The Ophthalmology Survival Guide

Optics – The Basics for Survival

In order to see clearly and attain optimal visual acuity, incoming rays of light must be sharply focused on the retinal photoreceptors, a process known as refraction. For this to happen the eye must have the properties of a lens. The major refractive structures of the eye are the cornea (including the tear film on the corneal surface) and the crystalline lens. In many eyes, however, these structures do not do a particularly good job, either because of errors in their combined refractive power, or the presence of opacities or other defects (e.g. scars, infiltrates, cataract, edema, surface defects, lack of normal tear film). The results of such defects are optical blur and suboptimal visual acuity. It is critically important, therefore, to have a basic understanding of optics and the way in which optical issues are detected and corrected.

What are Refractive Errors (and are they really errors)?

When an eye accurately refracts light rays from distant objects onto the retina the eye is said to be emmetropic. When the light rays from distant objects are blurred, but the light from near objects is clear, the eye is said to by myopic, or near-sighted. When the light from distant objects is blurred, and the light from near objects is even more blurred, the eye is said to be hyperopic, or far-sighted. There is little that a myopic (i.e. near-sighted) eye can do to compensate except for moving closer to the object being viewed. A hyperopic (i.e. far-sighted) eye, on the other hand, can actively reduce or eliminate its hyperopia by using accommodation, the same mechanism used by the emmetropic eye to increase its focal power when viewing objects up close. Accommodation increases the optical or focal power of the eye through ciliary body contraction. This reduces the tension on the lens zonules, causing the lens to assume a more convex contour, thereby increasing its refractive power.

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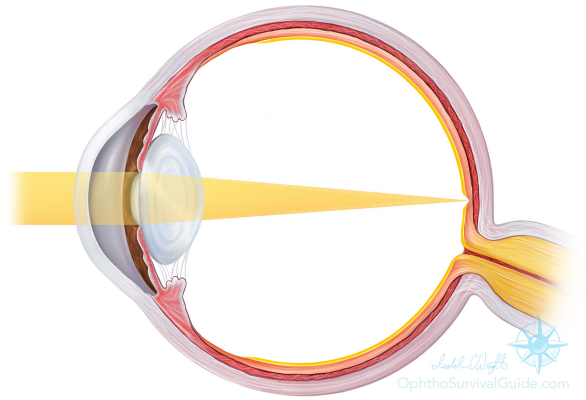
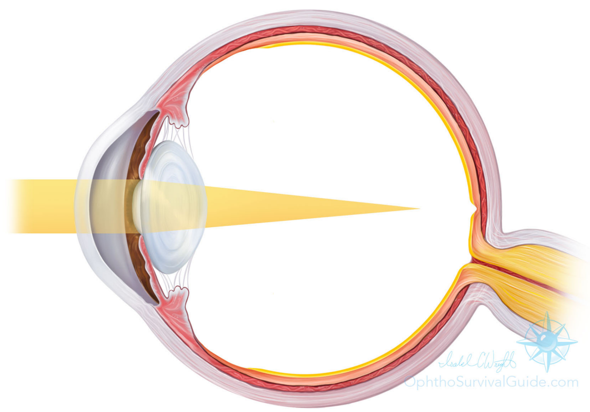
Emmetropia:



Myopia:



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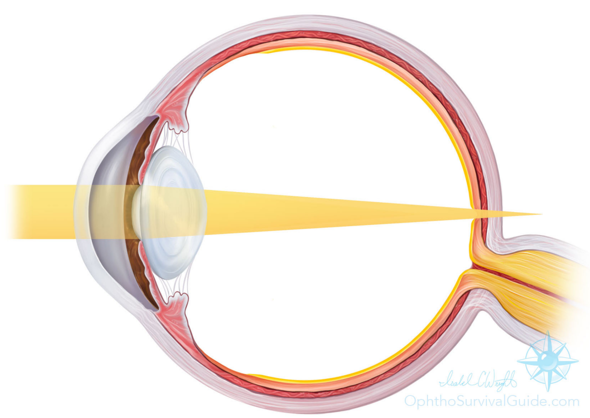

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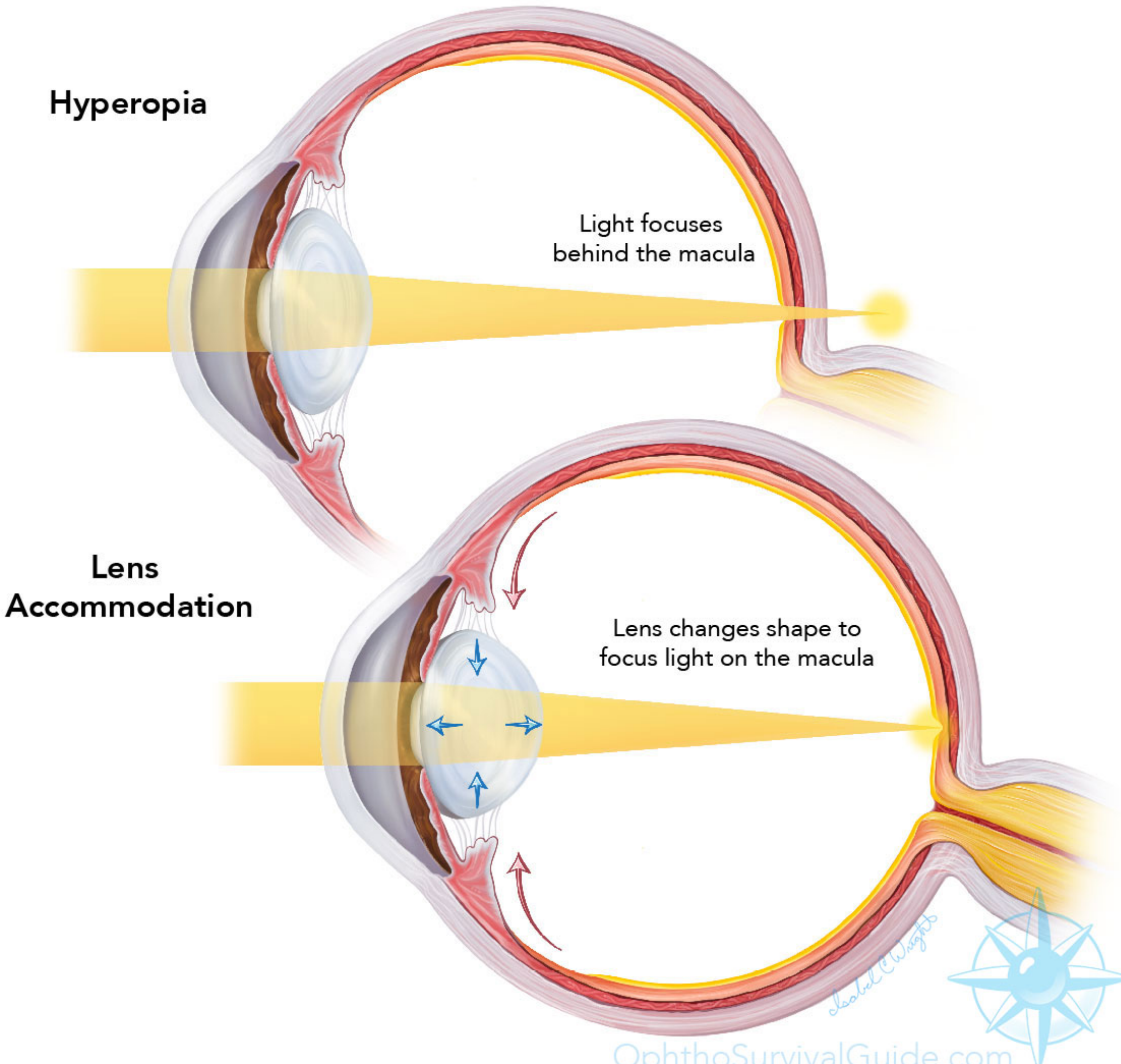

It is important to understand that accommodation is an active mechanism. It requires effort, and one's ability to use it tends to wane, predictably, with age due to many factors. The decline in our ability to accommodate with age is known as presbyopia, and generally begins to develop in the late 30's to early 40's, and peaks in the late 50's to early 60's, though this can vary significantly from person to person. Accommodation is also reflexively linked to pupillary constriction and convergence of the eyes. This combination is sometimes referred to as the near triad (i.e. accommodation, pupillary constriction, convergence). The link to convergence, which helps the eyes to maintain simultaneous focus (i.e. binocular fusion) on a near object, can sometimes be problematic if it is either insufficient (i.e. convergence insufficiency) or excessive (i.e. convergence excess, or accommodative esotropia). The proper ratio of accommodative convergence to accommodation (i.e. the AC:A ratio) is important.

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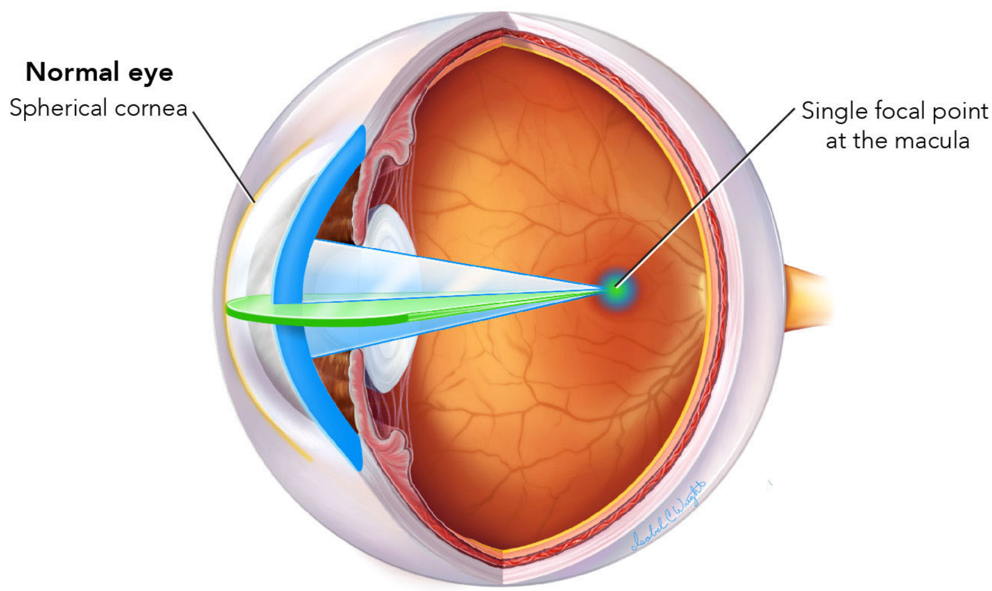
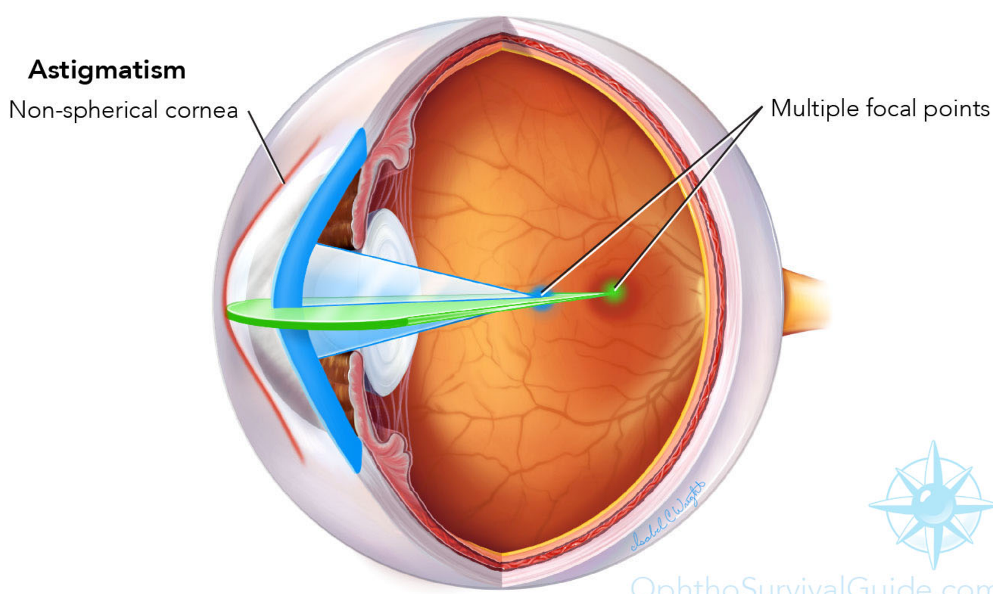
In contrast to myopia and hyperopia, astigmatism is an optical problem in which the refractive power of the eye is not perfectly spherical, but instead is sphero-cylindrical. Light rays are focused differently depending on the meridian in which they are oriented, leading to multiple focal points. These focal points can be myopic, hyperopic, or a combination of both. To make things even more complicated the astigmatism can be regular (i.e. perfectly sphero-cylindrical with two principle focal points) or irregular (i.e. numerous focal points). Unlike hyperopia or myopia, the blur caused by astigmatism is not eliminated by accommodation or changes in viewing distance.





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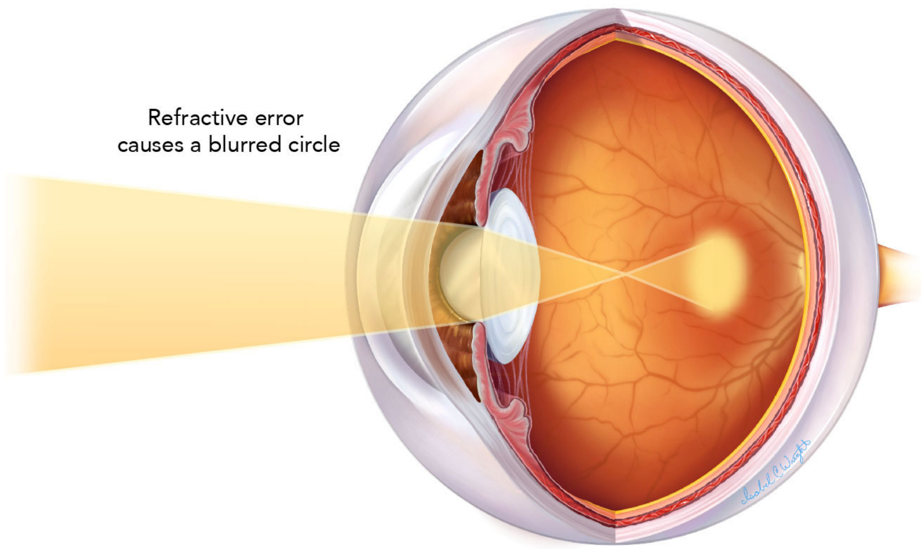
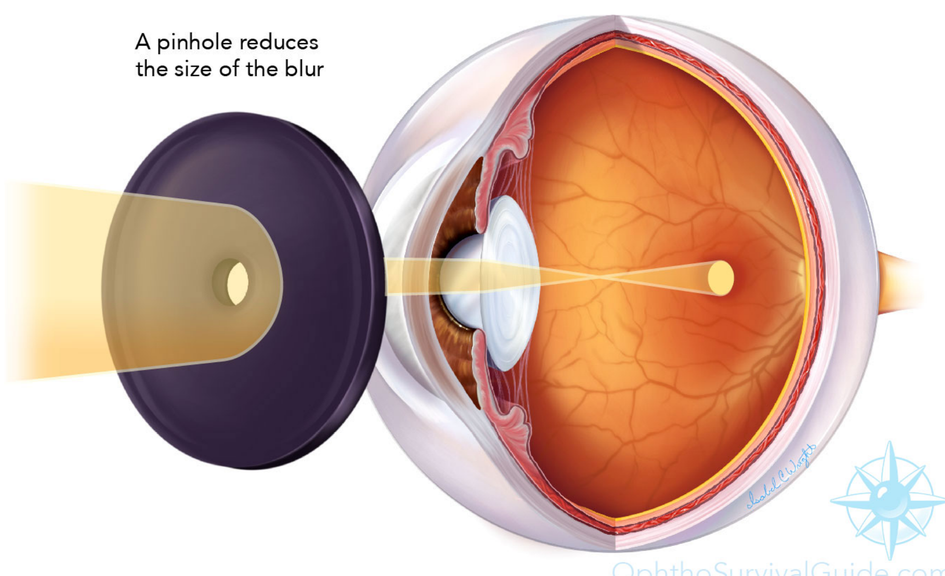
Refractive errors can occur naturally as the result of poor emmetropization, or they can be the result of injury, disease, or surgery. Regardless of how they occur, the result is the same. Blurry vision.

Interestingly, almost any refractive error can be largely eliminated by viewing through a pinhole. A pinhole acts like a universal lens. By limiting the incoming light to a small central ray, the optical effects of refractive error are markedly reduced, regardless of the type of refractive error. Pinhole viewing can therefore be used in the clinic to help determine if a patient's poor visual acuity is due to underlying refractive error. If the visual acuity is significantly improved by viewing through a pinhole, it can be inferred that at least some of the reduced acuity is due to refractive blur.





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How Are Refractive Errors Detected?

Because the appearance of the red reflex depends on the refractive state of the eye, it can be used to detect refractive error. One of easiest ways is to observe the red reflex through a direct ophthalmoscope (i.e. the Bruckner test). This technique can be used in virtually all ages, providing there are no significant opacities, and the patient is capable of at least a modicum of cooperation. With the ophthalmoscope set to plano, or 0 (assuming the examiner has no refractive error), the examiner views the red reflexes of the patient from a distance of about 0.5 to 1 meter away through an undilated pupil. Eyes with significant refractive error will show a characteristic red reflex appearance depending on the nature of the refractive error. Automated photoscreening devices utilize this principle. With practice, the Bruckner test can be used to detect significant hyperopia, myopia, and astigmatism, as well as anisometropia.

Another technique to detect refractive errors is retinoscopy. The sole purpose of retinoscopy is the determination of the refractive state of the eye. To accomplish this task, it projects a streak of light onto the patient's retina. The reflected light is viewed by the observer as the streak is moved from side to side. The motion of the reflected light indicates the refractive error of the eye in that particular meridian (i.e. the orientation of the streak may be rotated). Trial lenses are then introduced until the motion in the reflected streak is neutralized. When this occurs the observer has reached an endpoint, and the refractive error has been measured.

Although it requires considerably more training and experience, retinoscopy allows a much more quantitative and detailed assessment of refractive error than the Bruckner test. Unlike the Bruckner test, which must be performed without the use of dilating drops, retinoscopy is often easiest and most accurate when the pupils are dilated with cycloplegic drops. Cycloplegia not only increases pupil size, allowing a much larger and brighter reflex, but also inhibits accommodation, thereby stabilizing the optical state of the eye. A complete discussion of retinoscopy is beyond the scope of this survival guide, but understanding its principles and purpose is not.

Finally, as with many aspects of the ophthalmic examination, technology can be effectively used to detect refractive error. Automated refractors are widely available. They require minimal training and can be performed with or without cycloplegia. They are generally quite accurate and depending on the model can also provide measures of corneal curvature (i.e. keratometry). Like any technology however, it is important to

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understand the sources of error, and not be completely dependent upon them. Being able to detect and measure refractive errors manually will always be a useful survival skill.

How Are Refractive Errors Treated?

If refractive errors are not highly irregular, they can be corrected with sphero-cylindrical spectacle or contact lenses. The determination of the correct lens power can be a passive process for the patient, as in the cases of retinoscopy or autorefraction, or an interactive one, as in the case of manifest refraction. If, on the other hand, refractive errors are highly irregular, they will not be fully correctable by the application of simple sphero-cylindrical lenses. Retinoscopy is a very effective way to detect irregular astigmatism, regardless of its source. Corneal topography, on the other hand, can provide a very detailed understanding of the refractive power of the cornea, and illustrate the location and magnitude of any irregularities.

Manifest refraction is an interactive technique to determine the best refraction for a patient. It relies on the patient's continued feedback as lenses are changed. It requires considerable skill on the part of the person doing the refracting, and considerable cooperation and concentration on the part of the patient. When done correctly it provides the lenses that give the best-corrected spectacle visual acuity (i.e. BCVA). The device most often used to perform a manifest refraction is the phoropter. Performing manifest refractions properly is also a bit of an art. A complete discussion of refractions is beyond the scope of this survival guide, but explaining the fundamentals is not.

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