Lecture 08, 18 Sept 2003
Chapters 7 (and 8?)

Vertebrate Physiology
ECOL 437
University of Arizona
Fall 2003

instr: Kevin Bonine
t.a.: Bret Pasch
Vertebrate Physiology 437

1. Nervous System (CH7, CH8)

2. Term paper topic and annotated references due

3. Exam Thurs next week -old exam on website -review sheet later today

7-24 Randall et al. 2002
Enhancing Receptor Sensitivity

- Lateral Inhibition

e.g., improve touch sensitivity and visual acuity (edges especially)
External Chemoreception (Taste and Smell)

-Taste
  ~ direct contact

-Smell
  ~ distant signal source

-Chemoreception very sensitive

-\textit{Bombyx} moth antenna example:

Male responds to female pheromone at low \([\ ]\) of 1 molecule in \(10^{17}\)!
Taste Chemoreception

-Taste

Usually oral cavity
Some fish fins!

4-5 qualities:
1. Salt
2. Sour
3. Sweet
4. Bitter
5. Umami
   ("savory" or "meaty")

Differing Receptor Properties

7-17 Randall et al. 2002
Taste

- microvilli
- basal cells give rise to new receptor cells every 10 days

- Generate AP’s but no axons
- 1º afferent neurons in facial, glossopharyngeal, and vagus nerves

7-16 Randall et al. 2002
**Figure 10-14 Taste buds**  (a) The taste buds for different sensations are located in specific regions on the dorsal surface of the tongue. The umami receptors (not shown) are located in the back of the pharynx. (b) A light micrograph of a taste bud. (c) Each taste bud is composed of taste receptor cells and support cells, joined near the apical surface with tight junctions. Taste ligands bind to the receptors and create calcium signals that release neurotransmitters onto primary sensory neurons.
**Figure 10.15** Taste transduction
Bitter and sweet ligand signal transduction uses G protein-coupled membrane receptors. Transducin releases Ca\(^{2+}\) from intracellular stores. Gustducin activates a cAMP second messenger pathway that closes K\(^+\) channels. Ionic ligands alter ion channels and depolarize the taste receptor, which allows Ca\(^{2+}\) entry from the extracellular fluid. For all taste ligands, the Ca\(^{2+}\) signal triggers exocytosis of neurotransmitter.
Smell/ Olfaction

1. Nasal Cavity
   - Turbinates (↑s.a.)

2. Vomeronasal organ
   - Usually conspecific communication

Vertebrate olfactory receptor 7-16 Randall et al. 2002
Smell/ Olfaction

-Nasal and Vomeronasal:

-Epithelial tissue origin
  -Cilia or Microvilli covered in mucus
-Receptor proteins with 7-transmembrane helices
  -Coupled to G-protein cascade
Smell/ Olfaction

- Nasal and Vomeronasal:
- Thousands of receptor proteins
  - but different for nasal and vomeronasal
- Receptor cells contain axons
  - Glomeruli in olfactory bulb/accessory olfactory bulb

7-21 Randall et al. 2002
Mechanoreception

- Several Types:

  1. Undifferentiated nerve endings in connective tissue

  2. More specialized
     - e.g., Pacinian Corpuscle
     - e.g., Muscle stretch receptors

  3. Hairlike sensory receptors

Activated by stretch or distortion of plasma membrane
Mechanoreception

- **Hair Cells** in **cupula**
  - one Kinocilium (or none)
  - many stereocilia

  e.g.,
  - lateral line system in fish and amphibians (motion/electricity)
  - hearing and equilibrium

7-24 Randall et al. 2002
Hearing and Equilibrium

- Both are functions of the ear

Equilibrium:
2 chambers

Sacculus

Utriculus w/ 3 semicircular canals in three perpendicular planes

These three planes can detect movement in any direction as endolymph moves and cilia are bent

Sacculus and Utriculus also contain patches of hair cells that detect position relative to gravity via otoliths
**Figure 10-24  Otolith organs**  The crystalline otoliths are attached to gelatinous material in the maculae. When the head tilts, gravity causes the otoliths to slide, pulling the stereocilia of the hair cells out of their vertical position and increasing the action potentials in the sensory neurons.
Hearing (in a nutshell...1)

- **external** ear funnels sound
- sound is **oscillating air pressure**
- funneled to **tympanic membrane** (eardrum)

- **auditory ossicles** transfer sound across air-fluid boundary to **oval window** (another membrane)
  - [auditory ossicles are **malleus, incus, stapes**]

- tympanum area **19x** oval window area
  = **amplification**
Hearing (in a nutshell...2)

- **cochlea** is fluid filled chamber on other side of oval window and it contains **hair cells**

- hair cells in cochlea bathed in **endolymph (high in K+)**

- when cilia bent, ion channels for **K+ open** and cell **depolarizes**, causing **transduction**

- **different hair cells** (and location in cochlea) for different **frequencies** of sound

- (skipped a lot of detail about the cochlea)
Vision

Disappearing Head Trick!
Disappearing Head Trick!
Vision

FOCUS
- light is focused by cornea to create an image on the retina
- refraction by cornea (85%) and by lens (15%)
- alter focal length by altering shape and curvature of lens (zonular fibers and ciliary muscle ‘sphincter’)
- binocular convergence (both eyes on same part of retina)

LIGHT INTENSITY
- pupil for variable aperture via iris and radial muscle
(b) Cross section of the eye

- **Zonulas**: attach lens to ciliary muscle
- **Aqueous humor**
- **Cornea**
- **Pupil**: changes amount of light entering the eye
- **Lens**: bends light to focus it on the retina
- **Iris**
- **Ciliary muscle**: contraction alters curvature of lens
- **Vitreous chamber**
- **Optic nerve**
- **Central artery and vein**
- **Optic disc**
- **Fovea**
- **Retina**: layer that contains photoreceptors
Figure 10-29  Optics  (a) Light reflecting off a distant object reaches the eye as nearly parallel rays. The lens is flattened so that the focal point falls on the retina. (b) If an object moves within 20 feet, the light rays from it are no longer parallel. The object is seen out of focus because the light beam is not focused on the retina. (c) To keep an object in focus as it moves closer, the lens becomes more rounded. This adjustment is known as accommodation.
Vision

~ANATOMY
- sclera white tough outer layer
- choroid lots of blood vessels
- pigment layer with photoreceptors
- fovea where highest acuity and highest # cones
  -(visual streak?)

TRANSDUCTION
- photoreceptors (rods and cones)
  - Transduce photons (light) into electrical signal
- rhodopsins (visual pigments)
  opsin (7-transmembrane lipoprotein)
  plus
  retinal (absorbs photon)
Vision

Receptor Cells

Rods - Dim light, low resolution
and
Cones - Bright light, high resolution
The optic disk, or blind spot, is the region of the retina where the optic nerve and blood vessels leave the eye.

Absorbs excess light

Pigment layer of retina

Optic disk

Optic nerve

Central retinal artery and vein

Pigment layer of retina

Nervous layer of retina

Rods and Cones

Light

Color vision

Monochromatic vision

Cone

Rod

Neurons where signals from rods and cones are integrated

Ganglion cell

Bipolar cell
Rhodopsins (visual pigments) - located in stacked lamellae

Membranes hyperpolarize in response to light

Na⁺ ‘dark current’

When light hits, the Na⁺ current into the cell is stopped and membrane hyperpolarizes stopping release of NT
Rhodopsin mechanism: cis-trans isomerization of retinal molecule

Changes conformation of opsin molecule and therefore initiates transduction

7-43 Randall et al. 2002
Activated retinal changes conformation of opsin molecule (opsin and retinal separate) and initiates transduction.

Need to reconstitute the rhodopsin (night blindness).
Rod and Cone details

**Action spectrum** (where absorb light)

3 (e.g., humans, fish)-5 (e.g., birds) different photopigments

**Different opsins, same retinal**

Porphyropsins (different retinal) seem better than rhodopsins in freshwater

**Sensitivity vs. Acuity**
Physiology Players
Theatre Slam

- 3 competing casts
- Judge(s)
  - accuracy
  - enthusiasm

Actors:
1. Photon
2. Retinal
3. Opsin
4. Transducin
5. PDE
6. cGMP
7. Ion channel
8. Cation (Na⁺)

Act I
Photon enters stage right. Other players assembled within or near membrane. ...photo transduction...
Dark current reduced as curtain closes.
END