Types of Muscle:

- Muscle tissues are responsible for most types of movement. Muscle cells have myofilaments, actin, and myosin that contract, giving movement.

3 kinds of skeletal tissue: skeletal (voluntary), cardiac, and smooth (both involuntary)

- Skeletal muscle tissue: packaged by connective tissue sheets into organs attached to bones. These muscles form the flesh of the body, and as they contract they pull bones or skin, causing body movements
- Skeletal muscle cells (muscle fibers): long, cylindrical, with many nuclei. Obvious banded/striated appearance reflects the precise alignment of myofilaments

	Skeletal Muscle	**Cardiac Muscle**	**Smooth Muscle**
Function:	Voluntary movement; locomotion; manipulation of the environment; facial expression; voluntary control	As it contracts, it propels blood into the circulation; involuntary control	Propels substances or objects (foodstuffs, urine, a baby) along internal passageways; involuntary control
Location:	In skeletal muscles attached to bone or occasionally to skin	The walls of the heart	Mostly in the walls of hollow organs

Structural Organization:

Each skeletal muscle is a discrete organ - tissues include skeletal muscle fibers as well as blood vessels, nerve fibers, and connective tissue

- Usually 1 nerve, 1 artery, and 1 vein branch profusely through connective tissue sheaths. Every skeletal muscle fiber has a nerve ending that controls its activity
- Rich blood supply: contracting muscle fibers use huge amounts of energy, oxygen, and nutrients and give off higher metabolic wastes. Capillaries are long and winding path through muscle - straighten when muscle stretches, contort when it contracts
- Connective tissue sheaths support each cell, reinforce/hold muscle together
- Epimysium: overcoat of dense irregular CT; muscle fibers grouped into fascicles - surrounding each layer of dense irregular CT (perimysium)
- Endomysium: wispy sheath of connective tissue - surrounds individual muscle fibers

Muscle Action:

- Body muscle arrangement either works together or in opposition.
- Muscles can only pull, they never push
- Generally, as a muscle shortens, its insertion (attachment on the movable bone) moves towards its origin (its fixed or immovable point of attachment)
- Whatever one muscle or muscle group can ‘do’ another group of muscles can ‘undo’

Muscles are classified into 3 functional groups:

- Prime Mover/Agonist:
  - Major responsibility for producing a specific movement
- Antagonist:
  - opposes/reverses a particular movement. When the prime mover is active, the antagonist may stretch, remain relaxed or contract
  - Regulates the action of the agonist by providing resistance to prevent movement from going too far, slow or stop it
  - Prime mover and its antagonist are located on opposite sides of the joint across which they act
- Synergist:
  - Help prime movers
  - Adds a little extra force or reduce undesirable/unnecessary movements
    - Eg: although finger flexors cross both wrist and finger joints, you can't make a fist without bending your wrist because synergistic muscles stabilize the wrist
- Summary:
  - All 3 types - prime movers, antagonists, and synergist muscles all produce smooth, coordinated, precise movements. A muscle may act as a prime mover in one movement, an antagonist for another, and a synergist for a third movement

- Fixator muscles that immobilize a bone/muscle's origin so prime mover has a stable base on which to act
  - Eg: fixators that immobilize otherwise freely movable scapula so that only desired movements occur at the mobile shoulder joint; muscles that help maintain upright posture

Muscle Naming Criteria:

- Muscle location:
  - bone/body region with which the muscle is associated
    - Eg: temporalis overlies temporal bone
- Muscle shape:
  - Some muscles have distinctive shapes
    - Eg: deltoid is roughly triangular, R/L trapezius together form a trapezoid
- Muscle size:
  - Maximus (largest), minimus (smallest), longus (long), and brevis (short)
    - Eg: gluteus maximus and gluteus minimus
- Direction of muscle fibers:
  - How fibers/fascicles run in reference to an imaginary line/axis
  - Rectus (fibers fun parallel), transversus (fibers at right angles), oblique (fibers run obliquely)
    - Eg: rectus femoris (straight muscle of the thight)

- Number of origins:
    - Number of heads (each on different origin)
    - Biceps (2), triceps (3), quadriceps (4)
        - Eg: biceps brachii is an arm muscle with 2 origins
- Location of attachments:
    - Points of origin (named first) and insertion
        - Eg: sternocleidomastoid - dual origins on sternum and clavicle, inserts on mastoid process of temporal bone
- Muscle action:
    - Movement produced - flexor, extensor, or adductor
        - Eg: adductor longus, thigh adduction
- Several criteria sometimes combined in naming
    - Eg: extensor carpi radialis longus

Aside: Tendons and Aponeuroses:

- Tendon cord of dense regular connective tissue attaching muscle to bone
- Aponeurosis: fibrous or membranous sheet connecting a muscle and part it moves

Muscles of the Head:

Muscles of Facial Expression:

- Muscles clothing facial bones lift eyebrows, flare nostrils, open/close eyes, provide smile. Tremendously in nonverbal communication
- CN 7 (facial nerve) innervates all
- Insert into skin or other muscles, not bones.
- Format [origin to insertion]
- Includes
    - Epicranius: main muscle of scalp. Consists of:
        - Frontalis: raises eyebrows, wrinkles forehead
        - Occipitalis: pulls scalp posteriorly
    - Orbicularis oculi: surrounds rim of orbit; protects eyes from light/injury - blinking, squinting, also draws eyebrows down
    - Zygomaticus: [cheek to corner of mouth]: smiling muscle
    - Orbicularis oris: lips; multi-layered; closes, purses, protrudes lips
    - Mentalis: [mandible to chin]: V-shaped pair - protrudes lower lip; wrinkles chin
    - Buccinator: [mandible/maxilla to orbicularis oris]: deep to masseter - whistling, sucking, holding food in place when chewing; especially important for nursing infants
    - Platysma: [fascia of chest to mandible]: helps depress mandible; tenses skin of neck
    - Corrigator supercilii: [arch of frontal bone above nasal bone to eyebrow]: pulls eyebrows medially and inferiorly; wrinkles skin of forehead vertically when frowning

Extrinsic Eye Muscles:

- 6 strap like extrinsic eye muscles control the movement of each eyeball. These muscles originate from walls of orbit and insert into the outer surface of the eyeball. Allows eyes to precisely follow a moving object and help maintain shape of eyeball, and hold it in orbit
    - 4 Rectus muscles originate from a common tendinous ring at the back of the orbit and run straight to their insertion on eyeball. Locations and movements promoted clearly indicated by names: superior, inferior, lateral, and medial rectus
    - 2 oblique muscles move eye in vertical plane when eyeball is already turned medially by rectus muscles
        - Superior oblique muscle: originates in common with rectus muscles, runs along medial wall of orbit, then makes a right-angle turn and passes through a loop (trochlea) suspended from frontal bone before inserting on superolateral aspect of eyeball. It rotates eye downward and laterally
        - Inferior oblique muscle: originates from orbit and inserts on infolateral eye surface. Rotates the eye up and laterally
    - The 4 rectus muscles would seem to provide all the eye movements we require - medial, lateral, superior, and inferior - so why the 2 obliques?
        - The superior and inferior recti cannot elevate or depress the eye without also turning it medially. For an eye to be directly elevated or depressed, lateral pull of the oblique muscles is necessary to cancel medial pull of the superior and inferior recti
    - Extrinsic eye muscles are among the most precisely and rapidly controlled skeletal muscles in the entire body. This precision reflects their high-axon-to-muscle-fiber ratio: motor units of these muscles contain only 8-12 muscle cells and in some cases as few as 2 or 3
    - In addition to the extrinsic eye muscles, the eye also contains intrinsic eye muscles - the ciliary body and the iris - that are controlled by the autonomic nervous system

Muscle	Action	Controlling cranial nerve
Lateral rectus	Moves eye laterally	VI (abducens)
Medial rectus	Moves eye medially	III (oculomotor)
Superior rectus	Elevates eye and turns it medially	III (oculomotor)
Inferior rectus	Depresses eye and turns it medially	III (oculomotor)
Inferior oblique	Elevates eye and turns it laterally	III (oculomotor)
Superior oblique	Depresses eye and turns it laterally	IV (trochlear)

Muscles of the Neck and Vertebral Column:

Head and Trunk Movement:

- Head moved by muscles originating from axial skeleton
  - Sternocleidomastoid: [manubrium/clavicle to mastoid process of temporal bone]: 2-headed; deep to platysma; prime mover (both muscles) of head flexion; individual muscle action for head rotation to side, lateral head tilts
  - Scalenes: [cervical vertebrae to first 2 ribs]: more laterally and deep to platysma and sternocleidomastoid - elevate first 2 ribs. Coughing, flex, and rotate neck
  - Splenius: [vertebrae to mastoid process of temporal bone]: superficial. 'Bandage muscle'. Head extension (both sides) or lateral rotation, tilting

Deep Muscles in Back:

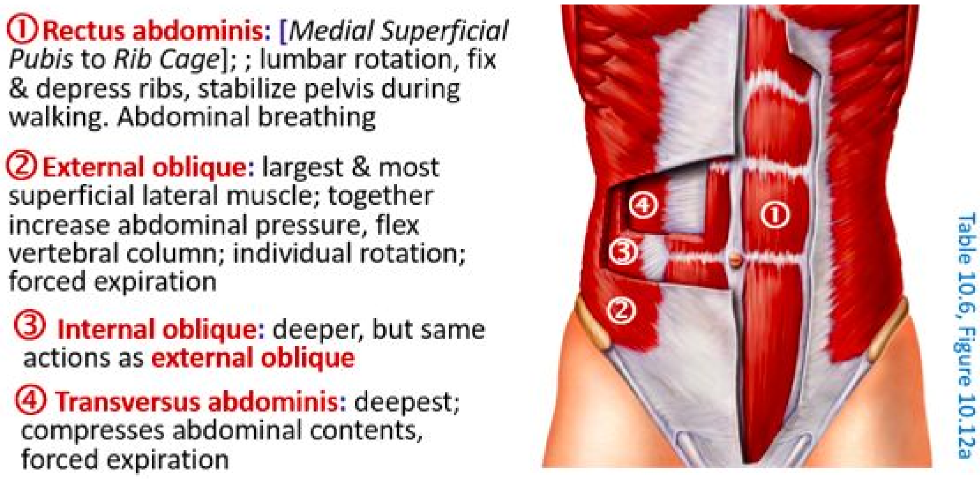
- Erector spinae: prime mover of back extensions; consists of 3 columns of muscles - iliocostalis, longissimus, spinalis ('I Like Standing'):
  - Provides resistance to bending forward and extensors for return to erect position
- Semispinalis: deeper, composite muscle from thoracic region to head; extends vertebral column and head, rotation of head, synergistic with sternocleidomastoid muscles of opposite side
- Quadratus lumborum: [iliac crest to lumbar vertebrae]:
  - Individual muscles flex vertebral column laterally
  - Jointly to extend lumbar spine and fix the 12th rib
  - Maintain upright posture

[origin to insertion]

Muscles of Respiration:

- Inhales: diaphragm contracts
  - Moves down
- Exhales: diaphragm relaxes
  - Moves up
- External Intercostals: 11 pairs, between ribs. Runs obliquely (down and forward). Pulls ribs together to elevate the rib cage = inspiration. Fixed by scalene muscles attached to first ribs
- Internal Intercostals: 11 pairs, between ribs. Deep and at right angles to external intercostals; draws ribs together to depress rib cage = expiration. Fixed by quadratus lumborum attached to 12th ribs
- Diaphragm: dome-shaped when relaxed, flattens on contraction, prime mover of inspiration

Abdominal Wall Muscles:




Rectus abdominus SOURCE


External oblique SOURCE


Internal oblique SOURCE


Transversus abdominis SOURCE

Muscles of the Pelvic Floor and Perineum:

- Levator ani: [pubis to inner coccyx]: supports visceral organs of the pelvis. Supportive sling at anorectal junction and vagina - resists downward increases in intraabdominal pressure (eg: during coughing, vomiting)
- Coccygeus: [spine of ischium to sacrum and coccyx]: supports pelvic viscera and coccyx (eg: pulls it forward after childbirth)
- Levator ani + Coccygeus = Pelvic Diaphragm
- Urogenital Diaphragm: supports pelvis organs and constricts urethra

Superficial Muscles of Thorax: Movements of Scapula and Arm

- Scapula joins shoulder girdle to axial skeleton. Muscles fix scapula - necessary for proper arm movements
    - Most extrinsic shoulder muscles
    - Act in combination to fix shoulder girdle (mostly scapula) and move it to increase range of arm movements
    - Actions include circumduction, elevation, depression, rotation, lateral and medial movements, protraction, and retraction
    - 2 groups of muscles: anterior and posterior
- Serratus anterior [ribs 1-8 to anterior vertebral border of scapula]: holds scapula to chest wall
- Subclavius: [rib 1 to inferior clavicle]: stabilize and depress pectoral girdle

- Pectoralis minor: [ribs 3-5 to coracoid process of scapula]: draws scapula forward and down
- Trapezius: [occiput and vertebrae to clavicle and scapula]: superficial; stabilizes, raises, retracts, rotates scapula
- Rhomboid (major and minor): [vertebrae to scapula]: deep to trapezius; aid in scapula movements
    - Eg: when squaring shoulders, rotation when lowering arm
- Levator scapulae: [C1-4 to scapula]: elevates and adducts scapula
- Rotator Cuff Muscles:
    - Subscapularis, teres minor, supraspinatus, infraspinatus

Muscles Crossing Shoulder Acting on Arm and Forearm:

- 9 muscles cross the shoulder joint to insert on and move humerus
- 3 prime movers of arm:
    - Pectoralis major, latissimus dorsi, and deltoid
        - Flex, extend, adduct, abduct, and rotate
- 4 rotator cuff muscles:
    - Reinforce capsule of shoulder as synergists and fixators
- 2 additional muscles are synergists
    - Coracobrachialis and teres major

- Biceps brachii: [2 points on scapula to radius]: anterior, flexes elbow joint and supinates forearm
- Triceps brachii: [scapula/humerus to ulna]: only muscle of the posterior compartment of arm. Powerful forearm extensor. May help stabilize shoulder joint
- Brachialis: [humerus to ulna]: immediately deep to biceps brachii. Major forearm flexor (strong) - lifts ulna as biceps lifts radius
- Brachioradialis: [distal humerus to distal radius]: superficial. Synergist in forearm flexion
- Latissimus dorsi: [iliac crest/vertebrae/ribs to humerus]: broad, flat back muscle. Prime mover of arm: extension/hyperextension, adductor, medially rotates arm at shoulder
    - Rowing, swimming
- Deltoid: [clavicle/scapula to humerus]: thick and rounded. Site of intramuscular injections. Prime mover of arm abduction (all fibers used); lateral and medial rotations, flexion or extensions (some fibers used)
- Pectoralis major: [sternum/rib cartilages/clavicle to humerus]: prime mover of arm flexion. Adducts and medially rotates arm.
    - Climbing, throwing, pushing

watch video on slide 16 and make note of all the muscles named

Muscles that Move Forearm and Hand:

- Most anterior - flexors; insert via flexor retinaculum
- Most posterior - extensors; insert via extensor retinaculum

- Actions: movements of wrist, fingers, thumbs, and pronation and supination of the forearm

Forearm and Hand:

- Flexor carpi radialis: [humerus to metacarpals]: diagonally across forearm. Powerful flexor of wrist. Abducts hand
- Flexor carpi ulnaris: [humerus/ulna to metacarpals]: powerful flexor of wrist and hand adductor. Finger extension stabilizes wrist
- Flexor digitorum superficialis: [humerus/ulna to middle phalanges, fingers 2-5]: 2 headed, deeper. Flexes wrist and middle phalanges of fingers 2-5. Separate tendons for each finger and separate muscle

  Intrinsic Hand Muscles:

  - Small, weak muscles that lie entirely within the palm of the hand.
  - Control precise movements of metacarpals and fingers

Muscles of Thigh and Leg:

- Muscles act on thigh (at hip) and/or leg (at knee)
- Provides stability, locomotion, maintenance of posture
- Thigh:
  - Muscles anchored to pelvic girdle
  - Produce flexion/extension/abduction/adduction, rotation
- Leg:
  - Muscles cross knee
  - Produce flexion/extension of leg, foot, and toes
- Muscles in 3 compartments. In general,
  - Anterior: flex thigh at hip and extend leg at knee - foreswing of walking phase
  - Posterior: extend thigh at hip and flex leg at knee - backswing of walking phase
  - Medial: only adduct thigh - no effect on leg

- Movements of the thigh:
  - Occur at hip joint. Anchored to pelvic girdle. Amongst the most powerful
    - Flexion: pass in front of hip. Iliopsoas (prime mover), tensor fascia latae, rectus femoris. Synergists: adductor magnus/longus/brevis, sartorius
    - Extension: hamstrings (semitendinosus/membranosus, biceps femoris = prime movers), gluteus maximus
    - Abduction: gluteus medius/minimus (buttocks)
    - Adduction: adductors
    - Rotation (medial and lateral) involves many different muscles
- Movements of the leg:
  - Occur at knee joint. Mainly limited to flexion and extension
    - Flexion: hamstrings (prime movers) - Posterior compartment. Antagonize quadriceps

        - Extension: quadriceps femoris (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius, only movers) anterior thigh is the most powerful muscle group in body

Muscles Crossing Hip and Knee Joints: Movements of the Thigh and Leg:

- Adductors (magnus, longus, brevis) [ischium and pubis to femur]: all adduct, flex, medially rotate thigh
- Gracilis: [pubis to medial tibia]: adducts thigh, medially rotates leg
- Iliopsoas: [iliac crest and lumbar vertebrae to femur]: composite of 2 muscles. Prime mover of hip flexion
- Pectineus [pubis to femur]: adducts, flexes, and medially rotates thigh
- Quadriceps femoris: [iliac spine and femur to patella and tibial tuberosity]
    - Rectus femoris: extends the knee extensors; flexes thigh at hip
    - Vastus lateralis/medialis/intermedius: all extend the knee
- Gluteus maximus: [ilium/sacrum to femur]: largest and most superficial buttock muscle; major thigh extensor
- Gluteus medius: [ilium to femur]: abducts and medially rotates thigh; especially during walking
- Hamstrings: [ischial tuberosity to tibia/fibula]: 3 muscles; all extend thigh and flex knee

Ankle and Toe Movements:

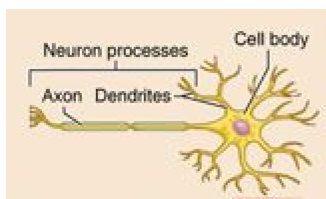
- Extensor digitorum longus: [tibia to phalanges toes 2-5]: prime mover of toe extension. Dorsiflexes foot
- Extensor hallucis longus: [fibula shaft to great toe]: extends great toe and dorsiflexes foot
- Fibularis (peroneus) longus/brevis: [fibula (under foot) to 1st metatarsal]: plantar flexes and everts foot. Helps keep foot flat on the ground
- Tibialis anterior: [tibia to tarsals and metatarsals]: prime mover of dorsiflexion. Inverts foot
- Flexor digitorum longus: [posterior tibia to distal phalanges toes 2-5]: plantar flexes and inverts foot, flexes toes
- Flexor hallucis longus: [fibula/interosseous membrane to distal phalanx of great toe]: plantar flexes and inverts foot, flexes great toe
- Gastrocnemius: [femur to calcaneus (via calcaneal tendon)]: plantar flexes foot when knee is extended, flex knee if foot is dorsiflexed
- Soleus: [proximal tibia/fibula to calcaneus (via calcaneal tendon)]: deeper, plantar flexes ankle. Walking, running, dancing
- Tibialis posterior: [tibia/fibula/interosseous membrane to tarsal and metatarsals]: prime mover of foot inversion
- **Calcaneal (Achilles) Tendon: largest tendon in body. Common tendon for gastrocnemius and soleus for insertion into calcaneus of heel

Intrinsic Foot Muscles:

- Help to flex, extend, abduct, and adduct toes. Single muscle on foot's dorsum and several on plantar aspect. Very similar to muscles in the palms of hands. Dorsal (superior) aspect: single muscle: extensor digitorum brevis plantar aspect (the sole): four layers. Superficial to deep
- Abductor digiti minimi: abducts and flexes little toes
- Abductor hallucis: abducts great toe
- Flexor accessorius: straightens out oblique pull of flexor digitorum longus
- Flexor digiti minimi: abducts and flexes little toes
- Flexor digitorum brevis: helps flex toes
- Flexor hallucis brevis: flexes great toes at metatarsophalangeal joint
- Lumbricals: flex toes at metatarsophalangeal joints, extend toes at interphalangeal joints
- Plantar/Dorsal Interossei: adduct/abduct toes

Nervous System Review:

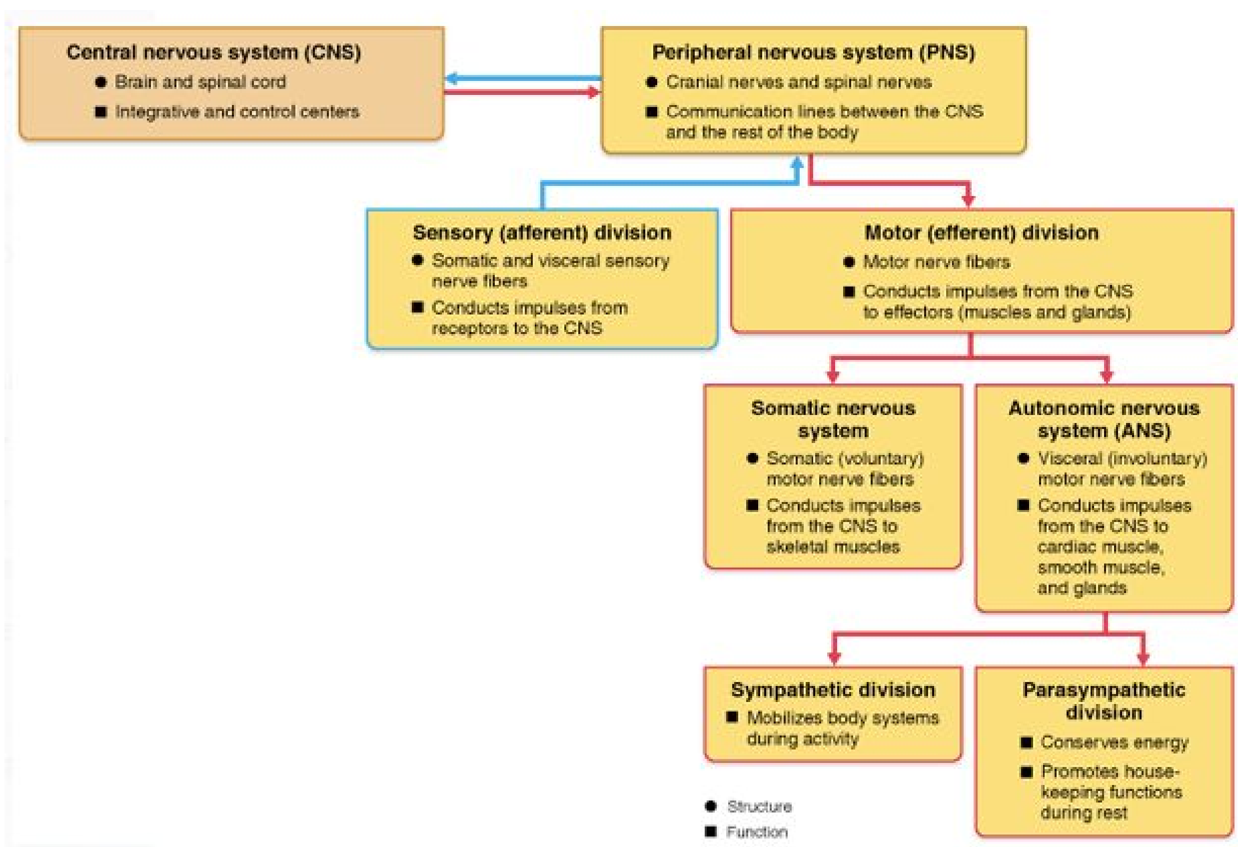
Histology of Nervous Tissue:
- Description: neurons are branching cells; cell processes that may be quite long extend from the nucleus-containing cell body; also contributing to nervous tissue are non excitable supporting cells



- Function: neurons transmit electrical signals from sensory receptors and to effectors (muscles and glands); supporting cells support and protect neurons
- Location: brain, spinal cord, and nerves

Role and Divisions of Nervous System:
- Sensory Input: millions of sensory receptors monitor changes inside/outside body
- Integration: sensory input processed and interpreted. Nervous system decides what should be done at each moment
- Motor output: effector organs - muscles and glands - are activated to cause a response
- Brain and spinal cord make up the central nervous system. Peripheral nervous system mostly consists of pairs of cranial nerves, spinal nerves, and associated ganglia
- Central Nervous System (CNS):
  - Brain and spinal cord, in dorsal body cavity
- Peripheral Nervous System (PNS):
  - Part of the nervous system outside of CNS - links all parts of the body to the CNS. Nerves (axon bundles) and ganglia (neuron cell body collections). Spinal nerves to/from spinal cord and cranial nerves to/from brain
  - 2 subdivisions:

        - Sensory (afferent): nerve fibers (axons) convey impulses to CNS from sensory receptors located throughout the body. 2 divisions: somatic - from skin/skeletal muscles/joints; visceral - from organs within ventral body cavity
        - Motor (efferent): transmits impulses from CNS to effector organs - muscles (contract) and glands (secrete)
        - 2 parts for spinal nerves:
            - Somatic Nervous System: motor nerves. CNS to skeletal muscles. Called ‘voluntary nervous system’ - conscious control
            - Autonomic Nervous System (ANS): visceral motor nerve fibers regulate the activity of smooth muscle/cardiac muscle/glands. Called ‘involuntary nervous system’ - generally can’t control actions governed
                - 2 functional subdivisions, sympathetic and parasympathetic, that typically work in opposition



CNS and PNS Neuroglia:

- Neurons associate closely with much smaller cells called neuroglial or glial cells. 6 types - 4 in CNS / 2 in PNS. Not just the ‘glue’/scaffolding that supports neurons, have many other important and unique functions

- Neuroglia in the CNS:
  - Outnumber neurons but much smaller. Includes astrocytes, microglial cells, ependymal, and oligodendrocytes. Like neurons, most have branching processes (extensions) and a central cell body
  - Astrocytes: most abundant and versatile. Cling to neurons and their synaptic endings, cover nearby capillaries. Support/brace neurons, anchor them to nutrient supply lines. Help determine capillary permeability - play role in making exchanges between capillaries and neurons. Guide migration of young neurons and formation of synapses between neurons. Control chemical environment around neurons
  - Microglial cells: processes touch/monitor health of neurons - when injured they migrate, transform into 'macrophage' that phagocytizes invading microorganisms/dead neuronal debris (immune system cells limited CNS access)
  - Ependymal cells: line central cavities of brain and spinal cord - permeable barrier between cerebrospinal fluid (CSF) in those cavities and tissue fluid bathing cells of CNS. Beating cilia circulates CSF
  - Oligodendrocytes: wrap thicker CNS nerve processes with insulating myelin sheath
- Neuroglia in the PNS:
  - Satellite cells: surround neuron cell bodies. Functionally similar to CNS astrocytes
  - Schwann cells: surround nerve fibers, forming myelin sheaths around thicker fibers. Functionally similar to CNS oligodendrocytes. Vital to regeneration of damaged peripheral nerve fibers

Term	**Definition**
Nucleus	A collection of neuron cell bodies in the CNS
Ganglion	A collection of neuron cell bodies in the PNS
Tract	A bundle of axons in the CNS
Nerve	A bundle of axons in the PNS

Central Nervous System Anatomy:

Ventricles of the Brain:

- Continuous with one another and with the central canal of spinal cord. Hollow - filled with cerebrospinal fluid, lined with ependymal cells

    - Paired lateral ventricles within cerebral hemispheres, C-shaped. Separated by thin median membrane (septum pellucidum). Each communicates with narrow third ventricle in diencephalon via interventricular foramen. Third ventricle continuous with fourth ventricle via cerebral aqueduct
    - Fourth ventricle in hindbrain. Continuous with the central canal of the spinal cord. Three openings on walls (2 lateral and 1 median aperture) connect ventricles to subarachnoid space, a fluid-filled space surrounding the brain

Cerebral Hemispheres:
- Cerebral hemispheres form superior part of the brain - most conspicuous ~83% of total brain mass
    - Elevated ridges (gyri) separated by shallow grooves (sulci) mark surface. Deeper grooves (fissures) separate large brain regions:
        - Median longitudinal fissure separates cerebral hemispheres
        - Transverse cerebral fissure separates cerebral hemispheres from cerebellum below
    - Several sulci divide each hemisphere into 5 lobes - frontal, parietal, temporal, occipital, and insula
    - Cerebral hemispheres fit snugly in the skull. Frontal lobes in anterior cranial fossa, anterior temporal lobes in middle cranial fossa, brain stem, and cerebellum in posterior cranial fossa. Occipital lobes are located well superior to that cranial fossa
    - Each of the cerebral hemispheres has 3 basic regions:
        - Superficial cerebral cortex of gray matter
        - Internal white matter
        - Basal nuclei, islands of gray matter situated deep with the white matter

Cerebral Cortex:
- ‘Executive suite’ of nervous system, where conscious mind found. Enables us to be aware of ourselves/our sensations, to communicate, remember, understand, and initiate voluntary movements
    - Composed of gray matter: neuron cells bodies, dendrites, associated glia and blood vessels, but no fiber tracts. Billions of neurons arranged in 6 layers. Only 2-4 mm thick, but accounts for ~40% of total brain mass. Many convolutions triple its surface area
    - PET scans show maximal metabolic activity in the brain, and functional MRI scans reveal blood flow. Show that specific motor and sensory functions are localized in discrete cortical areas called domains. However, many higher mental functions, such as memory and language, appear to be spread over large areas of the cortex in overlapping domains. No functional area of cortex acts alone. Conscious behaviour involves entire cortex in one way or another
    - Contains 3 kinds of functional areas: motor areas, sensory areas (NOT sensory and motor neurons - all neurons are interneurons) and association areas

    - Each hemisphere is chiefly concerned with sensory and motor functions of contralateral (opposite) side of body
    - Although largely symmetrical in structure, two hemispheres not entirely equal in function - there is lateralization (specialization) of cortical functions

Motor Cortex:

- The following motor areas of cortex, controlling voluntary movement, lie in the posterior part of frontal lobes:
    - Primary (somatic) motor cortex: long axons of neurons (pyramidal cells) project to spinal cord, forming massive voluntary motor tracts (pyramidal/corticospinal tracts)
    - Premotor cortex: plans movements. selects/sequences basic motor movements into more complex tasks, eg. typing, using sensory feedback, ‘staging area for skilled motor activities’
    - Broca’s area: present in one hemisphere (usually left). Once considered a special motor speech area, directing muscles involved in speech production. Now known to also be active, in preparing to speak/planning other activities
    - Frontal eye field: controls voluntary movements of eyes
- Homeostatic Imbalance: damage to localized areas (eg. from a stroke) paralyzes body muscles controlled by those areas. Only voluntary control - not reflexes lost. Eg: if promotor area controlling flight of fingers over a computer keyboard damaged, you couldn’t type with your usual speed, but you could still make the same movements with your fingers. Reprogramming skill into another set of premotor neurons would require practice, just as initial learning process did

Motor Cortex:

Somatotopy: entire body represented spatially in each primary cortex

- Relative amount/location of cortical tissue devoted to each function proportional to distorted body diagram
- Motor innervation of body contralateral: left primary motor cortex controls muscles on right side of body and vice versa
- Not a 1-1 correspondence between cortical neurons and muscles controlled, since a given muscle controlled by multiple spots on cortex, individual cortical neurons send impulses to >1 muscle. Motor neurons work together syergistically to perform a given movement

Sensory Cortex:

- Areas concerned with conscious awareness of sensation occur in parietal, insular, temporal, and occipital lobes
    - Primary somatosensory cortex: receives information from general sensory receptors in skin and from proprioceptors in skeletal muscles, joints, and tendons, to inform brain of body’s position in space (spatial discrimination)

    - Somatosensory association cortex: many connections with primary somatosensory cortex, which relays information to it. Integrates this to produce and understanding of an object being felt. Eg, feeling in your pocket and drawing upon stored sensory memories to figure out what it is
    - Primary visual (striate) cortex: largest cortical sensory area, receiving visual information from opposite eye
    - Visual association area: covers much of occipital lobe. Communicates with primary visual cortex, using past visual experiences to interpret. Complex visual processing involves entire posterior half of cerebral hemispheres
- Homeostatic Imbalance: damage primary visual cortex results in functional blindness - although unable to consciously see, individuals may still have certain visual reflexes. By contrast, individuals with a damaged visual association area can see, but they do not comprehend what they are looking at
- Primary auditory cortex: impulses transmitted from inner ear interpreted as pitch, loudness, and location
- Auditory association area: permits perception of sound we ‘hear’ as speech, a scream, music, thunder, etc, using memories of sounds heard in the past
- Vestibular (equilibrium) cortex: the part of the cortex responsible for conscious awareness of the position of the head in space and balance. Also receives impulses from inner ear
- Primary olfactory (smell) cortex: lies in the medial aspect of the temporal lobe in uncus of the piriform lobe. Impulses sent from the smell receptors in the nasal cavity, giving conscious awareness of different odors. Part of limbic system - the brain area which handles emotions and memory, but also includes olfactory bulbs and tracts
- Homeostatic Imbalance: tumors/other lesions of the anterior association area may cause mental/personality disorders including loss of judgement, attentiveness, and inhibitions. Individual may be oblivious to social restraints, perhaps becoming careless about personal appearance, or rashly attacking a 7-foot opponent rather than running. Different problems arise for individuals with lesions in posterior association area that provides awareness of self in space: may refuse to wash or dress side of their body opposite to lesion because ‘that doesn’t belong to me’
- Gustatory (taste) cortex: involved in perceiving taste stimuli
- Visceral sensory area: conscious perception of visceral sensations
- Somatotopy: as with primary motor cortex, body represented spatially and upside down according to site of stimulus input, with right hemisphere receiving input from left side of the body
    - Amount of sensory cortex devoted to a particular body region related to that region’s sensitivity (how many receptors it has, not its size). Face, especially lips, and fingertips are most sensitive body areas - these regions are largest parts of somatosensory homunculus

Multimodal Association Areas:

- Most of the cortex consists of complexly connected multimodal association areas that receive inputs from multiple senses and send outputs to multiple areas. In general, information flows as follows: sensory receptors - primary sensory cortex - sensory association cortex - multimodal association cortex
    - Gives meaning to information received, stores it in memory, ties it to previous experience/knowledge, and decide what action to take. Where sensations, thoughts, and emotions become conscious. Makes us who we are
    - Three parts:
        - Anterior association area (prefrontal cortex - in frontal lobe): most complicated cortical region. Involved with working memory, intellect, complex learning abilities (cognition), recall, personality, abstract ideas, judgement, reasoning, persistence, and planning
        - Posterior association area (temporal, parietal, and occipital lobes): recognizes patterns and faces, localizes us, attends to our own body/surroundings in space, binds different sensory inputs into coherent whole. Many parts (including Wernicke's area) involved in understanding language
        - Limbic association area: provides emotional impact that makes a scene important to us. Hippocampus establishes memories that allow us to remember an incident

Lateralization of Cortical Functioning:

- Although, we use both cerebral hemispheres for almost every activity, and hemispheres appear nearly identical, there is a division of labor
    - One cerebral hemisphere or other directs each task (cerebral dominance)
    - Most with L-cerebral dominance are R-handed. Typically, R-cerebral-dominant people L-handed. Some "lefties" are ambidextrous - cortex functions bilaterally
    - 2 hemispheres have almost instantaneous communication via connecting fiber tracts, as well as complete functional integration. While each hemisphere better than the other at certain functions, neither better at everything

Cerebral White Matter:

- White matter: second of three basic regions of each cerebral hemisphere. Deep to cortical gray matter. Responsible for communication between cerebral areas and between cerebral cortex and lower CNS centers. Consists largely of myelinated fibers bundled into large tracts. Fibers and tracts classified into 3 groups according to direction in which they run
    - Association fibers: connect different parts of the same hemisphere. Short fibers connect adjacent gyri (outward folds of surface of hemisphere). Long fibers are bundled into tracts and connect different cortical lobes. Run horizontally
    - Commissural fibers: connect corresponding gray areas of the two hemispheres, allowing them to function as a coordinated whole. Largest commissure: corpus callosum. Anterior and posterior commissures are less prominent. Run horizontally

    - Projection fibers: enter cerebral cortex from lower brain or cord (sensory information), or descend from cortex to lower areas (motor output). Tie cortex to rest of nervous system and to body's receptor and effectors. Run vertically. At the top of the brain stem, projection fibers form a compact (internal capsule). Superiorly, fibers radiate fanlike through cerebral white matter to cortex (corona radiata)

The Basal Nuclei:

- Basal Nuclei (Basal Ganglia): deep within cerebral white matter. Third basic region of each hemisphere. Primarily involved in control of movement. Includes caudate nucleus, putamen, and globus pallidus
    - Caudate nucleus + putamen = striatum, globus pallidus + putamen = 'lentiform nucleus'
    - Precise role is elusive. Receives input from the entire cerebral cortex, other subcortical nuclei and each other. Project via thalamus to premotor/prefrontal cortices - influence muscle movements
    - Also play a role in cognition and emotion
        - On both roles, filter out incorrect/inappropriate responses - pass only best response on to cortex
            - Particularly important in starting/stopping/monitoring intensity of movements executed by cortex. Also inhibit antagonistic/unnecessary movements
    - Disorders of basal nuclei include Huntington's and Parkinson's disease

Diencephalon:

- Includes 3 paired structures: thalamus, hypothalamus, and epithalamus. Central core of forebrain, surrounded by cerebral hemispheres, enclose third ventricle
    - Thalamus: deep, well-hidden brain region - 80% of diencephalon. The relay station for information coming into cerebral cortex. Each of its nuclei has functional specialty and projects fibers to/from specific region of the cortex
        - Eg: ventral posterolateral nuclei from general somatic sensory receptors (touch, pressure, pain, etc), lateral/medial geniculate bodies from eye and ear respectively
        - Within thalamus, information is sorted out/'edited' and relayed as group via internal capsule to appropriate areas of the sensory cortex. In thalamus, crude recognition of sensation (pleasant/unpleasant); specific stimulus localization and discrimination in cortex
        - Virtually all inputs - not just sensory - ascend to cortex by funneling through thalamus nuclei: inputs from hypothalamus that regulate emotion and visceral function; instructions from cerebellum and basal nuclei that direct motor cortex; inputs for memory/sensory integration
        - Thalamus: 'gateway to cerebral cortex': plays a key role mediating sensation/motor activities/cortical arousal/learning/memory

- Hypothalamus: like thalamus, many functionally important nuclei, eg: mammillary bodies - relay stations from nose, infundibulum - connects pituitary gland to hypothalamus. Main visceral control center - importance is vital to homeostasis
    - Autonomic nervous system: influences blood pressure, rate/force of heartbeat, digestive tract motility, pupil size, other visceral activity
    - Endocrine system: releasing and inhibiting hormones control secretion of hormones by anterior pituitary gland; also directly produces other hormones (ADH and oxytocin)
    - Physical responses to emotions: at 'heart' of limbic system: involved in perceiving pleasure, fear, rage, sex drive. Acts through ANS to initiate physical expressions of emotion (eg: pounding heart, high BP, pallor, sweating, dry mouth)
    - Body temperature: body's thermostat, monitors blood pressure using other thermoreceptors in brain/periphery
    - Food intake: responds to changing blood levels of nutrients/certain hormones, regulates feelings of hunger and satiety
    - Sleep-wake cycles: suprachiasmatic nucleus, biological clock, sets timing of sleep cycle in response to daylight-darkness cues from visual pathways
    - Water balance and thirst: when body fluids are too concentrated, osmoreceptors trigger the release of antidiuretic hormone - causes kidneys to retain water, stimulates thirst center so we drink more fluids
    - Homeostatic Imbalance:
        - Hypothalamic disturbances cause a number of disorders including severe body wasting, obesity, sleep disturbances, dehydration, and emotional imbalances. The hypothalamus can be damaged by tumors, radiation, surgery, or trauma
- Epithalamus: contain pineal gland/body - secretes the hormone melatonin (sleep-inducing and antioxidant) and, along with hypothalamic nuclei, helps regulate sleep-wake cycle

The Brain Stem:

- From superior to inferior, brain stem regions are midbrain, pons, and medulla oblongata. ~2.5% of total brain mass. Rigidly programmed, automatic behaviours necessary for survival. Pathway for fiber tracts between higher and lower neural centers. Almost all cranial nerves - so heavily involved with innervating head
    - Midbrain: contains 2 cerebral peduncles - crus cerebri with corticospinal motor tract to spinal cord, and superior cerebellar peduncles, connecting midbrain to cerebellum
        - Cerebral aqueduct: hollow, runs through midbrain. Connects third and fourth ventricles
        - Periaqueductal gray matter: surrounds aqueduct. Pain suppressions; links fear-perceiving amygdaloid body and 'fight-or-flight' ANS pathways. Includes oculomotor and trochlear nuclei - control CN 3 and 4

        - Other nuclei: corpora quadrigemina; superior colliculi - visual reflex centers - coordinate head/eye movements following a moving object
        - Inferior colliculi: relay from ear to sensory cortex. Also act in reflexive responses to sound
        - Substantia nigra: high content of pigment melanin (precursor of neurotransmitter dopamine released by these neurons. Degeneration of these neurons is the ultimate cause of Parkinson's disease
        - Red nucleus: colour from rich blood supply and iron pigment. Relay descending motor pathways for limb flexion. Embedded in reticular formation
    - Pons: between midbrain and medulla oblongata. Mainly, two conduction tracts:
        - Deep fibers - part of pathway between brain centers and spinal cord
        - Superficial fibers - form middle cerebellar peduncles connecting pons with cerebellum. CN 5 (trigeminal), 6 (abducens), and 7 (facial) issue from some. Others part of reticular formation, some help medulla oblongata maintain normal rhythm of breathing
    - Medulla Oblongata: most inferior part, blending imperceptibly into spinal cord at level of the foramen magnum of the skull. Central canal of spinal cord continues upward into medulla, where it broadens out to form cavity of fourth ventricle
        - Pyramidal (corticospinal) tracts: descend from motor cortex. Cross over to the opposite side then continue into the spinal cord. As a result, each cerebral hemisphere chiefly controls voluntary movements of muscles on the opposite side of the body.
        - Inferior cerebellar peduncles: fiber tracts connect medulla to cerebellum
        - Inferior olivary nuclei: relay sensory information on degree of muscle/joint stretch to cerebellum
        - Cochlear and vestibular nuclei: auditory and equilibrium-maintenance relays
        - Cranial nerves: CN 7 (vestibulocochlear), 9 (glossopharyngeal), 10 (vagus), and 12 (hypoglossal) associated with medulla
        - Nuclei gracilis/cuneatus: medial lemniscus tract relays somatic and proprioceptive sensory signals up spinal cord to somatosensory cortex
        - Crucial role as autonomic reflex center maintaining homeostasis:
            - Cardiac and vascular centers: adjusts force/rate of heart contraction and changes blood vessel diameter to regulate blood pressure
            - Respiratory centers: generate respiratory rhythm. Together with pontine centers control rate/depth of breathing
            - Various other centers: regulate. Eg: vomiting, hiccupping, swallowing, coughing, and sneezing. Note that medullary centers relays for hypothalamus, which controls visceral functions

Cerebellum:

- Exceeded in size only by cerebrum (11% of brain mass). Protrudes under occipital lobes, separated by transverse cerebral fissure
  - Processes inputs from motor cortex, various brain stem nuclei, and sensory receptors - provides precise timing/appropriate patterns of skeletal muscle contraction, giving smooth, coordinated movements and agility needed for daily living. Activity occurs subconsciously - without our awareness
  - Bilaterally symmetrical. Vermis connects 2 cerebellar hemispheres medially. Surface heavily convoluted - gyri termed folia. Each hemisphere is subdivided into anterior, posterior, and flocculonodular lobes
  - Like cerebrum, has thin outer cortex of gray matter (eg: dentate nuclei)
  - Purkinje cells: in cerebellar cortex. Extensively branched dendrites (arbor vitae). Axons through white matter, synapse with central nuclei of cerebellum
  - Anterior and posterior lobes: coordinate movements. 3 sensory maps of entire body
    - Medial - trunk and girdle muscles; intermediate - distal parts limbs and skilled movements; lateral most - integrate information from association areas cerebral cortex, play a role in planning - rather than executing - movements
  - Flocculonodular lobes: inputs from equilibrium apparatus of inner ears, adjust posture to maintain balance
  - Cerebellar peduncles: 3 paired fiber tracts connect cerebellum to brain stem. Unlike contralateral fiber distribution to/from cerebral cortex, all fibers entering/leaving cerebellum ipsilateral - from/to same side of body
  - Superior cerebellar peduncles: connect cerebellum and midbrain. Carry instructions from deep cerebellar nuclei to motor cortex via thalamic relays (like basal nuclei the cerebellum has no direct connections to cortex)
  - Middle cerebellar peduncles: 1 way communications from pons to cerebellum, advising the cerebellum of voluntary motor activities initiated by the motor cortex (via relays in the pontine nuclei)
  - Inferior cerebellar peduncles: connect medulla and cerebellum. Convey sensory information to cerebellum from (1) muscle proprioceptors throughout the body, and (2) vestibular nuclei of brainstem, which are concerned with equilibrium and balance

Cerebellar Peduncles:

- Motor areas of cerebral cortex, via relay nuclei in brain stem, notify cerebellum of intent to initiate voluntary muscle contractions
- At same time, cerebellum proprioceptors (tension in muscles/tendons, joint position) and visual and equilibrium pathways communicate with cerebellum to evaluate where the body is/will be going
- Cerebellar cortex coordinates force/direction of muscle contraction - prevents overshoot, maintains posture/coordinated movement

- Then, via superior peduncles, cerebellum dispatches to motor cortex ‘blueprint’ for coordinating movement. Also sends information to brain stem nuclei, which in turn influence motor neurons of spinal cord

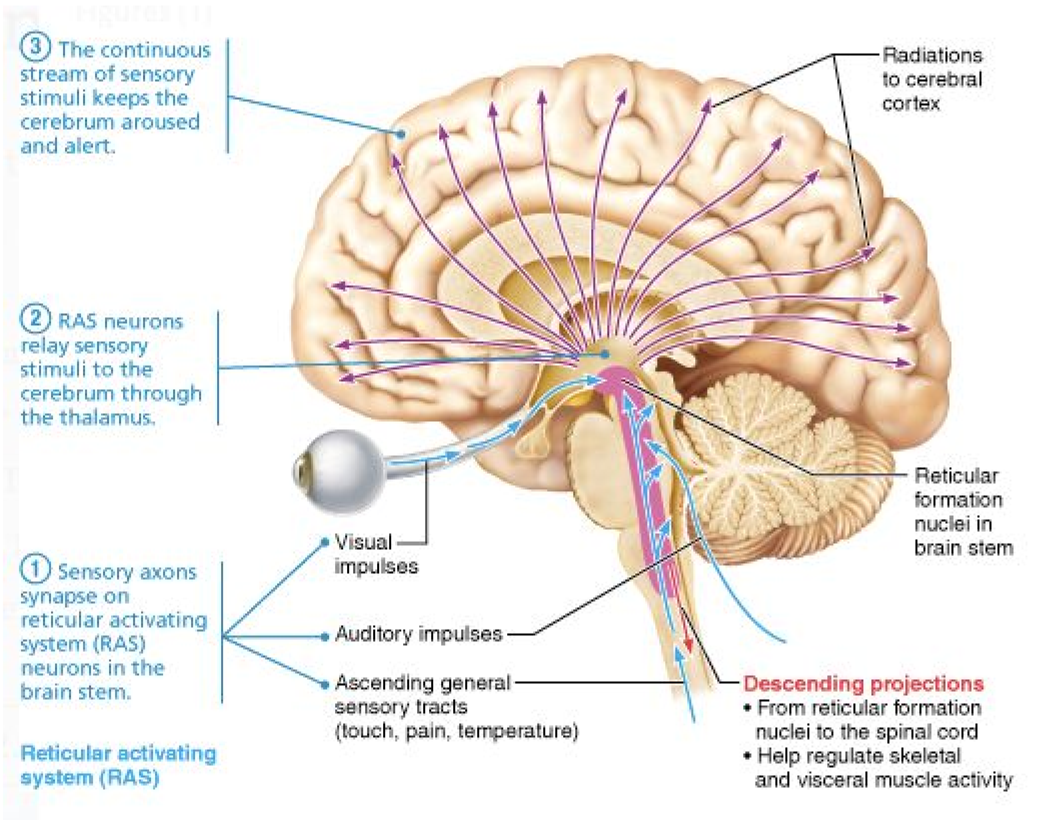
Cognitive Functions of Cerebellum:

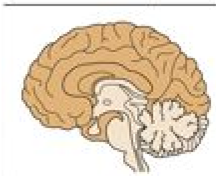
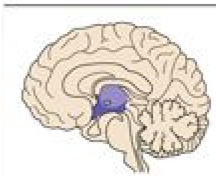
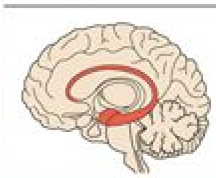
- neuroanatomy/imaging studios/observations of pts with cerebellar injuries suggest cerebellum also plays a role in thinking/language/emotion: compares actual with expected output, adjusts accordingly, but much still remains to be discovered

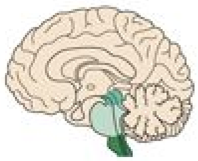
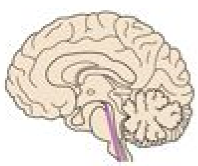
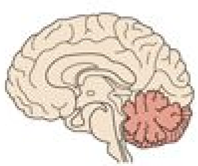
Functional Brain Systems:

- Networks of neurons that work together but span relatively large distances in the brain - not localized to specific regions. Eg: limbic system, reticular formation
    - Limbic System:
        - Group of structures located on medial aspect of each cerebral hemisphere and diencephalon, encircling upper part of brain stem. Includes amygdaloid body and other parts of rhinencephalon (cingulate gyrus, septal nuclei, hippocampus, dentate gyrus, and parahippocampal gyrus)
        - In diencephalon, limbic structures: hypothalamus and anterior thalamic nuclei
        - Fornix and other tracts link these limbic system regions together
        - Our ‘emotional-visceral brain’
            - Emotional brain:
                - Amygdaloid body: critical for responding to perceived threats
                - Cingulate gyrus: role in emotional expression through gestures, and in resolving mental conflicts when we are frustrated
                - Odors often trigger emotional reactions and memories: responses reflect the origin of the limbic system in primitive ‘smell brain’ (rhinencephalon)
        - Extensively connected with both lower/higher brain regions - can integrate/respond to a variety of environmental stimuli
        - Since output via hypothalamus - neural clearinghouse for both autonomic (visceral) function and emotional response - under acute/unrelenting emotional stress fall prey to visceral illnesses (eg: high BP, heartburn; ‘psychosomatic illnesses’)
        - Interacts with prefrontal cortex - so intimate relationship between our feelings (mediated by emotional barrier) and thoughts (mediated by cognitive brain) thus:
            - We react emotionally to what we consciously understand to be happening
            - We are consciously aware of emotional richness of our lives

        - Explains why emotions sometimes override logic and converesley, why reason can stop us from expressing our emotions inappropriately
    - Certain limbic system structures - eg: hippocampus, amygdaloid body - also play a role in memory
- Reticular Formation:
    - In central core of medulla oblongata, pons, and midbrain. Loosely clustered neurons in white matter. Three broad columns along the length of the brain stem: midline raphe nuclei, medial group, lateral group
    - Governs arousal of whole brain: far-flung axonal connections project to hypothalamus, thalamus, cerebral cortex, cerebellum, and spinal cord
    - Motor arm. Some nuclei project to spinal cord motor neurons via the reticulospinal tracts - help control coarse limb movements of skeletal muscles. Other nuclei autonomic centers regulate visceral motor functions
    - Parts of it forms reticular activating system (RAS)
        - Continuous impulses - cortex, so alert/conscious, excitability enhanced
        - All ascending spinal cord sensory tracts synapse with RAS - keep it active, and arouses cerebrum
            - RAS filters the flood of sensory inputs - repetitive/familiar/weak signals removed, unusual/strong/significant impulses reach consciousness (unaware of shoes but would quickly notice if one came off)
        - RAS and cerebral cortex disregard ~99% of sensory stimuli; otherwise, sensory overload would drive us crazy (Like LSD)
        - RAS is inhibited by sleep centers in the hypothalamus and other regions, depressed by alcohol, sleep-inducing drugs, and tranquilizers
        - Although RAS is central to wakefulness, some of its nuclei are also involved in sleep



REGION	FUNCTION
Cerebral Hemispheres (pp. 439–447)	
	**Cortical gray matter:** • Localizes and interprets sensory inputs • Controls voluntary and skilled skeletal muscle activity • Functions in intellectual and emotional processing **Basal nuclei (ganglia):** • Subcortical motor centers • Help control skeletal muscle movements
Diencephalon (pp. 447–450)	
	**Thalamus:** • Relays sensory impulses to cerebral cortex for interpretation • Relays impulses between cerebral motor cortex and lower (subcortical) motor centers, including cerebellum • Involved in memory processing **Hypothalamus:** • Chief integration center of autonomic (involuntary) nervous system • Regulates body temperature, food intake, water balance, thirst, and biological rhythms and drives • Regulates hormonal output of anterior pituitary gland • Acts as an endocrine organ, producing posterior pituitary hormones ADH and oxytocin
	**Limbic system** (pp. 456–457)—A functional system: • Includes cerebral and diencephalon structures (e.g., hypothalamus and anterior thalamic nuclei) • Mediates emotional response • Involved in memory processing

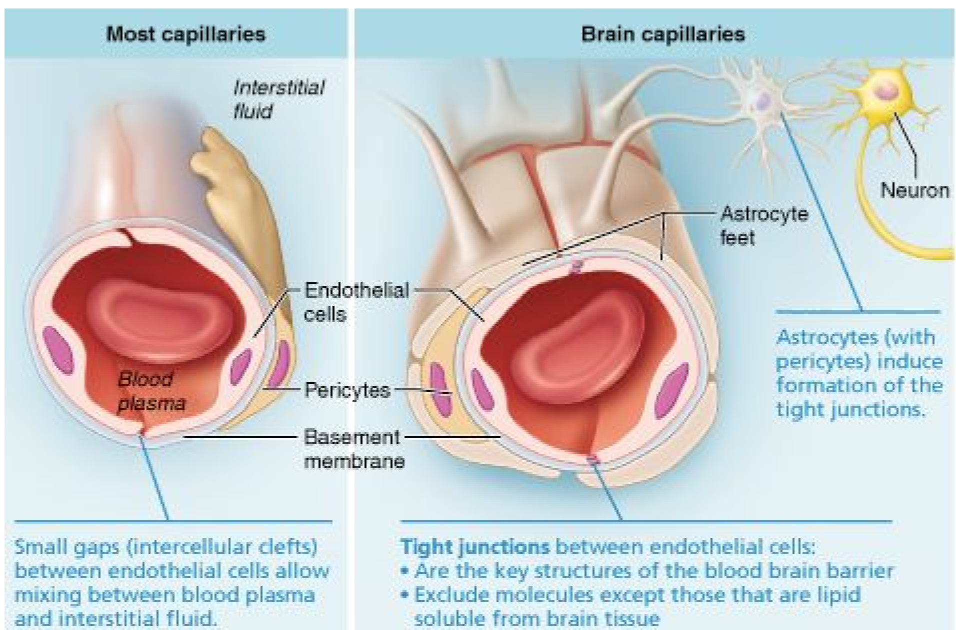
REGION	FUNCTION
Brain Stem (pp. 450–454)	
	**Midbrain:** • Contains visual (superior colliculi) and auditory (inferior colliculi) reflex centers • Contains subcortical motor centers (substantia nigra and red nuclei) • Contains nuclei for cranial nerves III and IV • Contains projection fibers (e.g., fibers of the pyramidal tracts) **Pons:** • Relays information from the cerebrum to the cerebellum • Cooperates with the medullary respiratory centers to control respiratory rate and depth • Contains nuclei of cranial nerves V–VII • Contains projection fibers **Medulla oblongata:** • Relays ascending sensory pathway impulses from skin and proprioceptors through nuclei cuneatus and gracilis • Contains visceral nuclei controlling heart rate, blood vessel diameter, respiratory rate, vomiting, coughing, etc. • Relays sensory information to the cerebellum through inferior olivary nuclei • Contains nuclei of cranial nerves VIII–X and XII • Contains projection fibers • Site of decussation of pyramids
	**Reticular formation** (pp. 457–458)—A functional system: • Maintains cerebral cortical alertness (reticular activating system) • Filters out repetitive stimuli • Helps regulate skeletal and visceral muscle activity
Cerebellum (pp. 454–456)	
	**Cerebellum:** • Processes information from cerebral motor cortex, proprioceptors, and visual and equilibrium pathways • Provides "instructions" to cerebral motor cortex and subcortical motor centers, resulting in smooth, coordinated skeletal muscle movements • Responsible for balance and posture

Protection of the Brain:

- Meninges: connective tissue, external to CNS organs: cover/protect CNS (soft/delicate), blood vessels; enclose venous sinuses; contain cerebrospinal fluid; form partitions. Listed below (external to internal):
    - Dura mater: 1 or 2 layered sheets - superficial periosteal layer (not in cord) attaches to periosteum (inner skull surface), deeper meninges layer is true external covering of the brain. Becomes spinal dura mater. 2 dural layers are generally fused together, sometimes separate to enclose dural venous sinuses - collect venous blood from the brain = internal jugular veins of the neck. Extends inward at time, forming dural septa: falx cerebri, falx cerebelli, tentorium cerebelli, subdivides the cranial cavity, limits excess brain movement
    - Arachnoid mater: separated from dura mater by subdural space (serous cavity with fluid film). Subarachnoid space underneath secures arachnoid mater to underlying pia mater. Filled with CSF, contains largest brain blood vessels serving the brain - since arachnoid mater is fine and elastic, these vessels are

poorly protected. Arachnoid granulations: projections of arachnoid mater protrude through dura mater into superior sagittal sinus - absorbs CSF into venous blood of sinus
    - Pia mater: delicate, with many tiny blood vessels. Clings tightly to every brain convolution like plastic wrap
- Cerebrospinal fluid (CSF): in/around brain and spinal cord, liquid cushion - CNS structures float - brain weight accounts for less than 97%, preventing crushing of the delicate brain. Protects brain/spinal cord from trauma. Helps nourish the brain. Carries chemical signals (eg: hormones) throughout the brain. Watery 'broth' ~the same as blood plasma (formed from), but less protein, the ion concentrations are different
- Homeostatic Imbalance:
    - Meningitis (meningeal inflammation): serious brain infection that may spread to CNS resulting in encephalitis (brain inflammation). Diagnosed by obtaining a CSF sample via a lumbar tap (puncture - LP) and examining it for signs of infection
    - In spinal cord, CSF in subarachnoid space between arachnoid and pia mater. Dural and arachnoid membranes extend to level of S2, well beyond the end of the spinal cord, which typically ends between L1 and L2. so, subarachnoid space within meningeal sac inferior to that point provides an ideal spot for removing CSF for testing since cord absent and delicate nerve roots drift away from the point of needle insertion, so "little/no danger" of damaging cord/spinal beyond L3
        - Same location where epidurals are given
- Choroid plexuses: on the roof of each ventricle. Make CSF. each consists of a knot of porous capillaries surrounded by a single layer of ependymal cells lining ventricles joined by tight junctions and bearing long cilia that beat and stir CSF. Although capillaries are permeable to plasma - 'filtering' it - ependymal cells pump some filtrate back, regulating CSF composition
    - CSF volume (~150mL) replaced every 8 hours, ~500mL formed daily. Choroid plexuses also help cleanse the CSF
    - CSF moves freely through ventricles, enters subarachnoid space (via fourth ventricle), bathes outer surfaces of brain/spinal cord, then returns to blood in dural sinuses
- Homeostatic Imbalances:
    - If CSF is produced faster than it drains, it builds up in ventricles. Resulting increased pressure causes brain damage. In adults, the skull is rigid, so the head cannot enlarge and it can be fatal - the brain begins to be pushed down through the foramen magnum causing the brain stem and higher structures to herniate, cutting off their blood supply. In infants whose cranial sutures have not yet fused, it causes the child's head to enlarge. Also caused by the obstruction of CSF flow from blood clots in ventricles/tumor/meningitis/trauma
    - Rx: inserting a tube (shunt) into ventricle to allow CSF to drain into the abdominal cavity/cardiovascular system
- Blood Brain Barrier (BBB): brain not exposed to variations (hormones, amino acids, ions, etc) as other body regions, so neurons won't fire uncontrollably.

- Tight junctions join capillary endothelial cells with surrounding astrocytes and pericytes (smooth muscle-like cells). Simple diffusion allows lipid-soluble substances (eg: fats, fatty acids, O2, CO2, drugs that affect the brain [alcohol, nicotine, anesthetics, etc]) to pass freely. Basement membrane of endothelial cells are also a part of BBB - contains enzymes that destroy certain chemicals
- BBB structure is not completely uniform - eg: entirely absent in brain areas surrounding third and fourth ventricles - allowing bloodborne molecules easy access to neural tissue: vomiting center of brain stem (monitors for poisonous substances), hypothalamus (essential to allow it to sample the chemical composition of blood), newborn/premature infants (can cause problems not seen in adults), brain injury
- Specific transport mechanisms move substances important to the brain: eg: nutrients (glucose, amino acids), ions via facilitated diffusion, larger substances via transcytosis. Bloodborne metabolic wastes, proteins, certain toxins, most drugs are denied entry. Small nonessential amino acids and K+ not only are prevented from entering the brain, but are also actively pumped out



Spinal Cord:

- Inside vertebral column extends from foramen magnum to 1st/2nd lumbar vertebra, just inferior to ribs. Length ~42cm, diameter 1.8cm. Glistening white. 2 way conduction pathway to/from brain. Spinal reflexes initiated/completed at cord level. Like the brain, the cord is protected by bone/meninges/CSF. Single-layered spinal dura mater is not attached to the bony vertebral column. Epidural space between the vertebrae and spinal dura mater is filled with soft fat padding and a network of veins
  - Inferiorly, the cord terminates in tapering cone-shaped structure (conus medullaris) Filum terminale, fibrous extension of conus, covered by pia mater,

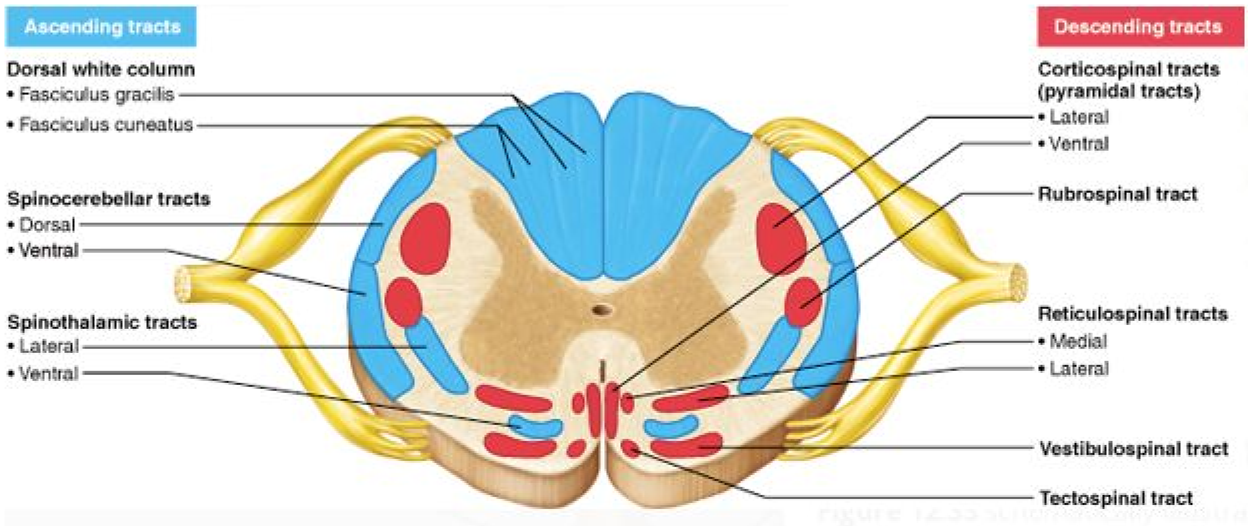
extends inferiorly to coccyx - anchors the cord. Saw-toothed shelves of pia mater (denticulate ligaments) secure cord to dura mater throughout its length

- Spinal cord is about the width of a thumb for most of its length, with cervical and lumbar enlargements where nerves serving upper/lower limbs arise
- 31 pairs of spinal nerves (in peripheral NS) attach to cord by paired roots
    - Each spinal cord segment designated by paired spinal nerves that arise from it - eg: 1st thoracic cord segment (T1) where spinal nerves T1 exit from cord
    - Although nerve pair defines a segment, the spinal cord is in fact continuous along its length; internal structure changes gradually
    - Each nerve exits from the vertebral column by passing adjacent to its corresponding vertebra via intervertebral foramen, and travels to the body region it serves
    - Cord doesn't reach the end of the vertebral column so segments are superior to where their spinal nerves go through the intervertebral foramen
- Lumbar and sacral spinal nerve roots angle sharply downward and travel inferiorly through the vertebral canal for some distance before reaching their intervertebral foramina
    - Collection of nerve roots at the inferior end of the vertebral canal is named cauda equina because it resembles a horse's tail
- Ventral (anterior) median fissure and dorsal (posterior) median sulcus are grooves that run the length of the cord - partially R/L divide it. Gray matter of cord is located in the core. White matter is on the outside. The CSF-filled central canal runs the length of the cord
    - B1 matter resembles an H/butterfly: mirror-image lateral masses connected by gray commissure - encloses the central canal. Gray matter projects as dorsal (posterior) horns, and ventral (anterior) horns that form columns running the entire length of the cord. In thoracic and superior lumbar segments, there are additional gray matter columns - lateral horns
        - All neurons in cord gray matter are multipolar. Dorsal horns are entirely inter - [joining] neurons, ventral horns mainly cell bodies of somatic motor neurons - send axons to skeletal muscles via ventral roots of cords
        - Amount of ventral gray matter at a given level of the cord reflects the amount of skeletal muscle innervated: ventral horns are largest in limb-innervating cervical and lumbar regions
- Afferent fibers carrying impulses from peripheral sensory receptors form dorsal roots that enter the spinal cord
- Cell bodies of associated sensory neurons are found in the enlarged region of the dorsal root (dorsal root/spinal ganglion). After entering the cord, their axons either
    - (1) enter dorsal white matter directly and travel to synapse at higher cord/brain levels

        - (2) synapse at entry level with interneurons in dorsal horns of cord gray matter.
    - Ventral and dorsal roots are very short, they fuse laterally to form the spinal nerves
    - Gray matter is further divided per its neurons' relative involvement in innervating somatic and visceral regions of the body into 4 zones:
        - (1) somatic sensory (SS)
        - (2) visceral sensory (VS)
        - (3) visceral (autonomic) motor (VM)
        - (4) somatic motor (SM)
    - Note the difference between a horn (in gray matter of cord, CNS) and a root (nerves exiting or entering cord, PNS)

HORN	IMPORTANT NEURON CELL BODIES	ASSOCIATED NERVE ROOT
Dorsal horns	Interneurons (receive input from somatic and visceral sensory neurons)	Dorsal roots
Lateral horns (when present)	Autonomic (visceral) motor neurons	Ventral roots
Ventral horns	Somatic motor neurons	Ventral roots

- White matter: myelinated and unmyelinated fibers: communication between different parts of cords and between cord and brain. 3 directions:
    - ascending - up to higher centers (sensory inputs to brain)
    - descending - down to cord from brain or within cord to lower levels (motor outputs from brain)
    - transverse - across from one side of the cord to the other (commissural fibers)
        - ascending and descending tracts make up most of the white matter
        - White matter on each side of the cord divided into 3 white columns (funiculi):
            - (1) dorsal (posterior)
            - (2) lateral
            - (3) ventral (anterior)
                - Each funiculus contains several fiber tracts, and each tract is made up of axons with similar destinations and functions



Neuronal Tracts Up/Down Cord:

- Multi Neuron pathways that connect the brain to body periphery.
- Four key properties:
    - Decussation: cross from one side of CNS to the other
    - Relay: chain of 2 or 3 neurons
    - Somatotopy: orderly mapping of body also in cord
    - Symmetry: all pathways and tracts are paired R/L, on each side of the cord/brain
        - Pathways to/from head similar to those of trunk and limbs; 2 exceptions: axons of tracts servicing head located in cranial nerves, not spinal nerves; cell bodies located in brain stem, not spinal cord

Ascending Tracts are Sensory:

- Three successive neurons:
    - 1st order: cell bodies in dorsal root or cranial ganglia. Impulses from skin receptors and proprioceptors to cord/brain stem. Synapse with 2nd order neurons (cranial nerves transmit from facial area, spinal nerves to rest of the body)
    - 2nd order: cell bodies in cord dorsal horn/medullary nuclei. Transmit the thalamus/cerebellum
    - 3rd order: cell bodies in thalamus. Relay to somatosensory cortex (no 3rd order neurons in cerebellum)
- 3 main pathways on each side of the cord
    - Dorsal column - medial lemniscal and spinothalamic: via thalamus to sensory cortex for conscious interpretation. Provides discriminative touch and conscious proprioception. Both pathways decussate - 1st in medulla, 2nd in cord
    - Spinocerebellar terminates in cerebellum - no sensory perception

Cross sections up to the cerebrum, which is shown in frontal section:

a) Spinocerebellar Pathway:

        i) Transmits proprioceptive information only to the cerebellum, and so is subconscious
    b) Dorsal column-medial lemniscal Pathway:
        i) Transmits discriminative touch and proprioception signals to the cerebral cortex
    c) Lateral Spinothalamic Pathway:
        i) Transmits pain and temperature information

Descending Tracts are Motor:

- Efferent impulses from brain to cord: 2 types:
    - Upper motor neurons: (pyramidal tracts): pyramidal cells of motor cortex and neurons of subcortical motor nuclei (eg: rubrospinal tract) - latter control reflex activity
    - Lower motor neurons (all others) ventral horn motor neurons. Innervate skeletal muscles
- 2 pathways for descending motor tracts:
    - Direct (pyramidal) Pathways: originate mainly with pyramidal cells in precentral gyri. Impulses through the brainstem via pyramidal (corticospinal) tracts. 'Direct' don't synapse between pyramidal cells and cord, they synapse with interneurons/ventral horn motor neurons. Stimulation of ventral horn neurons and associated skeletal muscles. Regulate fast and fine/skilled movements (eg: texting, playing an instrument)
    - Indirect Pathways: brain stem motor nuclei and all motor pathways except pyramidal. Termed extrapyramidal but pyramidal tract neurons project to/influence most extrapyramidal nuclei, so modern anatomists prefer indirect/multi neural pathways. Use names of individual motor pathways. Complex and multisynaptic. Regulate: axial muscles (balance and posture); coarse limb movements; head/neck/eye movements (to follow objects)

Descending Cord Tracts:

Cross sections up to the cerebrum, which is shown in the frontal section

a) Pyramidal (lateral corticospinal and ventral corticospinal) pathways are direct pathways that control skilled voluntary movements
b) The Rubrospinal Tract, one of the indirect pathways, helps regulate muscle tone

Cranial Nerves:

- 12 pairs: first 2 attach to forebrain, rest is associated with brain stem. Other than the vagus nerves, which extend into the abdomen, serve only head and neck
    - Names: structures served/functions. Numbered: I to XII (rostral to caudal)
    - Sensory/mixed: many are mixed but olfactory [i] and optic [ii] are purely sensory
        - What does mixed mean?
            - Both sensory and motor

- Cell bodies: CN i and ii within respective special sense organs. Other sensory neurons contributing to CNs [V, VII, VIII, IX, X], cell bodies in cranial sensory ganglia near brain (some CNs single ganglion, others several, others none)
  - Motor fibers: several BLANK2 CNs have both somatic and autonomic motor fibers - serve both skeletal muscles and visceral organs
- On Occasion Our Trusty Truck Acts Funny - Very Good Vehicle AnyHow (all the nerves)
- Some Say Marry Money, But My Brother Believes (it's) Bad Business (to) Marry Money (remember if it's mixed, sensory, or balance)

1. I olfactory: sensory nerves of smell. From nasal mucosa via olfactory tracts to olfactory bulbs
2. II optic: sensory nerve of vision
3. III oculomotor: supplies four of six extrinsic eye muscles that move the eyeball
4. IV trochlear: innervates an extrinsic eye muscle that loops through a pulley
5. V trigeminal: largest. Three branches. Sensory from face, motor to chewing muscles
6. VI abducens: controls extrinsic eye muscle that abducts eyeball (turns laterally)
7. VII facial: innervates muscles of facial expression (among others)
8. VIII vestibulocochlear: mostly sensory nerve for hearing and balance
9. IX glossopharyngeal: helps innervate tongue and pharynx
10. X vagus: only CN to extend beyond head and neck to thorax and abdomen
11. XI accessory: an BLANK part of vagus nerve
12. XII hypoglossal: runs inferior to tongue, innervates tongue muscles

MEMORIZE:

Cranial nerves I – VI	Sensory function	Motor function	PS* fibers
I Olfactory	Yes (smell)	No	No
II Optic	Yes (vision)	No	No
III Oculomotor	No	Yes	Yes
IV Trochlear	No	Yes	No
V Trigeminal	Yes (general sensation)	Yes	No
VI Abducens	No	Yes	No

Cranial nerves VII – XII	Sensory function	Motor function	PS* fibers
VII Facial	Yes (taste)	Yes	Yes
VIII Vestibulocochlear	Yes (hearing and balance)	Some	No
IX Glossopharyngeal	Yes (taste)	Yes	Yes
X Vagus	Yes (taste)	Yes	Yes
XI Accessory	No	Yes	No
XII Hypoglossal	No	Yes	No

(b)

*PS = parasympathetic

Spinal Nerves:

- 31 pairs, each with thousands of mixed nerve fibers: supply the entire body except head/some of the neck. Emerge from under/over vertebrae of the same name:
  - 8 cervical (C1-C8)
  - 12 thoracic (T1-T12)
  - 5 lumbar (L1-L5)
  - 5 sacral (S1-S5)
  - 1 coccygeal (C1)
- Each connects to cord by dorsal root and ventral root, each root forming from a series of rootlets

- Ventral Roots:
  - Motor fibers [ventral horn to skeletal muscles]
  - Efferent
- Dorsal Roots:
  - [sensory fibers peripheral receptors to cord]
  - Afferent
- Cervical region shoots short/horizontal; lumbar and sacral regions nerves extend inferiorly through lower vertebral canal (cauda equina) before exiting vertebral column
- After emerging from its foramen, spinal nerve divides into dorsal and ventral rami (also rami communicantes for autonomic fibers)
  - Spinal nerve rami supply the entire somatic region of the body (skeletal muscles and skin) from neck down. Dorsal - posterior body trunk. Ventral - rest of trunk and limbs

Spinal Nerve Plexuses:

- Ventral (motor) rami (not T2-12) branch, join laterally to vertebral column. Mainly for limbs
  - Within plexus, fibers cross one another and redistribute, so:
    - Each resulting branch of plexus contains fibers from several spinal nerves
    - Fibers from each ventral ramus travel to body periphery via several routes
  - As a result, each muscle in a limb receives its nerve supply from at least 1 spinal nerve
    - Damage to one spinal segment/root cannot completely paralyze a limb
- Roots: medial to and from spinal nerves. Strictly sensory or motor
- Rami: lie distal to and are lateral branches of spinal nerves. Sensory and motor

Plexus	Ventral Rami	Major Nerves
Cervical	C1-C4	Phrenic
Brachial	C5-T1	Axillary, musculocutaneous, median, radial, ulnar
Lumbar	L1-L4	Femoral, obturator
Sacral	L4-S4	Sciatic (composed of tibial and common fibular)

Homeostatic Imbalances: Spinal Nerve Plexus Injuries:

- Phrenic Nerve:
  - Irritation causes spasms of the diaphragm (hiccups). If both phrenic nerves severed, or if C3-C5 region of the cord is crushed/destroyed, diaphragm is paralyzed and respiratory arrest occurs. Mechanical ventilators keep victims alive by forcing air into their lungs - literally breathing for them

- Brachial Plexus:
  - Common for injuries. When severe can weaken or paralyze the entire upper limb. Such injuries may occur when upper limb is pulled hard, stretching the plexus (eg: football tackler yanking arm of opponent), or by blows to the top of the shoulder that force the humerus inferiorly
- Ulnar Nerve:
  - Can be very vulnerable to injury. Striking 'funny bone (where this nerve rests against the medial epicondyle) makes the little finger tingle. Severe/chronic damage can lead to sensory loss, paralysis, muscle atrophy, causing the individual trouble to make a fist and gripping objects. Little and ring fingers become hyperextended at knuckles and flexed at distal interphalangeal joints: contorted claw hand results
- Radial Nerve:
  - Trauma results in wrist drop - the inability to extend the hand at the wrist. Improper use of a crutch or prolonged compression and impaired blood supply ('saturday night paralysis') can cause damage
- Lumbar Plexus:
  - When spinal roots are compressed (eg: from herniated disc), gait problems - femoral nerve serves prime movers to flex thigh/extend leg. Also: anterior thigh pain/numbness. If obturator nerve is impaired it is the medial thigh that is affected
- Sciatic Nerve:
  - Proximal injury around the sacral region. Can impair the lower limbs in a number of ways depending on the nerve roots injured. Sciatica (stabbing pain radiating over the course of the nerve) is common. When nerve transected the leg is nearly useless: hamstrings are paralyzed, foot/ankle can't move, foot drop can result. If the lesion is below the knee the thigh muscles are spared
- Tibial Nerve:
  - Injury paralyzes calf muscles - can't plantar flex foot = shuffling gait
- Common Fibular Nerve:
  - Susceptible to injury because of its superficial location at the head/neck of the fibula. Even with a tight leg cast, or lying too long on your side on a firm mattress can compress the nerve and lead to footdrop

Innervation of Synovial Joints:
- Hilton's Law: any nerve serving a muscle that produces movement at a joint also innervates the joint and the skin over that joint
  - Eg: quadriceps, gracilis, and hamstring all cross the knee. Nerves to these muscles (femoral anteriorly, branches of sciatic and obturator posteriorly) innervate the knee joint as well

Dermatomes:
- Area of skin innervated by cutaneous branches of a single spinal nerve. Every spinal nerve except C1 innervates dermatomes

  - With spinal cord injury patients, affected dermatomes pinpoint damaged nerves and injured region of the cord
  - Crucial clinicians understand the general pattern of sensory nerve distribution. Eg: in areas where several dermatomes overlap, 2-3 spinal nerves must be blocked (anesthetized) to perform local surgery
  - Adjacent dermatomes are not as cleanly separated as the dermatomes map indicates:
    - In trunk, they can overlap considerably (~50%). Thus, destruction of a single spinal nerve won't cause complete numbness anywhere.
    - In limbs, overlap is less complete. Some skin regions are innervated by just 1 spinal nerve

Integumentary System:

Cutaneous Membrane:
- = your skin
- Unique organ consisting of a keratinized stratified squamous epithelium (epidermis) firmly attached to a thick layer of connective tissue (dermis)
- Skin and appendages (sweat and oil glands, hairs, and nails) make up a complex set of organs that serves several functions, mostly protective
- Dry, unlike other epithelial membranes - exposed just to air

Two Layers of the Skin:
- Skin ('integument'): "architectural marvel". Covers the entire body, surface area is 1.2-2.2 metres squared. ~7% of total body weight. Much more than a 'bag' for body contents. Pliable yet tough: constant abuse from external agents: without it, we would quickly fall prey to/perish from bacteria/water and heat loss. 1.5 - >4 mm thick.
- 2 layers:
  - Epidermis: composed of epithelial cells; outermost protective shield
  - Dermis: bulk of skin; tough, leathery layer - mostly dense CT
    - Only the dermis is vascularized
    - Nutrients reach the epidermis by diffusing through tissue fluid from blood vessels in dermis
- Subcutaneous tissue (hypodermis/superficial fascia):
  - Just deep to skin, superficial to tough CT wrapping (fascia) of skeletal muscles. NOT part of the skin but shares some of the skin's protective functions. Consists mostly of adipose tissue (fat storage) with some areolar CT
  - Anchors skin to underlying structures (mostly to muscles), but loosely enough so that it can slide relatively freely - ensures that everyday bumps and bruises often just glance off our bodies
  - Also acts as a shock absorber, insulator to reduce heat loss

Epidermis:

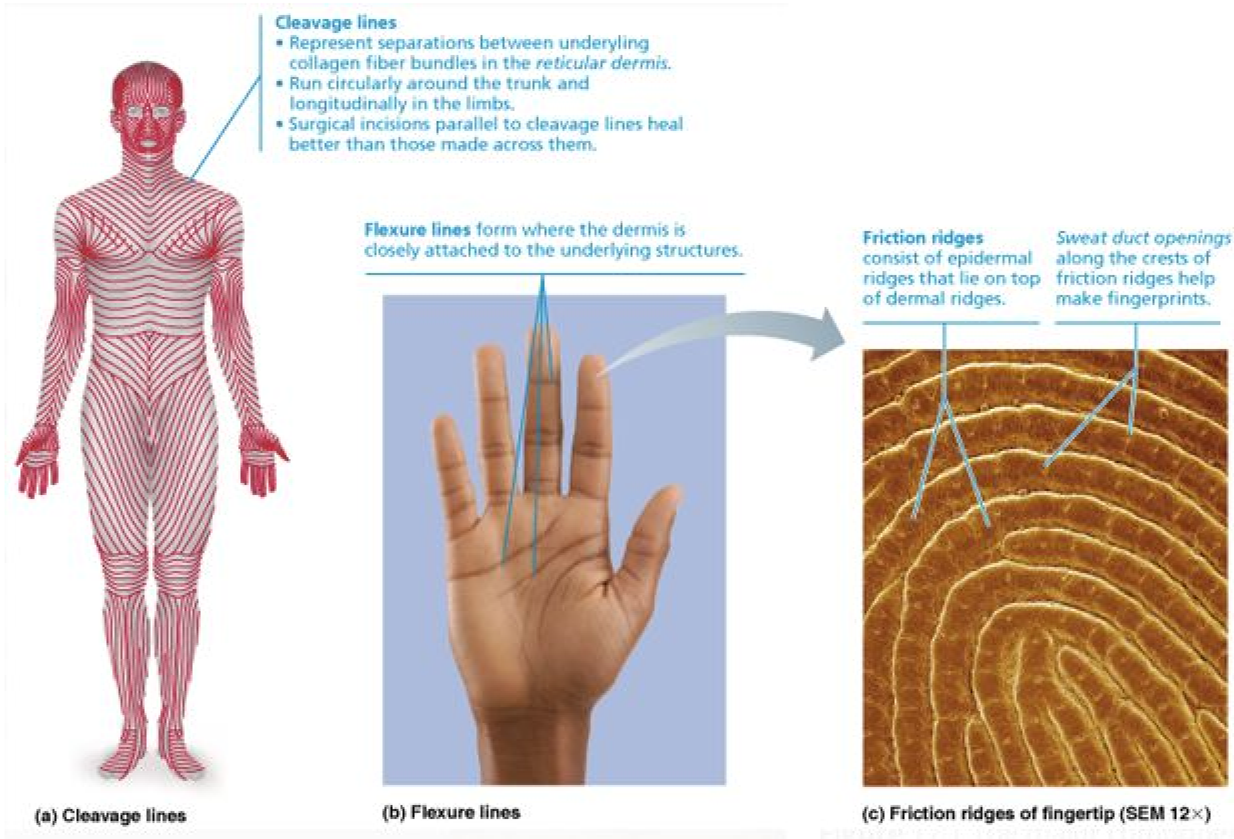
- Keratinized stratified squamous epithelium.
- 4 distinct cell types:
    - Keratinocytes: produce keratin (fibrous protein that helps give the epidermis protective properties). Most abundant type. Tied together by desmosomes (for strength) and tight junctions (for waterproofing)
        - Arise in the deepest part of the epidermis (stratum basale) - cells undergo ~continuous mitosis in response to epidermal growth factor. Newly formed keratinocytes are pushed up by the production of new cells from beneath, while making keratin that fills them. Keratinocytes near skin surface are dead, scale-like flat sacs completely filled with keratin
        - Millions of dead keratinocytes rub off every day, giving totally new epidermis every 25-45 days
    - Melanocytes: melanosomes synthesize black pigment melanin - clusters on keratinocyte nucleus, protects it from damaging UV sunlight radiation
    - Dendritic (Langerhans) cells: arise from bone marrow, migrate to the epidermis. Ingest foreign substances and are key activators of the immune system
    - Tactile epithelial (Merkel) cells: present at epidermal-dermal junction. Intimately associated with sensory nerve ending - combination is sensory receptor for touch
- Epidermis also has 4-5 cells layers/strata; stratum basale, stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum (deep to superficial). Thick skin (covers palms, fingertips, soles of feet - is subject to abrasion) has 5 layers. Elsewhere, thin skin lacks the stratum lucidum layers
    - Stratum basale/germinativum: attached to underlying dermis. Single row of stem cells - a continually renewing cell population. Each time a basal cell divides, one daughter cell is pushed into the cell layer just above to begin specialization into a mature keratinocyte; the other daughter cell remains in the basal layer to produce new keratinocytes. 10-25% of cells in the stratum basale are melanocytes
    - Stratum spinosum: several cell layers thick. Cells contain thick bundles of intermediate filaments pre-keratin (a tension-resisting protein) that are anchored to the desmosomes. Dendritic cells (most abundant) are also scattered in this epidermal layer
    - Stratum granulosum: 1-5 cell layers. Process of keratinization (cells fill with keratin) begins. Cells flatten, nuclei and other organelles begin to disintegrate, accumulate keratohyaline (help form keratin in upper layers) and lamellar granules (contain water-resistant glycolipid secreted into extracellular space; together with tight junctions, it plays a major part in slowing water loss
        - All layers above the stratum granulosum (stratum lucidum and stratum corneum), the epidermal cells are too far from the dermal capillaries to survive, as well as the glycolipids coating their external surfaces cut them off from nutrients. As a result, they die as a normal sequence of events
    - Stratum lucidum: found only in thick skin, just above the stratum granulosum. Few rows of flat, dead keratinocytes. Cells identical to those at the bottom of the next layer

- Stratum corneum: outermost layer. 20-30 cell layers thick (up to ¾ of the epidermal's thickness). Cells are flat and anucleate (and dead). Consists of pre-keratin intermediate filaments embedded in 'glue' from the keratohyaline granules; both accumulate inside the plasma membrane of cells - protects the skin against abrasion and penetration and keep a nearly waterproof layer
    - Cells shed regularly (eg: dandruff, flaky skin)

Dermis:

- Strong, flexible CT. typical CT cells: fibroblasts, macrophages, occasional mast cells and white blood cells. Semifluid matrix, embedded with fibers, binds the entire body together like a body stocking. Corresponds to animal hides used to make leather. Its 2 layers lie next to one another with an indistinct boundary
    - Papillary Dermis: thin, superficial. Areolar CT with fine interlacing collagen and elastic fibers form loosely woven mat with many small blood vessels. Phagocytes and other defensive cells wander freely, patrolling the area for bacteria that have prevented penetration
        - Dermal papillae: peglike projections from the surface indent overlying the epidermis. Many contain capillary loops. Others house free nerve endings (pain receptors) and touch receptors (tactile/Meissner's corpuscles). In thick skin, papillae lie atop larger mounds (dermal ridges) and under epidermal ridges. Both ('friction ridges') help our gripping ability and contribute to the sense of touch - enhancing vibrations detected by lamellar corpuscles (receptors) in the dermis
            - Friction ridge patterns are genetically determined and unique to each of us. Because sweat pores open along their crests, our fingertips leave identifying films of sweat called fingerprints on almost anything we touch
    - Reticular Dermis: deeper. 80% of dermis' thickness. Coarse, dense, irregular CT.
        - Dermal vascular plexus: blood vessel network that nourishes the layer - lies between it and the subcutaneous tissue. Extracellular matrix has thick bundles of interlacing collagen fibers
            - Most collagen fibers run parallel to the skin surface. Separations between bundles form externally invisible cleavage (tension) lines in skin.
            - Collagen fibers of the dermis give the skin strength and resilience - preventing minor scrapes and jabs from penetrating. Elastic fibers give stretch recoil properties
            - Flexure lines: dermal folds that occur at/near joints where the dermis is tightly secured to deeper structures. (notice the deep creases on your palms). Since the skin cannot slide easily to accommodate joint movement in such regions, the dermis folds and deep skin creases form. Flexure lines are also visible on wrists, fingers, soles, and toes

- Homeostatic Imbalance:
  - Extreme stretching of the skin (eg: during pregnancy) can tear the dermis, leaving silvery white scars (striae, aka stretch marks).
  - Short-term, acute trauma (eg: burn) can cause a blister, a fluid-filled pocket that separates the epidermal and dermal layers



Skin Colour:

Three pigments contribute to skin colour:

- Melanin:
  - Reddish-yellow to brownish-black. Made in melanocytes. Found only in the deeper epidermis. All humans have the same relative number of melanocytes; differences in skin colour reflect the kind and amount of melanin is made and retained: black and brown skinned people produce more and darker melanosomes than fair-skinned individuals, keratinocytes retain it longer
    - Sunlight stimulates melanocytes = melanin buildup: defensive - protects skin cell DNA from UV photodamages that can lead to skin cancers (melanoma is the worst)
  - Carotene: yellow-orange. In stratum corneum and subcutaneous tissue fat. Converted to vitamin A, essential for vision and epidermal health

    - Hemoglobin: red. In RBCs in dermal capillaries. Gives a pinkish hue to light-skinned people (epidermis is almost transparent because of the small amount of melanin which allows for the hemoglobin colour to show

Hair:

- Millions of hairs over the entire surface of the skin except or palms, soles, lips, nipples, parts of the external genitalia (eg: head of penis).
- Functions: senses insects on skin, guards head, shields eyes, filters inhaled particles.
- Structural units: hairs (long filaments) + hair follicles (invaginations of the epidermis where hairs grow).
- Structural Details:
    - Hairs/pili: flexible strands. Dead, keratinized cells. Keratin of hairs/nails is tougher/more durable than that of our epidermal cells)
        - Regions: root (embedded in skin) and shaft (projects above)
        - 3 concentric layers: medulla (central core), cortex, and outermost cuticle
    - Hair pigment: melanocytes at the base of the hair follicle are transferred to cortical cells. Different melanin concentrations give blond-brown-black hair; red hair is from pheomelanin; gray/white hair - melanin production decreases.
    - Hair follicles: deep end expands (hair bulb) with sensory nerve endings (hair follicle receptor/root hair plexus wrapped around - touch receptors
        - Hair papilla follicle: protrude in hair bulb. Has a capillary knot - nutrients and signals hair growth. If destroyed, hair production permanently stops
        - Walls have 3 sheaths (external to internal):
            - Peripheral connective tissue (fibrous sheath)
            - Glassy membrane (middle sheath) - basement membrane of follicle epithelium
            - Epithelial root sheath - external and internal root sheaths
    - Hair growth: cells in bulb of follicle divide rapidly (hair matrix) produces new hair cells. Older hair is upward - keratinized and die. Matrix cells replenished by stem cells. Average growth: 2 mm/week. Follicle lifespan: scalp = 4 years, eyebrows = few months
    - Each hair follicle has smooth muscle (arrector pili) - contracting from cold/fear) the follicle is pulled upright - produces goosebumps, sebum forced from follicles to skin surface, acts as a lubricant
    - Hair classified: vellus hair (pale/fine, body hair of children and adult females). Terminal (coarser, longer, darker - appears in axillary/pubic regions of both sexes and face, arms, chest, arms and legs in boys, in response to androgens/testosterone
    - Hair thinning/baldness: hair grows fastest from teens to 40s. When no longer replaced as quickly, hair sheds/thins. At age 60-65, both sexes have some balding. Terminal is replaced by vellus hairs, and the hairs get increasingly wispy

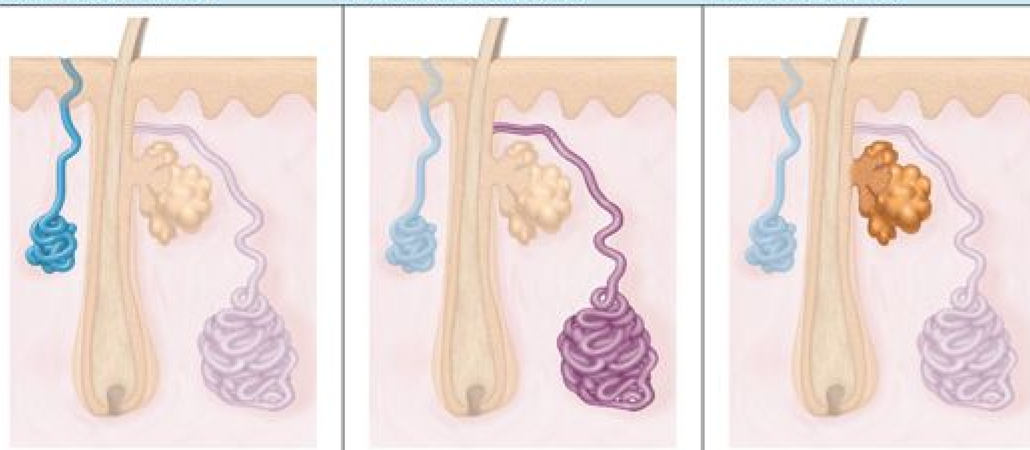
Homeostatic Imbalances of Hair:

- Hirsutism:
    - Women develop coarse terminal hairs in masculine distribution. Cosmetic problem but may be underlying medical issue (eg: polycystic ovary syndrome, adrenal tumors)
- Hair Thinning:
    - loss/change in texture - may signal low thyroid hormone levels, or may be caused by medications (eg: some antidepressants, chemotherapy) or severe dietary deficiencies (protein or minerals)
- Telogen Effluvium (TE):
    - Abrupt hair thinning - too many hair follicles enter the resting phase at the same time. Often after a 'shock to the system' (eg: surgery, car crash, hormonal changes, emotional stress)
- Male Pattern (true) Baldness:
    - Genetically determined, gender influenced. Androgen response of hair follicles changes. Shorter and shorter growth cycles - many hairs never even emerge from follicles before being shed or those that do are fine vellus hairs. Treatments only partly successful

Nails:

- Clear protective covering on dorsal surface of the distal finger/toe
    - Like hairs, they contain hard keratin
    - Components: root (embedded in skin), visible nail plate/body, free edge, and the nail matrix (thick proximal portion of the bed) that rests on the nail bed of the epidermis. Responsible for nail growth, lie beneath the lunule
- Homeostatic Imbalances:
    - Changes in appearance suggests certain conditions:
        - Yellow tinge = respiratory/thyroid disorder
        - Thick and yellow = fungus infection
        - Outward concavity (Spoon nail) = iron deficiency
        - Horizontal (Beau's) lines = severe systemic condition (eg: diabetes, heart attack, etc)

Cutaneous Glands:



	ECCRINE SWEAT GLANDS	APOCRINE SWEAT GLANDS	SEBACEOUS GLANDS
Functions	• Temperature control • Some antibacterial properties	May act as sexual scent glands	• Lubricate skin and hair • Help prevent water loss • Antibacterial properties
Type of Secretion	Hypotonic filtrate of blood plasma	Filtrate of blood plasma with added proteins and fatty substances	Sebum (an oily secretion)
Method of Secretion	Merocrine (exocytosis)	Merocrine (exocytosis)	Holocrine
Secretion Exits Duct At	Skin surface	Usually upper part of hair follicle; rarely, skin surface	Usually upper part of hair follicle; sometimes, skin surface
Body Location	Everywhere, but especially palms, soles, forehead	Mostly axillary and anogenital regions	Everywhere *except* palms and soles

Homeostatic Imbalances:

- Acne - active inflammation of sebaceous glands accompanied by 'pimples' (pustules or cysts) on the skin. If accumulated sebum blocks the sebaceous gland duct it can cause a whitehead (closed comedone) or blackhead (open comedone). Associated with infection by Propionibacterium acne. Can range from mild to so severe that it leads to permanent scarring
- Seborrhea (cradle cap) - from overactive sebaceous glands. Begins on scalp as pink, raised lesions, gradually become yellow-brown, slough off oily scales

Roles of the Skin:

Skin and its appendages (hair, nails, glands) serve multiple roles:

1. Protection: skin is the most vulnerable organ system - microorganisms / abrasions / temperature extremes / harmful chemicals / UV rays. 3 types of barriers:
    a. Chemical: low pH of skin secretions (acid mantle) retards the multiplication of bacteria. Dermcidin (in sweat) and bactericidal substances (in sebum) kill many outright. Skin cells secrete antibiotics (defensins). Wounded skin releases protective peptides (cathelicidins) against group A streptococcus. Melanin pigment prevents UV damage to skin cells
    b. Physical: via hardness of keratinized cells. "Remarkable compromise": thicker epidermis is more impenetrable, but would lose suppleness and agility

c. Biological: dendritic cells are part of the immune system; macrophages
    i. Substances that do penetrate the skin: lipid soluble substances (eg: O_2, CO_2, fat-soluble vitamins, steroids); oleoresins from plants (poison oak/ivy); organic solvents (eg: acetone); heavy metal salts (eg; lead and mercury); some drugs; penetration enhancers (help ferry other drugs into the body)

2. Body Temperature Regulation: skin can lose heat to air; evaporation of sweat from skin dissipates body heat. When the external environment is cold, dermal blood vessels constrict - warm blood bypasses the skin temporarily to conserve body heat
3. Cutaneous Sensation: skin is supplied with cutaneous sensory receptors - part of the nervous system; considered exteroceptors.
4. Metabolic Functions: makes a vitamin D precursor - Ca^{++} metabolizes keratinocyte enzymes can disarm cancer-causing chemicals, activate some steroid hormones, make several biologically important proteins
5. Blood Reservoir: dermal vascular holds ~5% of blood volume. Nervous system can constrict dermal blood vessels, shunting more blood to muscles or other body organs if needed
6. Excretion: limited amounts of nitrogen-containing wastes - ammonia, urea, uric acid - eliminated in sweat (most such wastes excreted in urine). Profuse sweating is important for H_2O/NaCl loss