BI 358 Lecture 18

I. **Announcements** Quiz 5 returned at end of lecture. Eye Dissection & Vision lab next Tuesday > Lecture by Dr. Sims! Final Quiz (6) next Thurs in class, then thoughts on grad schools in medicine & allied health.

II. **Physiology in the News** The sight-saving diet?

III. **Eye I: Anatomy & Optics of Vision** G&H ch 49 + LS +...

IV. **Eye II: Retinal Receptor & Neural Function** G&H ch 50

V. **Eye III: Overview of Visual Pathways & Pathologies** G&H ch 51 + LS1 + Silverthorn +...
WellnessFacts

- Smoking worsens the prognosis in men with prostate cancer. In a Harvard study of 5,366 male health professionals with the disease, smokers were much more likely than nonsmokers to have a recurrence and to die from this cancer, cardiovascular disease or any cause. Men who had quit smoking had prostate cancer mortality rates similar to those who had never smoked, unless they were heavy smokers who stopped less than 10 years earlier. Previous research has suggested that smoking also increases the risk of developing prostate cancer.

- More bad news about television viewing: For every two hours watched daily, death rates rise by 13 percent, according to a recent analysis in the Journal of the American Medical Association, which pooled data from eight large studies. That works out to about one extra death each year per 1,000 adults who watch TV two hours a day. And the risk rises with longer viewing hours. The study also found a 20 percent increased risk of diabetes for every two hours watched daily. That’s not surprising, since heavy TV viewing often leads to heavy TV viewers.

The sight-saving diet?

No one knows how to prevent the eye disorders that often come with aging, though not smoking and avoiding strong sunlight may help reduce the risk of cataracts. That’s why there has been so much interest in the role of nutrition in eye health, which has generated hundreds of studies in recent years—and many promising leads.

It’s clear that malnutrition harms vision. A shortage of vitamin A, for example, causes night blindness and other problems. Thus, carrots really are good for your eyes, since they’re rich in beta carotene, which the body converts into vitamin A. Vitamin deficiencies can also cause eye disorders such as cataracts in lab animals.

Other nutrients and plant compounds may help protect vision, perhaps by acting as antioxidants and reducing inflammation in the progression of AMD if you do develop it (see page 2).

Eye on research

Here are the nutrients and supplements most often promoted as ways to preserve vision in healthy people and prevent AMD and/or cataracts, along with what the research shows:

- Lutein and zeaxanthin. Most (but not all) observational studies have found that people with high dietary intakes or high blood levels of these carotenoids have a reduced risk of AMD and cataracts. Some small short-term clinical trials have also suggested protective effects in people with healthy eyes, as well as benefits in those who already have AMD. More research is needed.

- Vitamin C and E, selenium, beta carotene and other antioxidants. Again,
1. High intakes of lutein & zeaxanthin (carotenoids) may reduce risk of macular degeneration (AMD) & cataracts.

2. Consuming plant-foods rich in antioxidants including vitamins C & E, selenium & β-carotene also may reduce risk of macular degeneration & cataracts.

3. Older vegetarians are 30-40% less likely to develop cataracts compared to daily meat eaters.

4. The above holds for foods, but there is little evidence that anti-oxidant supplements have this effect.

5. Zinc is essential to good vision & is found in the retina & may protect eyes from light damage & inflammation. Get zinc from food (oysters, shrimp, whole grains, yogurt...)

6. High intakes of fish rich in Ω-3 fats also reduce AMD.
Eye: Elaborate sensory receptor $\equiv$ Camera

Aperture + Lens + Film!
Lens Separates Major Compartments

Aqueous Humor → Vitreous Humor/Body
Eye (L), Anterior View

L Lacrimal Gland

Canal for tear drainage
Pupil
Iris
Sclera

L Sherwood 2012
Eye: Sagittal View

- Suspensory ligament
- Ciliary body
- Iris
- Pupil
- Lens
- Cornea
- Aqueous humor
- Vitreous humor
- Optic nerve
- Optic disc
- Blood vessels in retina
- Extrinsic eye muscle
- Choroid
- Retina
- Sclera
- Fovea
The Blind Spot?

- Optic disk (blind spot)
- Central retinal artery and vein (+ optic nerve)
- Fovea
- Macula

D. Silverthorn 2010
Convex lens convergence + focal length
Concave lens divergence

Light from distant source
Image formation by convex lens

A

Point sources  Focal points

B

G&H 2011 fig 49-7
What's a diopter? Refractive power measurement = \( f^{-1} \) or 1m divide by \( f \)

Focal length = \( f \)

G&H 2011 fig 49-8
Refractive index?

Total refractive power = 59 diopters

- Vitreous humor: 1.34
- Lens: 1.40
- Aqueous humor: 1.33
- Cornea: 1.38
- Air: 1.00

G&H 2011 fig 49-9
Mechanism of accommodation

G&H 2011 fig 49-10
Mini-tramp analogy

Suspensory ligaments

Lens

Ciliary muscle

http://trampolinefiend.com/
Accommodation ≡ Lens Thickens + Pupils Constrict + Eyes Adduct!
Normal, far- & near-sighted vision

- Emmetropia
- Hyperopia
- Myopia
Correcting near- & far-sightedness

Myopia

Hyperopia

G&H 2011 fig 49-13
Astigmatism?

G&H 2011 fig 49-15
Fluid formation & flow

- Aqueous humor
- Iris
- Flow of fluid
- Formation of aqueous humor
- Spaces of Fontana
- Canal of Schlemm
- Ciliary body
- Lens
- Vitreous humor
- Diffusion of fluid and other constituents
- Filtration and diffusion at retinal vessels
- Optic nerve

G&H 2011 fig 49-19
Aqueous humor formation

- Ciliary processes
- Formation of aqueous humor
- Ciliary muscle
- Vascular layer

G&H 2011 fig 49-20
Glaucoma & intraocular pressure (IOP)?

IOP Normal 12-20 mm Hg
\[ \bar{x} = 15 \pm 2 \text{ mm Hg} \]

Glaucoma ≥ 25-30 mm Hg
up to 60-70 mm Hg!
Retinal layers

- Pigmented layer
- Outer nuclear layer
- Outer plexiform layer
- Inner nuclear layer
- Inner plexiform layer
- Ganglion cell layer
- Stratum opticum
- Inner limiting membrane

G&H 2011 fig 50-1
Optic nerve
Retina
Direction of light
Direction of retinal visual processing

Front of retina
Fibers of the optic nerve
Ganglion cell
Amacrine cell
Bipolar cell
Horizontal cell
Cone Rod Photoreceptor cells

Retina

Back of retina
Pigment layer
Choroid layer
Sclera
Macula & fovea hot spot!

Direction of light

G&H 2011 fig 50-2
Exposed Cones @ Fovea/Macular Region

Normal Fovea

Photoreceptors Inner & Outer Segments!

Peripheral (L) vs. foveal (R) retina
Rod & cone functional parts

- Membrane shelves lined with rhodopsin or color pigment
- Mitochondria
- Inner segment
- Outer segment
- Outer limiting membrane
- Nucleus
- Synaptic body

G&H 2011 fig 50-3
Rod & cone outer segments
In rods, *light* converts *cis* to *trans* retinal.
Rhodopsin-retinal visual cycle

Rhodopsin

Light energy

(p sec)

Bathorhodopsin (nsec)

Lumirhodopsin (µsec)

Metarhodopsin I (msec)

Metarhodopsin II (sec)

Scotopsin

(minutes)

11-cis retinal

Isomerase

all-trans retinal

11-cis retinol

Isomerase

all-trans retinol (Vitamin A)
### TABLE 6-2
Properties of Rod Vision and Cone Vision

<table>
<thead>
<tr>
<th>Rods</th>
<th>Cones</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 33 x more!</td>
<td></td>
</tr>
<tr>
<td>100 million per retina</td>
<td>3 million per retina</td>
</tr>
<tr>
<td>Vision in shades of gray</td>
<td>Color vision</td>
</tr>
<tr>
<td>High sensitivity</td>
<td>Low sensitivity</td>
</tr>
<tr>
<td>Low acuity</td>
<td>High acuity</td>
</tr>
<tr>
<td>Night vision</td>
<td>Day vision</td>
</tr>
<tr>
<td>More numerous in periphery</td>
<td>Concentrated in fovea</td>
</tr>
</tbody>
</table>
Intermediate Colors Are Produced When 1\textsuperscript{0} Colors Are Superimposed
Ratios of cone stimulation determine color interpretation: orange 99:42:0
Color Deficiencies Can Impact Daily Activities, Pleasure & Work!

Red Cone Deficiency = Protanopia

Green Cone Deficiency = Deuteranopia

Blue Cone Deficiency = Tritanopia

http://www.color-blindness.com/coblis-color-blindness-simulator/
Ishihara Chart for Normal (74) vs. Red-Green Color Blindness (21)
Ishihara chart for red-blind protanope (2) vs. green-blind deuteranope (4)
(Viewing brain from above with overlying structures removed)

Left

- Left eye

Right

- Right eye

1. Optic nerve
2. Optic chiasm
3. Optic tract
4. Lateral geniculate nucleus of thalamus
5. Optic radiation
6. Optic lobe
Visual deficits with specific lesions

1. Left optic nerve

2. Optic chiasm

3. Left optic tract (or radiation)

= Site of lesion  = Visual deficit

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Rods in Darkness $\rightarrow$ Rhodopsin Not Active, cGMP High, CNG and $K^+$ Channels Open

Rods – 3 Main Cation Channels

1. **CNG** (Cyclic Nucleotide-Gated) Channel
   Enable $Na^+$ and $Ca^{2+}$ entry into Rod

2. **$K^+$ Channel**
   Enables $K^+$ to leak out of Rod

3. **$Ca^{2+}$-Voltage-Gate Channel**
   Enables $Ca^{2+}$ Entry into Synaptic Terminal to Regulate Glutamate Exocytosis
Sodium flows in photoreceptor - A
Sodium flows in photoreceptor - B

**Dark**
- High (cGMP), open channels

**Light**
- Low (cGMP), closed channels

G&H 2011 fig 50-6b
Phototransduction (outer segment)
Summary: Let There Be Light!

- Light → Bleaches Rhodopsin → Opsin → cGMP → Closes CNG Channel
- (No more free inflow of Na⁺, Ca²⁺)
- Hyperpolarizes Membrane (to -70 mV)
- ↓ NT Release → Light
- Light → Bleaches Rhodopsin