Biology 325
Fall 2004

The Central Nervous System

I. **The brain.**

A. Basic pattern of CNS organization

- note cerebral hemispheres, diencephalon, brainstem and the cerebellum.

- in cross section, generally have a central cavity surrounded by a gray matter core (nuclei), external to which is white matter (myelinated fiber tracts); cerebral hemispheres and cerebellum have an outer "bark" or cortex of gray matter.

B. Ventricles of brain

- CSF fluid-filled cavities within brain, continuous with each other and central canal of spinal cord, lined with ependymal cells.

1. Lateral ventricles: c-shaped, w/in cerebral hemispheres.

2. Third ventricle: in diencephalon, communicates with lateral ventricles via interventricular foramen.

3. Fourth ventricle: lies dorsal to pons and superior medulla, continuous with central canal of spinal cord (SC).

- three openings, lateral apertures (2), and median aperture, connect it to subarachnoid space.

C. Protection of the brain: brain protected by skull, membranes (meninges) and a watery cushion (CSF).

1. Meninges: three connective tissue membranes, just external to CNS organs, besides protection of CNS also enclose blood vessels and venous sinuses and contain CSF.

> a. Dura mater: double layered membrane; outer layer is periosteum of skull, periosteal layer; inner layer, meningeal layer, forms outermost brain covering, continues down SC as dural sheath; the two layers are fused together except in areas where they form dural sinuses.
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> b. Arachnoid mater: forms loose brain covering, does not dip into sulci; separated from dura by subdural space; beneath arachnoid have wide subarachnoid space, filled with CSF, also contains largest vessels serving brain; arachnoid villi project into dural sinuses (CSF drainage)

c. Pia mater: delicate connective tissue membrane,richly invested with blood vessels, only meninx that clings tightly to brain and follows its every convolution.

d. Note: in some places dura mater extends inward to form flat septa that anchor brain to skull, include falx cerebri, falx cerebelli, tentorium cerebelli.

2. Cerebrospinal fluid (CSF): found in and around brain and spinal cord, forms liquid cushion; helps nourish brain.

- produced by choroid plexuses, clusters of capillaries enclosed by layers of ependymal cells found in the roofs of ventricles; a filtrate of plasma the composition of which is finely tuned by permeability properties of ependymal cells and ion pumps in their membranes; CSF fills ventricles, continuous with subarachnoid space and central canal: drained by arachnoid villi.

3. The blood-brain barrier: helps maintain stable environment of brain; formed by tight junctions of brain capillary endothelium, very impermeable.

D. Cerebral hemispheres (CHs).

- most superior part of brain, separated from each other by median longitudinal fissure, and from cerebellum by transverse fissure; note gyri and sulci on surface, divided into five lobes, frontal, parietal, temporal, occipital, and insula lobes.

- central sulcus delineates frontal and parietal lobes, forms precentral gyrus and postcentral gyrus.

- parieto-occipital sulcus, lateral sulcus and insula.

- frontal section of brain, outer cortex, internal white matter, basal nuclei.

1. Cerebral cortex: perception, communication, memory, understanding, appreciation, initiation of voluntary movements.

- gray matter: neuron cell bodies, dendrites, no fiber tracts.

- contains three kinds of functional areas: motor areas, sensory areas, association areas; each hemisphere concerned with sensory/motor functions of opposite side of body; hemispheres symmetrical in structure but not function; no functional area acts alone.

a. Motor areas: located in posterior part of frontal lobes, control voluntary motor function.

(i) *primary motor cortex (PMC):* in precentral gyrus, pyramidal cells giving rise to long axons (corticospinal, pyramidal tracts).

- allow conscious control of movements of skeletal muscle.

(ii) *supplementary motor area:* programming of complex movements

(iii) *premotor cortex (PC):* anterior to precentral gyrus, frontal lobe; controls learned motor skills of repetitive nature.

(iv) *Brocca's area:* located in one hemisphere, special motor speech area.

(v) *Wernicke's area*: language comprehension

(vi) *Frontal eye field:* controls voluntary movements of the eyes.

b. Sensory areas: not confined to a single lobe; concerned with conscious awareness of sensation.

(i) *primary somatosensory cortex (PSSC):* in postcentral gyrus.

- neurons receive information from somatic sensory receptors and proprioreceptors to identify the body region being stimulated - spatial discrimination.

(ii) *somatosensory association area (SSA):* posterior to PSSC, many connections with it; integrates and analyzes somatosensory inputs into comprehensive evaluation of what is being felt.

(iii) *visual areas*.

(iiia) primary visual cortex (PVC): largest of cortical sensory areas, receives visual information originating in retinas.

(iiib) visual association area: surrounds PVC, interprets/evaluates visual input in light of past experiences.

(iv) *auditory areas:*

(iva) primary auditory cortex (PAC): input from cochlear receptors of inner ear.

(ivb) auditory association area: integration/perception of sound stimulus.

(v) *olfactory cortex (OC):* input from olfactory receptors; part of rhinencephalon.

(vi) *gustatory cortex:* perception of taste stimuli.

c. Association areas: each sensory area, as seen, has nearby association area with which it communicates; these latters in turn communicate with motor cortex and

other association areas to analyze, recognize, and act on sensory input; these other association areas are:

(i) *prefrontal cortex (PFC):* intellect, cognition, personality.

(ii) *parietal-temporal-occipital association area :* receives input from all sensory association areas, integration of all sensory input.

(iii) *limbic association area: motivation, emotion, memory*

2. Cerebral white matter: provides for communication between areas of cerebral cortex, and areas of cerebral cortex and lower CNS centers.

- largely composed of myelinated fibers bundled into,large tracts.

a. commissural fibers: connect corresponding areas of two hemispheres.

b. association fibers: connect adjacent gyri, within a single hemisphere or adjacent cortical lobes.

c. projection fibers: run vertically, fibers connecting cortex to lower brain or spinal cord centers.

3. Basal nuclei: islands or gray matter deep within cerebral hemispheres, includes corpus striatum (caudate nucleus and lentiform nucleus) and amygdala.

- have extensive inputs from entire cerebral cortex, from other subcortical nuclei and each other; via relays through thalamus, basal nuclei project to premotor and prefrontal cortices, influence motor movements (however no direct access to motor pathways).

E. Diencephalon: central core of forebrain, surrounded by CHs; includes thalamus, hypothalamus, epithalamus.

1. Thalamus: composed of bilateral masses of gray matter held together by midline commissure, the intermediate mass; forms superolateral walls of third ventricle.

- w/in thalamus, sorting out or editing of information occurs, impulses having to do with similar functions are relayed to appropriate area of sensory cortex and cortical association areas.

-virtually all impulses ascending to cerebral cortex funneled through thalamus; thus thalamus is gateway to cortex.

2. Hypothalamus: located below thalamus, caps top of brainstem, constitutes inferolateral walls of third ventricle; extends from optic chiasm to posterior margin of mammary bodies.

- main visceral control center of body, has several homeostatic roles:

a. autonomic control center: controls activity of autonomic centers in brain/SC; influences blood pressure, rate and force of heart contraction, GI motility, respiratory rate/depth, eye pupil size.

b. center for emotional response/behavior: lies at heart of emotional brain, limbic system.

- many connections with cortical association areas, lower brainstem centers.

c. body temperature regulation: body's thermostat in hypothalamus; receives input from thermoreceptors located in other brain areas & body periphery; other thermoreceptors in hypothalamus itself.

- according to such signals can initiate cooling (sweating) and heat retention (shivering) mechanisms.

d. regulation of food intake: appetite center, monitors level of glucose and amino acids in blood.

e. regulation of water balance and thirst: some hypothalamic neurons are osmoreceptors, monitor osmolarity of blood.

f. regulation of sleep/wake cycles

g. control of endocrine system functioning: produces releasing hormones that influence anterior pituitary.

3. Epithalamus: most dorsal part of diencephalon, helps form roof of the third ventricle.

-most noticeable landmark is pineal gland.

F. The brain stem.

-includes midbrain, pons, medulla oblongata; general function is to produce the automatic involuntary behaviors necessary for our survival; provides pathways for fiber tracts running between higher and lower neural centers.

1. Midbrain: located between diencephalon superiorly and pons inferiorly.

- note cerebral peduncles containing pyramidal tracts; also superior cerebellar peduncles, fiber tracts connecting midbrain to cerebellum dorsally.

- cerebral aqueduct connects third and fourth ventricles.

- a number of nuclei scattered in white matter of pons, corpora quadrigemina, substancia nigra, red nuclei.

- midbrain is most superior portion of CNS that contains motor neurons.

2. The pons: bulging stem region wedged between the midbrain and medulla oblongata; dorsally forms part of the walls of the fourth ventricle; composed mostly of conduction tracts.

- other features: projection fibers, pontine nuclei, middle cerebellar peduncles; several cranial nerves originate from pons nuclei (trigemminal nerve V, facial nerve VII).

- pneumotaxic center, a respiratory center, works with medullary respiratory centers to keep normal breathing rate.

3. Medulla oblongata: most inferior portion of the brainstem

-features: pyramids (large ridges) on ventral surface; inferior cerebellar peduncles; olives; number of cranial nerves associated with medulla, hypoglossal nerve (XII), glossopharyngeal (IX), vagus (X), accessory (XI), vestibulocochlear (VIII); some nuclei in medulla associated with ascending tracts, nucleus gracilis, nucleus cunneatus -- relay nuclei in pathway by which somatic sensory information ascends to somatosensory cortex.

- plays crucial role as autonomic reflex center, contains following important visceral motor nuclei:

    a. cardiovascular center: cardiac center (heart rate/force), and vasomotor center (TPR/blood pressure).

    b. respiratory centers: control rate/depth of breathing.

    c. other centers: vomiting, hiccuping, swallowing, coughing, sneezing.

G. Cerebellum: located dorsally to pons/medulla and to intervening fourth ventricle.

- processes input received from cerebral motor cortex, various brain stem nuclei, and sensory receptors to provide the precise timing and appropriate patterns of skeletal muscle contraction required for smooth, coordinated functioning.

- landmarks: two cerebellar hemispheres separated by vermis medially, convoluted surface, exhibits folia; each hemisphere divide into anterior, posterior, flocculonodular lobes.

- recall cerebellar peduncles, superior, inferior, middle.

- general processing pattern: cerebral motor cortex initiates voluntary contractions; cerebellum receives input from proprioreceptors, assesses information, determines how it can best coordinate force/extent of contraction with existing body state; it dispatches this information to cerebral motor cortex which makes appropriate adjustments.

H. Functional brain systems: networks of neurons that work together, yet are found quite far apart in brain.

1. Limbic system: spaced widely through forebrain; a complex group of tracts and gray matter located on medial aspect of hemispheres and diencephalon: main limbic structures are hypothalamus, part of thalamus, amygdala.

- it is emotional or affective brain.

2. Reticular formation: extends through the central core of medulla, pons and midbrain; connections to thalamus, hypothalamus, cerebellum, SC.

-governs the arousal state of brain; also a filter for flood of sensory inputs, filters out repetitive signals.

II. **The spinal cord (SC)**

- the spinal cord is enclosed within the vertebral column, extends from foramen magnum of the skull to the level of the first lumbar vertebra; it is a two way conduction pathway to and from the brain, and a major reflex center.

- it is protected by meninges, the spinal dural sheath, arachnoid mater and pia mater; inferiorly SC terminates in a tapering cone-shaped structure, conus medularis; the filum terminale, a fibrous extension of the pia mater, extends from the conus medularis to posterior coccyx where it attaches -- anchors SC; SC also anchored to bony walls of vertebrae by denticulate ligaments.

- thirty-one pairs of spinal nerves arise from the SC by paired roots and exit from vertebral column via intervertebral foramina; enlargements in SC at cervical and lumbar regions correspond to areas where nerves serving the upper and lower limbs arise; note that the SC does not reach end of vertebral column, thus lumbar and sacral nerve roots angle sharply downward and travel inferiorly through the vertebral canal before reaching their intervertebral foramina -- this gives rise to the cauda equina.

A. Cross sectional anatomy: two major grooves, anterior median fissure, posterior median sulcus.

1. Gray matter/spinal roots

- gray matter is a mix of neuron cell bodies, unmyelinated processes and neuroglia, has appearance of an "H", two lateral gray masses connected by gray commissure.

- the two anterior projections of gray matter are the anterior (ventral) horns, the lateral projections are the lateral horns, and the posterior gray matter projections are the posterior (dorsal) horns.

a. anterior (ventral) horns: contain nerve cell bodies of somatic motor neurons, send their axons via ventral roots of SC to skeletal muscles.

b. lateral horns: are autonomic (sympathetic division) motor neurons that serve visceral organs, their axons leave SC via ventral roots along with those of somatic motor neurons (see above).

c. afferent fibers carrying impulses from peripheral sensory receptors form the dorsal roots of SC; nerve cell bodies of these sensory fibers form enlarged portion of dorsal root, dorsal root ganglion; after entering SC their axons can enter the posterior white matter directly and travel to synapse at higher cord/brain levels; or their axons can synapse with interneurons in posterior (ventral) horns.

d. note that dorsal and ventral roots fuse laterally to form spinal nerves.

2. White matter: composed of myelinated/unmyelinated nerve fibers, run in ascending and descending directions, and also can be commissural.

a. general:

(i)white matter on each side of cord can be divided into three white columns, posterior, anterior and lateral funiculi; each funiculus contains several fiber tracts, each tract made up of axons with similar destinations and functions.

(ii) all spinal tracts are part of multineuron pathways that connect brain to periphery; most pathways decussate, and consist of two to three neuron chains; all pathways are paired, 1 per side of SC.

b. ascending tracts: conduct sensory impulses (afferent) upward through chains of two or three successive neurons; most incoming information is from stimulation of general sensory receptors in skin and proprioreceptors in muscles, joints, tendons; four of these pathways transmit impulses to sensory cortex for conscious interpretation; two remaining pathways convey impulses from proprioreceptors to cerebellum for coordination of muscle activity.

c. descending tracts: deliver efferent impulses from brain to the SC; divided into two subgroups, pyramidal tracts and all others; in both cases, neurons originating in either the motor cortex or subcortical motor nuclei are called upper motor neurons (UMN, functionally they are really interneurons); the anterior horn neurons with which upper motor neurons synapse are called lower motor neurons (LMN, these are truly functional motor neurons).

(i) pyramidal tracts: originate in the motor cortex, UMN extend all the way without synapsing to SC, anterior horn; there they synapse with anterior horn motor neurons (LMN), which in turn innervate skeletal muscles.

(ii) "other" descending tracts: originate in various subcortical motor nuclei of brainstem, complex motor pathways.