Axial and Appendicular Skeleton -3Q (just read over slides)

Muscular System -3Q (just read over slides)

PNS (Zeroual) -15Q

Cranial Nerves

- 12 pairs pass through multiple foramina
- 1 and 2 attach to forebrain, rest start at brain stem
- all serve only head and neck
    - exception: vagus nerve
- most are mixed nerves
- On Occasion Our Trusty Truck Acts Funny; Very Good Vehicle Any How (names)
- Some Say Marry Money But My Brother Says it's Bad Business to Marry Money (func)

1. Olfactory nerves – sensory (smell)
    - nasal mucosa ⟶ olfactory bulbs
    - fibers of olfactory bulb neurons ⟶ olfactory tract ⟶ 1ary olfactory cortex
2. Optic nerves – sensory (vision)
    - formed by retina fibres
    - pass through optic foramen of orbit ⟶ optic chiasma ⟶ optic tracts ⟶ thalamus ⟶ optical radiation ⟶ occipital cortex
    - optic chiasma: point where both optic nerves converge
3. Oculomotor nerves – motor (eye movement)
    - supplies extrinsic muscles of eyeball
    - ventral midbrain ⟶ through bony orbit ⟶ eye
    - motor nerves to extrinsic eye
    - parasymp fibers to iris/lens/sensory afferents to midbrain
4. Trochlear nerves – motor (pulley)
    - innervates extrinsic eye muscle that loops through pulley ligament
    - dorsal midbrain ⟶ superior oblique eye muscle
5. Trigeminal nerves – both
    - largest cranial nerve
    - sensory fibres to face
    - motor fibres for chewing
    - Opthalmic, Maxillary, and Mandibular divisions
6. Abducens nerves – motor
    - controls extrinsic eye muscle that abducts eye
    - mixed nerve; mostly motor to lateral rectus muscle
7. Facial nerves – both (facial expression)
    - pons ⟶ lateral face
    - motor to lateral face
    - parasymp to lacrimal glands
    - sensory from anterior tongue
8. Vestibulo-cochlear nerves – sensory (hearing and balance)
    - cochlear (hearing) and vestibular (balance) branches fuse

9. Glosspharyngeal nerves – both (tongue and pharynx)
    - mixed nerves from medulla
    - motor to swallowing and gag reflex
    - parasymp to parotid glands
    - sensory from pharynx, posterior tongue (taste, touch, pressure, pain), and carotid sinus (chemoreceptor, baroreceptor)
10. Vagus nerves – both (goes beyond head/neck)
    - mixed nerves from medulla
    - parasymp motor to heart, lungs, viscera; somatic to pharynx/larynx
    - sensory from carotid sinus, pharynx/larynx (taste from proprioreceptors)
11. Accessory nerves – motor (head and neck)
    - accessory of vagus nerve
    - starts from spinal cord
    - formed by junction of cranial root and spinal root
    - mixed; mostly motor to pharynx/larynx/soft palate
        - spinal root supplies motor fibres to trapezium and sternocleidomastoid
12. Hypoglossal nerves – motor (beneath tongue)
    - primary tongue motor
    - mixed; mostly motor for mixing, swallowing, speech

Spinal Nerves

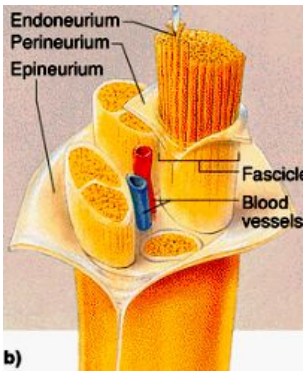
- 31 pairs
- all mixed nerves
- named by point of origin
- spinal cord → rootlets → root →spinal nerve → foramen → dorsal and ventral rami
    - rami carry both sensory and motor fibres
- except for T2-T12, all ventral rami branch and make lateral connections outside of spinal cord (nerve plexuses)
- fibres from different rami criss-cross in plexuses
    - each branch of a plexus has fibres from multiple spinal nerves
    - fibres from each ventral ramus travel to body periphery via different routes
    - each muscle in a limb gets nerve supply from multiple spinal nerves
    - if one spinal segment/root is damaged, whole limb muscle won't be paralyzed

1. Cervical plexus and neck (C1-C4)
    - deep in neck, under sternocleidomastoid muscle
    - most branches are cuteaneous nerves
    - phrenic nerve: most important; both motor and sensory fibres to diaphragm
2. Brachial plexus and upper limb (C5-C8, T1)
    a. Axillary nerve → shoulder (deltoid muscle)
    b. Musculocutaneous nerve → biceps brachii and brachialis
        i. Flex arm
    c. Median nerve → flexor muscles in anterior forearm and palm
        i. pronate forearm
        ii. flex wrist/fingers
        iii. oppose thumb

    d. Ulnar nerve (funny bone) → medial to elbow, follows ulna along medial forearm
        i. flex wrist/finger
        ii. abduct fingers
    e. Radial nerve (largest) → to humerus and dorsal hand
        i. extend elbow
        ii. supinate forearm
        iii. extend wrist/fingers
        iv. abduct thumb
3. Back - dorsal rami follows segmented plan
4. Anterolateral Thorax (T1-T12)
    - simple and segmented
    - intercostal nerves: to intercostal muscles, anterolateral thorax
5. Lumbar plexus (L1-L4)
    a. Femoral nerve: anterior thigh muscles
        i. flex thigh
        ii. extend knee
    b. Obturator nerve: medial thigh
        i. adductor muscles
6. Sacral plexus (L4-S4) – behind lumbar plexus
    a. Sciatic nerve: posterior thigh, then diverges into
        i. Tibial nerve: behind knee joint to posterior calf and sole of foot
        ii. Common fibular nerve: to knee joint, calf, dorsum of foot
    b. Superior and inferior gluteal nerves: to buttocks
    c. Pudendal nerve: muscles of skin and perineum (erection, urinatino)

Dermatone

- Dermatone: an area of skin innervated by cutanous branches of a single spinal nerve
- Endoneurium: loose CT that encloses nerve fibre; associated myelin or neurilemmal sheath
- Perineurium: coarser CT around group of fibres (fascicle)
- Epineurium: tough fibrous sheath around al fascicles to make a nerve



Integumentary System 4Q

- Integumentary system = skin and derivatives (sweat, oil glands, hair, nails)

Structure of Skin

- 2 regions: epidermis (epithelial layer, thick, keratinized, stratified squamous epithelium), and dermis (CT)

Epidermal Cells

1. Keratinocytes: produce keratin
2. Dendritic cells (Langerhans' cells): star shaped, move to epidermis from bone marrow; macrophages activate immune system
3. Melanocytes: produce melanin, deepest layer of epidermis, transfer melanosomes to adjacent keratinocytes (skin colour)
4. Tactile cells (Merkel cells): at epidermis/dermis boundary, have disc-like sensory nerve ending (touch receptors)

Layers of the Epidermis

Thick Skin

1. Stratum corneum (most superficial) – dead cells
2. Stratum lucidum – clear layer
3. Stratum granulosum – deteriorating organelles
4. Stratum spinosum
5. Stratum basale (deepest) – mitotic cells
6. Dermis

Thin skin – does NOT have stratum lucidum

Layers of the Dermis

- cell types in dermis: fibroblasts, macrophages, amst cells, WBCs
- semi-fluid matrix; collage, elastin, reticular fibres, nerve fibres, blood/lymphatic vessels, hair follicles, oil, sweat glands

1. Papillary layer (thin, superficial) – areolar CT
    a. Dermal papillae: has capillaries and nerve endings for touch, pain; indents epidermis
    b. Friction ridges: dermal papillae over ridges (hands, soles) which form dermal ridges and epidermal ridges; enhance grip
2. Reticular layer (thick, deep) – dense irregular CT
    a. thick bundles of collagen (strength, maintain hydration)
    b. elastic fibres (stretch/recoil)
    c. Cleavage (tension) lines

Lines

- Striae: from extreme stretching, dermis tears
- Blister: fluid-filled pocket that separates epidermis and dermis
- Flexure lines: dermal folds; where dermis is closely attached to underlying fascia

Hypodermis

- below dermis
- superficial fascia, subcutaneous
- aerolar CT, blood vessels, adipose tissue

- anchors skin to underlying structures
- absorbs shock
- insulates/stores fat

Pigments

1. Melanin: made in skin; colour produced depend on type/amount/keratinocyte retention of pigment
    a. long sun exposure – causes elastic fibres to clump (leathery skin), can alter DNA of skin cells (skin cancer)
2. Carotene: yellow-orange, in plant products; deposits in keratinocytes and hypodermis
3. Hemoglobin: from capillary circulation; gives pink-blue hue
    a. Cyanosis: occurs when hemoglobin is poorly oxygenated in white people; is apparent in nailbeds of darker people

Accessories

- Hair/hair follicles: sense, guard head, shield eyes, filter inhaled air; made of hard keratin
    - Hair shaft
        - Medulla: large cells with air in between (absent in fine hair)
        - Cortex: layers of flat keratinocytes (pigmented)
        - Cuticle: single layer of cells
        - split ends – occurs when cuticle wears away at end of hair shaft, exposing keratin fibrils in cortex and medulla
        - hair turns gray when melanin production decreases and air bubbles replace melanin in hair shaft
    - hair shaft shape/size determines hair texture
        - round – straight
        - thick oval – wavy
        - medium oval – curly
        - thin oval – spiral/coiled
        - larger follicle = thicker hair
    - Hair structure
        - Shaft: projects from skin
        - Root: embedded in skin (in follicle)
        - Bulb: deep end of follicle; has papilla and root hair plexus
        - Follicle: hair matrix; cT root sheat and epithelial root sheath
        - Arrector pili muscle: one per follicle; contracts to pull hair up
        - Sebaceous gland: holocrine gland; secretes sebum (oily)
- Nails: scale-like modification of epidermis
    - Free edge
    - Body (hyponychium, nail bed, nail plate, nail matrix)
    - Nail folds (2 lateral, 1 proximal)
    - nail can indicate health
        - yellow – fungal infection, respiratory or thyroid gland problem
        - thick – fungal infection
        - spoon – iron deficiency

        - Beau's lines (horizontal): malnutrition
- Sweat glands
    - Merocrine: common; on palms, soles, forehead; coiled tubular glands with pore
        - thermoregulation
    - Apocrine: axillary and anogenital areas: larger, empty into hair follicles; make sweat/fat/proteins
        - 'sexual scent glands'
    - Ceruminous glands: secrete wax (cerumen) in ear
    - Mammary glands: secrete milk

Functions of Skin

1. Protection
    a. Chemical
    b. Physical
    c. Biological (macrophages, Langerhans cells)
2. Body temperature
3. Cutaneous sensation
4. Metabolic (vitamins, carcinogens)
5. Blood reservoir
6. Excretion

Burns

- First degree: only epidermis
- Second degree: epidermis and upper dermis
- Third degree: epidermis and all of dermis
- repairs
    - first and second degrees heal on their own
    - major burn patients must have lots of nutrients and water supplied via IV
    - must avoid infections
    - skin grafts suggested
- rule of 9s: each section of body is 9%

Nervous System Fundamentals -7Q

Membrane Potential

- membrane potential = -70mV
- gives rise to current flow
    - Ohm's law: current (I) proportional to voltage (V)
- changes in RMP = allow neurons to receive/send signals
- Graded potential: brief, short distance in all directions; dies in few mm; may make AP
    - opposite charges attract → create local currents that depolarize adjacent sections of membrane
- Action potential: long distance in one direction (away from origin)
    - only membranes with excitable membranes make AP

- all-or-nothing response

1. Resting state (-70): no ions flowing
2. Depolarization (+30): Na+ rushes in, when threshold reached, all Na+ channels open
3. Repolarization (-70): K+ flows out
4. Hyperpolarization (-80): K+ keeps flowing out; Na/K ATPase pump restores RMP

Synapses

- presynaptic neuron → synapse → postsynaptic neuron
- synaptic cleft is 40x larger than NT size
- Chemical synapse: receive chemical NTs
  - Ca enters → binds to synaptotagmin → changes conformation and interacts with Snare proteins
  - v-snare and t-share fuse and NT released; 300 vesicles per AP
  - stimulus increase = impulse frequency increase = more vesicles released
  - when NT binds to receptor, ion channels open = graded potential
  - NT effects end via
    - reuptake by astrocytes/presynaptic neuron
    - diffusion away from synapse
    - degradation by enzymes
  - Prozac → Serotonin selective reuptake inhibitor
  - postsynaptic graded potential strength increases with amount of NT and length of time NT is in synapse
- Electrical synapse (uncommon): direct contact of neurons via gap junctions

NTs

- language of NS
- can stimulate/inhibit other neurons/effector cells
- most neurons make 50+ NTs
- possible to co-release 2 NTs from same vesicle
- Classification by Structure
  1. Acetylcholine
  2. Biogenic amines (serotonin, NE, dopamine)
  3. Amino acids
  4. Peptides
  5. Purines
  6. Gasses/lipids
- Classification by Function
  1. Excitatory (glutamate)
  2. Inhibitory (GaBA, glycine)
  3. Both (ACh, NE)
     a. ACh excites at neuromuscular junction (skeletal muscle)
     b. Ach inhibits in cardiac muscle
- Classification by Action
  1. Direct (ACh, a.a.): bind to ion channels

    a. rapid response
2. Indirect (biogenic amines, peptides, gasses): via G protein second messenger
    a. long lasting

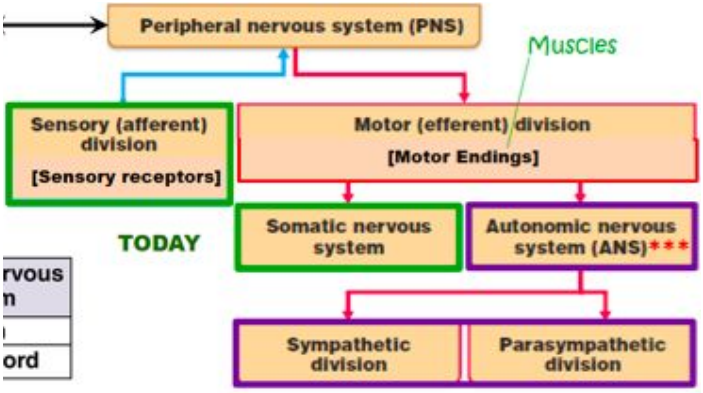
Receptors

- Channel linked (ionotropic) receptors
    - direct, simple, fast
    - chemically-gated ion channel
    - Excitatory receptors: channels for Na, K, Ca cause depolarization
    - Inhibitory receptors: channels for Cl- cause hyperpolarization
- GPCR (Metabotropic receptors)
    - indirect, complex, slow, long-lasting
    - ligand (1st messenger) → receptor → G-protein → enzyme → second messenger
    - cAMP: opens/closes ion channels, activates enzymes, activates genes

PNS -16Q

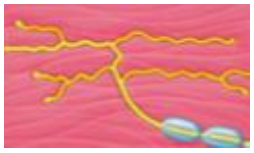
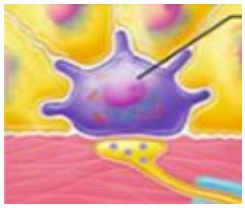
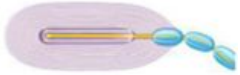
Sensory Receptors

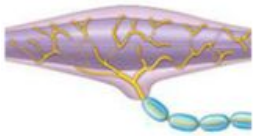
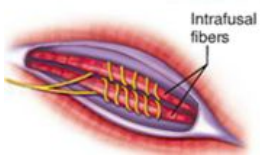
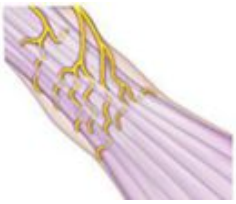
- stimulus → GP → AP along afferent nerves → CNS
- Sensation: awareness of stimulus
- Perception: interpretation
- Classification by Type of Stimulus
    a. Mechanoreceptors
    b. Thermoreceptors
    c. Photoreceptors
    d. Chemoreceptors
        i. molecules smelled/tasted
        ii. changes in blood/fluid chemistry
    e. Nociceptors
    f. ESP – mind reading (not proven)
- Classification by Location
    1. Exteroreceptors – near body surface, senses external stimuli
    2. Interoreceptors (visceroceptors) – inside body, senses chemical change/temp/pain/thirst/hunger



3. Proprioreceptors – inside body on muscles/joints/etc, monitor stretch/movement

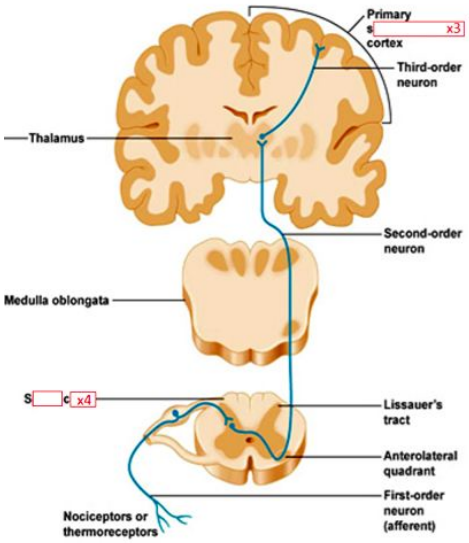
- Classification by Structure
  - 5 special senses: vision, hearing, equilibrium, smell, taste
    - housed in complex sense organs
  - General senses – monitor most sensory info
    - touch, temp, pain, muscle
    - may or may not be encapsulated by CT

Structural Class	**Location**	**Stimulus**
Free nerve endings 	Body tissues, CT, joints, epithelia, glands	Thermos, chemo, mechano, noci
Modified free nerve endings: Tactile Merkel discs 	Basal layer of epidermis	Mechano
Hair follicle receptors 	In and around hair follicle	Mechano
Tactile Meissner's corpuscles 	Dermal papillae of hairless skin	Mechano (low freq vibration)
Lamellar (Pacinian) corpuscles 	Dermis, hypodermis, bones, tendons, ligaments, hairless skin	Mechano (hi freq vibration)
Bulbous corpuscles (Ruffini Endings)	Dermis, hypodermis, joints	mechano

		
Muscle spindles 	Skeletal muscles	Muscle stretch/length
Tendons 	Tendons	Tendon strength, tension
Joint kinesthetic receptors 	Joint capsules	Joint stretch

Levels of Sense Perception

- Somatosensory System: 3 levels of neural integration
  1. **Receptor** (input from extero/intero/prorprio)
     - transduction: receptor converts stimulus to electrical event
     - if AP created, travels to CNS
     - frequency of AP encodes strength/duration of stimulus
     - stimulus must be in receptive field of receptor, and much match receptor
     - Generator Potential: 1 type of GP; receptor part of sensory neuron
     - Receptor Potential: 1 type of GP; separate receptor cell releases NT to sensory neuron
     - Response of sensory receptor to constant stimulus declines over time
     - Phasic response: fast-adapting, report changes in environment
       i. stimulus creates jump in potential, but potential decreases again when stimulus stays constant
       ii. lamellar, tactile corpuscles
     - Tonic response: slow, sustained; no adaptation



i. Nociceptors, proprio (protects us from dangers))

2. **Circuit** (processing in ascending pathways)
   - impulses delivered along spinal cord to 1ary somatosensory cortex
   - First order: receptor → cell body in spinal cord
   - Second order: move up spinal cord to brain
   - Third order: send message to cerebral somatosensory cortex
3. **Perceptual** (processing in cortical sensory areas)
   - sensory input interpreted by cerebral cortex
   - ability to identify sense depends on location of target neuron in cortex
   - each sensory nerve fibre projects to a specific location in the cortex
     i. 'labelled line'
   - Features of sensory perception:
     i. Perceptual detection (presence of stimulus)
     ii. Magnitude estimation (intensity of stim)
     iii. Spatial discrimination (site of stim) – tongue discriminates location better than back
     iv. Feature abstraction (complex aspects like velvet)
     v. Quality discrimination (tastes)
     vi. Pattern recognition (face, melody)

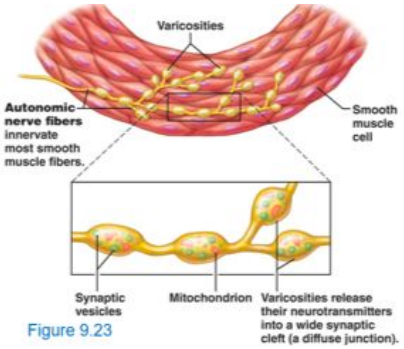
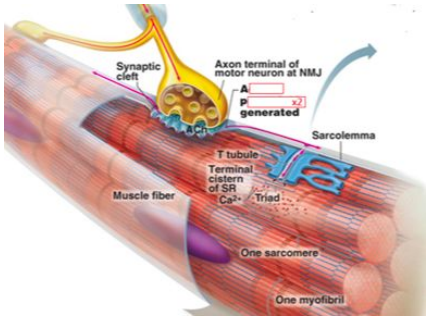
- Note: sensory info is both afferent (going to brain) and efferent (coming from brain) so brain talks to receptors

Pain Perception

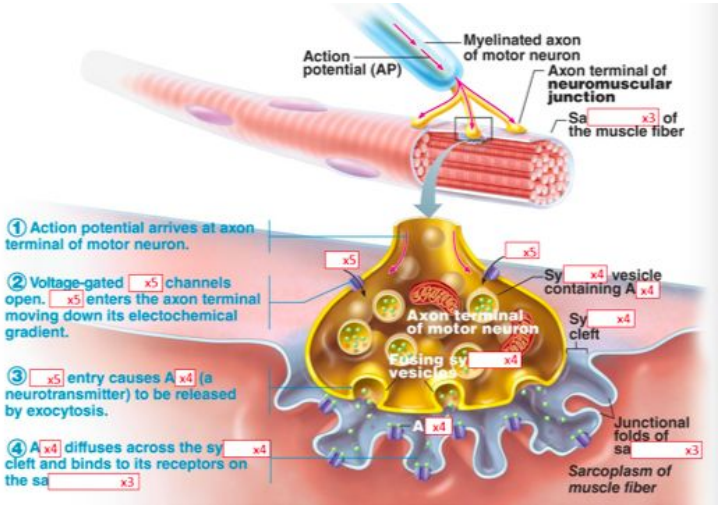
- pain is valuable warning of danger
- pain receptors activated by temp, pressure, chemicals from injured tissue (Bradykinin)
- signals transmitted via NTs (substance P or glutamate → spinal cord → CNS)
  - fast A fibres (sharp) vs slow C fibres (burning) release NTs
  - NTs activate 2nd order fibres in spinothalamic tract
- brain relays descending pain-supressing signals (endorphins, enkephalins)
  - somatosensory impulses travel both ways (to and from brain)

- we all have same pain threshold, but varying tolerance
- Visceral Pain
  - noxious stimulation of thoracic/abdominal organs
  - dull ache/burn
  - tissue stretch, ischemia, chemicals, muscle spasm
- Referred Pain
  - visceral pain afferents travel along same pathway as somatic pain fibres
  - pain stimuli from heart attack felt in left arm/jaw

Hyperalgesia and Phantom Limb Pain
- body maintains steady state injury-pain correlation
- can be disrupted by long-lasting/intense pain
- Hyperalgesia: pain magnification (chronic pain)
- Phantom Limb Syndrome: perceived pain in an amputated limb
  - via NMDA receptors in spinal cord
  - 'learned' hyperalgesia
- surgeons now do amputations with general AND spinal anesthesia
  - blocks neurotransmission in spinal cord; decreases chance of PLS

Neuro-Smooth Muscle Junction	**Neuro-Skeletal Muscle Junction**
 Figure 9.23 - autonomic branch of PNS - simple varicosity network - ACh/NE - slow (2nd messenger)	 - somatic branch of PNS - complex nerve terminals - always ACh - fast: ion channels

Neuro-Skeletal Muscle Junction
- end plate potential produced at the neuromuscular junction when ACh binds to receptors on sarcolemma
  - EPP is type of GP
- as EPP spreads to adjacent areas of membrane, AP formed



- AP → contraction of muscle fibre

Motor vs Sensory Divisions

Motor	Sensory
- motor endings connect to muscle fibres - descending efferent circuits - result: movement - 3 levels: segmental → projection → precommand	- sensory receptors connect to sensory nerves - ascending afferent circuits - result: perception - 3 levels: receptor → circuits → perception

Motor Control

- 3 levels of control
    1. Segmental – only in spinal cord (lowest level)
        a. Reflexes: autonomic, only CNS involved
        b. Central pattern generator (CPG): control rhythmic motor activities (not autonomic), oscillating inhib/excit neurons set rhythms
    2. Projection –in motor cortex; consciousness
        a. Direct pyramidal tract: initiated by upper motor neurons of motor cortex (voluntary skeletal movement)
        b. Indirect: initiated by brainstem motor nuclei (modify/control segmental level movements)
        c. highest level of consciousness, BUT not ultimate planner
    3. Precommand – in basal nuclei and cerebellum (highest level);
        a. complex motor activity, stop/start, coordinate movements with posture, block unwanted motions, monitor muscle tone
        b. Cerebellum: sensorimotor integration, target of ascending inputs, corrects errors via thalamus, linked indirectly to spinal cord via basal nuclei in brainstem
        c. Basal nuclei: inputs from cortical areas, outputs to premotor/prefrontal cortex via thalamus, deals with more complex control than cerebellum
- for projection and segmental levels, there is always feedback to precommand level
- cortex says 'I want to do this' and precommand lays out groundwork to do so

Types of Reflexes

1. Inborn reflex – intrinsic, present from birth
    a. rapid and predictable
    b. unlearned, involuntary
    c. may or may not be aware of reflex response (drop hot pot vs change in BP)
    d. can be modified
2. Learned reflex – acquired
    a. from practice and repetition
    b. driving a car

Reflex Arc (brain not involved)

1. Receptor
2. Sensory neuron (afferent impulse → CNS)
3. Integration center
    a. sensory neuron may branch when it enters gray matter of spinal cord
    b. monosynaptic link (no interneuron)
    c. polysynaptic link
4. Motor neuron (efferent impulse → effector)
5. Effector

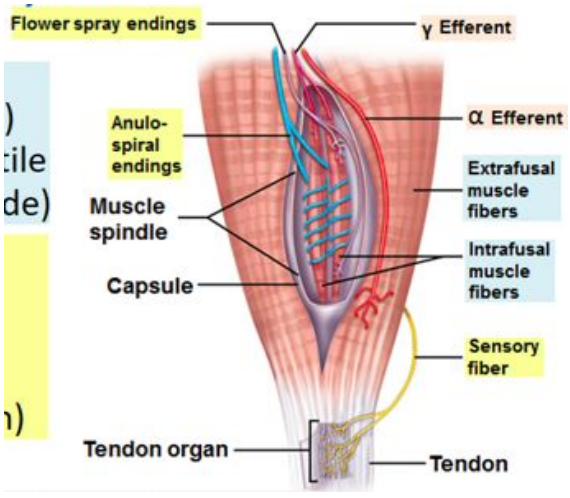
Spinal Reflexes

- somatic actions mediated by spinal cord
- brain is advised and can modify response, but brain not directly involved
    - pulling arm away vs deciding to scream or not
    - must still be conscious to have reflexes, so brain signals required
- strange reflexes = pathology of specific higher cortical regions

Muscle Spindle

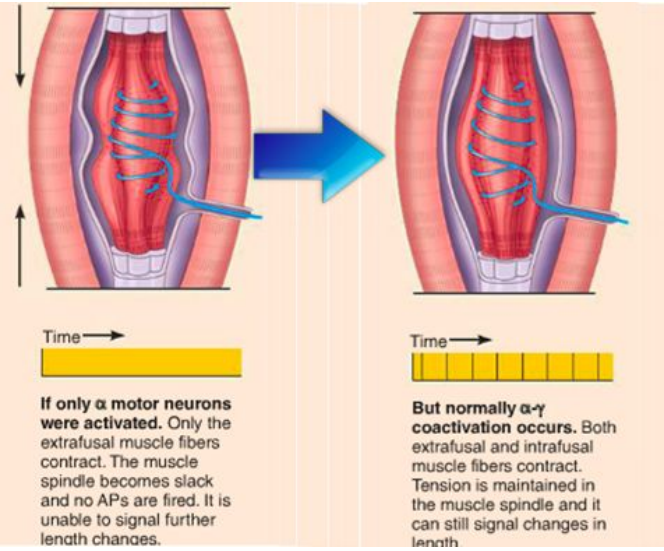
- sensory proprioceptor in muscle fibre measures its length
- mediates stretch reflex; FB loop controls rate of lengthening
- muscle lengthens → MS detects change → spinal cord → muscle contracts (spinal reflex)
- protective: prevents tearing
- CNS can override spinal reflex and tell muscle to keep lengthening

- **Anatomy of MS**
    - capsule
    - muscle fibres (intrafusal vs extrafusal)
        - intrafusal has non-contractile region in center)
    - sensory nerves
        - anulospiral: wrap around intrafusal
        - flower spray: attach to ends of intrafusal
        - sensory fibre to TO
    - motor nerves
        - y Efferent to MS
        - a Efferent to extrafusal fibres



Muscle Lengthens/Spindle Stretch

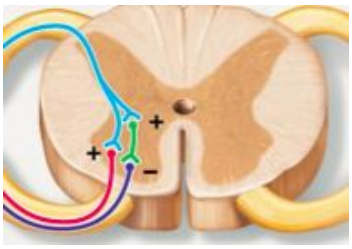
- when muscle stretches, MS is activated, APs change and brain informed that muscle is moving



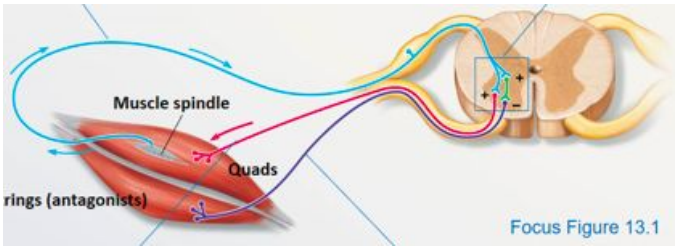
Muscle Shortens/Spindle Slack
- both a and Y motor fibres are co-activated (extrafusal and intrafusal contract); MS can signal changes in length, telling CNS muscle has slacked

Tendon Organ
- sensory proprioceptor in tendon measures its tension
- mediates stretch reflex; FB loop controls amount of tension
- muscle lengthens → force on tendon → TO detects force → spinal cord → muscle told to stop lengthening
- prevents tendon from ripping off bone

Antagonistic Muscles
- flexing vs extending of opposing muscles
  - hamstrings vs quadriceps (when one contracts, other relaxes)
  - single sensory stimulus can give rise to opposite effects in flexors and etensors



Patellar Stretch Reflex
- reciprocal inhibition ensures constant muscle length
  - stand → knees start buckling → quads stretch



1. quad stretch activates MS: output goes to spinal cord (blue)
2. sensory neurons synapse with alpha motor neurons → excite extrafusal fibres of quads; sensory neurons also synapse with interneurons that inhibit motor neurons of hamstrings
3. efferent impulses (red) cause stretched quad to contract
4. efferent impulses (purple) to opposing muscles reduced, further dampening quad stretch

Knee-Jerk Stretch Reflex
- test sensory and motor connections and spinal cord functioning

1. tap patellar ligament = quadriceps stretch and MS excited
2. afferent impulses (blue) go to spinal cord and synapses with motor/inter neurons
3. motor neurons (red) send activating impulses to quadriceps to make it contract (extends knee)
4. interneurons make inhib synapse with ventral horn neurons (purple) that prevent antagonist muscle from resisting quad contraction

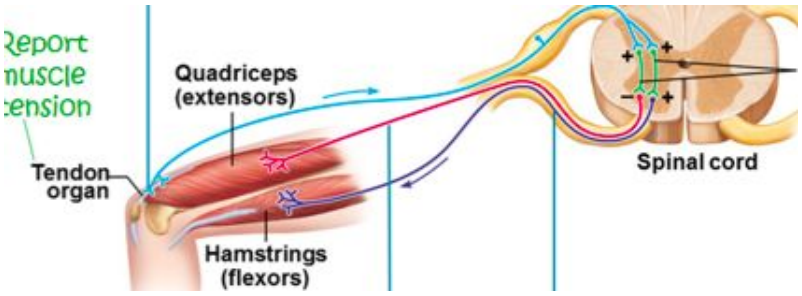
Clinical Importance of Stretch Reflexes

- hyperactive reflexes: when lesions of corticospinal tract reduce reciprocal inhibition
  - ex stroke patients
- hypoactive/absent reflexes: peripheral nerve damage/ventral horn injury
  - ex Chronic diabetes, neurosyphillis, coma
  - tertiary syphilis, tabes dorsalis = dorsal horn injury
    - after decades of infection, morbid cutaneous sensations, formication, etc.

Tendon Reflex

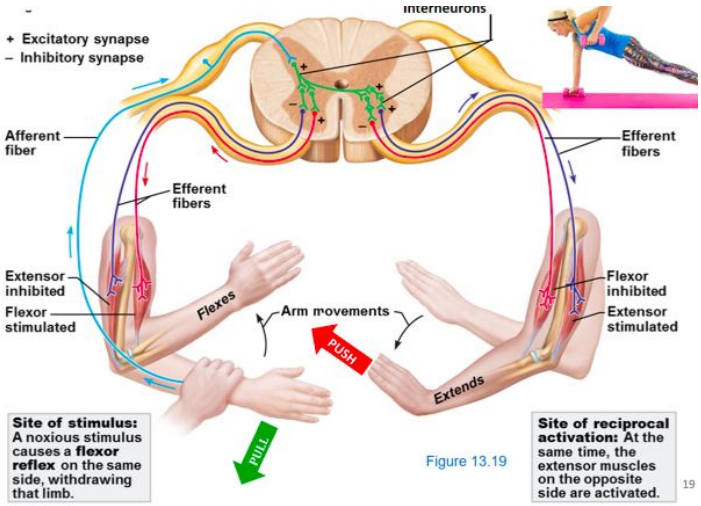
- opposite of stretch reflex
- reciprocal activation of antagonist prevents muscles from tearing
- ensures smooth start/finish of contraction

1. knee begins to straighten, quads contract, TO activated
2. afferent fibres synapse with interneurons
3. efferent impulses (red) to muscle with stretched tendon (quads) dampened so muscle relaxes and reduces tension
4. efferent impulses purple) to antagonist cause it to contract



Flexor and Crossed-Extensor Reflex

- pull sensation of one arm talks to muscles on opp side of body
- ex; attacker pulls your right arm towards him → your right arm resists by pulling towards yourself, but left hound pushes outwards to attacker



Overview of Spinal (Deep) Reflexes

	Same side		Opp side	
Reflex	Agonist	Antagonist	Agonist	Antagonist
Patellar	+	-		
Knee-Jerk	+	-		
Tendon	-	+		
Flexor and Crossed-Extensor	+	-	-	+

Superficial Reflexes

- tests for intact corticospinal tract and cord-level structure
- Plantar Reflex
  - draw blunt object up along lateral sole of foot
  - normal: toes curl downwards
  - abnormal: Babinski sign; toes spread apart and big toe goes up
    - normal in infants, otherwise there is upper motor neuron lesion
- Abdominal Reflex
  - stroke skin of abdomen towards belly button
  - normal: belly button moves towards stimulus
  - checks integrity of ventral rami from T8-T12

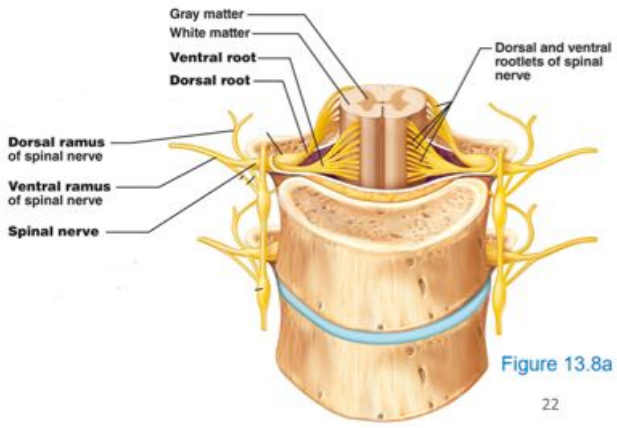
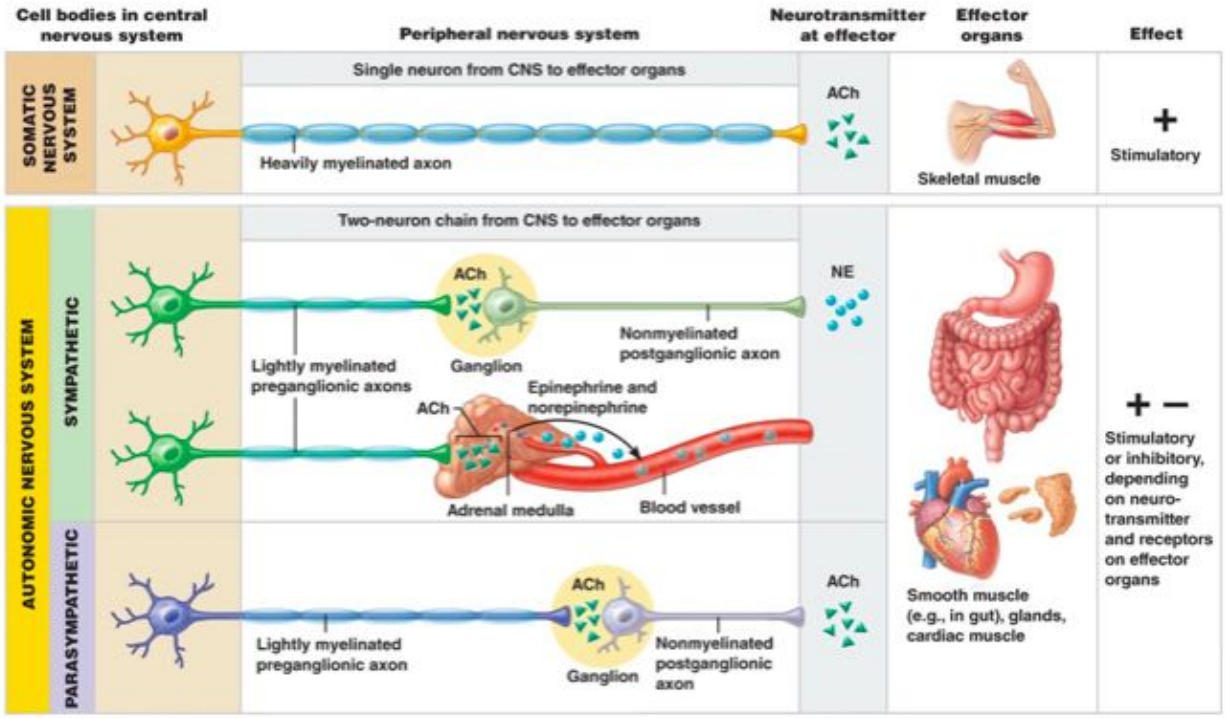


Figure 13.8a

ANS -11Q

- there are some sensory nerves in the ANS, even though it falls under motor division
- motor neurons that innervate viscera and stabilize internal environment
- respond to sensory signals from viscera
- functions: support for body activities, shunts blood to needy areas, controls HR, BP, temp, stomach secretions

Somatic VS Autonomic



	Somatic	Autonomic
Target Organ	Skeletal muscle	Smooth/cardiac muscle, glands
Pathway	1 neuron from CNS → target no synapse between neurons	2 neurons from CNS → target synapse in autonomic gangli or adrenal medulla
Axonal Fibres	Thick myelination	Thin myelination
NT	ACh	ACh or NE
Effect	Excites	Inhibits or excites

PSNS vs SNS

- PSNS: defacation, digestion, diurises
- SNS: exercise, excitement, emergency

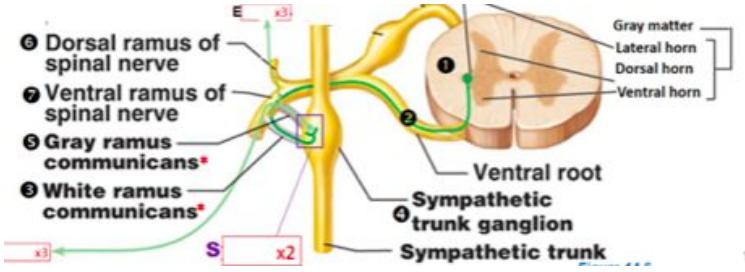
	Parasympathetic	Sympathetic
Origin	Brain, sacral cord Go close to target organ	Thoracic, lumbar cord
Location of ganglia	Near or in effector organs	Near cord
Fibre length	Long preganglionic Short postganglionic	Short preganglionic Long postganglionic
NTs	ACh - rapidly destroyed after use	ACh and NE -NE inactivated slowly
Duration	Short, localized	Long , widespread (or local)

PSNS

- Innervation of head via terminal ganglia close to organs; preganglionic fibres
  - CN 3 (occulo): pupils, lenses
  - 7 (facial): nasal, lacrimal, salivary glands
  - 9 (glossophary): parotid salivary glands
- CN 10 (vagus): HR, constricts lungs, digestion, urination, relaxed genatalia
  - Serve almost all organs in thorax/abdomen
  - Arise from dorsal motor nuclei of medulla
  - Synapse in terminal ganglia within walls of organ
- Vagus Nerve Stimulation: treatment for intractable epilepsy; drug-resistant depression

SNS

- More complex than PS division: innervates more organs



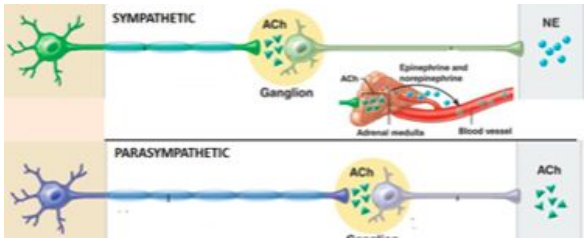
- All same as PSNS, but also visceral superficial structures (sweat glands, hair-rising pili muscles, smooth muscles in walls of vessels
- Preganglionic fibres from cell bodies of lateral horns of T1-L2, leave via ventral root
- Spinal cord → preganglionic fibres leave via ventral root → myelinated white ramus → synapse in sympathetic trunk ganglia (paravertebral ganglia) → unmyelinated gray ramus → dorsal/ventral ramus of spinal nerve → effector
- 3 pre-postganglionic connections possible in symp trunk
    1. synapse at same level
    2. preganglionic axon ascends/descends before synapsing (paired)
    3. preganglionic axon passes through sympathetic trunk ganglion without synapse (unpaired)
        a. form a preganglionic splanchnic nerve
        b. synapse in a collateral ganglion
        c. isolated ganglia
- head and thorax: preganglionic fibres synapse in superior, middle, inferior cervical ganglia
- abdomen: splanchnic nerves → abdominal organs / pelvis
    - most pre nerves T5 and below use collateral ganglia
- adrenal gland synapses: some splancnic nerves synapse only when they reach adrenal medulla
    - pregang → medulla secretes hormones into blood (NE, E)

Visceral Reflex Arc

1. Receptor in viscera
2. Visceral sensory neuron (afferent)
3. Integration centre (pregang neuron, or dorsal horn interneuron, or in walls of GI)
4. Motor neuron (2 neuron chain)
    a. Preganglionic motor neuron
    b. Post ganglionic motor neuron
5. Visceral effector

- Ex; baroreceptor reflex, referred pain, etc.

ANS NTs



- Cholinergic Receptors: Nicotinic, Muscarinic
- Adrenergic Receptors: beta 1, beta 2, beta 3, alpha 1, alpha 2

Drug Effects

Drug Class	Receptor Effect	Effects	Ex	Use

PS-mimetic	Mimics ACh in muscarinic	Enhances PS	bethanechol	Difficulty peeing
PS-lytic	Blocks ACh in muscarinic	Inhibits PS	atropine	Decrease saliva
S-mimetic	Mimics NE in adrenergic	Enhances S	Albuterol	Asthma
S-lytic	Blocks NE in adrenergic	Inhibits S	Propranolol	Hypertension

Interactions of ANS Divisions

- Antagonistic interactions
- Usually one predominates
- Sometimes both cooperate (PS-erection, S-ejaculation)
- Blood vessels only have SNS innervation
  - Blood shunted to needy organs in circulatory shock
- Renin released from kidney to increase BP by SNS
- Adrenal medulla hormones activated only by SNS

Target Organ	PSNS effects	SNS effects
Eye	Lens bulges	Lens flattens
Lacrimal glands	Secretions stimulated (tears)	Secretions inhibited
Lungs	Contracted bronchioles	Dilated bronchioles

Regulation of ANS by CNS

- Hypothalamus is boss
  - Anterior (PSNS)
  - Posterior (SNS)
  - Mediates emotions via amygdala
  - Emotional and visceral brain
- Brain stem: most direct influence
- Spinal cord
- Cerebral Cortex: modifies ANS unconsciously
  - Frightening memory = high HR
  - Think of food = saliva
  - Biofeedback = control HR, BP

ANS Problems

- Autonomic neuropathy (damage to autonomic nerves)
  - Common complication of diabetes, other illnesses
  - Erectile dysfunction, reduced vaginal lubrication, dizzy standing, urinary incontinence, sweating impaired
- Hypertension
  - Overactive sympathetic vasoconstriction
  - Heart/artery damage, etc
- Raynaud's Disease

- Increased vasoconstriction
- Cold stress → blue fingers/toes → ischemia/gangrene

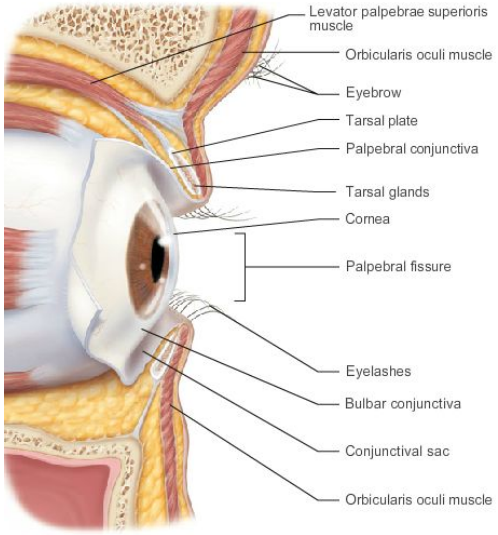
- Autonomic Dysreflexia
  - Seen in quadriplegia, spinal cord injuries above T6
  - Skin pain, full bladder, headache, stroke, death

Vision -15Q

Accessory Structures of the Eye

Surface Anatomy

1. Eyebrow hairs protect eye
2. Palpebrae (eyelids): mobile, protect eye
3. Eyelashes: hair follicle receptors sense touch; ciliary sweat glands at base
4. Palpebral fissure (between eyelids)
5. Medial and lateral commissures: medial/lateral angles of eye
6. Iris: coloured part
7. Pupil: opening where light enters eye
8. Sclera: white of eye
9. Conjunctiva: transparent membrane, covers eye and moistens
10. Lacrimal caruncle: contains sebaceous and sweat glands



Lateral View

1. Levator palpebral superioris muscle: raises eyelid to open eye
2. Orbicularis oculi muscle: encircle and closes eye
3. Tarsal plate: supports and anchors eyelid muscles
4. Palpebral conjunctiva: mucous membrane lines eyelids
5. Palpebral fissure: between eyelids
6. Orbicularis oculi muscle: same as 2
7. Tarsal glands: secrete oils that lubricate eye
8. Cornea: anterior transparent surface, focuses light
9. Bulbar conjunctiva: mucous membrane over anterior eyeball; doesn't cover cornea
10. Conjunctival sac: slit between eyeball and eyelids (contacts, eye drops)

Lacrimal Apparatus/Tears

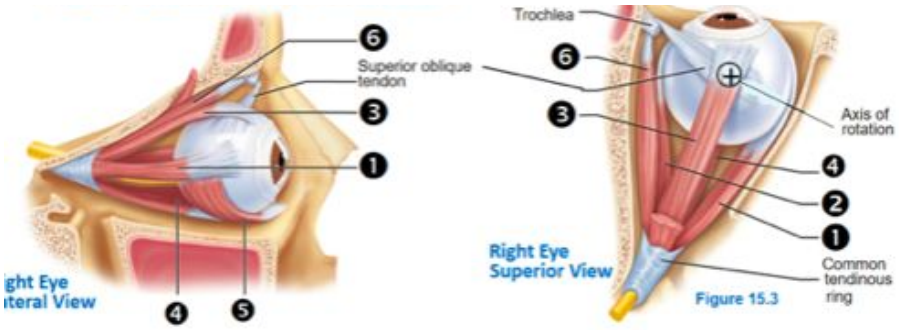
- Lacrimal gland (under eyelid, above lateral end of eye) produces lacrimal secretions:
  - mucus, antibodies, lysozyme
  - clean, protect, moisten eye surface
  - excessive production = nasal congestion
- lacrimal gland → lacrimal puncta → lacrimal canaliculi → lacrimal sac → nasolacrimal duct → nasal cavity

Infected Eye Accessories

- Chalazion: cyst from infected tarsal gland
- Stye: infected ciliary gland (base of eyelash)
- Conjunctivitis: inflammation of conjunctiva = red eyes
- Pink eye: bacterial/viral conjunctival infection (contagious)
- Watery eyes: cold/nasal inflammation swells lacrimal duct so tears cannot drain

Eye Muscles

1. Lateral rectus: moves eye laterally (abducens)
2. Medial rectus: moves eye medially (oculomotor)
3. Superior rectus: moves eye up, medially (ocu)
4. Inferior rectus: moves eye down, medially (ocu)
5. Inferior oblique: moves eye up, laterally (ocu)
6. Superior oblique: moves eye down, laterally (trochlear)



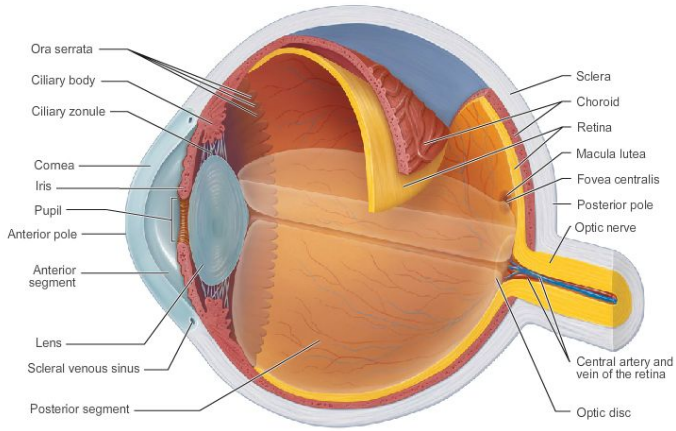
- All originate from orbit wallas and insert on outer surface of eyeball
- 2-12 muscle cells per motor unit
- 5 offsets medial turning when 3 elevates eye
- 6 offsets medial turning when 4 depresses eye

Eye Muscle Conditions

- Diplopia (double vision): external movements of both eyes uncoordinated due to weakness/paralysis of eye muscle(s)
    - due to chronic or acute neurologic disorder
- Strabismus (cross-eyed): congenital weakness of eye muscle(s), affected eye rotates to one side
    - body adapts by ignoring affected eye's input (blind)
    - treat: eye exercises, surgery, patch stronger eye

Structure of Eyeball

- hollow sphere, 2 poles (anterior, posterior)
- Lens: focusing, 2 regions (epithelium and fibres), avascular
- Optic nerve: CN 2 (sensory) connects eye to brain
- wall made of outer/middle/inner layers
- Outer Fibrous Layer (CT)
    - Sclera: protects, shapes, anchors muscles



    - Cornea: transparent, regenerative, well innervated (pain), avascular
- Middle Vascular Layer
    - Choroid: blood vessel rich, brown pigment absorbs light to minimize internal reflection
    - Ciliary body/muscles: encircle lens, ciliary zonule suspends lens
    - Iris: coloured part, has opening (pupil)
        - Sphincter pupillae layer: contracts to make pupil smaller = miosis (PSNS)
        - Dilator pupillae layer: contracts to make pupil bigger = mydriasis (SN)
- Inner Layer: **Retina**
    - Photoreceptors send light to brain via optic nerve
        - Rods: outside macula, more sensitive, dim, peripheral, B&W
        - Cones: in macula, bright light, colour
    - Optic disc: where optic nerve exits eye (blind spot)
    - Macula lutea with fovea centralis in its centre: most sensitive part
    - Central artery and vein: supplies blood
    - outer pigmented layer absorbs light and renews/nourishes photoreceptors
    - inner neural layer has photoreceptors, bipolar cells, ganglion cells
    - light strikes photoreceptors → electrical signal → bipolar cells → ganglion cells make AP → optic nerve
        - amacrine cells help visual processing (horizontal)
- 2 segments (anterior in front of lens, posterior behind lens)
    - posterior: vitreous humour, transmits light, maintains intraocular pressure
    - anterior: aqueous humour, also maintains IOP, supplies O2, nutrients, remove waste
        - iris divides anterior segment into anterior and posterior chambers
        - aqueous humour formed by ciliary process → posterior chamber → through pupil → anterior chamber (and vitreous humour) → reabsorbed by scleral venous sinus

Opthalmoscope
- can see central artery/vien, blood vessels, optic disc
- can give alpha agonist (phenylephrine) to dilate pupil
- can detect hypertension, diabetes, glaucoma, macular degeneration, retinal detachment

Eyeball Conditions
- Retinal detachment: vitreous humour separates pigmented and neural retinal layers; photoreceptors damaged → blindness
- Glaucoma: aqueous humour drainage blocked → increased IOP → halos/blurry → blindness (sudden or gradual development)
- Cataracts: lens clouds, crystalline clumps in lens fibres; remove/implant artificial lens

Light and Optics
- wavelength = colour
- rod and cone sensitivities
- Refraction and Lenses

- Light bends passing from air through lens (more dense)
- Two effects of convex lens of eye:
    4. Light rays converge at 1 focal point
    5. Real image in eye inverted: flipped and reversed

Focusing Light on Retina

- light → cornea → aqueous humour → lens → vitreous humour → neural layer of retina
- light is focused (bent) 3 times: entering cornea, entering lens, leaving lens
    - cornea refracts most, but is constant
    - lens is elastic, so curvature/focusing always changing
- for distant vision (SNS)
    - far point of vision: 6m (no change in lens shape beyond this distance)
    - eyes best adapted for distant vision; flat lens
- for close vision (PSNS) – 3 ways
    - without focusing, focal point would be behind retina; lens bulges to correct this
    1. Accommodation: bulging of lens, closest focus is 10cm, increases with age
    2. Constriction of pupils: reaction to light, pupillary reflex (sphincter pupillae contract)
        a. Prostitute's pupil – eye accommodates but pupil does not react (sign of neurosyphillis)
    3. Convergence of eyeballs: somatic motor fibers of CN III move eyes medially

Focusing Problems

- Myopia: nearsightedness (focus in front of retina, concave lenses needed)
- Hyperopia: farsightedness (focus behind retina, convex lenses needed)
- Presbyopia: old people, farsightedness (lens cant accommodate, magnifying lens needed)
- Astigmatism: blurry (unequal curvatures in different parts of cornea, lenses or laser)

Photoreceptors

- Outer pigmented layer
    - Outer segments of rods and cones (photoreceptor tips) immersed in this layer
        - filled with discs containing visual pigments made of opsin protein (spiraly stuff) with small retinal molecule inside
        - Rhodopsin: retinal + opsin pair
        - when rhodopsin absorbs light, photo-transduction results
        - discs very sensitive and destroyed by light; constantly replaced
- Inner neural layer:
    - Inner segments join photoreceptor tips to rod and cone cell bodies

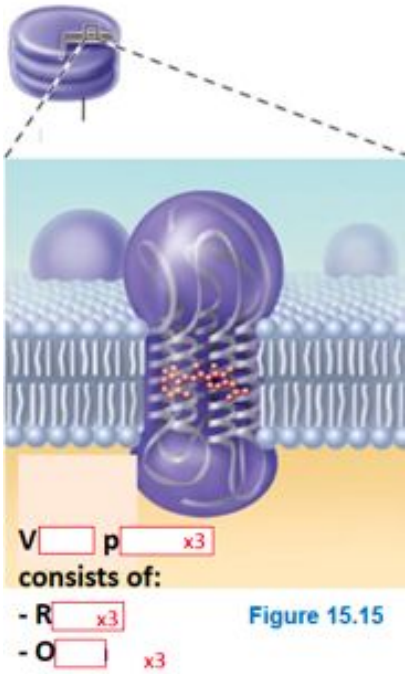


Figure 15.15

    - Synaptic terminals connect rod an cone cell bodies to bipolar cells
- Mitochondria supply ATP for photo-transduction

Rods	Cones
- black and white vision - high sensitivity - dim light - low acuity (many rods per ganglion cell) - many - mostly in peripheral retina	- colour vision - low sensitivity - bright light - high acuitiy (one cone per ganglion) - fewer - mostly in central retina

Visual Pigments

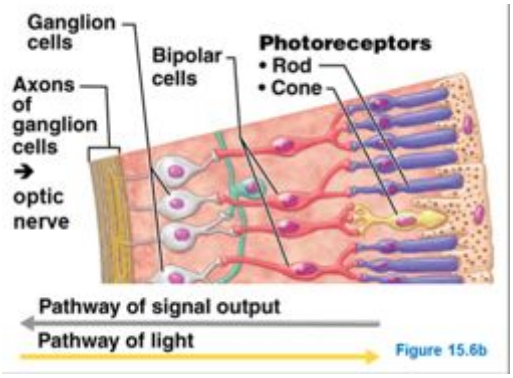
1. Pigment synthesis: 11-cis-retinal made from Vitamin A in pigmented layer
    a. oxidize vitamin A to make 11CR, reduce 11CR to make vitamin A
    b. 11-cis-retinal combines with opsin to make rhodopsin
2. Pigment bleaching: when light hits rhodopsin, cis-retinal becomes trans-retinal and is released
    a. rhodopsin is converted back to opsin
3. Pigment regeneration: enzymes convert trans to cis-retinal in cells of pigmented layer using ATP

- Congenital lack: if you lack one of the opsins/rhodopsins, you have colour blindness

Photo-Transduction

- rhodopsin (receptor) → transducing (G protein) → phosphodiesterase (enzyme) → GMP (2nd messenger)

1. Retinal absorbs light and changes shape (cis to trans), all visual pigments triggered
2. Visual pigment sets transducing (G protein) in motion
3. Transducin activates phosphodiesterase
4. Phosphodiesterase converts cGMP into GMP
5. As cGMP levels fall, cGMP-gated cation channels close (channels open in dark, close in light)



- Signal transmission in Retina (in DARK)
    1. cGMP gated channels are open; photoreceptor depolarizes; AP sent down axon
    2. voltage gated Ca channels open
    3. NTs released
    4. NTs causes IPSPs (inhibitory) in bipolar cells (hyperpolarization)

5. Causes voltage gated Ca channels to close, inhibiting NT release
6. No EPSPs occur in ganglion cell
7. No AP in optic nerve

- Signal transmission in Retina (in LIGHT)
    1. cGMP gated channels closed, photoreceptor hyperpolarizes
    2. voltage gated Ca channels close
    3. No NTs released
    4. Lack of IPSP in bipolar cell
    5. Causes voltage gated Ca channels to open, allowing NT release
    6. EPSPs occur in ganglion cell
    7. AP goes down optic nerve

Light VS Dark Adaptation

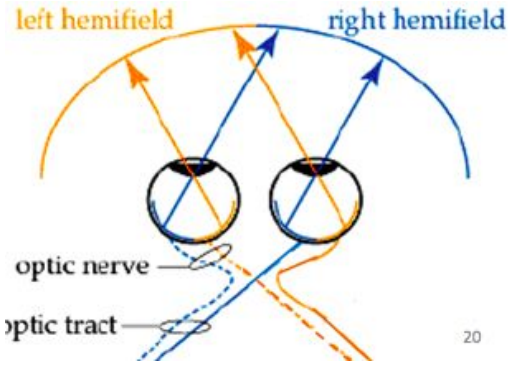
- When moving from dark to light
    - Momentary dazzle: lots of visual pigment break down
    - Rod transducins move to inner segment so light hitting rhodopsin in outer segment can't signal
    - Cones desensitize in 1 min, improve over 10 min
- When moving from light to dark
    - Initially see black: cones stop working, rods are offline still
    - Reverse of above; see something in 20 min, full adaptation takes hours

Problems with Photo-Transduction

- Night blindness (Nyctalopia): rod function limited, due to vit A deficiency (malnutrition)
- Retinitis Pigmentosa: more serious, causes eventual blindness, no treatment, genetic degenerative disease
    - cells in pigmented layer can't recycle rod tips
    - artificial retina still being tested (video camera mounted on eyeglass, video processing unit implanted)

Visual Pathways to the Brain

- lens reverses all images
    - Medial half of each retina receives light from temporal (lateral) fields
    - Lateral half of each retina receives light from nasal (central) fields
- left optic tract carries right visual field; right optic tract carries left visual field
- retinal ganglion cells exit as optic nerves
- Optic chiasma: where medial fibres cross, and continue via optic tracts
- each optic tract sends info of opposite visual field, but each visual cortex gets input from both eyes
    - contralateral vs ipsilateral fibres



- paired optic tract goes through lateral geniculate nucleus (balances retinal input, forms optic radiation), then to 1ary visual cortex
- optic tract also goes through superior colliculus of midbrain (reflex control of eye muscles)
- optic tract also goes through pretectal nucleus (pupillary light reflex) and suprachiasmatic nucleus (circadian rhythm)

Depth Perception
- humans: eyes set anterior to look ahead
  - visual fields overlap, visual cortex fuses images = depth perception
- many animals: eyes set lateral
  - visual fields DON'T overlap; complete optic nerve crossover = each visual cortex gets info from only 1 eye
  - panoramic view, no depth perception
- Gibson and Walk experiment: babies have depth perception

Blindness
- effect depends on location of damage
- left eye/left optic nerve destroyed = no depth perception, no left peripheral vision
- neural destruction beyond optic chiasma in left side:
  - part/all of opposite visual field lost
  - depth perception in left visual field still present (bilateral input in right cortex)

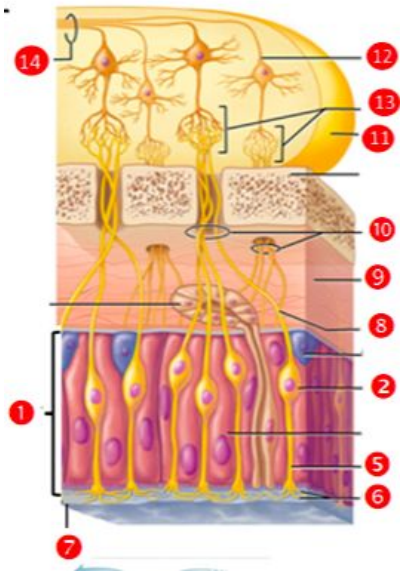
Visual Processing
1. retina cells condense rod and cone input; split into channels (aspects of image)
   a. involves lateral inhibition process via amacrine and horizontal cells
   b. image sharpened
2. primary visual (striate) cortex: accurate 3D map of retina, basic processing
3. prestriate corticies: higher level processing
4. temporal lobe: what
5. parietal cortex
6. postcentral gyrus: where
7. frontal cortex: response

Smell and Taste -6Q

Chemoreceptors
- sense chemicals in solution
- smell and taste receptors

Olfactory Anatomy
- olfactory epithelium: smell organ, in roof of nasal cavity, covers nasal conchae
- olfactory receptors: detect odourants in inhaled air
    - signals via olfactory bulb ⟶ olfactory tract ⟶ cortex

1) olfactory epithelium contains many olfactory receptor neurons
2) olfactory receptor neurons: short life span
3) supporting cells (pink)
4) olfactory cell stems (blue)
5) dendrites
6) olfactory cilia on dendrites (nonmotile, increase reception)
7) mucus covers olfactory cilia (traps odourants)
8) axons
9) filaments formed by axons
10) cribiform plate (roof of nose; axon filaments pass through)
11) olfactory bulb: axons synapse with mitral cells
12) mitral cells: in olfactory bulb
13) glomeruli: complex structures of mitral cells



14) olfactory tract: AP travel through here, to olfactory nerve CN1

Olfactory Specificity

- we can smell more than a trillion odours
- we have only about 400 smell receptors, but each senses more than one odour
- smell sent to CNS via trigeminal nerve CN5

Physiology of Smell

- G-protein linked 2nd messenger

	Smell	Vision
1st messenger	Odourant	Light
2nd messenger	cAMP	cGMP
Effect of 2nd messenger	Ion channels open → AP	Ion channels close → AP

- Olfactory adaptation
  - Na influx = AP
  - Ca influx = transduction process to adapt = decreased response to sustained stimulus

Pathway

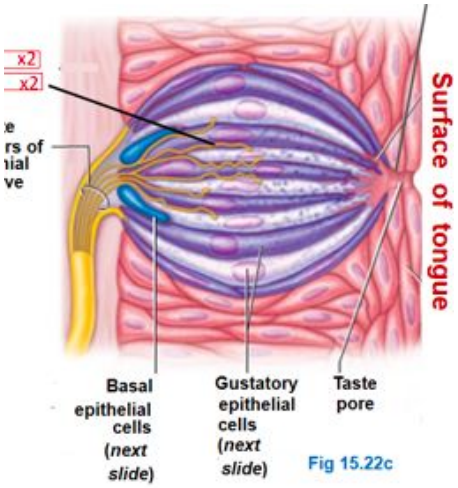
- Mitral cells in blub activated → olfactory tract → piriform lobe of olfactory cortex
  - Frontal lobes (some via thalamus) interpret
  - Limbic system gives emotional response
- Each glomerulus represents a single aspect of an odour; each odour activates diff set of glomeruli

Olfactory Receptors Not Just in Nose

- Found in liver, heart, lungs, kidneys, sperm, colon, brain, skin, etc.
- Specific odourants play role in physiological functions
  - Skin breaks heal faster
  - Cause stem cells in skeletal muscles to morph into muscle cells
  - Help sperm find egg

Tastebuds

- Mainly on papillae of tongue; 3 types
  1. Fungiform papillae – all over surface
  2. Foliate papillae – side walls
  3. Vallate papillae – largest, and least amount
- 2 types of epithelial cells
  1. gustatory: receptor cells for taste
     a. microvilli (gustatory hairs)
     b. receptor membranes bathed in saliva
     c. sensory dendrites coil around
     d. 3 types
        i. traditional synapse with dendrites, releases serotonin

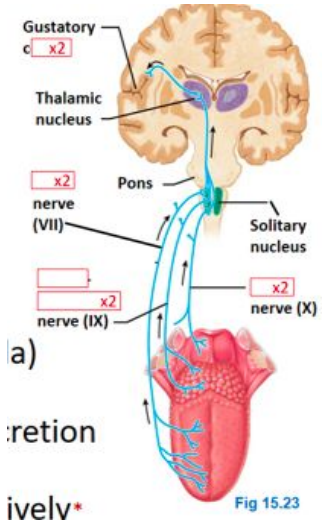


ii. no synaptic vesicles, NT is ATP
iii. no synaptic vesicles, ?NT

2. basal epithelial cells
   a. act as stem cells
   b. replaced damaged gustatory cells
   c. analogous to visual pigment discs in retina

Taste
- activation of taste receptors
  - tastant dissolves in saliva, diffuse into taste pore, contact gustatory hair membrane
  - binds to receptor → NT released → sensory dendrite → GP, AP
  - most sensitive receptors are for bitter taste
- 3 mechanisms of taste transduction: Salty, sour, bitter/sweet/umami (2nd messenger)

Gustatory Pathway
- via 3 CN pairs
  - 7 (facial): chorda tympani branch, anterior tongue
  - 4 (glossopharyngeal): posterior tongue, upper pharynx
  - 10 (vagus): epiglottis, lower pharynx
- synapse in solitary nucleus (medulla)
  - to thalamus → gustatory cortex
  - to PS nuclei to increase secretion, saliva, gastric juices
  - sometimes to gag/vomit
- hypothalamus/limbic = taste appreciation



Influence of Other Senses on Taste
- taste is 80% smell
- mouth also has thermoreceptors and mechanoreceptors, and nociceptors

Olfactory Disorders
- Anosmias/loss of smell
  - due to CN I tear, nasal cavity inflammation, Parkinson's
- Olfactory hallucinations
  - transient unicinate fits from epilepsy, olfactory aura before seizure
  - due to brain trauma, idiopathic

Gustatory Disorders
- less common because taste served by 3 CNs
- caused by colds, head injury, med side effects, radiation treatment

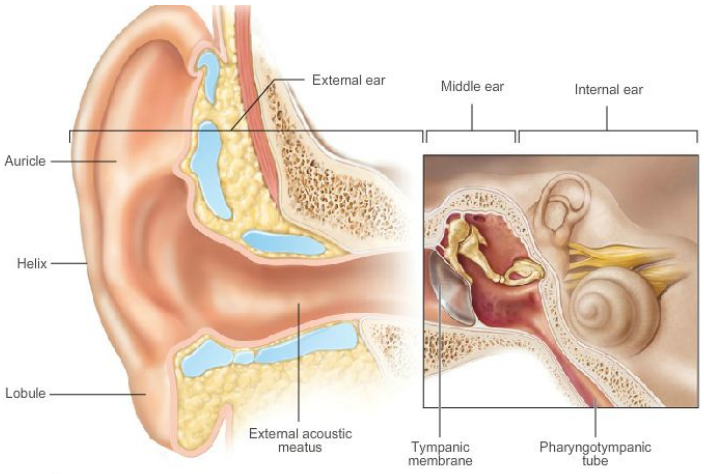
Hearing and Balance -13Q

The Ear

- hearing (outer and middle ear)
- balance: informs NS of head movement/position (inner ear)
- organs of ear activated independently

External Ear

- Auricle/Pinna
  - shell-shaped
  - funnels sound into external acoustic meatus
  - elastic cartilage, some hair, thin skin
  - rimmed by helix
  - fleshy lobe has no cartilage
- External acoustic meatus: auditory canal
  - curved tube, leads to eardrum
  - outer framework cartilage in temporal bone
  - lined with hairs, sebaceous glands, and cermunious glands: modified apocrine sweat glands, secret cerumen
- Tympanic membrane: ear drumb
  - flat, cone-shaped boundary
  - thin, translucent CT membrane



Middle Ear (Tympanic Cavity)

- air-filled mucosa lined cavity in temporal bone
- lateral: eardrum
- medial: bone/2 openings (round and oval windows)

- superior: epitympanic recess
    - mastoid antrum canal for communication with mastoid air cells
- anterior wall: next to internal carotid artery, has pharyngotympanic auditory tube opening (links middle ear to nasopharynx = yawn equalizes pressure)
- auditory ossicles: malleus, incus, stapes BONES\
    - skeletal muscles attach to ossicles
    - Stapedius: posterior wall of middle ear
    - Tensor tympani: PTT to malleus
- when loud sounds hit ear, muscles of ossicles contract to minimize vibration

Middle Ear Problems

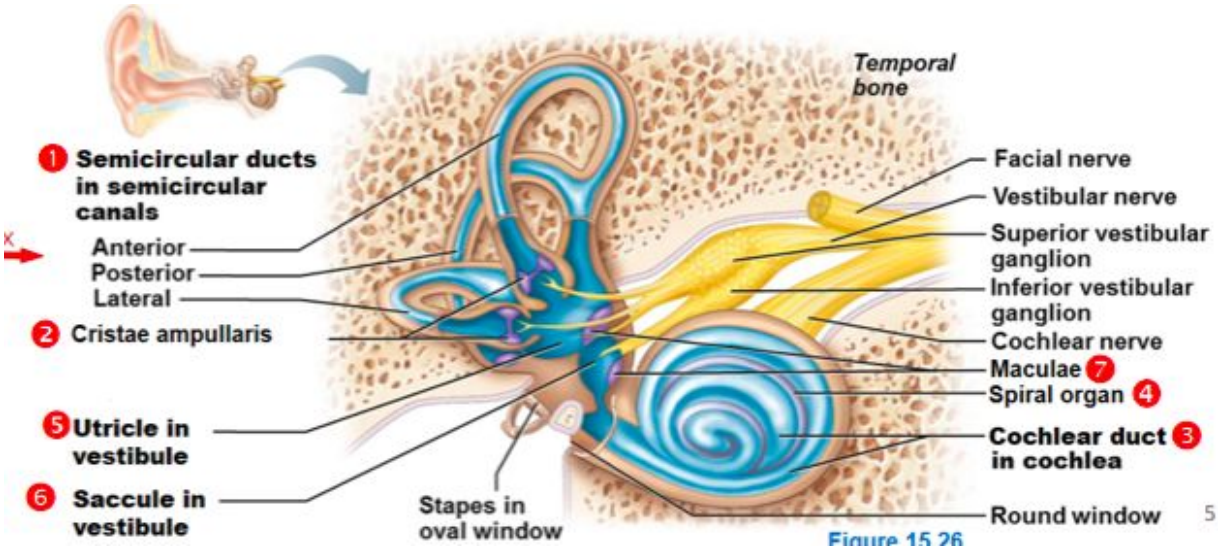
- Otitis Media: inflammation/infection
    - common result of 'sore throat' in children
    - PTT blocked, shorter, more horizontal
    - most frequent cause of childhood hearing loss
    - ear drum bulges, inflamed, red, painful
    - usually antibiotics used, sometimes myringotomy (eardrum drained of pus)
- mastoiditis: mastoid cells infected
    - can spread to brain
    - antibiotics and surger

Inner Ear

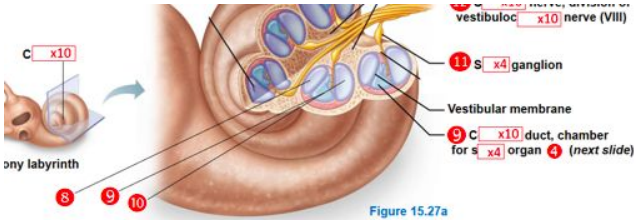
- Outer Bony Labyrinth: hollow cavity
    - semicircular canals and cochlea joined by vestibule
    - filled with perilymph (like CSF)
- Membranous Labyrinth (inside bony labyrinth)
    - for hearing and equ'm
    - filled with endolymph
    - 3 semicircular ducts – have cristae ampullaris
        - connected to utricle (house macula)
    - cochlear duct – has spiral organ (hearing)
        - connected to saccule (house macula)
    - maculae are for gravity, head position
- Vestibular and cochlear nerves: divisions of CN 8 that connect to membranous labyrinth structures; mediate equ'm and hearing

Table 15.2 Summary of the Internal Ear

BONY LABYRINTH	MEMBRANOUS LABYRINTH	FUNCTION	RECEPTOR REGION
Semicircular canals	Semicircular ducts 1	Equilibrium: rotational (angular) acceleration	Crista ampullaris 2
Vestibule	Utricle and saccule 5 6	Equilibrium: head position relative to gravity, linear acceleration	Macula 7
Cochlea	Cochlear duct (scala media) 3	Hearing	Spiral organ 4

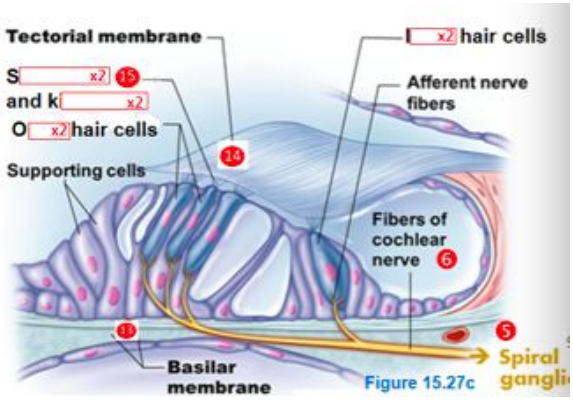


- Cochlea
  - 3 boney ducts in cochlea in bony labyrinth:
    - scala vestibule (begins at oval window, surrounded by vestibular membrane)
    - scala media (cochlear duct, has tectorial membrane)
    - scala tympani (terminates at round window, surrounded by basilar membrane)
    - note: spiral organ between media and tympani



  - cochlear duct contains spiral organ (organ of Corti)
  - spiral organ connects → spiral ganglion → sensory cochlear nerve → cochlea nuclei in medulla

  - spiral organ: rests on basilar membrane
    - has supporting cells, hearing receptors (hair cells)
    - stereocilia and kinocillium in overhanging tectorial membrane; gives rise to sound wave transduction



Sound

- light vs sound: sound is slower, needs medium is fastest in solid, slowest in gas

- sound: alternating areas of hi vs low pressure
  - compressions: high
  - rarefactions: low
- more pitches = better sound quality
- intensity vs loudness (subjective)

Sound Transmission to Inner Ear

1. vibrations of sound → tympanic membrane
2. eardrum pushes chain of bones in middle ear and push oval window
3. pressure waves in inner ear fluid, which move in scala vestibule
4. audible sounds go through cochlear duct (scala media)
5. spiral organ stimulated on basilar membrane
6. waves return via scala tympani
7. round window bulges out to relieve pressure
8. hair cells in cochlea → impules in nearby neurons → CN8 → brain

Basilar Membrane

- base: short, stiff
- apex: long, floppy fibres
- vibrates at diff places depending on sound frequency (tonotopic organization)
  - low freq = apex
  - medium = middle area
  - high freq = base
- sound mechanically processed before transduction

Excitation of Hair Cells in Spiral Organ

- when section of basilar membrane moves, stereocilia deflected towards/away from kinoclilium
- hair cells release/stop release of glutamate NT, thus start/stop AP

Protection of Hair Cells

- afferent sensory nerve fibres from spiral ganglion service inner hair cells and send info to brain
- outer hair cells receive efferent info from brain
  - changes basilar membrane stiffness
  - protects hair cells via negative FB loop

Inner Cochlear Hair Cells to Cerebral Cortex

- thalamus = relay station
- 1ary auditory cortex = conscious awareness of sound
- NOT all fibres from each ear cross to other side; each auditory cortex has input from both ears
- Perception of pitch: diff freq activate diff hair cells along basilar membrane
- Detection of loudness: higher volume = higher freq of APs
- Localization of sound: by olivary nuclei, relative intensity and timing between ears

Deafness – Beethoven

- Central deafness; cochlear ostosclerosis; degernation of organ of Corti; Paget's disease, lead poisoning; syphilis/smallpox/typhus/TB

Equ'm and Orientation

- Vestibular apparatus in ear: 3 equ'm receptors
  - 1 in semicircular canals
  - 2 in vestibule
- The Macula
  - receptor hair cells have stereocillia and kinocilium that project onto otolith membrane (has otoliths on them)
    - Note: kinocilium is tallest
  - utricle macula has vertical cilia: sideways motions detected
  - saccule macula has horizontal cilia: up/down motions
  - hair cells synapse with vestibular nerve
  - tilt forward: hairs bend towards kinocilium
  - macula responds to changes in head velocity, then adapts (APs normalize)
- Cristae Ampullaris
  - detect rotational head movement
  - semicircular canals in all 3 planes
  - cilia embedded in ampullary cupola
  - fibres of vestibular nerve encircle bases of hair cells

Spiral Organ	Macula	Cristae Ampullaris
Hearing Tectorial membrane	Equ'm: head position, linear acceleration Otolith membrane	Equ'm: rotational acceleration Ampullary cupola

Why figure skaters don't get dizzy

- rigid bony semicircular canals rotate with body
- inertia = endolymph rotates opposite way
- cupola bends → hair cells excite → AP
- after few sec, endolymph catches up with body = APs stop
- deceleration: same thing, except hair cells get inhibited when cupola bends

Vestibular Nystagmus

- semicircular canal impulses are transmitted into eyes
- as endolymph lags during rotation, eyes slowly drift in opposite direction
  - CNS compensates and eyes snap back
  - alternating drift/snap continue until endolymph and body in sync
  - same thing when decelerating
- Nystagmus often comes with vertigo (room spinning)
  - skaters focus on 1 object to minimize vestibular nystagmus
- can also be caused by CNS disease

Equ'm Pathway to Brain

- 3 sources of input
  - vestibular receptors
  - visual receptors
  - somatic receptors
- 2 destinations
  - Vestibular nuclei (brain stem): sends to CNS (eye, reflex neck, limb, trunk)
  - Cerebellum: fine coordination of muscle movement
- note: vestibular apparatus can't automatically compensate; need CNS to keep body balanced, equ'm

Hearing Problems

- Deafness
  - Conduction of sound to inner ear is blocked
    - earwax, ruptured eardrum, middle ear inflammation, otosclerosis
  - Sensorineural (Central) Deafness
    - damaged cochlear hair cells
    - due to aging, loud nose, stroke, etc
    - treat with cochlear stem cells, implants
- Tinnitus: ringing in ear without sound
  - due to nerve degen, inflammation, meds
  - Phantom cochlear noise: new neurons form near damaged ones

Equ'm Problems

- Motion sickness: sensory input mismatch
  - salivation, sweating, pallor
  - antimotion drugs, block inner ear input
- Meniere's Syndrome: severe constant car sickness
  - possibly due to too much endolymph, or peri and endolymph mixing

CNS 2 -7Q