

# THE BRAIN AND CRANIAL NERVES

## Chapter 14

### Anatomy and Physiology Lecture

## THE BRAIN AND THE CRANIAL NERVES

### I. BRAIN

#### A. PRINCIPAL PARTS

-Brain is made up of about 100 billion neurons.

-Is one of the largest organ in the body, weighing about 1300g.  
(3lb)

-Brain is Mushroom-shaped, and divided into four principal parts:

- a. Brain stem - Midbrain, Pons, & Medulla Oblongata
- b. Diencephalon - Thalamus & Hypothalamus
- c. Cerebrum - Right and left halves called cerebral hemispheres
- d. Cerebellum (Little brain)

#### Brain's many functions:

- the center for registering sensations;
- correlating sensations with one another and stored information
- making decisions
- taking action
- center for intellect
- emotions
- behavior
- memory
- directs our behavior towards others

## BRAINSTEM

Brain Stem { Medulla Oblongata  
Pons  
Midbrain

Connects the Spinal cord to the remainder of the brain and is responsible for many essential functions.

Damage to brainstem area often causes death.

### MEDULLA OBLONGATA (Medulla)

Is a continuation of the upper portion of the spinal cord and forms the inferior part of the brain stem.

Lies just superior to the level of the foramen magnum and extends upward to the inferior portion on the Pons.

\*Measures 3cm (about 1 inch) in length.

Function:

#### 1. Conduction Pathway for Motor and Sensory Impulses

-Contains all ascending and descending tracts that communicate between the spinal cord and various parts of the brain.

(These tracts constitute the white matter of the medulla.)

-\***Pyramids** are two roughly triangular structure on the ventral side of the medulla.

-Are composed of the largest motor tracts that pass from the outer region of the cerebrum (cerebral cortex) to the spinal cord.

-\*Just about the junction of the medulla with the spinal cord, most

of the fibers in, the left pyramid cross to the right side, and most of the fibers in the right pyramid cross to the left.

Note - this crossing is called the **Decussation of Pyramids**.

(**Decussation** explains why motor areas of one side of the cerebral cortex control muscular movements on the opposite side of the body.)

2. **Reticular Formation** - area of dispersed gray matter containing some white fibers.

-Functions in consciousness and arousal from sleep.

Unconsciousness

(The most common knockout blow is one that makes contact with the mandible. Such a blow twists and distorts the brain stem and overwhelms the reticular activating system (RAS) of the reticular formation by sending a sudden volley of nerve impulses to the brain, resulting in unconsciousness.)

- Think of blowing of fuse;
- Think of a "breaker" if current is over-loaded.

3. **Three vital reflex centers of the reticular system** (Regions within Medulla)
  - a. Cardiovascular Center - regulates the rate and force of heartbeat and the diameter of blood vessels.
  - b. Respiratory Center - adjusts the basic rhythm of breathing
  - c. Vestibular Nuclear Complex - for maintaining equilibrium
  - d. Other Centers (considered non-vital) - coordinate swallowing, vomiting, coughing, sneezing, and hiccuping.
4. Medulla also contains the nuclei of origin for several pairs of

cranial nerves.

- a. Cochlear and vestibular branches of the vestibulocochlear (VIII) nerves - concerned with hearing and equilibrium.
- b. Glossopharyngeal (IX) Nerves - relay nerve impulse related to swallowing, salivation, and taste;
- c. Vagus (X) Nerves - relay nerve impulse to and from many thoracic and abdominal viscera.
- d. Cranial Portion of the Accessory (XI) Nerves - convey nerve impulses related to head and shoulder movements.
- e. Hypoglossal (XII) Nerves - convey nerve impulses that involve tongue movements.

### **PONS** - means "bridge"

Lies directly above the medulla and anterior to the cerebellum.

\*Measures about 2.5 cm (1 inch) in length.

**Pons** is a bridge connecting the Spinal Cord with the brain and parts of the brain with each other.

#### Functions:

1. Nuclei of origin for several pairs of cranial nerves.
  - a. Trigeminal (V) Nerves - relay nerve impulses for chewing and for sensation of the head and face.
  - b. Abducens (VI) Nerves - regulate certain eyeball movements.

- c. Facial (VII) Nerves - conduct impulses related to taste, salivation, and facial expression.
- d. Vestibular branches of the Vestibulocochlear (VIII) Nerves - concerned with equilibrium.

## 2. Nuclei in the reticular formation of the pons

- a. Pneumotaxic Area
- b. Apneustic Area

Both with medullary rhythmicity area in the medulla, help control respiration (breathing movements).

## **MIDBRAIN OR MESENCEPHALON**

Extends from the pons to the lower portion of the Diencephalon.

Measures about 2.5 cm (1 inch) in length.

### Functions:

1. **Cerebral Peduncles** - is a pair of fiber bundles contained in the ventral portion of the midbrain.

Contain some motor fibers that convey impulses from the cerebral cortex to the pons, medulla, and spinal cord.

Constitute the main connection for tracts between upper parts of the brain and lower parts of the brain and the spinal cord.

2. **Red Nucleus** - A major nucleus in the reticular formation of the midbrain.

The origin of cell bodies of the descending rubrospinal tract:

- a. Superior Colliculi - serve as reflex centers for movement of

the eyes, head, and neck in response to visual and other stimuli.

b. Inferior Colliculi - serve as reflex centers for movements of the head and trunk in response to auditory stimuli (hearing).

c. Substantia Nigra (left and right) - control subconscious muscle activities.

d. Oculomotor (III) Nerves - mediate some movements of the eyeballs and changes in pupil size and lens shape.

e. Trochlear (IV) Nerves - conduct impulses that move the eyeballs.

**Reticular Formation** – Is a group nuclei scattered like a cloud throughout the length of the brainstem.

Receives axons from a larger number of sources and especially from nerves that innervate the face.

## **CEREBELLUM**

The second-largest portion of the brain.

Separated from the cerebrum by the transverse fissure

### Structure:

-Shaped somewhat like a butterfly.

-Central constricted area is the vermis (worm-shaped)

-Hemisphere - the lateral "wings" or lobes

\*The surface of the Cerebellum, called the cortex, consists of gray matter in a series of slender, parallel ridges called folia.

Note: (Folia - for cerebellum)  
(Gyrus- for cerebrum)

### Function:

1. Is a motor area of the brain concerned with coordinating subconscious movement of skeletal muscles.
2. The cerebellum also functions in maintaining equilibrium and controlling posture.
3. Is related to predicting the future position of a body part during a particular movement.

-Used in actions such as walking.

### **Clinical Application: Damage to Cerebellum**

Ataxia - lack of muscle coordination.

Intention Tremor- shaking during deliberate voluntary movement

## **DIENCEPHALON**

<u>Diencephalon</u>	{	Thalamus
		Subthalamus
		Epithalamus
		Hypothalamus

**THALAMUS** (Thalamus = inner chamber)

Oval structure above the midbrain

Measures about 3 cm (1 inch) in length - constitutes 4/5 of the diencephalon.

Function:

1. Some nuclei serve as relay stations for all sensory impulses, except smell, to the cerebral cortex.

- a. Medial Geniculate Nuclei - hearing
- b. Lateral Geniculate Nuclei - vision
- c. Ventral Posterior Nuclei - general sensation and taste

2. Other nuclei serve as centers for synapses in the somatic motor system.

- a. Ventral Lateral Nuclei - voluntary motor actions
- b. Ventral Anterior Nuclei - voluntary motor actions and arousal.

3. Thalamus also functions as an interpretation center for some sensory impulses, such as pain, light touch, temperature, and pressure.

4. In the Reticular formation

- a. Reticular Nucleus - in some way seems to modify neuronal activity in the thalamus
- b. Anterior nucleus - concerned with certain emotions and memory.

## **SUBTHALAMUS**

Small area immediately inferior to the thalamus that contains several ascending and descending nerve tracts and the Subthalamic nuclei.

**Subthalamic nuclei** are associated with basal nuclei and are involved to controlling motor functions.

## EPITHALAMUS

Small area superior and posterior to the thalamus.

Consists of:

**Habenular nuclei** – Are influenced by the sense of smell and are involved in emotional and visceral responses to odors.

**Pineal body** – Appear to play a role in controlling the onset of puberty. May also influence the sleep-wake cycle.

## HYPOTHALAMUS (hypo = under)

A small portion of the diencephalon located below the thalamus.

Forms the floor and part of the lateral walls of the third ventricle.

It is partially protected by the sella turcica of the sphenoid bone.

(\*Information from the external environment comes to the hypothalamus via afferent pathways originating in the peripheral sense organs.)

(\*Impulses from sound, taste, smell, and somatic receptors all come to the hypothalamus.)

(\*Afferent impulses, monitoring the internal environment arise from the internal viscera and reach the hypothalamus.)

The hypothalamus is divided into a dozen or so nuclei in four major regions:

**The Mammillary Region** - Adjacent to the midbrain; most posterior portion of the hypothalamus.

Includes: Mammillary bodies and posterior hypothalamus nucleus.

Are involved in olfactory reflexes and emotional responses to odors.

## **Chief Functions of the Hypothalamus**

1. Controls and integrates the autonomic nerve system, which regulates contraction of smooth muscle and cardiac muscle and secretion of many glands.
2. It is involved in the reception and integration of sensory impulses from the viscera.
3. It is the principal intermediary between the nervous system and the endocrine system - the two major control systems of the body.
4. It is the center for the mind-over-body phenomenon.
5. It is associated with feelings of rage and aggression.
6. It controls normal body temperature.
7. It regulates food intake through two centers:
  - a. Feeding (hunger) center - responsible for hunger sensations.
  - b. Satiety Center - stimulated when sufficient food has been ingested and sends nerve impulse that inhibit the feeding center.
8. It contains a thirst center.
9. It is one of the centers that maintains the waking state and sleep patterns.
10. It exhibits properties of a self-sustained oscillator and, as such, acts as a pacemaker to drive many biological rhythms.

## CEREBRUM

Forms the bulk of the brain

Supported on the brain stem (midbrain, pons, medulla oblongata)

Measures 1 to 4 mm (0.08 to 0.16 inch) thick

The surface is composed of gray matter (absence of myelin containing lipid substances)

The surface is referred to as cerebral cortex (cortex = rind or bark)

Beneath the cortex lies the cerebral white matter.

(During embryonic development, when there is a rapid increase in brain size, the gray matter of the cortex enlarges out of proportion to the underlying white matter.)

(As a result, the cortical region rolls and folds upon itself.)

\*The folds are called gyri or convolutions.

**Fissures** - the deep grooves between folds.

**Sulci** - the shallow grooves between folds.

**Longitudinal Fissure** - most prominent fissure that nearly separates the cerebrum into right and left halves or hemispheres.

**Corpus Callosum** - internally connect the hemispheres

### **LOBES**

Each cerebral hemisphere is further subdivided into four lobes by sulci or fissures.

- a. Frontal lobe
- b. Parietal lobe
- c. Temporal lobe
- d. Occipital lobe

**Central Sulcus** - separates frontal lobe from the parietal lobe

**Lateral cerebral sulcus (fissure)** - separates the frontal lobe from the temporal lobe

**Parietoccipital sulcus** - separates the parietal lobe from the occipital lobe

**Transverse fissure** - separates the cerebrum from the cerebellum

**CORTEX** – Is the **gray matter** on the outer surface of the cerebrum, and clusters of gray matter deep inside the brain nuclei.

**Cerebral Medulla** – Is the **white matter** of the brain between the cortex and nuclei.

(The white matter underlying the cortex consists of myelinated axons running in three principal directions):

- a. **Association Fibers** - connect and transmit nerve impulses between gyri in the same hemisphere.
- b. **Commissural fibers** - transmit impulses from the gyri in one cerebral hemisphere to the corresponding gyri in the opposite cerebral hemisphere.
- c. **Projection fibers** - form ascending and descending tracts that transmit impulses from the cerebrum to other parts of the brain and spinal cord. e.g. internal capsule

## **BASAL NUCLEI (BASAL GANGLIA)**

Are groups of functionally related nuclei located bilaterally in the inferior cerebrum, diencephalons, and midbrain.

Are involved in the control of motor functions.

The Nuclei are collectively called **Corpus Striatum**: (a) Lentiform nucleus, and (b) Caudate nucleus.

Subthalamis nucleus is the diencephalons

Substantia Nigra is in the Midbrain.

### **Clinical Application: Damage to Basal Ganglia**

Results in abnormal body movements, such as uncontrol labile shaking - tremor and involuntary movement of skeletal muscle.

\*Destruction of a substantial portion of the caudate nucleus results in almost total paralysis of the side of the body opposite to the damage.

\*The caudate nucleus is an area often affected by a stroke.

## **LIMBIC SYSTEM**

**Limbic System** – Play a central role in basic survival functions such as memory, reproduction, and nutrition.

It is also involved in emotions and memory.  
(Memory impairment results from lesions in the limbic system).

Although behavior is a function of the entire nervous system, the limbic system controls most of its involuntary aspects.

Other experiments have shown that the limbic system is associated with pleasure and pain.

\*It is sometimes called the "Visceral" or "Emotional" brain because it assumes a primary function in emotions such as pain, pleasure, anger, rage, fear, sorrow, sexual feelings, docility, and affection.

### **Clinical Application: Brain Injuries**

1. Concussion - an abrupt but temporary loss of consciousness following a blow to the head or a sudden stopping of a moving head. No visible bruising.
2. Contusion - a visible bruising of the brain due to trauma and blood leaking from the microscopic vessels.
3. Laceration - tearing of the brain, usually from a skull fracture or gunshot wound.

## **MENINGES AND CEREBROSPINAL FLUID**

### **MENINGES**

**Meninges** – Consists of three connective tissues that surround and protect the brain and spinal cord.

- a. Dura mater - the outermost
- b. Arachnoid - middle
- c. Pia mater - innermost

## VENTRICLES

**Ventricles** - Cavities in the brain that communicate with each other, with the central canal of the spinal cord, and with the subarachnoid space.

Lateral ventricles - located in a hemisphere of the cerebrum

Third ventricle- a vertical slit at the midline between the inferior to the right and left halves of the thalamus and between the lateral ventricles .

Interventricular foramen (foramen of Monro)- CSF formed in Choroid Plexus, lateral ventricles, flow through Interventricular foramen (foramen of Monro) into the third ventricle.

Fourth Ventricle - between brain stem and the cerebellum. CSF into 4th ventricle through cerebral aqueduct.

## CEREBROSPINAL FLUID (CSF)

Nourish and protect brain.

CSF further protects the brain and the rest of CNS against injury.

(**Choroid Plexus** of the lateral ventricle (network of capillaries) - CSF is formed here by filtration from blood plasma.)

(Choroid Plexus are covered by Ependymal cells which form the **Blood-Cerebrospinal Fluid Barrier**).

CSF serves as shock absorber and thus helps protect the delicate brain and spinal cord from trauma.

CSF circulates through the subarachnoid space (space between the arachnoid and pia mater) around the brain and spinal cord and through the ventricles of the brain.

Entire CNS contains between 80-150 ml (3-5 oz.) of cerebrospinal fluid (CSF).

-Is a clear colorless liquid of watery consistency.

-Chemically, contains proteins, glucose, urea, and salts.

-Also contains some lymphocytes (white blood cells that fight microbes)

## **FUNCTIONS OF CEREBROSPINAL FLUID (CSF)**

Cerebrospinal Fluid (CSF) Contributes to Homeostasis in three main ways:

1. **Mechanical Protection** - serves as a shock-absorbing medium to protect the delicate tissue of the brain and spinal cord from jolts that would otherwise cause them to crash against the bony walls of the cranial and vertebral cavities.  
  
-Also Buoy the brain so that it "floats" in the cranial cavity.
2. **Chemical Protection** - provides an optimal chemical environment for accurate neuronal signaling.
3. **Circulation** - medium for exchange of nutrients and waste products between the blood and nervous tissue.

\*Choroid Plexuses - are networks, of capillaries (microscopic blood vessels) in the walls of the ventricles.

-Capillaries are covered by ependymal cells that form cerebrospinal fluid from the blood plasma by filtration and secretion.

**\*Clinical Application: Hydrocephalus**

(If an obstruction, such as a tumor or a congenital blockage, or an

inflammation arises in the brain and interferes with the drainage of cerebrospinal fluid from the ventricles into the subarachnoid space, large amounts of fluid accumulate in the ventricles.

Fluid pressure inside the brain increases, and if the fontanelles have not yet closed, the head bulges to relieve the pressure. This condition is called Internal (noncommunicating) hydrocephalus.

(Hydro = water; enkephalus = brain)

(If an obstruction interferes with drainage somewhere in the subarachnoid space and cerebrospinal fluid accumulates inside the space, the condition is termed External (communicating) Hydrocephalus.)

## **BLOOD SUPPLY TO THE BRAIN**

Blood reaches the brain through the Internal Carotid Arteries, and Vertebral arteries.

Vertebral arteries join together to form the Basilar Artery.

Basilar Artery and Internal Carotid arteries contribute to the Cerebral Arterial Circle (Circle of Willis)

The Cerebral Cortex on each side of the brain is supplied by three branches from the cerebral arterial circle: anterior, middle, and posterior cerebral arteries.

Perivascular space - is the space between the penetrating blood vessel and pia mater.

Any interruption of the oxygen supply to the brain can result in weakening, permanent damage, or death of the brain cells.

If the blood flow to the brain is interrupted even briefly, unconsciousness may result.

-A one or two - minute interruption in blood flow may impair brain cells.

-If totally deprived of oxygen for about four minutes, many cell are permanently injured.

-If the condition persists long enough, Lysosomes break open and release enzymes that bring about self-destruction of brain cells.

(**Lysosomes** of brain cells are sensitive to decreased oxygen concentration.)

-Interruption of the mother's blood supply to child during childbirth before it can breath may result in paralysis, mental retardation, epilepsy, or death. (Results to **Stillborn babies**).

Brain composes only about **2%** of total body weight, it utilizes about **15%-20%** of blood pumped by the heart.

**Blood-Brain Barrier (BBB)** - a special mechanism that prevents the passage of materials from the blood to the cerebrospinal fluid and brain.

-Glucose, oxygen, carbon dioxide, water, and most lipid-soluble substances such as alcohol, caffeine, nicotine, heroin, and most anesthetics, pass through rapidly.

-Glucose, oxygen, and certain ions pass rapidly from the circulating blood into the brain cells.

-Creatine and urea enter quite slowly and most ions (Na<sup>+</sup>, K<sup>+</sup>, and Cl<sup>-</sup>)

-Protein and most antibiotics do not pass at all from the blood into brain cells.

\*Lipids or water-soluble substances cross the barrier.

Lipid-soluble - nicotine, alcohol, and heroin

Water-soluble - glucose, certain amino acids, and sodium

### **Functions of Blood-Brain Barrier:**

As a selective barrier to protect brain cells from harmful substances.

(Recent evidence suggests that the AIDS virus may penetrate the blood-brain barrier, producing dementia (irreversible deterioration of mental state), acute meningitis, back spasm, and other neurologic disorders before other symptoms of AIDS become apparent.)

### **Circumventricular Organs (CVOs)**

-Are several small brain regions lying in the walls of the third and fourth ventricles, includes:

- Part of the hypothalamus
- Pineal gland
- Pituitary gland

### **Function:**

- a. Coordinate homeostatic activities of the endocrine and nervous system:
  - Regulation of blood pressure
  - Fluid balance
  - Hunger
  - Thirst
- b. Monitor chemical changes in the blood because they lack the blood-brain barrier
- c. Are thought to be the entry for the AIDS virus into the brain.

## **DEVELOPMENT OF THE CNS**

Central Nervous System (CNS) develops from a plate of tissue, **Neural plate**, on the upper surface of the embryo, as a result of the influence of the underlying rod-shaped **Notochord**.

**Neural folds** – Is the lateral side of the neural plate that becomes elevated as waves.

**Neural crest** – Is the crest of each fold.

**Neural groove** – Is the center of the neural plate.

**Neural tube** – Formed as the neural fold move toward each other in the midline, and forms as a result of the crests fusing together.

**Neural crest cells** separate from the neural crests and give rise to sensory and autonomic neurons of the peripheral nervous system.

They also give rise to all pigment cells of the body, as well as facial bones and dentin of the teeth.

Three Brain Regions Identified in the Early Embryo:

1. **Forebrain (Prosencephalon)** – (a) Telencephalon, which becomes the Cerebrum, (b) Diencephalon, which stays diencephalon.
2. **Midbrain (Mesencephalon)** – Which remains as single structure.
3. **Hindbrain (Rhombencephalon)** – (a) Metencephalon, which becomes the pons and cerebellum, and (b) Myelencephalon, which becomes the medulla oblongata.

## CRANIAL NERVES

-12 pairs of cranial nerves (I - XII) (10 originate from the brain stem)

-Name indicate the distribution or function.

A given cranial nerve may have one or more of three functions:

1. Sensory
2. Somatic motor
3. Parasympathetic

**Sensory** – Its function include the special senses like vision and more general senses like touch and pain.

**Somatic motor** – Its functions refer to the control of skeletal muscles through motor neurons.

**Proprioception** – Informs the brain about the position of various body parts, including joints and muscles.

**Parasympathetic** – Its function involves the regulation of glands, smooth muscles, and cardiac muscle.

### **Functional Organization of the Cranial Nerves**

<u>Nerve Function</u>	<u>Cranial Nerve</u>
Sensory	I Olfactor
	II Optic
	VIII Vestibulocouchlear
Somatic	IV Trochlear
	VI Abducens
	XI Accessory
	XII Hypoglossal
Somatic Motor and Sensory	V Trigeminal
Somatic Motor and Parasympathetic	III Oculomotor
Somatic Motor Sensory, and Parasympathetic	VII Facial
	IX Glossopharyngeal
	X Vagus

## Cranial Nerves and Their Functions

Note:

### AGING AND THE NERVOUS SYSTEM

1. One of the effects of aging on the nervous system is that neurons are lost.
2. Conduction velocity decreases, voluntary motor movements slow down, and the reflex time for skeletal muscles increases.
3. Disorders that represent the most common visual problems and may be responsible for serious loss of vision are:
  - a. Presbyopia - inability to focus on nearby objects
  - b. Cataracts - cloudiness of the lens
  - c. Glaucoma - excessive fluid pressure in the eyeball
4. Presbycusis - impaired hearing associated with aging.