LECTURE 15:
Sensation -- From Physics to Biology

I. SENSATION: PHYSICS TO BIOLOGY
A. Overview: Hearing and Sight

- Sensation is the study of how sensory information is processed and the primitive experiences that the senses give us.
- Many of the senses work in similar ways and to demonstrate their general operation, this lecture will focus on Vision and Audition.
- I will also outline 5 processes that connect them
  - Distal Stimulus
  - Proximal Stimulation
  - Transduction
  - Sensory Adaptation
  - Coding

I. SENSATION: PHYSICS TO BIOLOGY
B. Distal Stimulus

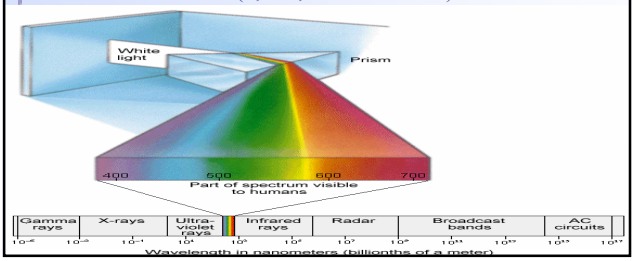
- **Distal stimulus** refers to the real world event or object that typically is some distance from the body (hence distal).
- **In vision** that would be the object or event that is seen.
- **In audition** that would be the object or event that is heard.

I. SENSATION: PHYSICS TO BIOLOGY
C. Proximal Stimulus

- **Proximal Stimulus** refers to the pattern of stimulus energies that takes its origin at the distal stimulus and finally impinges on the sensory surface of the organism.
  - **In vision** that would be the optical image of an object or event that is cast on the eye. The light energies that are **emitted** for light sources (Sun, light bulb, glow worm) or **reflected** by all other objects

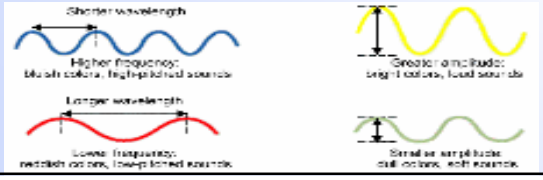
I. SENSATION: PHYSICS TO BIOLOGY
C. Proximal Stimulus

- The stimulus energies of light are a **small band of radiation** from the electromagnetic spectrum.
  - Light reflects wave lengths from **390-760 nanometers** (1,000,000 of a meter).



I. SENSATION: PHYSICS TO BIOLOGY
C. Proximal Stimulus

- **Wavelength** and **wave amplitude** are properties of light waves of interest here.
  - **Wavelength** is the distance between crests of a wave. Corresponds to psychological sensation of hue (or color)
  - **Amplitude** is the height of a wave. Corresponds to psychological sensation of brightness

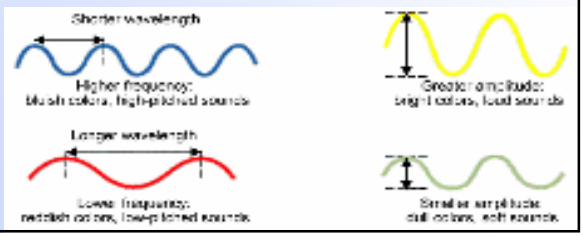


I. SENSATION: PHYSICS TO BIOLOGY
C. Proximal Stimulus

- **Audition**: The proximal stimulus is the pattern of sound waves of an object or event that is captured the ear.
  - Sound waves are not electromagnetic but are waves of air pressures.
  - **Frequency** and **amplitude** are properties of sound waves of interest here.
    - **Frequency** is the number of cycles that a sound wave completes in 1 second. Frequency corresponds to the psychology sensation of pitch and ranges from 20 to 20,000 cycles per second (hertz).
    - **Amplitude** is the height of the wave. Amplitude corresponds to loudness of a sound and is measured in decibels.

I. SENSATION: PHYSICS TO BIOLOGY
C. Proximal Stimulus

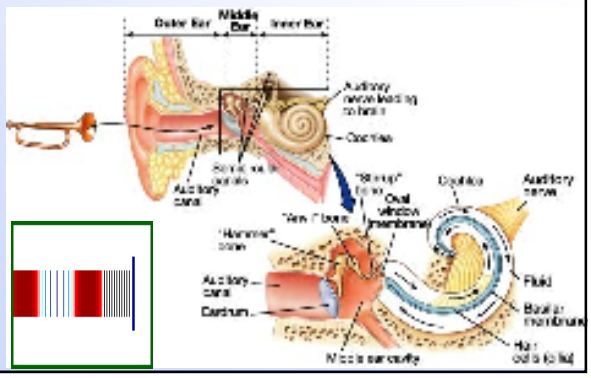
- So all light and sound are carried by waves of a certain **length** (corresponding to color and pitch) and a certain **height** (corresponding to brightness and loudness).



I. SENSATION: PHYSICS TO BIOLOGY
D. Transduction

- How does the physical properties become psychological sensations?
- **Transduction** -- the process of translating the physical stimulus energies into neural impulses.
- **D1. Auditory Transduction**
  - Sound waves are captured and focused by the ear, amplified by the eardrum, and sent to the cochlea through the three bones of the ear: Hammer, anvil and stirrup.
  - These bones translate sound waves into mechanical energy vibrating the oval window in the cochlea.
  - The vibrating oval window produces waves in the liquid-filled cochlea.

I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction



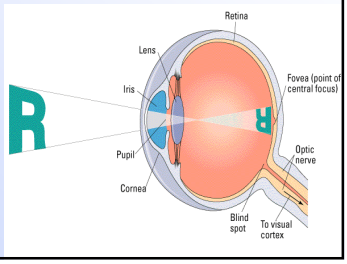
I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction

- In the cochlea there are receptor cells (Celia)
  - Celia are hair-like cells which are embedded in a rubbery membrane called the **Basilar Membrane** which stretches across the interior of the cochlea.
- As waves of sound move around the cochlea, it causes the basil membrane to vibrate and cilia to fire.
- The cilia tells the brain **where** and **how much** vibration there is along the basilar membrane.

I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction

- **C2. Visual Transduction**
- The structure of the eye is designed to fashion the proximal stimulus for the transudation of light waves.

Pupil: Regulates the amount of light allowed to enter eye. Under reflexive control to contract when there is an increase in illumination and dilate when there is a decrease in illumination.

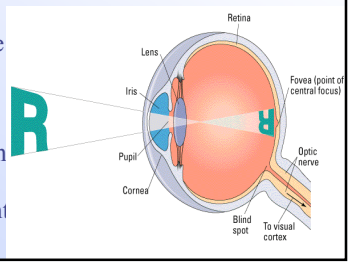


I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction

Lens: Transparent structure that focuses light -- like the lens on a camera. Images will be reversed with respect to right and left, and will upside down

Iris: Counteracting muscle bands controlling pupil size which gives the eye coloring

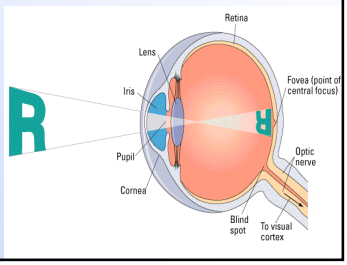
Retina: Neural tissue lining the back of the eyeball's interior, which contains the receptors for vision. Incoming light is focused on the retina.



I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction

Fovea: A small (1% of retina) region in the center of retina which contains the greatest concentration of visual sensory receptors.

Optic Nerve: Bundles of axons which leave each eye and is connected to the visual cortex through the Thalmus. Because there are no receptors at the optic nerve, it creates a "blind spot".



I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction

- The transduction of light energies involves:
  1. Focusing light for maximal sensory stimulation
  2. Refreshing the pattern of stimulation
  3. Stimulating visual receptor cells
  4. Sending visual info to the brain for processing
- **C2i. Focusing light**
- The eye focuses light on the retina
  - The fovea is where light to focused because of its high density of visual receptors.
  - **Visual acuity** is the ability to distinguish between separate points projected onto the retina.

I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction

- **C2ii. Refreshing the Image.**
- There is a tension between:
  - keeping light focused on the fovea
  - overcoming the effects of sensory adaptation.
- **Sensory Adaptation**: The tendency for neurons to decrease in firing to any stimulus that persists unchanged.
  - Small tremors in eye muscles move eye and changes region on fovea which is being stimulated.

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C. Transduction

- **C2iii. Sensory receptor cells**
- Two types of sensory receptors cells. **Rods and Cones.**
- **Cones:** Short stubby visual receptor cells.
  - They also contain visual pigment Rhodopsin (photo-chemical that causes the receptor cell to fire when light strikes it) and other visual pigments.
  - They are found also exclusively in the fovea.
  - The 7-8 million cones have a high sensitivity to light; they need lots of light to respond.
  - Receptors for day vision, and responsible for the sensation of color.

I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction

- **Rods**: Elongated visual receptor cells.
  - They contain exclusively Rhodopsin.
  - They are not found in the fovea, but found in greater concentrations further away from the fovea.
  - The 120-125 million rods are insensitive to color and instead are designed to operate in low light.
  - They are the receptors for night vision.
    - Sensitivity to low light is greater at periphery where rods are prevalent, than the center of the retina.
    - To see a faint star -- don't look directly at it.

I. SENSATION: PHYSICS TO BIOLOGY
C. Transduction

- The retina also contains other neurons: Bipolar cells, Horizontal cells, Amacrine cells, and Ganglion cells.
- These other cells are part of the wiring of the eye and help in the reduction of data
  - 130 million sense receptors (120-125 million rods and 8 million cones)
  - 1 million fibers in optic nerve.

I. SENSATION: PHYSICS TO BIOLOGY
C. Sensory Adaptation

- Vision and Audition share the concepts of **distal** stimulus, **proximal** stimulus, and **transduction**.
  - Vision and Audition are also similar in that over time, sensory stimulation cause a decease in neural firing.
  - This is called **SENSORY Adaptation**: The gradual decline in the reaction to any stimulus that persists unchanged.
    - Cold Water -- feels warm after a while
    - Monotonous Sounds -- ignored after a while
    - Color Patch -- color will eventually fade away
- This shows that the nervous system is built to detect changes in stimulation.

I. SENSATION: PHYSICS TO BIOLOGY
D. Coding

- All sensory receptors transduce the physical stimulus into neural impulses.
- But there is still a need to **code** information from the sensory receptors.
  - Coding is the translation of the stimulus information into the various **dimensions of sensations** that we experience.
- Such coding requires a fair amount of **data reduction** and **information extraction**.

I. SENSATION: PHYSICS TO BIOLOGY
D. Coding

- **Data Reduction:** The process of reducing a range of information into a manageable set.
  - Data Reduction in the eye: From 130 million Rods and Cones to 1 million nerve fibers going to visual cortex.
  - Similar reduction in the number of Celia to the number of nerve fibers going to the auditory cortex.
- **Information Extraction:** The identification of complex patterns from elementary forms.
  - How does the pattern of firing of sense receptors (Rod & Cones or Cilia) gives us information of pitch of sounds or the shape of objects?

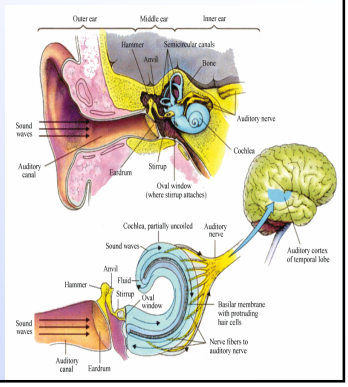
I. SENSATION: PHYSICS TO BIOLOGY
D. Coding

- The two go hand in hand : Good mechanisms for information extraction is a basis for effective Data Reduction e.g., Cliff notes of a book
  - Some data reduction and information extraction occurs at points near the sensory receptors. But, generally, much of the coding occurs at higher cortical regions in the brain.
  - This gives the brain maximal flexibility in coding information.
- **D1i Coding Auditory information**
- **Where** and **how much** vibration of Cilia along the basilar membrane tells the brain about **pitch**

I. SENSATION: PHYSICS TO BIOLOGY
D. Coding Sound

Longer waves (lower frequencies of sound) **travel further** long the basilar membrane than higher frequencies.
Place Theory of Pitch

Longer waves also cause **less vibration** of the basilar membrane than higher frequencies
Frequency Theory of Pitch

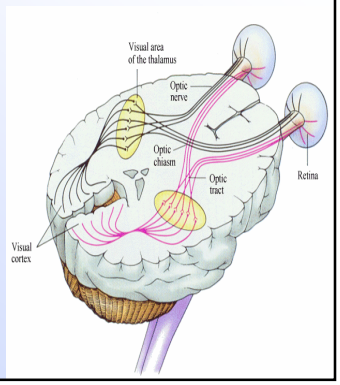


I. SENSATION: PHYSICS TO BIOLOGY
D. Coding Vision

D2. Visual Coding

The eye is where data reduction occurs. Four type of information are extracted from retinal stimulation and analyzed in the brain.

- Form
- Color
- Movement
- Depth



I. SENSATION: PHYSICS TO BIOLOGY
D. Coding Vision

Coding Form:

Retinal processing: To code form, the retina detects patterns of contrast. B/W cartoons are examples of a world of contrasts.

Feature Detection: Patterns of contrast integration into forms (angles, lines).

Abstraction: Visually constructed forms integrated into objects.

Recognition: Visual image matched with stored ones.