Sensory System
and
Sensory adaptation

Sensory Organs (Receptors)

- Monitor the internal and external environment
- Transmit signals from periphery to CNS for processing
- Critical for homeostasis

Types of Sensory Receptors
Functional Types

- Based on *modality* (type of environmental change they sense)

1. **Chemoreceptors**
   - respond to changes in chemical concentration (reflex responses to blood CO_2 , pH, olfaction, taste)
2. **Thermoreceptors**
   - respond to temperature changes (cutaneous receptors)
3. **Mechanoreceptors**
   - Respond to mechanical energy (touch, pressure vibration in skin, hearing and balance in the inner ear)
4. **Photoreceptors**
   - Respond to light (vision)
5. **Nociceptors**
   - respond to tissue damage (pain)
6. **Proprioceptors**
   - In muscles, tendons and ligaments (muscle spindle apparatuses, Golgi tendon organs)

Sensory adaptation

- **Neural adaptation** or **sensory adaptation** is a change over time in the responsiveness of the sensory system to a constant stimulus. It is usually experienced as a change in the stimulus. For example, if one rests one's hand on a table, one immediately feels the table's surface on one's skin. Within a few seconds, however, one ceases to feel the table's surface.

- All sensory and neural systems have a form of adaptation to constantly detect changes in the environment.
- **Neural receptor cells** that process and receive stimulation go through constant changes for mammals and other living organisms to sense vital changes in their environment. Some **key players** in several neural systems include **Ca^{2+}ions** that send negative feedback in second messenger pathways that allow the neural receptor cells to close or open channels in response to the changes of ion flow.
- There are also **mechanoreception systems** that use calcium inflow to physically affect certain proteins and move them to close or open channels.

- Current research shows that although adaptation occurs at **multiple stages** of each sensory pathway, it is often stronger and more stimulus specific at “cortical” level rather than “subcortical stages.” In short, neural adaptation is thought to happen at a more central level at the cortex.

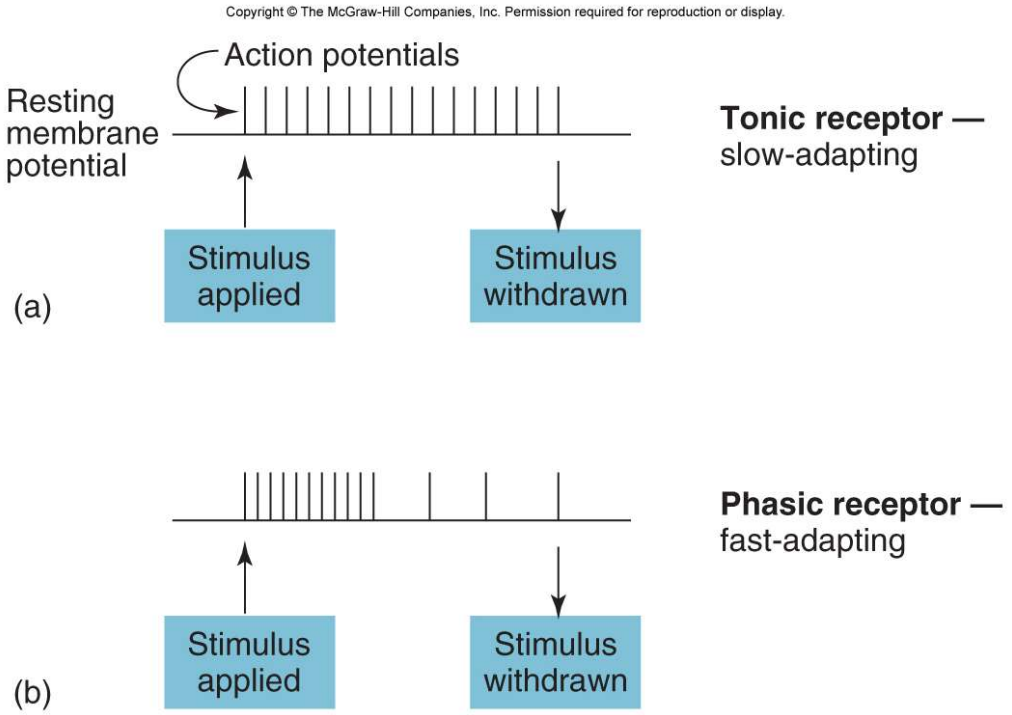
Fast and slow adaptation

- **Fast adaptation** occurs immediately after stimulus presentation i.e., within 100s of milliseconds.
- **Slow adaptive processes** can take minutes, hours or even days.
- The two classes of neural adaptation may rely on very different physiological mechanisms. The time scale over which adaptation builds up and recovers depends on the time course of stimulation.

- Brief stimulation produces adaptation which occurs and recovers while more prolonged stimulation can produce slower and more lasting forms of adaptation.
- Also, **repeated sensory stimulation appears to temporarily decrease the gain of thalamocortical synaptic transmission**. Adaptation of cortical responses was stronger and recovered more slowly.

Sensory Adaptation

- Two types of responses of sensors to constant stimulation:
- **Phasic receptors**
  - exhibit sensory adaptation
  - firing rate of receptor (# APs) decreases with constant stimulus
- **Tonic receptors**
  - exhibit little adaptation
  - maintain constant firing rate as long as stimulus is applied



Sensation

- Sensory Adaptation
  - Diminished responsiveness of sensory systems due to prolonged stimulation
  - (if it does not change; the sensation shifts to the background of our awareness)
- Absolute threshold
  - The minimum stimulation necessary to detect light, sound, pressure, taste, and odor
- Difference threshold
  - The smallest physical difference between 2 stimuli that can be recognized as a difference
- Difference threshold = JND (just noticeable difference)

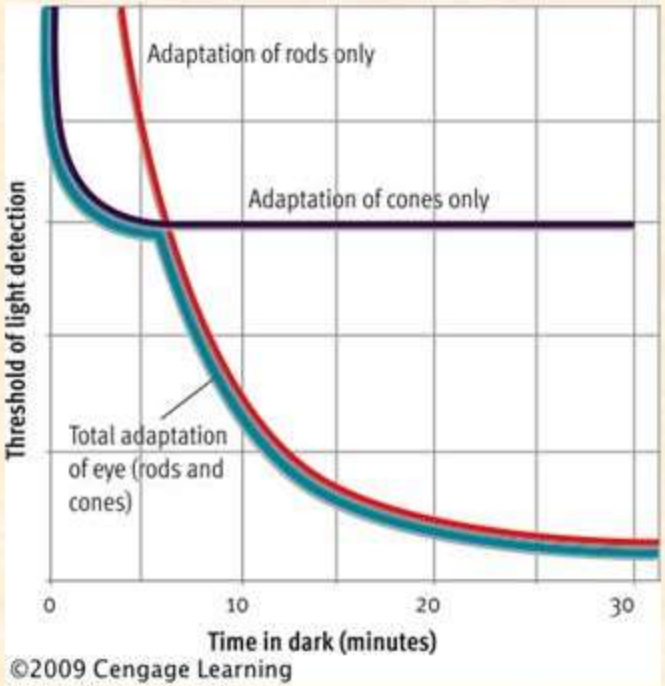
Perceptual adaptation is ability of the body to adapt to an environment by filtering out distractions. It is a phenomenon that occurs for all of the senses, including smell and touch.

ADAPTATION

Dark Adaptation: eyes become more sensitive to light in low illumination (enter dark theater on bright day)

- Complete in 30 minutes; major progress in first 10 minutes

Light Adaptation: eyes become less sensitive to light in high illumination (leaving school to go to your car/bus)



Light adaptation

- visual adaptation to increased levels of illumination.
- Promptly occurring over a period of 5 minutes
- With light adaptation, the eye has to quickly adapt to the background illumination to be able to distinguish objects in this background.

Mechanism of light adaptation

- Photochemical reaction

  Rhodopsin $\rightleftharpoons$ Retinal + Opsin

  - Rod:
    - Saturates once the light is moderately bright.
  - Cones:
    - Continue to adapt and respond to brighter illumination
    - Reaches to maximum after 5-10 mins.

Dark Adaptation

- Subject is exposed to a bright adapting light so that most of the photo pigments are bleached
- Light is then turned off and detection threshold is measured repeatedly over a period of time
- The background is totally dark
- The stimulus is large, centrally fixated
- Wavelength is 420 nm

Dark adaptation mechanism:

- When a person shifts from a bright light to a dim light, rhodopsin stores are depleted and vision is impaired
- After few minutes rhodopsin is resynthesized and vision is improved
- Called as dark adaptation and is increased in Vitamin-A deficiency

Adaptation of Taste

- taste sensations adapt rapidly
- adaptation of the taste buds themselves accounts for only about 50% of the adaptation
- central adaptation must occur but the mechanism for this is not known

Taste (Gustation) Saliva dissolves food molecules stimulating taste buds on tongue which create neural impulses which are sent to parietal lobe and interpreted as taste.

Olfactory Stimulation

- **Olfactory receptors undergo sensory adaptation rapidly**

- sense of smell drops by 50% within a second after stimulation
  - within a minute the receptors may become insensitive to a given odor

Olfactory

- An individual can adapt to a certain smell with time. Smokers, or individuals living with smokers, tend to stop noticing the smell of cigarettes after some time, whereas people not exposed to smoke on a regular basis will notice the smell instantly.
- The same phenomenon can be observed with other types of smell, such as perfume, flowers, etc.
- The human brain can distinguish smells that are unfamiliar to the individual, while adapting to those it is used to and no longer require to be consciously recognized.

How Does Smell Work?

- Volatile Substance (Odor) Chemical molecules released into the air at room temperature.
- Olfactory Bulb in Nose Receptor cells covered in mucus that dissolve molecules into electrical signals.
- Olfactory Nerve Transmits neural impulses to brain where they are interpreted as particular smell, associated with prior experiences or emotions.
- Qualities of smell: fruity, flowery, putrid, burnt, resinous, spicy

- Olfactory neurons utilize a feedback system from the levels of Ca^{2+}ions to activate its adaptation to prolonged smells. Due to the fact that the olfactory signal transduction uses a second messenger transduction system, the mechanism of adaptation includes several factors that mostly include CaMK or calmodulin bound to Ca^{2+}ions.

Hearing

- Neural perception of vibrations (sound waves) in the air
- Pitch
  - Frequency of sound waves
  - Humans can hear frequencies between 20 and 2000 Hz
- Loudness
  - Amplitude (size) of sound waves
  - Measured in decibels
    - Each 10 dB increase represents a tenfold increase in amplitude

The **auditory system** also adapts to loud sounds by cortical mechanisms as well as peripheral mechanisms through the middle ear muscles.

Adaptation of Touch sense

- Skin Senses Indicate Touch/Pressure, Temperature, Pain
- Located mostly in middle layer of skin.
- Hair follicles- Nerves at base respond to movement… bending = pressure/touch Free nerve endings- Respond to pain and temperature Once stimulated, pass through CNS to various areas of somatosensory cortex in brain.
- In case of pain the large mechanosensory neurons such as type I/group Aß display adaptation. As a result, pain does not usually subside rapidly but persists for long periods of time; in contrast, one quickly stops receiving touch or sensory information if surroundings remain constant.
- Kinesthesis (perception of body movements) Informs you about position and motion of parts of body. Sense receptors in joints, tendons, muscles Examples: Close eyes and touch nose w/finger. walking, talking, facial expressions, gestures, and posture etc

Somatosensory

- This phenomenon also applies to the sense of touch. An unfamiliar piece of clothing that was just put on will be noticed instantly; however, once it has been worn for a while, the mind will adapt to its texture and ignore the stimulus

Table Differences between Sensory Adaptation and Habituation

Responses involving physiological adaptation take place mostly in our sense organs, whereas responses involving cognitive habituation take place mostly in our brains (and relate to learning).

Adaptation	Habituation
Not accessible to conscious control Example: You cannot decide how quickly to adapt to a particular smell or a particular change in light intensity.	*Accessible to conscious control* Example: You can decide to become aware of background conversations to which you had become habituated.
Tied closely to stimulus intensity Example: The more the intensity of a bright light increases, the more strongly your senses will adapt to the light.	*Not tied very closely to stimulus intensity* Example: Your level of habituation will not differ much in your response to the sound of a loud fan and to that of a quiet air conditioner.
Unrelated to the number, length, and recency of prior exposures Example: The sense receptors in your skin will respond to changes in temperature in basically the same way no matter how many times you have been exposed to such changes and no matter how recently you have experienced such changes.	*Tied very closely to the number, length, and recency of prior exposures* Example: You will become more quickly habituated to the sound of a chiming clock when you have been exposed to the sound more often, for longer times, and on more recent occasions.

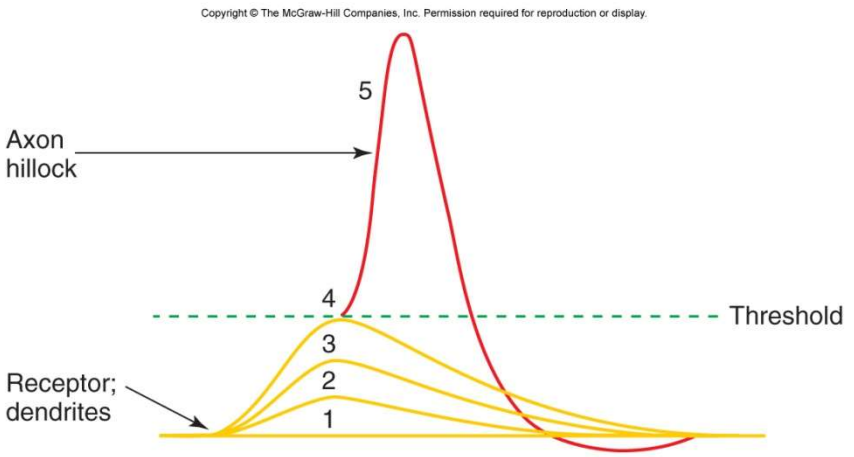
Occur in brain

Occur in body

Four Steps to Sensation

1. Stimulation

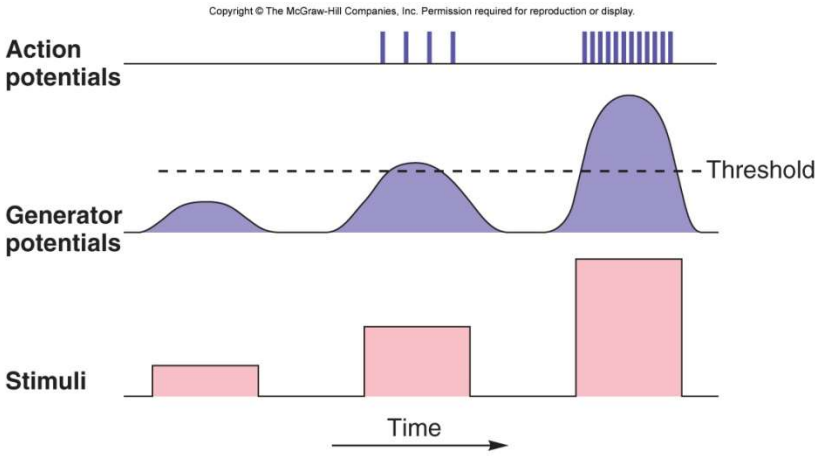
- application of stimulus
- Sensors are most sensitive to one particular stimulus (e.g., light stimulus versus punch to the eye)



2. Transduction

- Stimulation of sensor induces graded potentials in sensory neuron
- If strong enough → depolarization, AP results

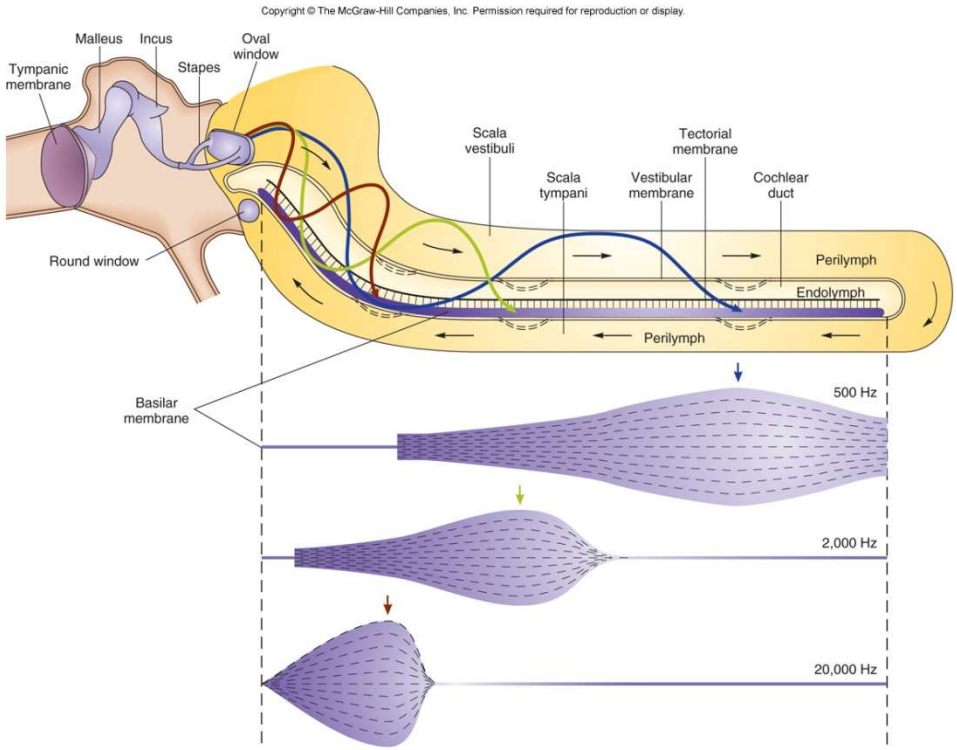
→ Generator potential = EPSP, depolarization in dendrites of sensory neurons



- ↑ stimulus strength above threshold → ↑ AP firing rate

Four Steps to Sensation

3. Conduction
   - relay information through a sensory pathway to a specific CNS region
4. Perception
   - Awareness of environmental change by CNS
   - Evaluation of nature and magnitude of stimulus



Special Senses

- Taste
- Smell
- Equilibrium
- Hearing
- Vision