THE EYE AS AN OPTICAL INSTRUMENT

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INTRODUCTION AND OVERVIEW

This chapter includes a review of:

- Introduction and overview
- Optical components of the eye

Assumed prior knowledge:

- Algebra
- Geometry
- Optics
- Basic ocular anatomy

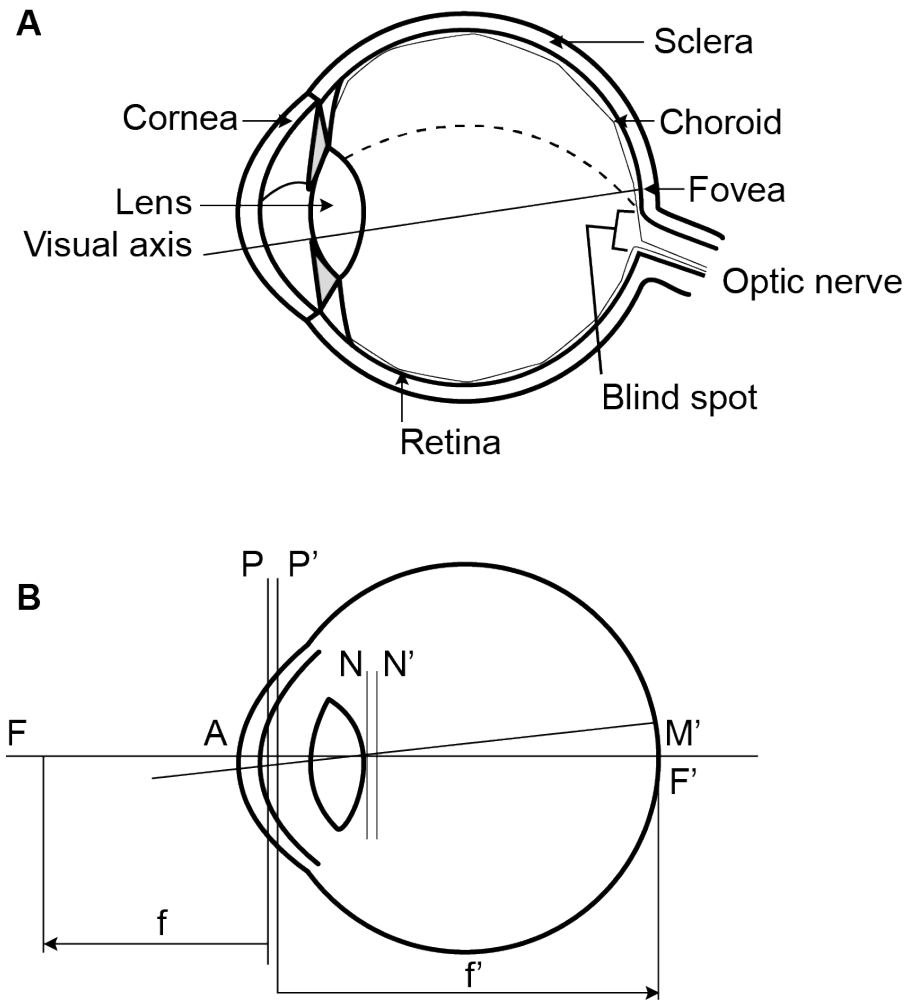
In this course we will study the optical characteristics of the eye. The course is designed to address a number of practical and theoretical questions ranging from 'How do the various optical components contribute to the formation of the retinal image?' to 'Why do people have refractive errors?' The eye is a compound optical system and because the exact dimensions of the eye vary considerably from one individual to the next, the easiest way to answer many of these questions is to first determine the dimensions for an 'average' eye and then to develop a schematic model which can be used for any necessary calculations. We will spend much of the course discussing the optical parameters of the average eye because this knowledge will help you understand the nature of refractive errors as well as the physiological basis for many clinical tests (e.g. the red-green test). To help you effectively manage the visual needs of your patients, we will use schematic eye models to obtain a working knowledge of the influence of correcting lenses on basic ocular characteristics (e.g. accommodative effort and the degree of aniseikonia). In addition, since you as optometrists will measure some of the optical parameters of the eye numerous times during your careers, we will also consider how various instruments can be used to measure these optical parameters and what are the advantages and disadvantages of the instruments that we use. This aspect of the course is particularly important since a thorough understanding of these instruments will enable you to use them more effectively.

OPTICAL COMPONENTS OF THE EYE

In order to represent the eye in a schematic form it is necessary to make two assumptions.

1. The eye is a system of coaxial spherical refracting surfaces, i.e. the centers of curvature for the entire refracting surfaces lie on a common axis. Coaxial optical systems are sometimes referred to as 'centered' or 'homocentric' optical systems.
2. The refractive indices of the media that surround the refracting surfaces are uniform (i.e. the cornea, aqueous, lens and vitreous each have unique, but uniform indices of refraction).

Although both of these assumptions concerning the optics of the eye are incorrect, they are important because they allow us to apply the Gaussian Theory of Cardinal Points to the eye. Cardinal points are important reference points for any optical system. Altogether there are 6 cardinal points (the first and second focal points, f and f'; the first and second nodal points, n and n'; and the first and second principal planes, p and p') that represent in a relatively simple manner the complex optics of a series of coaxial elements (Figure 1.1).



Cardinal Points
p, p' = principal planes
n, n' = nodal points
f, f' = focal points

Key Parameters
- radius of curvature
- position
- index of refraction

Major Optical Surfaces
- ant. & post. Cornea
- ant. & post. Crystalline Lens

Figure 1.1: *Major optical surfaces, key paramaters and cardinal points of the eye*

In order to calculate all of the cardinal points for the 'average' eye, 3 optical parameters for each of the refracting surfaces must be determined:

1. The radius of curvature of the refracting surface;
2. The position of each refracting surface; and
3. The indices of refraction which surround the refracting surfaces.

Unfortunately, it is not easy to determine these optical constants since the eye is not like a telescope that can be taken apart and physically measured. Because these optical constants cannot be measured directly in the living eye, historically investigators have made extensive use of the **Catoptric images** formed by the eye to estimate these optical constants. Catoptric images are images that are formed by reflection at an interface between two media with different indices of refraction (in contrast, 'dioptric' images are images formed by refraction). So in essence, investigators trying to determine the eye's optical constants have treated the various refracting surfaces of the eye as spherical mirrors.

The catoptric images formed by the eye were first described by Purkinje and later rediscovered by Sanson. Consequently, the catoptric images of the eye are called Purkinje-Sanson Images (or Purkinje images).

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