The Visual System: Eye Diseases

Problems in retinal image formation

The ability to focus an image on the retina depends on the refractive power of the both the cornea and the lens as well as on the shape of the eye globe. When the eye is able to bring distant objects to point focus on the retina without the need of a refractive aid, the eye is said to be in a state of *emmetropia*.

When an object is far from the eye, the light rays that reach the eye are essentially parallel, and they are normally brought to a focus on the retina. If the object is moved closer to the eye, the point at which light comes into focus then moves to behind the retina. To bring the image into focus on the retina, the lens refractive power is increased. This is the process of *accommodation*.

Accommodation has its limits! The distance at which your lens can no longer adjust to bring objects in focus is called the near point. The location of the near point depends on a person's age. The loss in the ability to accommodate at close distances is that the lens hardens with age and the ciliary muscles become weaker. This decreased ability is called *presbyopia*.
The solution to presbyopia is a corrective lens (convex spherical lens) that adds the necessary focusing power to bring the light to a focus on the retina.

Emmetropia is present in 30% of the adult population; the remaining 70% have a refractive error, or *ametropia*, in which light rays come to a point focus either behind the retina (*hyperopia*) or in front of it (*myopia*). These problems are caused by refractive defects or distorted eyeball shape. As for presbyopia, the solution to hyperopia is a corrective lens (convex spherical lens) that augments the eye's defective refractive power by converging the light rays to a focus on the retina. In contrast, the solution to myopia is a corrective lens (concave spherical lens) that reduces the eye's excess refractive power by diverging the light rays to a focus on the retina.

In a myopic eye, the distance at which an object - moving closer to the eye - becomes focused on the retina is called the far point. Thus, a myopic can see objects clearly if they are at the far point or closer. Corrective lenses, bending light so it enters the eye at the same angle as if it were coming from the far point, bring the light to a focus on the retina.
The strength of a lens required to correct myopic vision depends on the distance of the far point. Close far points require strong corrective lenses. Distant far points require weak corrective lenses. The strength of a lens needed to correct myopic vision is specified in diopters, the reciprocal of the distance of the far point (=1/far point in meters).

Even when refractive errors are corrected, objects do not come to clear focus on the retina if the lens is not transparent. Clouding of the lens, which is called *cataract*, also causes blurring of the retinal image. In this case, the lens opacity scatters light and precludes a clear retinal image.

Retinal diseases

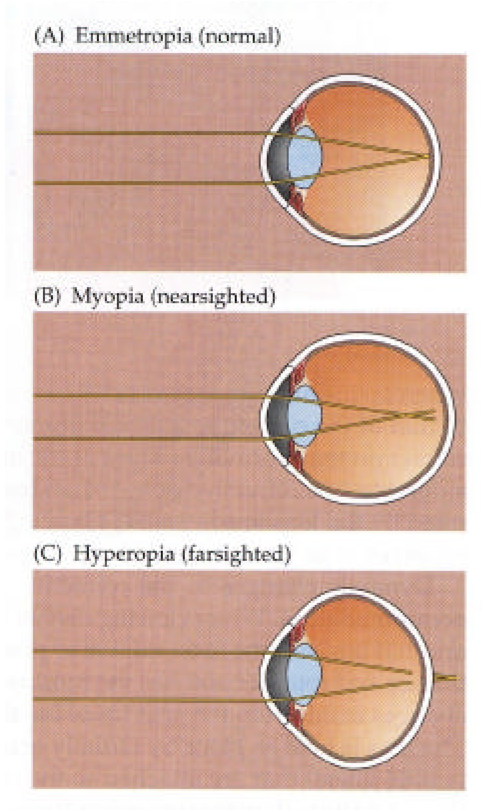
Damage to the retina itself results in a serious, and often irreversible, loss of vision.

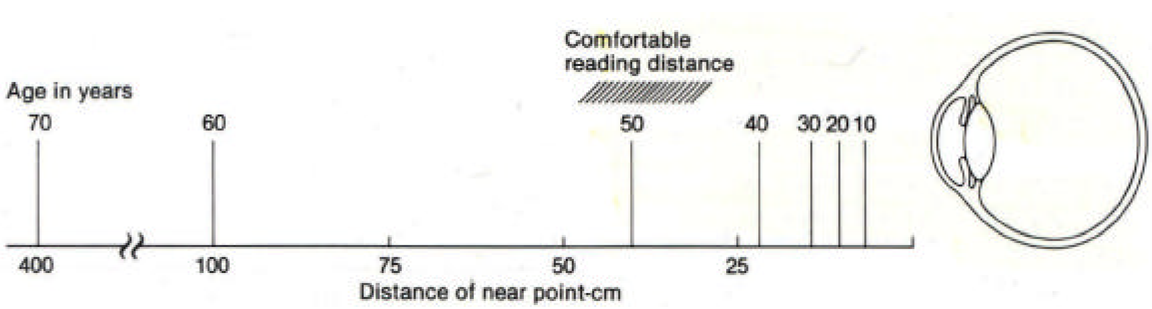
Because of the lateral displacement of the inner nuclear and ganglion cell layers, the central region of the retina (macula/fovea) critically depends on the underlying choroid and pigment epithelium for oxygenation and metabolic sustenance. With age, the blood vessels supplying the macula harden. Transport of vital oxygen into and waste materials/fluids out becomes more difficult. Expended photoreceptors' outer segments cells in the pigment epithelium are less easily disposed and their accumulation contributes to drusen. As drusen continues to accumulate, the pigment epithelium cells are lifted further away from their blood supply. They eventually die off along with their overlying photoreceptors. This causes first distortion and ultimately loss of central vision. This disease is called *age-related macular degeneration*.

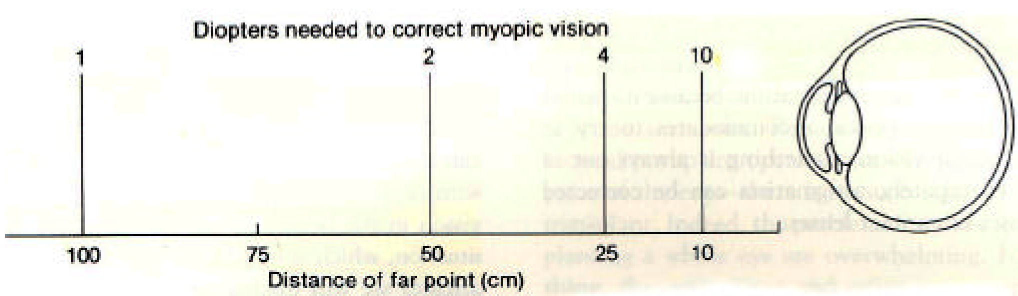
Retinitis pigmentosa is a hereditary eye disorder that is characterized by progressive vision loss due to the gradual degeneration of the rod photoreceptors, which are responsible for peripheral and night vision. The hallmarks of Retinitis Pigmentosa are night blindness, narrowing of the retinal blood vessels, and the migration of pigment from disrupted retinal pigment epithelium into the retina, forming clumps of various sizes.

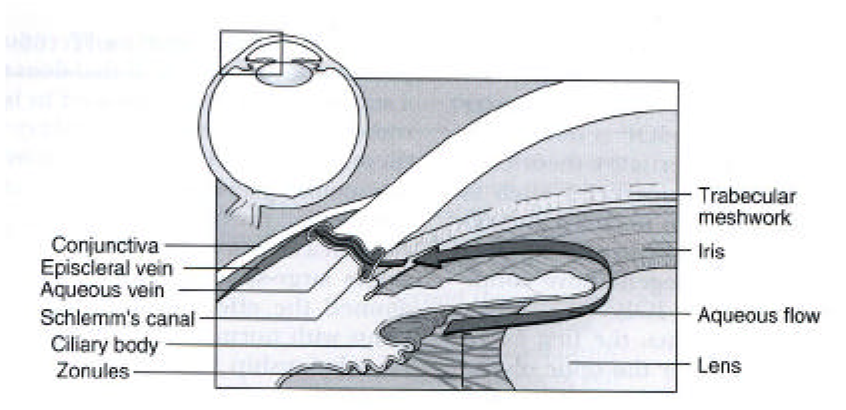
Normally, the aqueous humor secreted by the ciliary body courses through the posterior chamber, around the iris into the anterior chamber, and exits the eye via the trabecular meshwork, Schlemm's canal, aqueous, and episcleral veins. Resistance to the flow of the aqueous humor increases the intraocular pressure, which in turn presses on the optic disk, compressing the ganglion cells' axons and the incoming retinal blood vessels. This disease is called *glaucoma*.

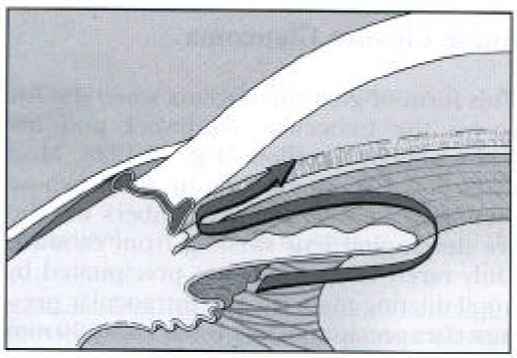
The outflow of aqueous humor can be impeded by dysfunction of the trabecular meshwork. A hole in the sclera can be surgically created to bypass the dysfunctional trabecular meshwork and restore normal aqueous outflow and intraocular pressure.
Increased intraocular pressure can also be caused by the iris root blocking the entrance to the trabecular meshwork to the flow of aqueous humor. A hole in the iris (iridectomy) can be surgically created to relieve the blockage, creating a new aqueous flow pattern and a normal intraocular pressure. Elevated intraocular pressure pushes in the optic disk, which then shows "cupping". The deleterious effect of the pressure is greatest on the large caliber axons that originate from the peripheral retina; the axons of the macula are usually spared until the disease is advanced.

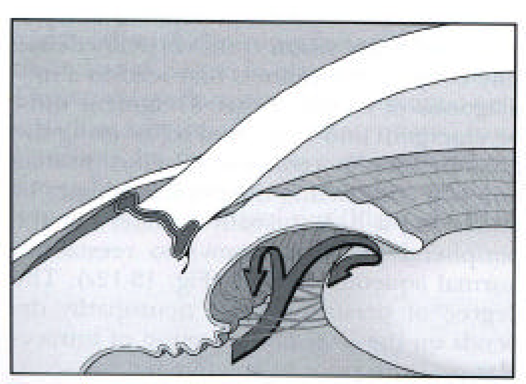

(A) Emmetropia (normal)
(B) Myopia (nearsighted)
(C) Hyperopia (farsighted)

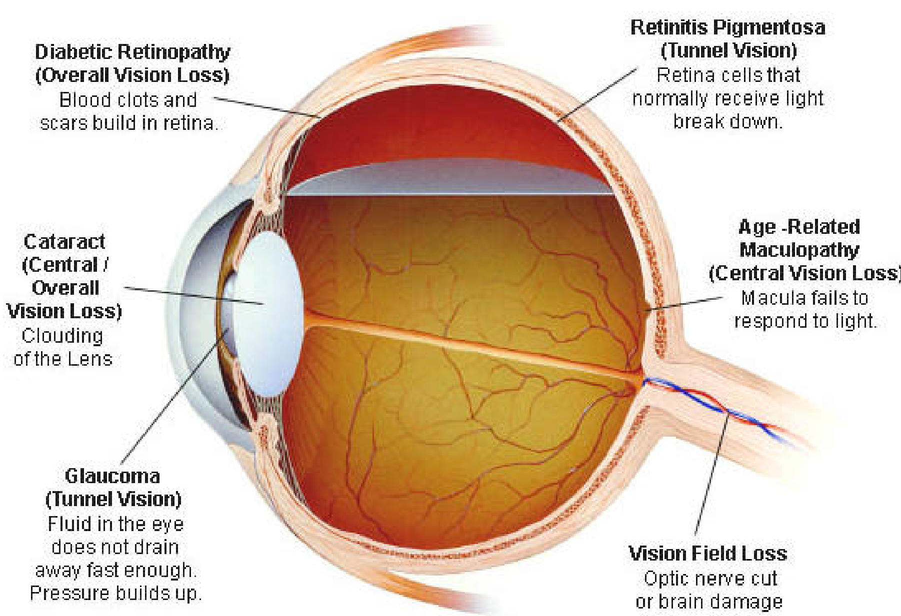

Comfortable
reading distance
Age in years
70
60
50
40
30 20 10
400
100
75
50
25
Distance of near point-cm


Diopters needed to correct myopic vision
1
2
4
10
100
75
50
25
10
Distance of far point (cm)


Trabecular meshwork
Iris
Aqueous flow
Lens
Conjunctiva
Episcleral vein
Aqueous vein
Schlemm's canal
Ciliary body
Zonules






Diabetic Retinopathy
(Overall Vision Loss)
Blood clots and scars build in retina.
Retinitis Pigmentosa
(Tunnel Vision)
Retina cells that normally receive light break down.
Cataract
(Central / Overall Vision Loss)
Clouding of the Lens
Age -Related Maculopathy
(Central Vision Loss)
Macula fails to respond to light.
Glaucoma
(Tunnel Vision)
Fluid in the eye does not drain away fast enough. Pressure builds up.
Vision Field Loss
Optic nerve cut or brain damage