Cornea
refraction of light
eye’s ability to focus image on retina
transparent
well innervated with touch and pain receptors
“corneal reflex”

Focusing Images on the Retina

- **Normal Eye**: Image in focus
- **Near-Sighted Eye**: Image in focus
- **Far-Sighted Eye**: Image in focus
Accommodation
changes in eye when we view objects

1) eyes move

2) pupils change diameter

3) lens changes shape

lens
focusing adjustments for images of objects at different distances
lens changes increases and decreases in thickness

primary stimulus for accommodation
elasticity of older lens
point of nearest focus
Cataracts

- **Lens**
  - Located behind cornea and iris and in front of vitreous and retina
  - Biconvex shape: approx. 0.40 inches (10 mm) tall, 0.16 inches (4 mm) thick
  - Helps refract light rays to focus images on retina
  - Approximately one-third of eyes ability to focus image
  - Does this by changing shape
    - "Accommodation"

  - One estimate: lens changes shape 17,000 times per day

- **Major Parts**
  1. **Lens capsule** - smooth membrane surrounds entire lens
  2. **Lens epithelium** - cells located beneath the capsule on front side of lens
  3. **Lens fibers** - long, thin cells fill up most of interior lens

  - **Lens epithelial cells produce new lens fibers**
Cataracts

- lens
  - no blood supply to lens - obtains nutrients from fluid
  - lens fibers are not very active cells
- transparent
  - lens fibers are organized in tightly-packed, and orderly layers
- 90% of protein in lens cells –
  - carefully packaged arrays within lens cells
  - maintains transparency and helps lens refract light

loss of lens transparency -

- major vision problem ~ 50 % of blindness worldwide

cataract symptoms
- “cloudy” or “filmy” vision
- difficulty with glaring light
- problems with driving at night
- changes in eyeglass prescriptions

an early sign of cataract formation
- “second sight” – improvement in ability to focus images of nearby objects
- farsightedness
Glaucoma medications

Timoptic (timolol)  Betaoptic (betaxolol)
aqueous humor
side effects: fatigue, low blood pressure, bradycardia, impotence, asthma / emphysema exacerbation

Xalatan (latanoprost)  Travatan (travoprost)
aqueous humor
used more than beta blockers; fewer side effects
side effects: change color of iris, darken / thicken eye lashes, eye redness, intraocular inflammation

Alphagan (brimonidine)  Propine (dipivefrin)
aqueous humor production  drainage
side effects: local inflammation in eye

Diamox (acetazolamide)  Neptazane (methazolamide)
aqueous humor  fluid loss from body
side effects: lower potassium level in body, kidney stones, indigestion, bitter taste, nausea, fatigue, tinnitus, tingling/ burning / prickling sensation in legs

combination medications
Glaucoma

traditional surgery

trabeculectomy

opening made in sclera (white part of eye) to drain fluid

drainage implant

tube implanted into anterior chamber of eye

tube connects to small plates on surface of the eye

aqueous humor drains to plates and is then absorbed

newer surgery

canaloplasty

a fine device is inserted into canal and used to improve drainage flow of aqueous humor

analogous to angioplasty

laser surgery

laser trabeculoplasty for open-angle glaucoma

alters trabecular meshwork to increase drainage of aqueous humor

laser peripheral iridotomy for closed-angle glaucoma

an opening is made in iris

cycloablation

destruction of the ciliary tissue that produces aqueous humor
Cataracts

causes and risk factors as we age

- aging
- ultraviolet radiation
- diabetes mellitus
- glaucoma; retinal detachment; chronic inflammation
- family history
- smoking
- steroids

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treatments

- non-surgical treatments
  - eyeglasses and other aids

- surgery – lens replacement

1. a small incision in side of cornea

2. a small instrument is inserted to break up the lens within the lens capsule

3. old lens material is removed from lens capsule

4. new lens inside of a hollow probe is placed in lens capsule and then unfolds

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prevention

- healthy food
- treatment of diabetes
- limit steroid exposure (if possible)
- sunglasses
Glaucoma

a leading cause of irreversible blindness
estimated that 2.5 - 3.0 million in US with diagnosed glaucoma
estimated that 2.0 million more in US with undiagnosed glaucoma

no symptoms early in disease
at first, a loss of peripheral vision
later, a loss of central vision

glaucoma is associated with a rise of pressure inside the eye
“intraocular pressure” or IOP
normal IOP:
rise in intraocular pressure commonly linked to a problem
production, circulation, drainage of aqueous humor

different sorts of problems with the flow of aqueous humor are linked
to the two major kinds of glaucoma -

_______-angle glaucoma and _______-angle glaucoma

IOP is normal is some glaucomas
in all types of glaucoma, however, there is damage to the optic nerve axons

the “head” of the optic nerve can appear more depressed in an eye with glaucoma

cup to optic disk ratio

looking at retina with ophthalmoscope
Glaucoma

aqueous humor
thin fluid
98% water
contains electrolytes, amino acids and a few proteins
supplies nutrients to nearby structures
also furnishes physical support of the eye
contributes to intraocular pressure
helps keep the eye inflated

aqueous humor
is present in the posterior chamber
and the anterior chamber
produced from cells in the ciliary processes
enters posterior chamber
passes through pupil
reaches anterior chamber
drains through meshwork
flows into canal
eventually exits via vein
Glaucoma

open-angle glaucoma

primary open-angle glaucoma
common type
aging
primary problem: intraocular pressure
in the end, optic nerve is damaged _______ condition

secondary open-angle glaucoma
associated with:

normal tension (pressure) glaucoma
problem with blood flow

recognized in increased numbers

closed-angle glaucoma
a basic problem: aqueous humor drainage system

risks
aging
Asian descent
far-sightedness
ciliary inflammation
open pupil

acute symptoms
IOP rises suddenly
eyes may redden
eye pain or discomfort experienced
headache
nausea / vomiting
blurred vision
halos around lights

retinal damage can take place within hours unless the drainage angle is _______
Retinal Disorders

retinitis pigmentosa

- family of inherited retinopathies
- dozens of genes implicated in a variety of RP conditions
- progress of symptoms
  - night vision problems and loss of peripheral vision
  - loss of central vision
- most common -
- sometimes -

color blindness

- trichromats: photopigments in long wavelength (blue), medium wavelength (green) and short wavelength (red) cones
- dichromats
  - protanopia: lack functional ______ cones
  - deuteranopia: lack functional ______ cones
  - tritananopia: lack functional ______ cones
- anomalous trichromats: “hybrid” genes for photopigment proteins in red and green cones

X chromosome
Light and Electromagnetic Radiation

shorter wavelengths
- gamma rays
- X rays
- ultraviolet
- visible
- infrared
- heat waves
- microwaves
- radio waves

longer wavelengths
- violet
- indigo
- blue
- green
- yellow
- orange
- red

energy that to interact with photoreceptors

Retina
- development
- several cell types
  - photoreceptors
  - horizontal cells
  - bipolar cells
  - amacrine cells
  - ganglion cells

Retinal connections
- photoreceptors
- horizontal
- bipolar
- amacrine
- ganglion cells

Retinal landmarks
- optic disk
- blind spot
- macula
- fovea

choroid
sclera
Macular Degeneration

macula (macula lutea)
small, but extremely important part of retina
approximately 6 millimeters in diameter
comprises less than 5% of retinal surface
responsible for our vision in well-lit settings

“X” marks the fovea within the macula
small (2 millimeter diameter) site
responsible for our most detailed color vision
or ganglion cells

macular degeneration (MD)
age-related macular degeneration (ARMD)
breakdown of structures in macula
leads to death of photoreceptors
limits what we can see in the center of our vision

normal vision  central vision lost

macular degeneration is the leading cause of vision loss among elderly
more than 10 million Americans affected -
a greater number than those affected by glaucoma and cataracts combined

Symptoms of MD
> slightly blurred vision at first
> greater difficulty seeing in dim light
> dark, blurred area in the center of vision
> altered or diminishes perception of colors
> wavy appearance of straight lines
Macular Degeneration

Risk Factors
> age
> a hereditary or genetic factor
> ethnic background
> gender
> smoking
> high blood pressure
> high cholesterol
> severe obesity
> cardiovascular disease
> over-exposure to sunlight

Stages of MD
> early MD: vision loss may not be apparent
  eye exams may reveal yellowish deposits in retina (drusen)

> intermediate MD: symptoms may be minimal
  eye exams reveal larger deposits and other retinal changes
  some vision loss may have occurred

> late MD: vision loss is apparent
  eye exams reveal progression of changes in retina

MD problems may be in one eye or more pronounced in one eye
MD problems usually appear to some degree in both eyes

Kinds of MD
> dry (non-exudative or atrophic) MD
  most common form
  characterized by retinal accumulation of *drusen*
  disruption of retinal structure
  loss of photoreceptors
Macular Degeneration

Kinds of MD
> dry MD

- front of eye
- healthy younger retina

- direction of light
- photoreceptors
- pigmented cell layer
- blood vessels in choroid layer

- front of eye
- healthy older retina

- direction of light
- photoreceptors
- pigmented cell layer
- blood vessels in choroid layer

- front of eye
- older retina with dry MD

- direction of light
- photoreceptors
- pigmented cell layer
- blood vessels in choroid layer
Macular Degeneration

Kinds of MD

> wet MD
some with dry MD develop wet MD
characterized by abnormal growth
of new blood vessels near retina
new blood vessels are fragile and leaky
leakage of fluids and blood
from the blood vessels
accompanies disruption of retinal structure
and loss of photoreceptors
often a more rapid progression
and a more serious loss of visual function

pigmented layer is disrupted
fluid pushed photoreceptors out of position
growth of blood vessels may continue

scar forms on damaged region of retina
photoreceptors lost
Macular Degeneration

Treatment

**dry MD**
- late / advanced MD cannot be treated
- slowing the progression of intermediate MD may be possible with anti-oxidant and mineral supplements

**treatments for wet MD**

- **laser surgery**
  - laser destroys the new fragile, leaky blood vessels
  - more effective on vessels at a distance from fovea
  - risk of laser injury to other retinal tissue
  - repeated treatments may be needed
  - growth of blood vessels may continue

- **photodynamic therapy**
  - *verteporfin* injected IV
  - attaches to walls of new blood vessels
  - light is shone into eye and activates *verteporfin*
  - activated *verteporfin* destroys new vessels
  - causes less collateral damage in retina
  - slows vision loss; does not halt vision loss or restore vision
  - retreatment may be necessary

- **anti-Vascular Endothelial Growth Factor (VEGF)**
  - VEGF promotes growth of new blood vessels
  - anti-VEGF binds to VEGF
  - limits VEGF influences on blood vessel growth
  - injections into eye:
    - *Macugen* (pegaptanib) targets one form of VEGF
    - *Lucentis* (ranibizumab) targets multiple forms of VEGF
    - *Avastin* (bevacizumab) off-label use and re-packaged, less expensive
    - *Eylea* (aflibercept) newer, targets multiple forms of VEGF
  - multiple injections over several months

  **possible side effects**
  - headache, eye discharge, eye discomfort / pain, light sensitivity, floaters,
  - retinal detachment, increased eye pressure, cataracts,
  - blood clots and bleeding
retinal pathways
multiple targets of retinal efferent projections
termination of optic radiation in primary visual cortex

retinal pathways
optic radiation
side view

lateral ventricle
LGN
primary visual cx

caudal
superior

cerebellum
parieto-occipital sulcus
calcarine sulcus

termination of optic radiation in primary visual cortex

medial surface of left occipital lobe

visual field of left eye
visual field of right eye

upper half
lower half
ON: optic nerve
OC: optic chiasm
OT: optic tract
ML: Meyer's Loop
UB: upper bank along calcarine sulcus
LB: lower bank along calcarine sulcus
LGN: lateral geniculate nucleus
OR: optic radiation

what the eyes see
Left
Right
visual processing in separate pathways

side view of brain

- eye
- LGN
- optic radiation
- primary visual cortex
- visual association cortex in parietal lobe
- visual association cortex in temporal lobe

- CN II

superior
caudal