Chapter 2:

First steps in Vision
Light: electromagnetic radiation within a narrow energy range

- A wave: can be bent by lenses
- A particle: “photons” - can travel through a vacuum, have minimum energy that can be emitted/absorbed (quanta)
**Food for thought:** Why are we sensitive to such a narrow range of the electromagnetic spectrum?

Other solutions are possible:
- bees: ultraviolet light
- pit vipers: infrared light
What happens to light?

- **Absorbed**: Energy (e.g., light) that is taken up, and is not transmitted at all

- **Scattered**: Energy that is dispersed in an irregular fashion (most light does this!)
What happens to light?

- **Refracted**: Energy that is altered as it passes into another medium, (e.g., light entering water from the air)

- **Reflected**: Energy that is redirected when it strikes a surface
• each point in space has light from all angles passing through it
Why do we need optics?

- without optics, light from everything hits the whole retina/screen/film
- with optics, we form an image
- i.e. light from a single point in space hits a single spot on the retina
Pinhole camera: problem of pinhole size

(A) Source

\[\text{Pinhole} \rightarrow \text{Image}\]

(B) Source

\[\text{Reduced pinhole} \rightarrow \text{Image}\]

smaller aperture
= fewer rays
= sharper image
= \textit{dimmer} image
Some pinhole images

(A) big pinhole  (B) small pinhole  (C) tiny pinhole

why?
**diffraction**

- bending of waves around small obstacles or through small apertures

\[
\text{slit} = 1 \times \text{wavelength} \quad \text{slit} = 5 \times \text{wavelength}
\]
the eye (viewed from above)
- **Cornea**: The transparent “window” into the eyeball (carries 2/3 of eye’s total refractive power)
- **Aqueous humor**: watery fluid in behind cornea
- **Lens**: allows changing of focus
- **Pupil**: The dark circular opening at the center of the iris in the eye, where light enters the eye
- **Vitreous humor**: transparent fluid that fills main cavity of the eye (gel-like; may contain “floaters”)
- **Retina**: light-sensitive membrane in the back of the eye that contains rods and cones.
• **photic sneeze reflex**
tendency to sneeze when walking from a dark room into bright light

**topic of debate:**
• Aristotle - “sun heats the nose.”
• Bacon - closed eyes and didn’t sneeze!
• current thinking: “crossed wiring”
Image formation with a lens

Goal is to focus the light rays emanating from a single point to a single point on the imaging surface.
lenses

converging

diverging
**Refraction:** necessary to focus light rays, carried out by lens

- **Accommodation:** process in which the lens changes its shape, altering its refractive power
- **Emmetropia:** no refractive error
Refractive errors in vision

(A) Emmetropia

(near-sightedness)

(B) Myopia

(C) Myopia with correction

• too fat / powerful
• eye is too long

(far-sightedness)

(D) Hyperopia

(E) Hyperopia with correction

• too thin / not enough accommodation
• eye is too short
normal eye - accommodation

far away object

min

max

Good

(courtesy ben backus)
normal eye - accommodation

far away object

near object

min

max

Good

Good

(courtesy ben backus)
myopic (near-sighted) eye

- lens too powerful

far away object

min

max
can’t get far objects in focus
myopic (near-sighted) eye

- lens too powerful

far away object

near object

Good

min

max

can’t get far objects in focus
hyperopic (farsighted) eye

- lens not powerful enough

\[
\begin{align*}
\text{far away} & \quad \text{min} & \quad \text{max} \\
\text{object} & \quad & \text{Good}
\end{align*}
\]
hyperopic (farsighted) eye

- lens not powerful enough

far away object

near object

min

max

Good
can’t get near objects in focus
The precipitous drop in amplitude of accommodation with age.
- **Astigmatism**: visual defect caused by the unequal curving of one or more of the refractive surfaces of the eye, usually the cornea

- if you have an astigmatism, some lines will have lower contrast
Camera analogy for the eye

- **Aperture** (F-stop) = **Iris/pupil**. Regulates the amount of light coming into the eye

- **Focus** = **Lens**. Changes shape to change focus

- **Film** = **Retina**. Records the image
Summary

• light, electromagnetic spectrum, visible spectrum
• light as a wave / particle
• pinhole cameras, lenses, image formation, blur, diffraction, optics of the eye
• anatomy of the eye (cornea, pupil, iris, aqueous, ciliary muscle, lens, vitreous, fovea, retina, and who could forget the Zonules of Zinn!)
• accommodation, emmetropia, refractive errors (hyperopia, myopia, astigmatism)
the retina
(“smart” film in your camera)
What does the retina do?

1. Transduction
   • Conversion of energy from one form to another (i.e., “light” into “electrical energy”)

2. Processing
   • **Amplification** of very weak signals (1-2 photons can be detected!)
   • **Compression** of image into more compact form so that information can be efficiently sent to the brain
     optic nerve = “bottleneck”
     analogy: jpeg compression of images
photoreceptors

?  100

ganglion cells