Organization and Overview of the Central Nervous System
CNS 424
By
Prof. Hisham Al-Matubsi
Components
- Brain, spinal cord, nerves, sensory receptors

Responsible for
- Sensory perceptions, mental activities, stimulating muscle movements, secretions of many glands

Subdivisions
- Central nervous system (CNS)
  - Consists of brain & spinal cord
- Peripheral nervous system (PNS)
Peripheral nervous system (PNS)

- Consists of nerve fibers that carry information between CNS & other parts of body (the periphery)

- **PNS** further subdivided into **Afferent** & **Efferent** divisions
  - **Afferent (sensory) division:**
    - Carries information to CNS
  - **Efferent (motor) division:**
    - Carries information away from CNS to effector organs
Two subcategories

- **Afferent or Sensory**
  - Sensory stimuli: carry conscious input
    - 1 – somatic (body sense) sensation OR
    - 2 – special senses
  - Visceral stimuli: carry subconscious input

- **Efferent or Motor**
  - **Divisions**
    - **Somatic nervous system**
    - **Autonomic nervous system** (ANS)
      - Sympathetic
      - Parasympathetic
      - Enteric (nerve network in wall of digestive tract)
Afferent neurons:
- Inform CNS about conditions in both external & internal environment
- At its peripheral ending, there is a Sensory Receptor that generates Action Potentials in response to stimulus
**Functional Classes of Neurons**

- **Efferent neurons:**
  - Carry instructions from CNS to effector organs – muscles & glands

- **Interneurons:**
  - Found entirely within CNS
  - Lie between Afferent & Efferent neurons
  - Responsible for:
    - Integrating afferent information & formulating an efferent response
    - Interconnections between interneurons are responsible for higher mental functions

*FIGURE 5-2 Structure and location of the three functional classes of neurons.* *Efferent autonomic nerve pathways consist of a two-neuron chain between the CNS and the effector organ.*
The figure illustrates the central nervous system (CNS) and peripheral nervous system (PNS) processes. The CNS, comprising the brain and spinal cord, receives input from the periphery and sends output to the periphery. The PNS has two divisions: afferent (sensory) and efferent (motor). Sensory stimuli travel to the CNS, while motor stimuli (efferent) travel from the CNS to activate effector organs.

**Key**
- Central nervous system (CNS)
- Peripheral nervous system (PNS)
  - Afferent division of PNS
  - Efferent division of PNS
  - Somatic nervous system
  - Autonomic nervous system
  - Enteric nervous system

**Effector organs** (made up of muscle and gland tissue)
- Skeletal muscles
- Smooth muscle
  - Cardiac muscle
  - Exocrine glands
  - Some endocrine glands

Stimuli in the digestive tract affect effector organs in the digestive tract, indicating the role of the nervous system in both somatic and autonomic functions.
Cells of Nervous System

- **Neurons or nerve cells**
  - Receive stimuli and transmit action potentials
  - **Organization**
    - Cell body or soma
    - Dendrites: Input
    - Axons: Output

- **Neuroglia or glial cells**
  - Support and protect neurons
Functional classification
- Sensory or afferent: Action potentials toward CNS
- Motor or efferent: Action potentials away from CNS
- Interneurons or association neurons: Within CNS from one neuron to another

Structural classification
- Multipolar, bipolar, unipolar
Also called **glial cells**
They do **not** initiate or conduct nerve impulses
- Do communicate with neurons & among themselves via chemical signals

Serve as Connective Tissue of CNS: therefore, they
- Physically, metabolically, and functionally support neurons

4 **major types of glial cells in CNS**:  
- Astrocytes  
- Ependymal cells  
- Microglia  
- Oligodendrocytes
Astrocytes

- Named for star-like shape (astro = “star”)
- **Most abundant glial cells**
- Main “glue” of CNS – holds neurons together
- Promote tight junctions & induce capillaries of brain to undergo changes that aid in establishment to **blood–brain barrier (BBB)**
- Guide neurons during fetal brain development
- Help **transfer nutrients** to neuron because of close association with both local capillaries & neurons
- Important in **repair** of brain injuries.
- Take up excess K⁺ from brain ECF
- Play role in neurotransmitter activity
  - Take up & degrade **Glutamate & GABA**
Ependymal Cells
- Line brain ventricles & spinal cord central canal
- In **ventricles** of brain, help form & circulate **cerebrospinal fluid**
- Serve as **neural stem cells** with the potential to form new neurons & glial cells
Microglia
- Specialized macrophages (i.e. immune defense cells of CNS)
- In resting state, release low levels of growth factors such as nerve growth factor that help neurons & other glial cells survive

Oligodendrocytes
- Form myelin sheaths if surround axon in CNS
Schwann cells or neurolemmocytes
- Wrap around portion of only one axon to form myelin sheath

Satellite cells
- Surround neuron cell bodies in ganglia, provide support and nutrients
Neuroglia

FIGURE 5-3 Glial cells of the central nervous system. The glial cells include the astrocytes, oligodendrocytes, microglia, and ependymal cells.
Neuroglia

Satellite cells:
- Surround neuron cell bodies in ganglia
- Regulate O₂, CO₂, nutrient, and neurotransmitter levels around neurons in ganglia

Peripheral Nervous System

Schwann cells:
- Surround axons in PNS
- Are responsible for myelination of peripheral axons
- Participate in repair process after injury

Oligodendrocytes:
- Myelinate CNS axons
- Provide structural framework

Astrocytes:
- Maintain blood-brain barrier
- Provide structural support
- Regulate ion, nutrient, and dissolved gas concentrations
- Absorb and recycle neurotransmitters
- Form scar tissue after injury

Central Nervous System

Ependymal cells:
- Line ventricles (brain) and central canal (spinal cord)
- Assist in producing, circulating, and monitoring of cerebrospinal fluid

Microglia:
- Remove cell debris, wastes, and pathogens by phagocytosis
CNS consists of brain & spinal cord
- 100 billion neurons in brain

Enables to:
- Subconsciously regulate internal environment by neural means
- Experience emotions
- Voluntarily control movements
- Be consciously aware of person own body and person’s surroundings
- Engage in other higher cognitive (=mental, intellectual) processes such as thought & memory
Protection of CNS

- Enclosed by hard, bony structures
  - Crainum (skull) encases brain
  - Vertebral column surrounds spinal cord

- Wrapped by 3 protective and nourishing membranes – **meninges** (from outermost to innermost layer)
  - Dura mater
  - Arachnoid mater
  - Pia mater

- Brain floats in cushioning fluid – **cerebrospinal fluid** (CSF).
Protection of CNS

- **Blood–brain barrier** limits access of blood–borne materials into brain tissue.
  - Regulate exchanges between blood & brain.
  - Protects brain from **chemical fluctuations** in blood.
  - Prevents certain circulating **hormones** that could also act as **neurotransmitters** from reaching brain.
  - Minimizes possibility that **harmful blood–borne substances** might reach central nervous tissue.
Cerebrospinal Fluid (CSF)

- Surrounds & cushions brain & spinal cord

- **Major function:**
  - Serves as a shock-absorbing fluid to prevent brain from bumping against hard skull
  - Exchange of materials between neural cells & interstitial fluid surrounding brain

- Formed primarily by choroid plexuses
Brain Anatomy

- **Brain components** (based on **anatomical location**, from bottom to top & their complexity of function from least to most specialized level)
  - **Brain stem**
    - Consists of
      - Midbrain
      - Pons
      - Medulla
  - **Cerebellum**
  - **Forebrain**
    - Diencephalon housed
      - Hypothalamus
      - Thalamus
  - **Cerebrum**
    - Divided into 2 halves:
      - Right and Left **Cerebral Hemispheres**, Connected to each other by **Corpus callosum**
    - Outer surface is highly **convoluted cerebral cortex**
    - Caps inner core that houses **basal nuclei**
      - Basal nuclei: masses of gray matter located deep within white matter
1. Sensory perception
2. Voluntary control of movement
3. Language
4. Personality traits
5. Sophisticated mental events, such as thinking, memory, decision making, creativity, & self-consciousness

1. Inhibition of muscle tone
2. Coordination of slow, sustained movements
3. Suppression of useless patterns of movement

1. Relay station for all synaptic input
2. Crude awareness of sensation
3. Some degree of consciousness
4. Role in motor control

1. Regulation of many homeostatic functions, such as temperature control, thirst, urine output, & food intake
2. Important link between nervous & endocrine systems
3. Extensive involvement with emotion & basic behavioral patterns
4. Role in sleep–wake cycle

1. Maintenance of balance
2. Enhancement of muscle tone
3. Coordination & planning of skilled voluntary muscle activity

1. Origin of majority of peripheral cranial nerves
2. Cardiovascular, respiratory, & digestive control centers
3. Regulation of muscle reflexes involved with equilibrium and posture
4. Reception & integration of all synaptic input from spinal cord; arousal & activation of cerebral cortex
5. Role in sleep–wake cycle
Each half of cortex divided into 4 major lobes:
- Occipital
- Temporal
- Parietal
- Frontal

are specialized for different activities.

keep in mind that even though a discrete activity is attributed to a particular region of brain, no part of brain functions in isolation.
Frontal lobe:
1- Voluntary motor control of skeletal muscle
2- Intellectual processes (concentration, planning & decision making)
3- Verbal communication (speaking ability)

Parietal lobe:
1- Receive sensory input = (perception) such as touch, pressure, heat, cold, & pain from surface of body (somatesthetic sensation)
2- Understanding speech & formulating words to express thought
3- Emotions

Temporal lobe
1- Contains auditory (= sound) centers;
2- Receives sensory info from cochlea
3- Also links & processes auditory & visual info

Occipital lobe:
1- House the visual cortex
2- Responsible for vision & coordination of eye movements
Damage to somatosensory cortex in left hemisphere produces sensory deficits on right side of body, whereas sensory losses on left side are associated with damage to right half of the cortex.

Motor cortex
- Controls muscles on opposite side of the body.
  - Accordingly, damage to the motor cortex on left side of brain produces paralysis on right side of body, & converse is also true.
Areas of brain responsible for language ability are found in left hemisphere (Broca’s area & Wernicke’s area).

- **Broca’s area:**
  - Governs speaking ability
  - Located in left frontal lobe in close association with motor areas of cortex that control muscles necessary for articulation.

- **Wernicke’s area:**
  - Located in left cortex at juncture of parietal, temporal, & occipital lobes
  - Concerned with language comprehension.
  - It plays a critical role in understanding both spoken & written messages.
There are three association areas:

1. The prefrontal association cortex,
   - planning for voluntary activity
   - decision making
   - creativity &
   - personality traits.
   - site of operation of working memory, where brain (temporarily stores & actively manipulates information used in reasoning & planning).
There are three association areas:

- **The parietal–temporal–occipital association cortex**, 
  - It pools & **integrates all sensory input** (somatic, auditory, & visual) for complex perceptual processing.
  - also involved in language pathway connecting Wernicke’s area to visual & auditory cortices.
There are three association areas:

3. The limbic association cortex
   - Consists of a group of forebrain nuclei & fiber tract that form a ring surrounding brain stem
   - Limbic system & hypothalamus involved in
     - Emotion (include aggression, docity, fear, happiness, anger, feeding, sex)
     - Basic survival (attack, search for food)
     - Motivation (include goal-directed behaviors (reward & punishment system), & physical responses that associated with these feeling (laughing, crying)
   - Limbic system Involved in memory
Also known as Basal Ganglia
Consists of several masses of grays matter located deep within white matter

Primary functions (inhibitory role in motor control)

1– Inhibiting muscle tone Throughout body
2– Suppressing useless or Unwanted patterns of movement
3– Helping monitor & coordinate slow, sustained contractions, especially those related to posture & support

- Parkinson’s disease characterized by increase muscle tone, useless involuntary movement & slowness in initiating & carry out different motor behavior (tend to be seated & if they got up they do it very slowly)
Diencephalon consists of two main parts:
- Thalamus & Hypothalamus

**Thalamus functions:**
- Relay center thru which all sensory info (except olfactory) passes to cerebrum
- & plays role in level of arousal (to awaken from sleep)
  - i.e direct our attention to stimuli of interest in cooperation with brain stem & cortical associated area

**Hypothalamus functions**
- Integrating center for many homeostatic functions (body temp., thirst, urine output, food intake) &
- serves as link between ANS & endocrine system.
- Brain area most involved in directly regulating internal environment as when body is cold person motivated to put on warmer clothing, close window, turn up thermostat, and so on.
- Hypothalamus, which, as a part of limbic system, functions together with cortex in controlling emotions & motivated behavior.
Cerebellum

3 different parts
- **Vestibulocerebellum**
  - Important in **maintaining balance & controls eye movements**
- **Spinocerebellum**
  - Enhances **muscle tone & coordinates skilled, voluntary movements** (e.g. typing, playing piano, running, pick up a pencil)
- **Cerebrocerebellum**
  - Plays role in **planning and initiating voluntary activity by providing input to cortical motor areas**

Thus cerebellum important in balance & in planning & executing voluntary movement
Brain Stem

- Critical connecting link between spinal cord & higher brain regions
- Continuous with spinal cord
- All incoming & outgoing fibers traversing between periphery & higher brain centers must pass Brain Stem
- Consists of
  - Midbrain
  - Pons
  - Medulla
Brain Stem

Functions
- Most of cranial nerves arise from brain stem
- House centers that regulate cardiovascular, respiration, & many digestive systems
- Plays role in regulating muscle reflexes involved in equilibrium and posture

- **Reticular formation** within brain stem receives & integrates all incoming sensory synaptic input that direct our attention toward specific events

- House centers that govern sleep (evidence suggests center promoting slow-wave sleep lies in hypothalamus)
- Sleep: An active process consisting of alternating periods of **slow-wave sleep** & **paradoxical sleep**.
Spinal Cord

- Extends from brain stem through vertebral canal
- **31 pairs of spinal nerves** emerge from spinal cord through spaces formed between arches of adjacent vertebrae
  - Named for region of vertebral column from which they emerge
    - 8 pairs *cervical* (neck) nerves
    - 12 pairs *thoracic* (chest) nerves
    - 5 pairs *lumbar* (abdominal) nerves
    - 5 pairs *sacral* (pelvic) nerves
    - 1 pair *coccygeal* (tailbone) nerves
- **2 vital functions**
  - Neuronal link between brain & PNS
  - Integrating center for spinal reflexes