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.


III. **Eye I: Anatomy & Optics of Vision** G&H ch 50 + LS +...

IV. **Eye II: Retinal Receptor & Neural Function** G&H ch 51

V. **Eye III: Overview of Visual Pathways & Pathologies** G&H ch 52 + LS1 + Silverthorn +...
The sight-saving diet?
A look behind the eye-health claims made for foods and supplements

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. 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
The Blind Spot?

Optic disk (blind spot)

Central retinal artery and vein (+ optic nerve)

Fovea

Macula

(b)

D. Silverthorn 2010
Convex lens convergence + focal length

Light from distant source

Focal length

G&H 2016 fig 50-2, G&H 2011 fig 49-2
Concave lens divergence

Light from distant source

G&H 2016 fig 50-3, G&H 2011 fig 49-3
Image formation by convex lens

A

Point sources

Focal points

B

G&H 2016 fig 50-7, G&H 2011 fig 49-7
What's a diopter? Refractive power measurement = $f^{-1}$ or $1 \text{m} \div f$

Focal length = $f$

G&H 2016 fig 50-8, 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 2016 fig 50-9, G&H 2011 fig 49-9
Mechanism of accommodation
Mini-tramp analogy

- Suspensory ligaments
- Ciliary muscle

Lens

http://trampolinefiend.com/
Accommodation ≡ Lens Thickens + Pupils Constrict + Eyes Adduct!

Normal, far- & near-sighted vision

- Emmetropia
- Hyperopia
- Myopia

G&H 2016 fig 50-12, G&H 2011 fig 49-12
Correcting near- & far-sightedness
Astigmatism?

G&H 2016 fig 50-15, G&H 2011 fig 49-15
Fluid formation & flow

- Aqueous humor
- Iris
- Spaces of Fontana
- Canal of Schlemm
- Ciliary body
- Formation of aqueous humor
- Flow of fluid
- Lens
- Vitreous humor
- Diffusion of fluid and other constituents
- Filtration and diffusion at retinal vessels
- Optic nerve
Aqueous humor formation
Glaucoma & intraocular pressure (IOP)?

IOP Normal 12-20 mm Hg

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

IOP Normal 12-20 mm Hg

\[ \bar{x} = 15 \pm 2 \text{ mm Hg} \]
Retinal layers

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

DIRECTION OF LIGHT

G&H 2016 fig 51-1
G&H 2011 fig 50-1
Optic nerve
Retina

Direction of light

Direction of retinal visual processing

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

Retina

Pigment layer
Choroid layer
Sclera

Front of retina

Back of retina
Macula & fovea hot spot!

Direction of light
Exposed Cones @ Fovea/Macular Region

Normal Fovea

Photoreceptors Inner & Outer Segments!

Peripheral (L) vs. foveal (R) retina

G&H 2011 fig 50-12

G&H 2016 fig 51-12
Rod & cone functional parts

- Membrane shelves lined with rhodopsin or color pigment
- Outer segment
- Mitochondria
- Inner segment
- Outer limiting membrane
- Nucleus
- Synaptic body
Rod & cone outer segments
In rods, light converts cis to trans retinal.
Rhodopsin-retinal visual cycle

G&H 2016
fig 51-5

G&H 2011
fig 50-5
# 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>
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</tbody>
</table>
Intermediate Colors Are Produced When $1^0$ Colors Are Superimposed
Ratios of cone stimulation determine color interpretation: orange 99:42:0

G&H 2011 fig 50-10
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 eye

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

L Sherwood 2006 fig 6-24b p 163
Rods in Darkness → Rhodopsin Not Active, cGMP High, CNG and K⁺ Channels Open

**Rods – 3 Main Cation Channels**

1. **CNG (Cyclic Nucleotide-Gated) Channel**
   
   Enable Na⁺ and Ca²⁺ entry into Rod

2. **K⁺ Channel**

   Enables K⁺ to leak out of Rod

3. **Ca²⁺-Voltage-Gate Channel**

   Enables Ca²⁺ Entry into Synaptic Terminal to Regulate Glutamate Exocytosis
Sodium flows in photoreceptor - A
Sodium flows in photoreceptor - B

G&H 2011 fig 50-6b

G&H 2016 fig 51-6b
Phototransduction (outer segment)
**Summary: Let There Be Light!**

Light → Bleaches Rhodopsin → Opsin → ↓cGMP → Closes CNG Channel (No more free inflow of Na⁺, Ca²⁺)

↓NT Release

Hyperpolarizes Membrane (to -70 mV)

Light ↔