CALICUT UNIVERSITY

SECOND SEMESTER

FOUR-YEAR UNDER GRADUATE PROGRAMME (CU-FYUGP)

NEUROPHYSIOLOGY

FYUGP PSYCHOLOGY-MINOR

PREPARED BY

ASIFA T

DEPARTMENT OF PSYCHOLOGY

CPA COLLEGE OF GLOBAL STUDIES, PUTHANATHANI

Group name: Human Physiology - 1

Course code	PSG2MN101				
Course title	Neurophysiology				
Type of course	Minor				
Semester	II				
Academic level	100-199				
Course details	Credit	Lecture per week	Tutorial per week	Practical per week	Total hours
	4	3		2	5
Pre requisites	+2/ VHSC or equivalent online courses.				
Course objectives					

MODULE 1: THE NERVOUS SYSTEM (11 hr)

Unit 1 Divisions of Nervous system and tissue (6 hr): (CNS, PNS - somatic and autonomic); Nervous tissue (neurons, nerve fibres, nerves, synapse); Non nervous tissue and other materials (neuroglia, meninges, Cerebro-spinal fluid, Blood- CSF and blood-brain barriers).
Unit 2: Nerve impulse (5 hr): Ceneration, conduction, synaptic transmission, the role of calcium ions,action of transmitter substances on the postsynaptic neuron, types of transmitter substances.

MODULE 2: THE CENTRAL NERVOUS SYSTEM (11 hr)

Unit 1: Brain (3 hr): An overview (Forebrain, midbrain, hindbrain).
Unit 2: Spinal cord (2 hr): An overview of its structure and organization.
Unit 3: Reflex action (4 hr): Reflex arc, muscle spindle, Golgi tendon organ, Types of reflexes-monosynaptic reflex, multi-synaptic reflex, crossed extension reflex, mass reflex.
Unit 4: Neural control of muscle tone and posture (2 hr):

MODULE 3: THE CEREBELLUM AND THE BASAL GANGLIA (11 hr)

Unit 1: The Cerebellum and its motor functions (2 hr):
Unit 2: Anatomical functions, areas of the cerebellum (3 hr):
Unit 3: Function of the cerebellum in overall motor control (2 hr):
Unit 4: The basal ganglia-their motor functions (4 hr): Role of the basal ganglia for cognitive control,functions of neurotransmitters with basal ganglia.

MODULE 4:THE CEREBRAL CORTEX, SLEEP AND TECHNIQUES IN NEUROPHYSIOLOGY (12 hr)

Unit 1: Functions of the specific cortical areas (4 hr): Association areas (parietooccipito temporal, prefrontal and limbic association areas with special emphasis on Wernicke's area and Broca's area), area for recognition of faces, the concept of the dominant hemisphere.
Unit 2: Function of the brain in communication (2 hr): Sensory and Motor aspects of communication
Unit 3: - Sleep (2 hr): Basic theories of sleep, Brain waves, Slow-wave sleep and REM sleep.
Unit 4: Techniques in neurophysiology (4 hr): Brain imaging - CT, MRI, PET, CBF, EEG, Lesioning, and Electrical Stimulation of Brain (ESB).

MODULE 5: PRACTICALS (1 CREDIT, 30 hr) MANDATORY EXPERIMENTS

1. Identification of parts of Brain using charts, models etc.
2. Identification of Brain waves - Slow wave sleep, REM sleep etc.
3. Demonstration of reflexes- Superficial reflexes, Deep tendon reflexes, Primitive or spinal reflexes. Tonic or brainstem reflexes.
4. Demonstration of cranial nerve integrity.
5. Demonstration of motor function.
6. Demonstration of assessment of cognitive function – Memory.
7. Demonstration of assessment of speech and communication.

For conducting the experiments from No. 3 to 7, the students can visit any Physiotherapy clinic or

institute, or the teacher can find the help of any professionals from Medical field. The total duration of the institutional visit or the consultation with the professional must not exceed 10 hr. Two experiments other than the listed should be selected by the supervising teacher and introduced to the students.

References

1. Text Book of Medical Physiology. Hall and Guyton W.B. Saunders Company, London.
2. Review of Medical Physiology – Ganong. W.F. McGraw Hill INC. New York.
3. Text Book of Anatomy and Physiology – Tortora. Harper Collins College Publications.
4. Text Book of Anatomy & Physiology – Patton & Thibodiau – Mosby.
5. Text book of Medical Physiology – AP Krishna, Scientific publications, New Delhi.
6. Sarada Subrhmanian and K. Madhavan Kutty. A Text Book of Physiology. Onent Longman Publication.
9. Schneider A.M &Tarshis B. An introduction to Physiological Psychology. Random House, New York.
10. Levinthal C.F. Introduction to Physiological Psychology, Prentice Hall. New Delhi.
11. Pinel PJ John, Biopsychology, Pearson.
12. Neil. R.Carlson, Physiology of behavior, Pearson publishers.
13. Carlson, Neil. R., Physiology of Behavior, 8 th edition, Pearson.
14. Chatterjee, C.C, Human Physiology, Medical Allied Agency.
15. Text book of Medical Physiology – AP Krishna, Scientific publications, New Delhi.

MODULE 1: THE NERVOUS SYSTEM (11 hr)

Unit 1: Divisions of the Nervous System and Nervous Tissue

Divisions of the Nervous System

1. Central Nervous System (CNS)

- Composed of the **brain** and **spinal cord**
- Main functions:
  - **Processes and integrates information**
  - **Controls body activities**
  - **Coordinates responses**

2. Peripheral Nervous System (PNS)

- Composed of **nerves and ganglia outside the CNS**
- Divided into:
  - **Somatic Nervous System (SNS)**
    - Voluntary control of skeletal muscles
    - Transmits sensory information to the CNS
  - **Autonomic Nervous System (ANS)**
    - Involuntary control of glands, smooth muscles, and internal organs
    - Further divided into:
      - **Sympathetic Nervous System** (Fight or Flight)
        - Increases heart rate, dilates pupils, increases respiration
      - **Parasympathetic Nervous System** (Rest and Digest)
        - Slows heart rate, stimulates digestion, constricts pupils

Nervous Tissue

1. Neurons (Nerve Cells)

- Functional units of the nervous system
- Specialized for electrical impulse transmission
- **Structure:**
  - **Dendrites:** Receive signals
  - **Cell Body (Soma):** Contains nucleus and organelles
  - **Axon:** Conducts impulses away from the cell body
  - **Axon Terminals:** Release neurotransmitters
- **Types of Neurons:**
  - **Sensory (Afferent) Neurons:** Transmit impulses from sensory receptors to CNS
  - **Motor (Efferent) Neurons:** Carry impulses from CNS to effectors (muscles/glands)
  - **Interneurons:** Connect sensory and motor neurons within CNS

2. Nerve Fibres and Nerves

- **Nerve Fibres:** Extensions of neurons (axons or dendrites)
- **Myelinated Fibres:** Covered by **myelin sheath** (fast conduction)
- **Unmyelinated Fibres:** Lack myelin (slower conduction)
- **Nerves:** Bundles of nerve fibres in PNS

    - **Sensory Nerves:** Carry sensory input to CNS
    - **Motor Nerves:** Carry motor commands from CNS
    - **Mixed Nerves:** Contain both sensory and motor fibres

3. Synapse

- **Definition:** Junction between two neurons or a neuron and an effector
- **Types:**
    - **Electrical Synapse:** Direct transmission of impulses via gap junctions
    - **Chemical Synapse:** Neurotransmitters are released into synaptic cleft

Non-Nervous Tissue and Other Materials

1. Neuroglia (Glial Cells) - Supporting Cells

- Provide support, protection, and nourishment to neurons
- **Types in CNS:**
    - **Astrocytes:** Maintain blood-brain barrier, structural support
    - **Oligodendrocytes:** Form myelin in CNS
    - **Microglia:** Act as immune cells, remove debris
    - **Ependymal Cells:** Produce cerebrospinal fluid (CSF)
- **Types in PNS:**
    - **Schwann Cells:** Form myelin in PNS
    - **Satellite Cells:** Support neuron cell bodies in ganglia

2. Meninges

- **Three protective membranes covering the CNS:**
    - **Dura Mater:** Outermost, tough layer
    - **Arachnoid Mater:** Middle layer, contains CSF
    - **Pia Mater:** Innermost, delicate layer, adheres to brain/spinal cord

3. Cerebrospinal Fluid (CSF)

- **Functions:**
    - Cushions brain and spinal cord
    - Provides nutrients and removes waste
    - Maintains homeostasis
- **Produced by:** Choroid plexus in ventricles
- **Circulates in:** Ventricles, subarachnoid space, spinal cord

4. Blood-CSF and Blood-Brain Barriers

- **Blood-CSF Barrier:**
    - Controls substances entering CSF
    - Formed by tight junctions in choroid plexus cells
- **Blood-Brain Barrier (BBB):**

- Restricts passage of harmful substances from blood to brain
- Formed by endothelial cells and astrocytes

Unit 2: Nerve Impulse

1. Generation of Nerve Impulse

- **Resting Membrane Potential:**
  - Neuron at rest (-70mV)
  - More Na^+ outside, more K^+ inside
- **Action Potential:**

1. **Depolarization:** Na^+ channels open → Na^+ enters neuron (+30mV)
2. **Repolarization:** K^+ channels open → K^+ exits neuron (-70mV)
3. **Hyperpolarization:** Brief overshoot before returning to resting state

- **All-or-None Law:** If threshold is reached, full action potential occurs

2. Conduction of Nerve Impulse

- **Continuous Conduction:** In **unmyelinated** fibres (slow)
- **Saltatory Conduction:** In **myelinated** fibres (fast, jumps between nodes of Ranvier)

3. Synaptic Transmission

- **Steps:**
  1. Action potential reaches presynaptic terminal
  2. **Calcium ions (Ca^{2+})** enter the terminal
  3. Vesicles release neurotransmitters into synaptic cleft
  4. Neurotransmitters bind to receptors on postsynaptic neuron
  5. Excitatory (EPSP) or Inhibitory (IPSP) response is triggered

4. Role of Calcium Ions (Ca^{2+}) in Synaptic Transmission

- Triggers release of neurotransmitters from synaptic vesicles
- Regulates synaptic strength and plasticity

5. Action of Transmitter Substances on Postsynaptic Neuron

- **Excitatory Postsynaptic Potential (EPSP):**
  - Depolarizes postsynaptic membrane
  - Increases chance of action potential
- **Inhibitory Postsynaptic Potential (IPSP):**
  - Hyperpolarizes postsynaptic membrane
  - Decreases chance of action potential

6. Types of Transmitter Substances

- **Excitatory Neurotransmitters:**
  - **Acetylcholine (ACh)** → Muscle contraction, learning
  - **Glutamate** → Major excitatory neurotransmitter in CNS
  - **Dopamine (DA)** → Mood, movement
- **Inhibitory Neurotransmitters:**
  - **Gamma-Aminobutyric Acid (GABA)** → Main inhibitory neurotransmitter
  - **Glycine** → Inhibitory in spinal cord
- **Modulatory Neurotransmitters:**
  - **Serotonin (5-HT)** → Mood, sleep, appetite
  - **Norepinephrine (NE)** → Fight or flight response

Summary of Key Concepts

- CNS = Brain + Spinal Cord; PNS = Nerves + Ganglia
- Neurons transmit electrical impulses; Glial cells provide support
- Synapse = Neuron communication site
- Action Potential = Electrical signal via ion movement
- Myelination speeds up impulse transmission
- Neurotransmitters can excite or inhibit neurons

MODULE 2: THE CENTRAL NERVOUS SYSTEM

Unit 1: Brain

Overview of Brain Divisions

1. **Forebrain (Prosencephalon):**
    - **Cerebrum:**
        - Largest part of the brain
        - Divided into **two hemispheres** (left & right)
        - **Four lobes:**
            - **Frontal lobe:** Decision-making, voluntary movements
            - **Parietal lobe:** Sensory processing, spatial awareness
            - **Temporal lobe:** Hearing, memory, language
            - **Occipital lobe:** Vision processing
    - **Thalamus:** Sensory relay center (except smell)
    - **Hypothalamus:** Regulates hormones, temperature, hunger, thirst
2. **Midbrain (Mesencephalon):**
    - Located between forebrain & hindbrain
    - Controls **eye movement, auditory & visual reflexes**
    - **Contains:**
        - Superior & Inferior Colliculi (Visual & Auditory processing)
        - Substantia Nigra (Dopamine production, movement control)
3. **Hindbrain (Rhombencephalon):**
    - **Cerebellum:** Coordination of movement, balance, posture
    - **Pons:** Bridge between brain regions, regulates sleep & respiration
    - **Medulla Oblongata:** Controls involuntary functions (breathing, heart rate, blood pressure)

Unit 2: Spinal Cord

Overview of Structure and Organization

- **Part of the CNS, extends from the brainstem to L1/L2 vertebra**
- **Protected by:**
    - Vertebrae
    - Meninges (Dura, Arachnoid, Pia mater)
    - Cerebrospinal Fluid (CSF)
- **Internal Structure:**
    - **Gray Matter:** Inner butterfly-shaped region (neuron cell bodies)
    - **White Matter:** Outer layer (myelinated nerve fibres)
- **Major Functions:**
    - Transmitting signals between brain & body
    - Reflex control
- **Divided into Regions:**
    - Cervical

- Thoracic
- Lumbar
- Sacra

Unit 3: Reflex Action

1. Reflex Arc

- The neural pathway involved in reflexes
- **Components:**
  1. **Receptor:** Detects stimulus
  2. **Sensory neuron:** Transmits impulse to CNS
  3. **Interneuron (optional):** Processes impulse
  4. **Motor neuron:** Sends response signal
  5. **Effector:** Muscle/gland executes response

2. Muscle Spindle & Golgi Tendon Organ

- **Muscle Spindle:** Detects muscle stretch, triggers contraction
- **Golgi Tendon Organ (GTO):** Detects tension, prevents overcontraction

3. Types of Reflexes

Monosynaptic Reflex:

- **Involves only one synapse** between sensory & motor neuron
- Example: **Patellar (knee-jerk) reflex**

Multisynaptic Reflex:

- **Involves interneurons** in the spinal cord
- More complex responses
- Example: **Withdrawal reflex**

Crossed Extension Reflex:

- **Occurs in limbs:** One limb withdraws, the opposite extends
- Example: **Stepping on a sharp object**

Mass Reflex:

- **Involves multiple muscle groups** contracting together
- Can be seen in spinal cord injuries

Unit 4: Neural Control of Muscle Tone and Posture

1. Muscle Tone

- Continuous, partial contraction of muscles
- Maintained by stretch reflexes and CNS control

2. Posture Maintenance

- **Cerebellum & Basal Ganglia**: Regulate balance and coordination
- **Vestibular System:** Controls body orientation
- **Reticular Formation:** Regulates muscle tone

Summary of Key Concepts

- Brain divided into Forebrain, Midbrain, Hindbrain
- Spinal cord is structured into gray & white matter, involved in reflexes
- Reflex actions are rapid, involuntary responses to stimuli
- Muscle tone & posture controlled by multiple brain regions

MODULE 3: THE CEREBELLUM AND THE BASAL GANGLIA

Unit 1: The Cerebellum and Its Motor Functions

Overview of the Cerebellum

- Located at the back of the brain, below the occipital lobe
- Part of the hindbrain, connected to the brainstem
- **Primary role:** Coordination of voluntary movements, balance, and posture

Motor Functions of the Cerebellum

1. **Coordination of Movements:**
   - Smooth execution of voluntary movements
   - Timing and precision of motor activity
2. **Balance and Posture Maintenance:**
   - Works with the **vestibular system** for equilibrium
   - Adjusts muscle activity to maintain posture
3. **Muscle Tone Regulation:**
   - Fine-tunes muscle contractions to prevent excessive movement
   - Involved in unconscious motor adjustments
4. **Motor Learning:**
   - Plays a key role in procedural memory (e.g., learning to ride a bike)
   - Adapts motor activity based on feedback from sensory systems

Unit 2: Anatomical Functions and Areas of the Cerebellum

Anatomical Divisions of the Cerebellum

- **Cerebellar Cortex:** Outer layer with gray matter
- **White Matter:** Contains myelinated nerve fibres
- **Deep Cerebellar Nuclei:** Relay motor signals

Functional Areas of the Cerebellum

1. **Vestibulocerebellum (Flocculonodular Lobe):**
   - Controls **balance and eye movements**
   - Works with the **vestibular system**
2. **Spinocerebellum (Vermis and Intermediate Zone):**
   - Regulates **posture and limb movements**
   - Provides **error correction during movement**
3. **Cerebrocerebellum (Lateral Hemispheres):**
   - Involved in **planning and initiation of movements**

- Works with the cerebral cortex for **skilled motor activities**

Unit 3: Function of the Cerebellum in Overall Motor Control

How the Cerebellum Controls Movements

- Receives sensory input from **muscles, joints, and eyes**
- Sends corrective signals to the **motor cortex**
- Works with **basal ganglia** to refine movements

Role in Motor Control

1. **Error Correction Mechanism:**
   - Compares intended and actual movement
   - Adjusts signals to fine-tune motor activity
2. **Coordination of Rapid Movements:**
   - Helps in activities like running, playing instruments
   - Ensures smooth execution of fast sequences
3. **Motor Adaptation and Learning:**
   - Adjusts motor patterns through trial and error
   - Essential for learning new movements

Unit 4: The Basal Ganglia - Their Motor Functions

Structure of the Basal Ganglia

- Group of nuclei located deep in the brain
- Includes:
  - **Caudate nucleus**
  - **Putamen**
  - **Globus pallidus**
  - **Subthalamic nucleus**
  - **Substantia nigra**

Motor Functions of the Basal Ganglia

1. **Regulation of Voluntary Movements:**
   - Helps initiate and control voluntary movement
   - Prevents unwanted movements
2. **Smooth Execution of Movement:**
   - Works with the cerebellum to refine motor commands
   - Helps coordinate repetitive movements (e.g., walking)
3. **Inhibition of Unwanted Movements:**
   - Controls **muscle inhibition** to prevent tremors or rigidity
   - Dysfunction leads to **Parkinson's disease or Huntington's disease**

Role of the Basal Ganglia in Cognitive Control

- Involved in **motor planning, habit formation, and decision-making**
- Works with the **prefrontal cortex** for cognitive control of movement
- Helps in **procedural learning** (learning through repetition)

Functions of Neurotransmitters in the Basal Ganglia

1. **Dopamine (DA):**
    - Produced by the **substantia nigra**
    - Regulates movement and reward-based learning
    - Deficiency leads to **Parkinson's disease**
2. **Gamma-Aminobutyric Acid (GABA):**
    - Inhibitory neurotransmitter
    - Prevents excessive motor activity
3. **Glutamate:**
    - Excitatory neurotransmitter
    - Helps stimulate movement
4. **Acetylcholine (ACh):**
    - Modulates activity between basal ganglia and motor cortex
    - Involved in **learning and memory**

Summary of Key Concepts

- **Cerebellum:** Controls movement coordination, balance, posture
- **Basal Ganglia:** Regulates voluntary movements, prevents unwanted actions
- **Motor Learning:** Both cerebellum and basal ganglia play a role
- **Neurotransmitters:** Dopamine, GABA, Glutamate, and Acetylcholine regulate movement

MODULE 4: THE CEREBRAL CORTEX, SLEEP, AND TECHNIQUES IN NEUROPHYSIOLOGY

Unit 1: Functions of the Specific Cortical Areas

1. Association Areas

These regions integrate sensory information and help in higher cognitive functions.

- **Parieto-occipito-temporal Association Area:**
  - Located where the parietal, occipital, and temporal lobes meet.
  - Functions:
    - **Language comprehension (Wernicke's area - left hemisphere)**
    - Spatial coordination
    - Interpretation of sensory information
- **Prefrontal Association Area:**
  - Located in the anterior part of the frontal lobe.
  - Functions:
    - Decision-making, problem-solving, planning
    - Personality, social behavior
    - **Broca's area (speech production - left hemisphere)**
- **Limbic Association Area:**
  - Located in the limbic system (around the medial brain structures).
  - Functions:
    - Emotions and motivation
    - Memory processing
    - Behavior regulation

2. Special Emphasis on Language Areas

- **Wernicke's Area (Language Comprehension - Left Temporal Lobe)**
  - Responsible for understanding spoken and written language.
  - Damage results in **Wernicke's aphasia** (fluent but nonsensical speech).
- **Broca's Area (Speech Production - Left Frontal Lobe)**
  - Controls motor aspects of speech.
  - Damage results in **Broca's aphasia** (difficulty speaking but comprehension intact).
- **Facial Recognition Area (Fusiform Gyrus - Temporal Lobe):**
  - Identifies faces and interprets facial expressions.
  - Damage leads to **prosopagnosia** (inability to recognize faces).
- **Concept of the Dominant Hemisphere:**
  - The **left hemisphere** is dominant in most people (controls language, logic, and analytical skills).
  - The **right hemisphere** is more involved in spatial ability, creativity, and emotion.

Unit 2: Function of the Brain in Communication

1. Sensory Aspects of Communication:

- Hearing and vision are processed in the **auditory cortex (temporal lobe)** and **visual cortex (occipital lobe)**.
- Information is sent to **Wernicke's area** for understanding language.

2. Motor Aspects of Communication:

- **Broca's area** plans speech articulation.
- The **motor cortex** sends signals to the muscles for speech production.
- Coordination with **respiratory muscles** is essential for speech.

Unit 3: Sleep

1. Basic Theories of Sleep:

- **Passive Theory:** Sleep occurs when the brainstem reduces stimulation.
- **Active Theory:** Sleep is an active process controlled by specific brain regions (e.g., the hypothalamus).

2. Brain Waves and Sleep Stages:

- **Electroencephalogram (EEG)** records electrical activity of the brain.
- **Brain wave types:**
  - **Beta waves (awake, alert, active thinking)**
  - **Alpha waves (relaxed, awake but calm)**
  - **Theta waves (light sleep, early stages)**
  - **Delta waves (deep sleep, slow-wave sleep)**

3. Stages of Sleep:

- **Non-REM Sleep (Slow-Wave Sleep, SWS):**
  - Four stages, progressively deeper sleep
  - Essential for **physical restoration** and growth
- **REM Sleep (Rapid Eye Movement Sleep):**
  - Dreaming occurs
  - Important for **memory consolidation and brain development**
  - Muscles are paralyzed to prevent acting out dreams

Unit 4: Techniques in Neurophysiology

1. Brain Imaging Techniques:

- **CT Scan (Computed Tomography):**
  - Uses X-rays to create detailed brain images.
  - Detects **tumors, hemorrhages, fractures**.

- **MRI (Magnetic Resonance Imaging):**
  - Uses magnetic fields to provide high-resolution brain images.
  - Useful for **soft tissue analysis, brain abnormalities**.
- **PET Scan (Positron Emission Tomography):**
  - Measures brain activity using radioactive tracers.
  - Detects **metabolic activity, neurotransmitter function**.
- **CBF (Cerebral Blood Flow Measurement):**
  - Measures blood flow in different brain regions.
  - Helps in diagnosing **strokes and brain perfusion issues**.
- **EEG (Electroencephalography):**
  - Records electrical activity of the brain.
  - Used to diagnose **epilepsy, sleep disorders, brain death**.

2. Lesioning and Electrical Stimulation of the Brain (ESB):

- **Lesioning:**
  - Experimentally damaging brain areas to study function.
  - Used in research and medical treatments (e.g., Parkinson's disease).
- **Electrical Stimulation of the Brain (ESB):**
  - Direct stimulation of brain regions using electrodes.
  - Used in **brain mapping and treating movement disorders**.

Summary of Key Concepts

- The **cerebral cortex** controls higher functions like communication, decision-making, and sensory processing.
- **Language areas (Wernicke's and Broca's)** are crucial for speech and comprehension.
- **Sleep stages** are essential for brain function and memory.
- **Neurophysiological techniques** like CT, MRI, PET, and EEG help in diagnosing brain disorders.