1. Synapses (Ch12)
2. Sensory Systems (Ch13)

http://eebweb.arizona.edu/eeb_course_websites.htm

Upcoming Readings

today: Ch13
Fri 08 Feb: Ch13
Mon 11 Feb: Ch13
Wed 13 Feb: Ch13
LAB Wed 13 Feb: none
Fri 15 Feb: Exam 1, through Ch13

Lab discussion leaders: 20 Feb
1pm – Vraheera, Matthew S. Arturo
3pm – Kat, Cliff, Amber

Lab discussion leaders: 06 Feb
1pm – Rittner, Whitney
3pm – Roxanne, Maria

These do not count as physiology lectures.
Neurotransmitters:

1. **small-molecule neurotransmitters**
   (often made in axon terminals; common)

2. **neuroactive peptides**
   (often made in soma and shipped down axon)

Nematodes use a lot of the same neurotransmitters.

**Synaptic Plasticity**

- Change synaptic efficacy
- Alter rate of NT production and release

**Learning and Memory**

- **Facilitation** vs. antifacilitation/depression
- **Retrograde** messengers (i.e., NO)
- **Calcium-dependent**
  - Research on-going
Long-term Potentiation

- Often in Hippocampus
  - Site of Learning and Memory
- "Neurons that fire together wire together"
- NMDA glutamate receptors...

NMDA = N-methyl-D-aspartic acid

Doogie Mice?

Genetic engineers upregulated production of juvenile subunit of NMDA receptor in adult mice (Doogie mice).

Ethical?

Should we do this in humans or other animals?

Under what conditions?

Sensing the Environment

Sensory Reception
- Environment
- Within body

Integrated and Processed by NS

Sensory Receptors send signals to brain so we perceive sensations

Sensory Receptor cells often organized into organs

Vertebrate Physiology 437

Chapter 13

Sensory Processes/Systems

Properties of Receptor Cells

Sensory Modality

Modalities include:
- vision, hearing, touch,
- taste, smell, chemical,
- thermal, proprioceptors

Qualities within each modality
- e.g., Red or yellow;
  High or low-pitched
### Mechanisms and Molecules

**Enzymatic Cascade to amplify**

**Threshold of Detection**
- e.g., 1 photon or hair cell movement of H diam.

**Sour** (pH, H+) and **salt** (Na+) move directly - no amplification

To measure quality need many receptors grouped into organ; different ‘tunage’ (e.g., wavelength of light or frequency of sound)

### Properties of Receptor Cells

**Receptor Cells**
- Specialized
- Selective for energy type and modality

- either is a neuron or Synapses immediately on a neuron

(1° afferent neuron to CNS)

Stimulus modifies conformation of receptor

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### Enhancing Sensitivity

- **Efferent Control**
  - E.g., stretch receptors in muscle control length so can perceive stretch

- **Feedback Inhibition**
  - Auto (helps keep in dynamic range) vs. Lateral...

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### Properties of Receptor Cells

**Transduction**
- Stimulus energy converted to nerve impulse

**Example**
- Mechanoreceptors (touch)
  - 1- Proteins respond to membrane distortion
  - 2- Ion channels opened directly or indirectly
  - 3- Current flows across membrane (often Na+)
  - 4- Vm changes (aka receptor potential changes)
  - 5- Signal often amplified
  - 6- AP sent or NT released causing AP
Mechanisms and Molecules

Sensory Adaptation
- orders of magnitude different stimulus strength
- often controlled via \( \text{Ca}^{++} \) availability
- local control or feedback from CNS

Type of stimulus received depends on where in CNS (\(~\text{brain}\) \(\text{AP} \) arrives (LABELED LINES).
Rub eyes and see light!

Intensity signalled by frequency of APs, but...

Stimulus Intensity and Dynamic Range
From lowest threshold, to upper limit imposed by refractory period:

![Graph showing stimulus intensity and dynamic range](image)

Note log axis

Dynamic Range

Shifting range of appropriate AP frequency
Detectable light intensity varies over 9 orders magnitude
Detectable sound intensity varies over 12 orders magnitude

Range Fractionation
- Function of sensory adaptation
- Also recruit receptors with different 'tunage' or sensitivity (e.g., rods and cones in eye)

Sensory Adaptation Possibilities:
1. Receptor cell mechanical properties may filter
2. Receptor cells may be depleted (e.g., visual pigments; need to be regenerated)
3. Enzyme cascade (during amplification) may be inhibited by (intermediate) product
4. Electrical properties change b/c \( \uparrow \[\text{Ca}^{++}\] \)
5. Accommodation of spike initiating zone
6. Sensory adaptation in downstream neurons (CNS)

Enhancing Sensitivity
- Spontaneous basal activity
- Constant rate of APs
- Directionality if \( \uparrow \) or \( \downarrow \) AP frequency
Tonic vs. Phasic receptors

Fast-adapting

Slow-adapting

Sensory Adaptation; Pacinian Corpuscle - Touch Example

Movement of Oil between layers is what triggers APs
Signal changes in pressure, not steady pressure

External Chemoreception (Taste and Smell)

- **Taste**
  - direct contact
- **Smell**
  - distant signal source

-Chemoreception very sensitive

-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
Taste

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

Vertebrate taste bud

7-16 Randall et al. 2002

Taste - Quasi Labelled lines

Facial nerve

- multiple receptor types/neuron

Glossopharyngeal nerve

n = 20 n = 42 n = 17 n = 1

Type A Type B Type C Type D

Number of Receptors stained

Successes (sweet) NaCl (salty) HCl (sour) Quinine (bitter)

n = 5 n = 52 n = 13

Type A Type B Type C Type D

Outer tongue

Inner tongue

7-15 Silverthorn 2001

Smell

-1 Nasal Cavity
-turbicates (?)

2 Vomeronasal organ
-usually conspecific communication

Vomeronasal organ

Randall et al. 2002

7-14 Silverthorn 2001
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

7-21 Randall et al. 2002

Smell/ Olfaction
-Thousands of receptor proteins (general & special)
-but different for nasal and vomeronasal
-Receptor cells contain axons
-Glomeruli in olfactory bulb/accessory olfactory bulb

7-21 Randall et al. 2002

Olfactory Neurons
In humans, $10^7$ olfactory receptor neurons
In dogs, $2 \times 10^8$

Human auditory nerve: $10^4$
Human optic nerve: $10^6$