**Introduction: Superhuman Senses**

- Three senses found in some animals but not humans
  - Echolocation—locating objects by detecting echoes of emitted sound waves
  - Electroreception—ability to detect electrical fields
  - Magnetoreception—ability to detect magnetic fields
Introduction: Superhuman Senses

- Animal senses gather information that guides
  - Predation
  - Migration
  - Other behaviors such as finding a mate
SENSORY RECEPTION
29.1 Sensory inputs become sensations and perceptions in the brain

- All senses trigger the same type of action potential
- The brain distinguishes the type of stimulus
- **Perception** is the brain’s integration of **sensations**
29.2 Sensory receptors convert stimulus energy to action potentials

- **Sensory receptors**
  - Specialized cells or neurons that detect stimuli
29.2 Sensory receptors convert stimulus energy to action potentials

- **Sensory transduction**
  - Conversion of stimulus energy to receptor potentials
  - **Receptor potentials** trigger action potentials
  - Action potentials are transmitted to the brain
Tongue

Taste bud

Sensory receptor cells

Sugar molecule

Sensory neuron

Taste pore

Signal transduction pathway

Ion channels

Sensory receptor cell

Ion

Receptor potential

Neurotransmitter

Sensory neuron

Action potential

Action potentials

No sugar

Sugar present
Taste bud

Sugar molecule

Taste pore

Sensory receptor cells

Sensory neuron
Taste bud

Sensory receptor cells

Sugar molecule

Sweet receptor

Membrane of sensory receptor cell

Sensory neuron

Signal transduction pathway

Ion channels

Ion

Receptor potential

Neurotransmitter

Action potentials

No sugar

Sugar present

mV

Action potential
29.2 Sensory receptors convert stimulus energy to action potentials

- Stimulus strength increases action potential frequency

- But a repeated stimulus
  - May lead to *sensory adaptation*
  - *Decreasing* sensitivity
Sugar receptor

“Sugar” interneuron

“Salt” interneuron

Salt receptor

Taste bud

Sensory neurons

Brain

Sugar

“Salt”

Taste bud

No sugar

No salt

Increasing sweetness

Increasing saltiness
29.3 Specialized sensory receptors detect five categories of stimuli

- Human skin has many types of sensory receptors
29.3 Specialized sensory receptors detect five categories of stimuli

1—Pain receptors detect dangerous stimuli

2—Thermoreceptors detect heat or cold

3—Mechanoreceptors respond to

- Mechanical energy
- Touch
- Pressure
- Sound
“Hairs” of receptor cell
Neurotransmitter at synapse
Sensory neuron
Action potentials

1. Receptor cell at rest
2. Fluid moving in one direction
3. Fluid moving in other direction

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Action potentials

“Hairs” of receptor cell

Neurotransmitter at synapse

Sensory neuron

Action potentials

1 Receptor cell at rest
More neurotransmitter

Fluid moving in one direction

2 Fluid moving in one direction
Fluid moving in other direction

Less neurotransmitter

3 Fluid moving in other direction
29.3 Specialized sensory receptors detect five categories of stimuli

- **Chemoreceptors** respond to chemicals
29.3 Specialized sensory receptors detect five categories of stimuli

- **Electromagnetic receptors** respond to
  - Electricity
  - Magnetism
  - Light (sensed by photoreceptors)
29.4 The ear converts air pressure waves to action potentials that are perceived as sound

- The human ear channels sound waves
  - From the **outer ear**
  - To the **eardrum**
  - To a chain of bones in the **middle ear**
  - To the fluid in the coiled cochlea in the **inner ear**
Outer ear

Middle ear

Inner ear

Eardrum

Bones

Organ of Corti (inside cochlea)
29.4 The ear converts air pressure waves to action potentials that are perceived as sound

- Pressure waves in the fluid of the cochlea
  - Bend hair cells in the *organ of Corti* against a membrane
  - Triggering nerve signals to the brain
Hammer
Anvil
Skull bones
Stirrup
Semicircular canals (function in balance)
Auditory nerve, to brain
Cochlea
Eardrum
Oval window (behind stirrup)
Eustachian tube

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Cross section through cochlea

Middle canal
Bone
Auditory nerve
Upper canal
Lower canal
Organ of Corti

Hair cells
Tectorial membrane
Sensory neurons
Basilar membrane
To auditory nerve
Hair cells

Basilar membrane

Tectorial membrane

Sensory neurons

To auditory nerve
29.4 The ear converts air pressure waves to action potentials that are perceived as sound

- Vibrations from the sound waves are amplified as they are transferred through the ear
The diagram illustrates the components of the ear and the process of sound transmission and amplification. It consists of three main sections: Outer Ear, Middle Ear, and Inner Ear.

### Outer Ear
- **Pinna**
- **Auditory canal**
- **Eardrum**

### Middle Ear
- **Hammer, anvil, stirrup**
- **Oval window**

### Inner Ear
- **Cochlear canals**
- **Organ of Corti**

The diagram also shows the relationship between pressure and time, with a single vibration amplifying in the middle ear, leading to stimulation of the Organ of Corti. The time axis runs horizontally, and the pressure axis runs vertically, indicating the amplification process.
29.4 The ear converts air pressure waves to action potentials that are perceived as sound

- Volume and pitch
  - Louder sounds generate more action potentials
  - Pitches stimulate different regions of the organ of Corti
Organs of balance are part of the inner ear

They include

- **Semicircular canals**
- Utricle
- Saccule

These organs sense body position and movement
Semicircular canals
Nerve
Cochlea
Utricle
Saccule
Flow of fluid
Cupula
Nerve fibers
Hair cell
Hairs
Flow of fluid
Cupula
Direction of body movement
29.6 CONNECTION: What causes motion sickness?

- Motion sickness
  - May be caused by conflicting signals between
    - Inner ear
    - Eyes
Motion sickness may be reduced by
- Sedatives such as Dramamine or Bonine
- Ginger tablets
- Pressure point wrist-bands

Motion sickness can be a severe problem for astronauts
VISION
Invertebrate eyes include

- Simple **eye cups** that sense
  - Light intensity
  - Direction
Eye cups
29.7 EVOLUTION CONNECTION: Several types of eyes have evolved among animals

- **Compound eyes** of insects
  - Many lenses
  - Acute motion detectors
  - Most see in color
29.7 EVOLUTION CONNECTION: Several types of eyes have evolved among animals

- **Single-lens eyes** are found in
  - Squids
  - Humans
Humans have single-lens eyes that focus by changing position or shape.

Vertebrate eyes

- Single-lens eyes
- Light is focused by the curved cornea and lens
- Changing the shape of the lens focuses near and far
- Photoreceptor cells in the retina detect light
Ciliary muscle contracted
Ligaments slacken
Light from a near object (diverging rays)
Near vision (accommodation)

Ciliary muscle relaxed
Ligaments pull on lens
Light from a distant object (parallel rays)
Distance vision
29.9 CONNECTION: Artificial lenses or surgery can correct focusing problems

- **Nearsightedness** and **farsightedness**
  - Result when the focal point is not on the retina
  - Corrective lenses bend the light rays to compensate
Shape of normal eyeball

Focal point

Converging corrective lens

Focal point

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29.9 CONNECTION: Artificial lenses or surgery can correct focusing problems

- **Presbyopia**
  - Decreased flexibility of lens due to age
  - Decreased ability to focus closely

- **Astigmatism**
  - Blurred vision
  - Misshapen lens or cornea
29.10 The human retina contains two types of photoreceptors: rods and cones

- Rods and cones send action potentials to the brain

- **Rods**
  - More sensitive to light
  - Detect shades of gray in dim light

- **Cones**
  - Less sensitive to light
  - Allow us to see color in bright light
Cell body

Rod

Synaptic knobs

Membranous disks containing visual pigments

Cone
Retina
Optic nerve fibers
Neurons
Photoreceptors
Cone
Rod

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TASTE AND SMELL
Taste and smell

- Depend on chemoreceptors that bind specific molecules
Taste receptors

- Located in taste buds on the tongue
- Produce five taste sensations
  - Sweet
  - Salty
  - Sour
  - Bitter
  - Umami
29.11 Taste and odor receptors detect chemicals present in solution or air

- Olfactory (smell) sensory neurons
  - Line the nasal cavity
- Odors and tastes result from taste and smell
Brain

Nasal cavity

Olfactory bulb

Bone

Epithelial cell

Sensory neuron (chemo-receptor)

Cilia

Mucus

Action potentials

Olfactory bulb

Bone

Epithelial cell

Sensory neuron (chemo-receptor)

Cilia

Mucus
29.12 CONNECTION: “Supertasters” have a heightened sense of taste

- Supertasters
  - Up to three times the sensitivity to bitter
  - Up to 25% of humans
  - More likely to avoid
    - Spinach, broccoli, cabbage
    - Coffee
    - Alcoholic beverages
29.12 CONNECTION: “Supertasters” have a heightened sense of taste

- Supertasters
  - May be less likely to eat vegetables
  - May result in a higher risk of obesity and related disease
29.13 Review: The central nervous system couples stimulus with response

- The nervous system
  - Receives sensory information
  - Integrates it
  - Commands appropriate responses
    - May be an action
    - May be no action
Iris
Retina
Cornea
Lens
Optic nerve
Sensory receptors are grouped into several types involved in many types found in pain and thermoreceptors electromagnetic receptors.

(a) involved in touch, hearing, balance
(b) involved in taste and smell
(c) sensitive to human skin
(d) many are
(e) most common are

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You should now be able to

1. Describe three senses found in animals but not humans

2. Compare sensations and perceptions

3. Define sensory transduction, a receptor potential, and sensory adaptation

4. Describe the five general categories of sensory receptors found in animals

5. List the structures of the ear in the order in which they participate in hearing
You should now be able to

6. Explain how body position and movement are sensed

7. Explain what causes motion sickness

8. Compare the structures and functions of the eyes of planarians, insects, and humans

9. Explain the causes and symptoms of myopia, hyperopia, presbyopia, and astigmatism

10. Explain how odor and taste receptors function