Schematic Eye Models

- 1924 - Gullstrand made a six surface eye model (crystalline lens with a high index core and a lower index shell). Later reduced to four surfaces since raytracing is time consuming.
- 1952 - Emsley made a single surface model for simplicity and speed of raytracing. Today, computers can quickly raytrace eye models, so sophistication is ok.

Big Problem with early models is that the surfaces are all spherical. Therefore, the paraxial properties (Cardinal Points) are accurate, but aberrations do not look like clinical findings.

Schematic Eye Models

- 1971 - Lotmar (JOSA Vol 61, p. 1522) made anterior cornea a polynomial based on clinical measurements and made posterior lens a parabola to give clinical levels of spherical aberration.
- 1983 and 1985 - Kooijman (JOSA Vol 73, p. 1544) and Navarro (JOSA A Vol 2, p. 1273) Added aspherics to all four surfaces of their models. Kooijman model is based on light distribution on the retina. Navarro added dispersion for chromatic effects

Arizona Eye Model

	R(mm)	K Conic Constant	t	n_d	n_F	n_C
Anterior Cornea	7.8	-0.25	0.55	1.3771	1.3807	1.37405
Posterior Cornea	6.5	-0.25	3.05	1.3374	1.3422	1.3354
Anterior Lens	11.03	-4.3	4.0	1.42	1.42625	1.4175
Posterior Lens	-5.72	-1.17	16.6423	1.336	1.3407	1.3341
Retina	-13.4 Petzval					

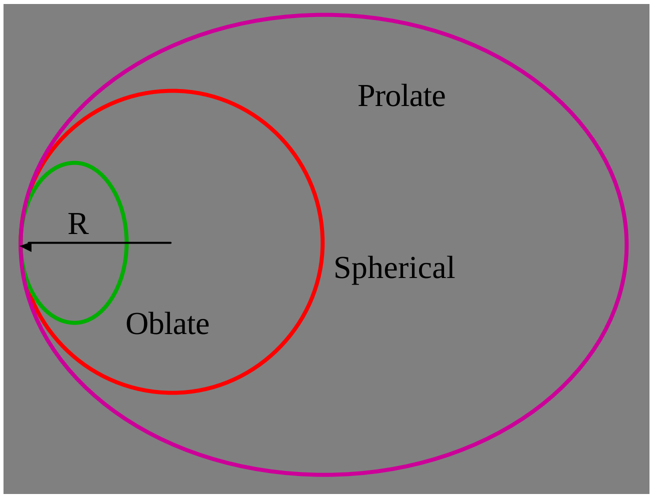
Conic Section

$$z = \frac{r^2 / R}{1 + \sqrt{1 - (K+1)\frac{r^2}{R^2}}}$$

z = sag of surface
$r^2 = x^2 + y^2$
R = radius of curvature
K = conic constant

K < -1	Hyperboloid
K = -1	Paraboloid
-1 < K < 0	Prolate Spheroid (Ellipsoid)
K = 0	Sphere
K > 0	Oblate Spheroid (Ellipsoid)

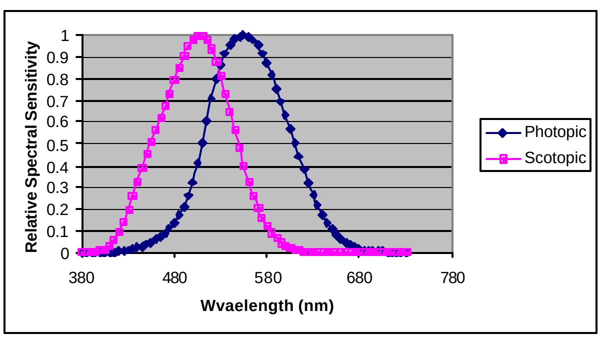
Ellipsoids



Cornea is prolate meaning that it flattens towards the periphery.

By adjusting the conic constant, the spherical aberration can be controlled without changing paraxial properties.

Schematic Eyes - Spectral Sensitivity



Scotopic - Low light level
Peak around 505 nm

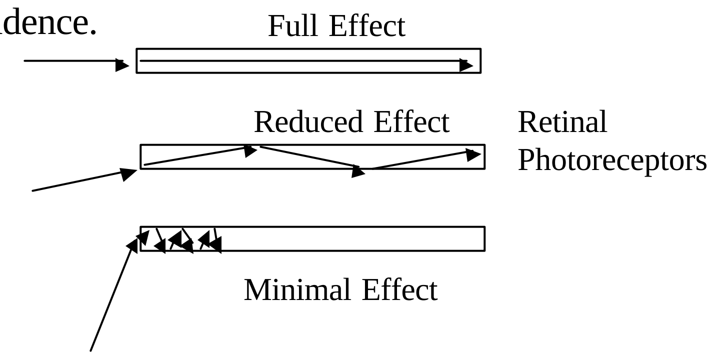
Photopic - High light level
Peak around 555 nm

Mesopic - In between

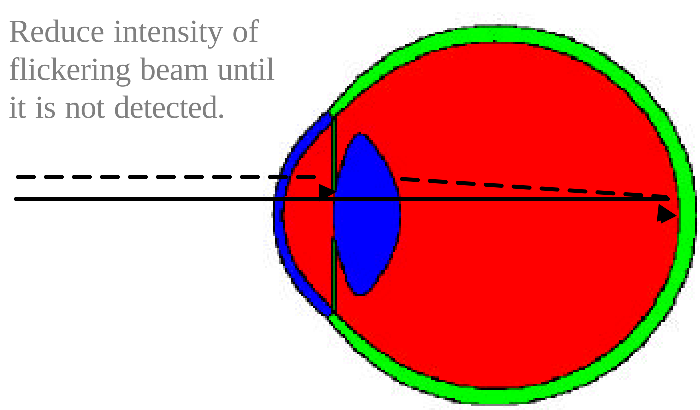
To include in raytracing code, weight wavelengths by appropriate curve.

Stiles-Crawford Effect

- 1933 - Stiles and Crawford found an effect where light striking photoreceptors with a low angle of incidence has a higher efficiency than light striking at a high angle of incidence.



Schematic Eye Model



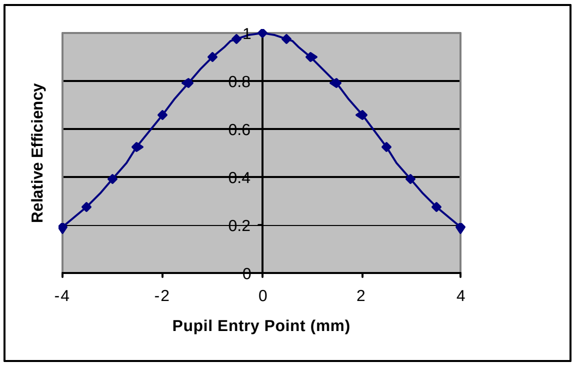
Stiles-Crawford Effect

The Stiles-Crawford effect acts like an apodizing filter.

Most raytracing problems allow for apodization.

Efficiency of peripheral ray fall to about 20% for 8 mm pupil.

$L(r) = \exp(-0.105r^2)$

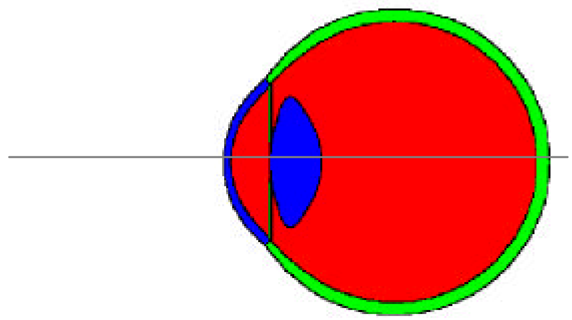


Stiles-Crawford Effect

The Stiles-Crawford effect is phototropic (i.e. the retinal photoreceptors realign themselves with the light source.

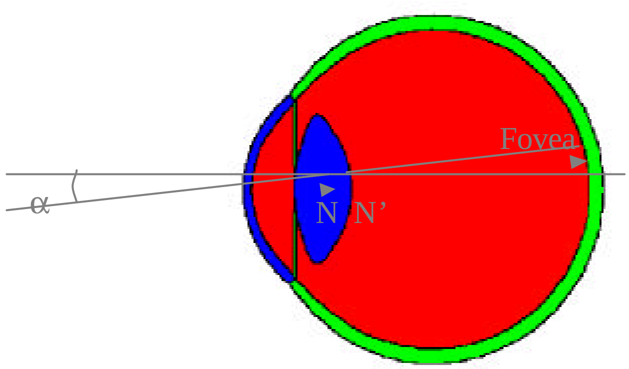
Eye Axes

Since the eye is not rotationally symmetric (i.e. the centers of curvature of each surface do not lie on a common axis), several axes can be defined which all collapse to the optical axis in rotationally symmetric systems.



Visual Axis

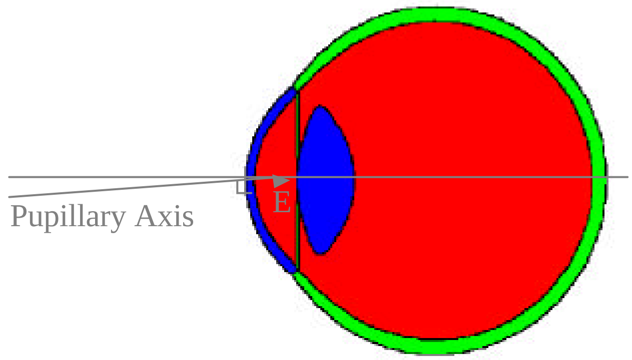
The visual axis connects the fixation point to the front nodal and the rear nodal to the fovea. Usually denoted by angle α measured from optical axis. Typically $4^\circ \le \alpha \le 8^\circ$



The fovea is usually displaced temporally and slightly inferior.

Pupillary Axis

The pupillary axis strikes the cornea at right angles and passes through the center of the entrance pupil. It is equivalent to the chief ray.



Line of Sight

The LOS connects the fixation point to the center of the entrance pupil and the center of the exit pupil to the fovea. Usually denoted by angle κ measured from pupillary axis. Typically $\kappa \leq \alpha$.