Basic Structural Components of the PNS

- **INPUT:** Sensory receptors—pick up stimuli from inside or outside the body
- **Nerves and ganglia**—connecting structures
  - **Nerves**—bundles of peripheral axons
  - **Ganglia**—clusters of peripheral neuronal cell bodies
- **OUTPUT:** Motor endings—axon terminals of motor neurons
  - Innervate effectors (muscle fibers and glands)

Peripheral Sensory Receptors

- Are structures that pick up sensory stimuli and initiate signals in sensory axons
- **Two** main categories of sensory receptors
  - **1. Free nerve endings of sensory neurons**
    - Monitor *general sensory* information
  - **2. Complete receptor cells**—specialized epithelial cells or small neurons
    - Monitor most types of *special sensory* information

Classification by Location

- **Exteroceptors**—sensitive to stimuli arising from outside the body
  - Located at or near body surfaces
  - Include receptors for touch, pressure, pain, and temperature
- **Interceptors**—receive stimuli from internal viscera
  - Located in digestive tube, bladder, and lungs
  - Monitor a variety of stimuli
    - Changes in chemical concentration
    - Taste stimuli
    - Stretching of tissues
    - Temperature
- **Proprioceptors**
  - Located in skeletal muscles, tendons, joints, and ligaments
  - Monitor degree of stretch
  - Send inputs on body movement to the CNS

Classification by Stimulus Detected

- **Mechanoreceptors**—respond to mechanical forces
  - Touch, pressure, stretch, vibration, and itch
- **Baroreceptors** monitor blood pressure
- **Thermoreceptors**—respond to temperature changes
- **Chemoreceptors**
  - Respond to chemicals in solution
- **Photoreceptors**—respond to light
  - Located in the eye
- **Nociceptors**
  - Respond to harmful stimuli that result in pain
Classification by Structure

- (Discussion here of General sensory receptors only, not special senses)
  - General senses are widely distributed
  - General senses include nerve endings of sensory neurons that monitor:
    - Touch
    - Pressure
    - Vibration
    - Stretch
    - Pain
    - Temperature
    - Proprioception
- So, classification of General Sensory Receptors by structure ....
  - Divided into two groups
    - Free nerve endings
    - Encapsulated nerve endings

Free Nerve Endings (or ‘unencapsulated’)

- Abundant in epithelia and underlying connective tissue
- Respond to pain and temperature
- Monitor affective senses
- Two specialized types of free nerve endings
  - Epithelial tactile complexes (Merkel discs)
    - Consist of tactile epithelial cell innervated by sensory nerve ending
    - Slowly adapting receptors for light touch
  - Hair follicle receptors—wrap around hair follicles
    - Rapidly adapting receptors

Unencapsulated Nerve Endings

- Abundant in epithelia and underlying connective tissue
- Respond to pain and temperature
- Monitor affective senses
- Two specialized types of free nerve endings
  - Epithelial tactile complexes (Merkel discs)
    - Consist of tactile epithelial cell innervated by sensory nerve ending
    - Slowly adapting receptors for light touch
  - Hair follicle receptors—wrap around hair follicles
    - Rapidly adapting receptors

Encapsulated Nerve Endings

- Consist of one or more end fibers of sensory neurons
- Enclosed in connective tissue
- Mechanoreceptors
  - Include four main types
    - Tactile (Meissner’s) corpuscles
      - Spiraling nerve ending surrounded by Schwann cells
      - Occur in the dermal papillae
      - Rapidly adapting receptors for discriminative touch
      - Occur in sensitive, hairless areas of the skin
    - Lamellar Corpuscles
      - Single nerve ending surrounded by layers of flattened Schwann cells
      - Occur in the hypodermis
      - Sensitive to deep pressure—rapidly adapting receptors
    - Bulbous Corpuscles
      - Located in the dermis and respond to pressure
      - Monitor continuous pressure on the skin—adapt slowly

Tactile Corpuscles
Lamellar Corpuscles and Bulbous Corpuscles

Table 14.1 (3 of 4)

<table>
<thead>
<tr>
<th>Structural Class</th>
<th>Functional Class</th>
<th>Body Location</th>
</tr>
</thead>
</table>
| Lamellar (Pelvic) | Muscle spindles  | Deciduous and 
| corpuscles       | — measure the  | hyperelastic, |
| Bulbous corpuscles| stretch in      | tendons,      |
|                  | locomotory      | joints,       |
|                  | organs          | nerve endings |

More Encapsulated Nerve Endings

- Proprioceptors
  - Monitor stretch in locomotory organs
  - Three types of proprioceptors:
    - Muscle spindles—measure the changing length of a muscle
      - Imbedded in the perimysium between muscle fascicles
    - Golgi tendon organs—monitor tension within tendons
      - Located near the muscles/tendon junction
    - Joint kinesthetic receptors—monitor stretch within synovial joints
      - Sensory nerve endings within the joint capsules

Proprioceptors

Table 14.1 (4 of 4)

<table>
<thead>
<tr>
<th>Structural Class</th>
<th>Functional Class</th>
<th>Body Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle spindles</td>
<td>Primary sensory</td>
<td>Muscle spindle</td>
</tr>
<tr>
<td>Tendon organs</td>
<td>endings (type Ia)</td>
<td></td>
</tr>
<tr>
<td>Joint kinesthetic</td>
<td>endings</td>
<td>Primary sensory</td>
</tr>
<tr>
<td></td>
<td>endings</td>
<td>endings</td>
</tr>
</tbody>
</table>

Structure of Proprioceptors

- Secondary sensory endings (type II fiber)
- Efferent (motor) fiber to muscle spindle
- Primary sensory endings (type Ia fiber)
- Efferent (motor) fiber to extrafusal muscle fibers
- Intrafusal muscle fibers
- Tendon
- Connective tissue capsule
- Sensory fiber
- Tendon organ
- Sensory nerve endings

The Special Senses

- Taste, smell, sight, hearing, and balance
- Characteristics of Special sensory receptors
  - Localized—confined to the head region
  - Receptors are not free endings of sensory neurons
  - Special receptor cells
    - Are neuron-like epithelial cells or small peripheral neurons
    - Transfer sensory information to other neurons in afferent pathways (i.e., cranial nerves)

The Chemical Senses: Taste and Smell

- Taste—gustation
- Smell—olfaction
- Receptors—classified as chemoreceptors
  - Respond to chemicals
    - Food dissolved in saliva
    - Airborne chemicals that dissolve in fluids of the nasal mucosa
Taste—Gustation

- Taste receptors
  - Occur in taste buds
  - Most are found on the surface of the tongue
  - Located within tongue papillae
  - Two types of papillae (with taste buds)
    - Fungiform papillae
    - Vallate papillae

Taste Buds

- Collection of 50–100 epithelial cells
- Contain two major cell types
  - Gustatory epithelial cells
  - Basal epithelial cells
- Contain long microvilli—extend through a taste pore to the surface of the epithelium
- Cells in taste buds replaced every 7–10 days

Taste Buds

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Taste Sensation and the Gustatory Pathway

- Five basic qualities of taste
  - Sweet, sour, salty, bitter, and umami
  - “Umami” is elicited by glutamate
- The “taste map” is a myth
  - All taste modalities can be elicited from all areas containing taste buds

Gustatory Pathway

- Taste information reaches the cerebral cortex
  - Primarily through the facial (VII) and glossopharyngeal (IX) nerves
  - Some taste information through the vagus nerve (X)
  - Sensory neurons synapse in the medulla
    - Relay neurons located in the solitary nucleus
    - Impulses are then transmitted to the thalamus and ultimately to the gustatory area of the cerebral cortex in the insula
  - Smell contributes to taste perception

Gustatory Pathway from Taste Buds

- Gustatory cortex
  - Thalamic nucleus (ventrolateral posterior thalamic nucleus)
  - Pons
  - Facial nerve (VII)
  - Glossopharyngeal nerve (IX)
  - Vagus nerve (X)
Smell (Olfaction)

- Olfactory receptors are part of the **olfactory epithelium**
- Olfactory epithelium is pseudostratified columnar and contains three main cell types:
  - Olfactory sensory neurons
  - Supporting epithelial cells
  - Basal epithelial cells

- Cell bodies of olfactory sensory neurons
  - Located in olfactory epithelium
  - Have an apical dendrite that projects to the epithelial surface
  - Ends in a knob from which olfactory cilia radiate
  - Olfactory cilia act as receptive structures for smell
  - Mucus captures and dissolves odor molecules

Smell (Olfaction)

- Axons of olfactory epithelium
  - Gather into bundles— these are the filaments/axons of the olfactory nerve (C.N. I)
  - These axons pass through the cribiform plate of the ethmoid bone
  - Attach to the olfactory bulbs and synapse with mitral cells
  - Mitral cells transmit impulses along the olfactory tract to
    1. Limbic system
    2. Piriform lobe of the cerebral cortex

Disorders of the Chemical Senses

- Anosmia—absence of the sense of smell
  - Due to injury, colds, allergies, or zinc deficiency
- Uncinate fits—distortion of smells or olfactory hallucinations
  - Often result from irritation of olfactory pathways
  - After brain surgery or head trauma; sometimes precedes seizures in olfactory cortex (auras)

The Eye and Vision

- Visual organ—the eye
  - 70% of all sensory receptors are in the eyes
  - 40% of the cerebral cortex is involved in processing visual information
  - Anterior one-sixth of the eye’s surface is visible
Accessory Structures of the Eye

- **Eyebrows**—coarse hairs on the superciliary arches
- **Eyelids** (palpebrae)—separated by the palpebral fissure
  - Meet at the medial and lateral angles (canthi)
  - **Lacrimal caruncle**—reddish elevation at the medial canthus
  - **Tarsal plates**—connective tissue within the eyelids
  - **Tarsal glands**—modified sebaceous glands

Accessory Structures of the Eye

- **Conjunctiva**—transparent mucous membrane
  - **Palpebral conjunctiva**
  - **Bulbar conjunctiva**
  - **Conjunctival sac**

Lacrimal apparatus—keeps the surface of the eye moist

- **Lacrimal gland**—produces lacrimal fluid
- **Lacrimal sac**—fluid empties into nasal cavity

Extrinsic Eye Muscles

- Six muscles that control movement of the eye
  - Originate in the walls of the orbit
  - Insert on outer surface of the eyeball
  - Annular ring or common tendinous ring—origin of the four rectus muscles

- **The six extrinsic eye muscles are:**
  - Lateral rectus and medial rectus
  - Superior rectus and inferior rectus
  - Superior oblique ("down and out") and inferior oblique ("up and out")

- **Strabismus:** misalignment of the eyes ("cross-eyes" or "squint-eyes")

Summary of Muscle Actions

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Action</th>
<th>Controlling cranial nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral rectus</td>
<td>Moves eye laterally</td>
<td>VI (abducens)</td>
</tr>
<tr>
<td>Medial rectus</td>
<td>Moves eye medially</td>
<td>III (oculomotor)</td>
</tr>
<tr>
<td>Superior rectus</td>
<td>Elevates eye and turns it medially</td>
<td>III (oculomotor)</td>
</tr>
<tr>
<td>Inferior rectus</td>
<td>Depresses eye and turns it medially</td>
<td>III (oculomotor)</td>
</tr>
<tr>
<td>Inferior oblique</td>
<td>Elevates eye and turns it laterally</td>
<td>IV (troclear)</td>
</tr>
<tr>
<td>Superior oblique</td>
<td>Depresses eye and turns it laterally</td>
<td>IV (troclear)</td>
</tr>
</tbody>
</table>

Extrinsic Eye Muscles

- (a) Lateral view of the right eye
- (b) Superior view of the right eye
- (c) Summary of muscle actions and innervating cranial nerves
Anatomy of the Eyeball

Components of the eye serve to...
- Protect and support the photoreceptors
- Gather, focus, and process light into precise images

Basic parts:
- Anterior pole—most anterior part of the eye
- Posterior pole—most posterior part of the eye
- Internal cavity—contains fluids (humors)
- External walls—composed of three tunics from superficial to deep:
  1. Fibrous layer (outer tunic)
  2. Vascular layer (middle tunic)
  3. Neural or inner layer (nervous tunic/inner tunic)

1. The Fibrous Layer
- Most external layer of the eyeball
  - Composed of two regions of connective tissue
    - Sclera—posterior five-sixths of the tunic
      - White, opaque region
      - Provides shape and an anchor for eye muscles
    - Cornea—anterior one-sixth of the fibrous tunic
      - Clear collagen fiber sheets sandwiched between thin epithelial layers
      - Avascular, but heals quickly
      - Richly supplied with nerve endings
  - Limbus—junction between sclera and cornea
  - Scleral venous sinus—allows aqueous humor to drain

2. The Vascular Layer
- The middle coat of the eyeball
  - Composed of choroid, ciliary body, and iris
    - Choroid—vascular, darkly pigmented membrane
    - Forms posterior five-sixths of the vascular tunic
    - Brown color—from melanocytes
    - Prevents scattering of light rays within the eye
    - Choroid corresponds to the arachnoid and pia mater
    - Ciliary body—thickened ring of tissue, which encircles the lens
      - Composed of ciliary muscle (smooth muscle)
      - Ciliary processes—posterior surface of the ciliary body
      - Ciliary zonule (suspensory ligament): extend from ciliary processes and attached around entire circumference of the lens
  - Iris (third part of vascular layer)
    - Visible colored part of the eye
    - Attached to the ciliary body
    - Composed of smooth muscle (2 muscles):
      - Sphincter pupillae muscle (parasympathetic innervation / ACh)
      - Dilator pupillae muscle (sympathetic innervation /NE)
    - Pupil—the round, central opening
    - Pupillary light reflex
      - Protective response of pupil constriction when a bright light is flashed in the eye

3. The Inner Layer (Retina)
- Retina—the deepest tunic
  - Composed of two layers:
    - Pigmented layer—single layer of melanocytes
    - Neural layer—sheet of nervous tissue
      - Contains three main types of neurons
        - Photoreceptor cells
        - Bipolar cells
        - Ganglion cells
      - Also present: 2 other neuron types:
        - Horizontal cells
        - Amacrine cells
The Inner Layer (continued)

- Photoreceptor cells send signals to bipolar cells
- Bipolar cells send signals to ganglion cells to generate nerve impulses in ganglion cell axons
- Axons from ganglion cells run along internal surface of the retina
  - Converge posteriorly to form the optic nerve

Photoreceptors

- Two main types
  - Rod cells—more sensitive to low levels of light and to movement
    - Allow vision in dim light
  - Cone cells—operate best in bright light
    - Enable high-acuity, color vision
- Considered neurons

Photoreceptors

- Rods and cones have an inner and outer segment
  - Outer segments are receptor regions where light absorbing pigments are present
- Light particles/energy modify the visual pigment and generate a nerve impulse
Photoreceptors

- Photoreceptors
  - Vulnerable to damage by light or heat
  - Cannot regenerate if destroyed
  - Continuously renew and replace their outer segments

Regional Specializations of the Retina

- Ora serrata retinae
  - Neural layer ends at the posterior margin of the ciliary body
  - Pigmented layer covers ciliary body and posterior surface of the iris
- Macula lutea — contains mostly cones
- Fovea centralis — contains only cones
  - Region of highest visual acuity
- Optic disc — area of no receptors (where ganglion cell axons exit the eye as C.N.II) and therefore a "blind spot"

View of the Eye

- Ora serrata
- Ciliary body
- Ciliary processes (suspensory ligament)
- Cornea
- Iris
- Pupil
- Anterior pole
- Anterior segment (contains aqueous humor)
- Lens
- Scleral venous sinus
- Posterior segment (contains vitreous humor)

(a) Diagrammatic view. The vitreous humor is illustrated only in the bottom part of the eyeball.

Blood Supply of the Retina

- Retina receives blood from two sources
  - Outer third of the retina — supplied by capillaries in the choroid
  - Inner two-thirds of the retina — supplied by central artery and vein of the retina

Internal Chambers and Fluids

- The lens and ciliary zonules divide the eye
- Posterior segment (cavity)
  - Filled with vitreous humor
  - Clear, jelly-like substance
  - Transmits light
  - Supports the posterior surface of the lens
  - Helps maintain intraocular pressure
- Anterior segment
  - Divided into anterior and posterior chambers
  - Anterior chamber — between the cornea and iris
  - Posterior chamber — between the iris and lens
  - Filled with aqueous humor
  - Renewed continuously
  - Formed as a blood filtrate
  - Supplies nutrients to the lens and cornea

Internal Chambers and Fluids

- Aqueous humor is formed by filtration from the capillaries in the ciliary processes.
- Aqueous humor flows from the posterior chamber through the pupil into the anterior chamber. Some also flows through the vitreous humor (not shown).
- Aqueous humor is reabsorbed into the venous blood by the scleral venous sinus.

Figure 16.7a

Figure 16.10

Figure 16.11
The Lens

- A thick, transparent, biconvex disc
- Held in place by its ciliary zonule
- Lens epithelium—covers anterior surface of the lens
- Lens fibers form the bulk of the lens
- New lens fibers are continuously added
- Lens enlarges throughout life

The Eye as an Optical Device

- Structures in the eye bend light rays
- Light rays converge on the retina at a single focal point
- Light bending structures (refractory media) are interfaces between media:
  - The lens, cornea, and humors
- Accommodation—curvature of the lens is adjustable
  - Allows for focusing on nearby objects

The Eye as an Optical Device

(a) Lens is flattened for distant vision. Sympathetic input relaxes the ciliary muscle, tightening the ciliary zonule, and flattening the lens.

(b) Lens bulges for close vision. Parasympathetic input contracts the ciliary muscle, loosening the ciliary zonule, allowing the lens to bulge.

Visual Pathways

- Most visual information travels to the cerebral cortex
- Responsible for conscious "seeing"
- Other pathways travel to nuclei in the midbrain and diencephalon

Visual Pathways to the Cerebral Cortex

- Pathway begins at the retina ...
  - Light activates photoreceptors
  - Photoreceptors signal bipolar cells
  - Bipolar cells signal ganglion cells
  - Axons of ganglion cells exit eye as the optic nerve (C.N. II)
  - After optic chiasm, where partial decussation occurs, optic tracts send axons to ...
    - Lateral geniculate nucleus (LGN) of the thalamus, where axons synapse with thalamic neurons
      - Thalamic neuron axons form optic radiation & reach the primary visual cortex in occipital lobe
Disorders of the Eye and Vision

- **Age-related macular degeneration (AMD)**
  - Involves the buildup of visual pigments in the retina
- **Retinopathy of prematurity**
  - Blood vessels grow within the eyes of premature infants
  - Vessels have weak walls—causes hemorrhaging and blindness
- **Trachoma**—contagious infection of the conjunctiva
- **Presbyopia**: "old eye"—loss of lens plasticity with age

Embryonic Development of the Eye

- **Ectoderm thickens and forms lens placodes**
- **By week 5, a lens vesicle forms**
- **Internal layer of the optic cup becomes**
  - **Neural retina**
- **External layer becomes**
  - **Pigmented retina**
- **Optic fissure—pathway for blood vessels**

Embryonic Development of the Eye

- **Eyes develop as outpocketings of the brain**
- **By week 4, optic vesicles protrude from the diencephalon**

Embryonic Development of the Eye

- **Mesenchyme surrounds and invades the optic cup to form the fibrous and vascular layers and the vitreous humor**
- **Lens vesicle forms the lens**
- **Surface ectoderm forms the corneal epithelium and the conjunctiva**

Embryonic Development of the Eye

- **By week 6, the neural and pigmented layers of the retina differentiate from the optic cup**
- **Central artery reaches the interior of the eye**
- **Mesenchyme derived from neural crest invades**
- **Lens vesicle forms the lens**
- **Deteriorating internal blood vessels**

Embryonic Development of the Eye

- **By week 7, mesenchyme surrounds and invades the optic cup**
- **Developing neural layer of the retina invaginates and forms the lens**
- **Developing pigmented layer of the retina invaginates and forms the lens**
- **Central artery invaginates and forms the lens**
- **Surface ectoderm invaginates and forms the lens**
- **From the neural crest, mesenchyme derived**
- **Sclera and choroid invaginate and form the lens**
- **Retina and vitreous humor form**
- **Lens vesicle forms the lens**
- **Optic fissure forms the lens vesicle**
- **Central artery forms the lens**
- **Blood vessels forms the lens**
The Ear: Hearing and Equilibrium

- The ear—receptor organ for hearing and equilibrium
- Composed of three main regions:
  - Outer ear—functions in hearing
  - Middle ear—functions in hearing
  - Internal ear—functions in both hearing and equilibrium

The Outer (External) Ear

- Composed of
  - The auricle (pinna)
    - Helps direct sounds
  - External acoustic meatus
    - Lined with skin
    - Contains hairs, sebaceous glands, and ceruminous glands
  - Tympanic membrane
    - Forms the boundary between the external and middle ear

The Middle Ear

- Composed of
  - The tympanic cavity
    - A small, air-filled space
    - Located within the petrous portion of the temporal bone
  - Medial wall is penetrated by
    - Oval window
    - Round window
  - Pharyngotympanic tube (auditory or Eustachian tube)
    - Links the middle ear and pharynx

Structures of the Middle Ear

- Ear ossicles—smallest bones in the body
  - Malleus—attaches to the eardrum
  - Incus—between the malleus and stapes
  - Stapes—vibrates against the oval window
- Tensor tympani (C.N. V) and stapedius (C.N. VII)
  - Two tiny skeletal muscles in the middle ear cavity

The Middle Ear

- Tensor tympani (C.N. V) and stapedius (C.N. VII)
  - Two tiny skeletal muscles in the middle ear cavity
**The Internal Ear**

- **Internal ear**—also called the labyrinth
- Lies within the petrous portion of the temporal bone
- **Bony labyrinth**—a cavity consisting of three parts
  - Semicircular canals
  - Vestibule
  - Cochlea

**The Internal Ear**

- **Membranous labyrinth**
  - Series of membrane-walled sacs and ducts
  - Fit within the bony labyrinth
  - Consists of three main parts
    - Semicircular ducts
    - Utricle and saccule
    - Cochlear duct
  - Filled with a clear fluid—endolymph
  - Confined to the membranous labyrinth
  - Bony labyrinth is filled with perilymph
  - Continuous with cerebrospinal fluid

**The Cochlea**

- A spiraling chamber in the bony labyrinth
- Coils around a pillar of bone—the modiolus
  - Spiral lamina—a spiral of bone in the modiolus
  - The cochlear nerve runs through the core of the modiolus
  - Has three areas/chambers: scala media, scala vestibuli, and scala tympani
- **The cochlear duct (scala media)**—contains the receptors for hearing
  - Lies between two chambers
    - The scala vestibuli
    - The scala tympani
  - The **vestibular membrane**—the roof of the cochlear duct
  - The **basilar membrane**—the floor of the cochlear duct
The Cochlea

The cochlear duct (scala media) (continued)
- The Spiral organ (of Corti) is the receptor epithelium for hearing.
- Consists of:
  - Supporting cells
  - Inner and outer hair cells (receptor cells)
    - Inner hair cells are the receptors that transmit vibrations of the basilar membrane.
    - Outer hair cells actively tune the cochlea and amplify the signal.

The Role of the Cochlea in Hearing

- The central part of the bony labyrinth
- Lies medial to the middle ear
  - Utricle and saccule—suspended in perilymph
  - Two egg-shaped parts of the membranous labyrinth
- House the macula—a patch of sensory epithelium.
The Vestibule

- **Macula**—contains receptor cells
  - Monitor the position of the head when the head is still
  - Contains columnar supporting cells
  - Receptor cells here are also called **hair cells**
  - Synapse with the vestibular nerve
    - Tips of hair cells are embedded in otolithic membrane
    - Membrane contains crystals of calcium carbonate called **otoliths**

The Maculae in the Internal Ear

- **Macula of saccule**
  - Otoliths
  - Hair bundle
  - Kinocilium
  - Stereocilia
  - Otolithic membrane
  - Vestibular nerve fibers
  - Hair cells
  - Supporting cells

The Semicircular Canals

- Lie posterior and lateral to the vestibule
- Anterior and posterior semicircular canals
  - Lie in the vertical plane at right angles
  - Lateral semicircular canal
  - Lies in the horizontal plane

The Semicircular Canals

- **Semicircular duct**—snakes through each semicircular canal
- **Membranous ampulla**—located within bony ampulla
  - Houses a structure called a **crista ampullaris**
  - Cristae contain receptor cells of rotational acceleration
  - Epithelium contains supporting cells and receptor hair cells
Structure and Function of the Crista Ampullaris

Figure 16.23a, b

(a) Anatomy of a crista ampullaris in a semicircular canal
(b) Scanning electron micrograph of a crista ampullaris (45X)

Crista ampullaris
Hair bundle (kinocilium plus stereocilia)
Hair cell
Supporting cell
Membranous labyrinth
Endolymph
Cupula
Cupula
Flow of endolymph
During rotational acceleration (a), endolymph moves opposite to the rotation (it lags behind due to inertia). This bends the cupula, exciting the hair cells. As rotational movement slows (b), endolymph keeps moving in the direction of the rotation, bending the cupula in the opposite direction from acceleration and inhibiting the hair cells.

Figure 16.23c

Structure and Function of the Crista Ampullaris

Equilibrium and Auditory Pathways

- The equilibrium pathway
  - Transmits information on the position and movement of the head
  - Most information goes to lower brain centers (reflex centers)
  - Cortical input to posterior insula
- The ascending auditory pathway
  - Transmits information from cochlear receptors to the cerebral cortex
  - To the Superior temporal gyrus

Auditory Pathway from the Organ of Corti

- Medial geniculate nucleus of thalamus
- Primary auditory cortex in temporal lobe
- Inferior colliculus
- Lateral lemniscus
- Superior olivary nucleus (pons-medulla junction)
- Cochlear nucleus
- Medulla
- Vestibulocochlear nerve
- Spiral ganglion of cochlear nerve
- Spiral ganglion of organ of Corti

Disorders of Equilibrium and Hearing

- Motion sickness—carsickness, seasickness
  - Popular theory for a cause—a mismatch of sensory inputs
- Meniere’s syndrome—equilibrium is greatly disturbed
  - Excessive amounts of endolymph in the membranous labyrinth

Disorders of Equilibrium and Hearing

- Deafness
  - Conduction deafness
    - Sound vibrations cannot be conducted to the inner ear
      - Ruptured tympanic membrane, otitis media, otosclerosis
  - Sensorineural deafness
    - Results from damage to any part of the auditory pathway
The Special Senses Throughout Life

- Smell and taste
  - Sharp in newborns
  - In the fourth decade of life
    - Ability to taste and smell declines

- Photoreceptors—fully formed by 25 weeks
- All newborns are hyperopic
- By 3 months—image can be focused on the retina
- By 6 months—depth perception is present

The Special Senses Throughout Life

- With increased age
  - The lens loses its clarity
  - The dilator muscles of the iris become inefficient
  - Visual acuity is dramatically lower in people over 70

- In the newborn
  - Responses to sounds are reflexive
  - Low-pitched and middle-pitched sounds can be heard
- In the elderly
  - Hair cells are gradually lost
  - Ability to hear high-pitched sounds fades
  - Presbycusis—gradual loss of hearing with age