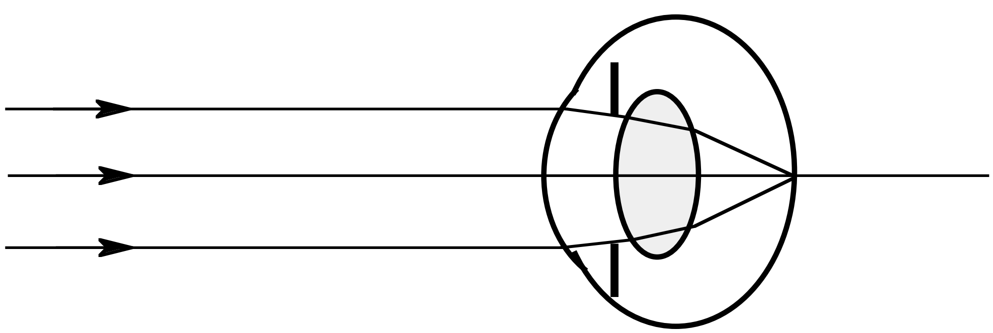
In hyperopia collimated light focusses in back of the retina, resulting in a blurred retinal image.



The hyperopic eye is a "small" eye. Hyperiopia is corrected by placing a convergin lens, a plus lens, before the eye.



Without lenses, hyperopes can accommodate to focus distant objects if they're not too close. Doing so, however, may cause eyestrain. Young hyperopes often get by without corrective lenses but eventually require them when presbyopia sets in.



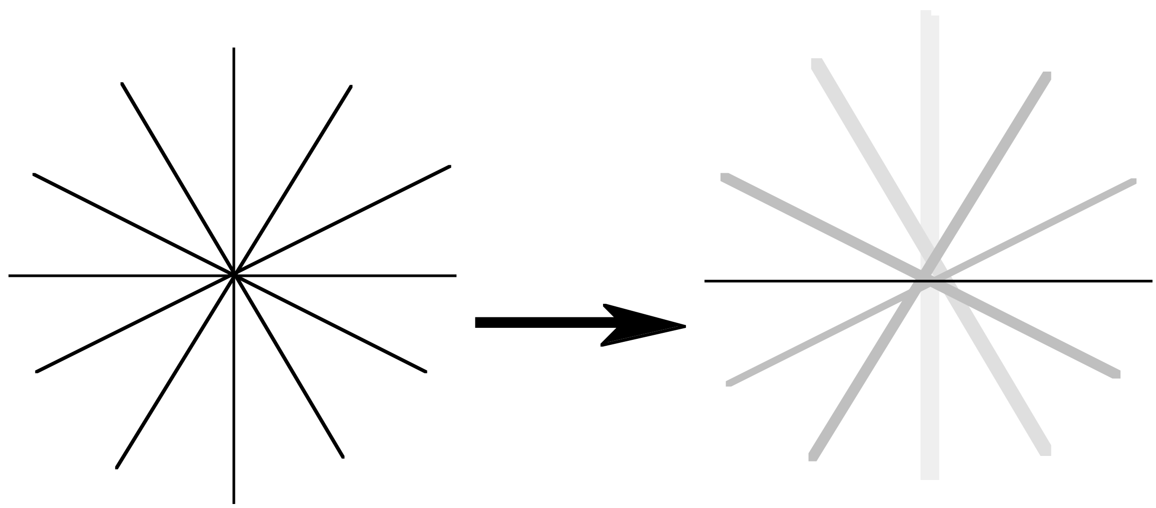
The degree to which light is bent is determined by the *power* of the correcting lens in *diopters* (abbreviated *D*). The greater the power the more the lens bends light. Each diopter of spectacle correction corresponds to about an axial length of the eye about 1/3 millimeters longer than it should be for the optics.

The following table gives some idea of the impairment corresponding to given amounts of hyperopia.

±0.00D to +3.00D	low hyperopia. Common. Fairly thin lenses, patient can use just about any eyewear. Patient can see at distance without prescription, but may need lenses to read.
+3.00D to +6.00D	moderate hyperopia. Uncommon. Somewhat thick lenses require care in selecting eyeware which minimizes weight and thickness. Patient wears glasses full time.
+6.00D to +9.00D	high hyperopia. Rare. Lenses are quite thick and it's worthwhile considering high index plastic lenses or polycarbonate lenses which may be made with a thinner center thickness. Special spheric lenses may be considered. The power of the corrective lens depends somewhat on the distance from lens to eye. Contact lenses are recommended.
+9.00D to +12.00D	extreme high hyperopia. Extremely rare. Most commonly encountered with aphakics. Lenses are very thick and great care must be taken in choosing eyeware and lens design. Contact lenses are strongly recommended. The exact power of the corrective lens depends strongly on the distance from lens to eye. Patients often have lowered visual acuities.
>+12.00D	pathologically high hyperopia. Extremely rare.

Astigmatism

In astigmatism, different meridians of the eye have different refractive errors. This results in horizontal and vertical lines being focused different distances from the retina. Here, for example, is the image of a fan dial chart formed by an astigmatic eye.



object image

The amount of astigmatism is characterized by the dioptric difference of the two meridians that differ the most. These meridians are invariably at right angles to one another. Usually they are roughly horizontal and vertical, but sometimes they may be oblique. While the myope can at least see near objects clearly and the hyperope may, through the exercise of accommodation, see distant objects clearly, the astigmat sees objects at all distances as being blurred.

The most common cause of astigmatism is a cornea with a surface shaped more like that of a football than a basketball. High astigmatism is almost always corneal. Smaller contributions come from *internal astigmatism* thought to be due mainly to the crystalline lens.

Astigmatism can be and usually is combined with myopia or hyperopia.

Astigmatism can be corrected with *cylinder* lenses. In practice it is corrected with lenses which have *toric* surfaces (just like that football). The prescription for a toric lens is written as if it were a superposition of a *spherical* lens (which has the same prescription in all meridians) and a cylinder lens. For example

-5.00/-2.00x175

corresponds to five diopters of myopia on top of two diopters of astigmatism with the correcting cylinder lens oriented at 175°.

The amount of visual impairment with astigmatism depends on its orientation and on the presence of other refractive errors. The following table gives an some idea of the impairment corresponding to given amounts of astigmatism when other refractive errors have been corrected.

0.00D to 0.50D	low astigmatism. Common. Doesn't usually require correction.
0.50D to 1.50D	moderate astigmatism. Common. May or may not require a correction depending on symptoms.
1.50D to 2.50D	high astigmatism. Not uncommon. Correction required.
2.50D to 5.00D	very high astigmatism. Uncommon.
>5.00D	Extremely high astigmatism. Rare.

Ocular Refraction

Ocular refraction is the process of determining the spectacle prescription for the eye. It is an iterative process proceding through a series of progressively more accurate estimates. The usual steps are as follows:

(1) Visual acuity. The approximate magnitude of the refractive error can be determined from the 20/20 Snellen fraction by dividing the denominator of the refraction by 100, e.g. 20/200 $\Rightarrow$ 200÷100=2D.

(2) Keratometry. The refractive astigmatism may be estimated from the corneal astigmatism.

(3) Direct ophthalmoscopy. The prescription may be estimated from the ophthalmoscope lens that permits best visualization of the central retina.

(4) Retinoscopy. When photos are taken with a cheap camera and flash, sometimes there is a "red reflex" in the pupil of the subject's eyes resulting from light reflected from the retina. Retinoscopy uses that same red reflex. The retinoscope sends a beam of light straight into the retina. The refractionist wiggles the retinoscope and can judge from the corresponding motion of the reflex across the patient's pupil whether the patient is myopic, hyperopic, or astigmatic. Knowing his distance from the patient the refractionist can, with the help of additional lenses held in the spectacle plane of the patient, get an estimate of the magnitude of the refractive error.

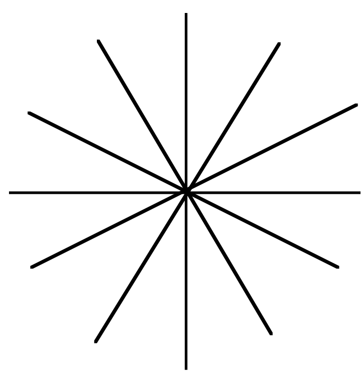
(5) Auto-refractors. Auto-refractors are, for the most part, automated retinoscopes.

(6) Subjective refraction. The patient is presented with a variety of targets and asked their clarity under various conditions. Most typically the patient is shown a visual acuity chart and asked which of two lenses makes it most clear, hence the question, "Which is better, lens one or lens two?" Subjective refraction is usually the <u>last</u> step in the refractive procedure and with a reliable patient is extremely accurate. There is a huge number of techniques, most of only historical interest. Here are a few of the more common ones in use nowadays.

Unfogging to best acuity. The patient views an acuity chart through succesive lenses of less plus or minus power until the chart comes into focus.

Red-green test. A filter in the projector makes half the acuity chart red and half green. Successive lenses of less plus or minus power are put into place until the letters on the two sides of the chart are equally clear.

Fan dial test. A test for astigmatism. Lenses are changed until all the legs of a fan dial target are equally clear or equally unclear.



fan dial target

Cross-cylinder test. The most common test for astigmatism. The patient compares the clarity of the acuity chart through a cylinder lens and through that same lens when it is flipped 90°.

