

CHAPTER-7

SECTION-A

The Nervous System

Objectives

1. To know the derivatives germ layer of the nervous system
2. To know the anatomical position of the sensory and motor nerve cell bodies within the spinal cord
3. To understand the basic types of neuronal cells and their main functions
4. To have basic knowledge of the development of the spinal cord and its change in position in the spinal canal in relation to vertebral level
5. To know the main parts of the developing brain and how these have developed in the embryo
6. To understand the development of the pituitary gland and how this relates to its functions
7. To understand the common developmental anomalies of the nervous system



Early Embryological Developments of the Nervous System

The Neural Tube

When the trilaminar germ disc has been established, the nervous system develops from the ectodermal layer. The central nervous system appears at the beginning of the 3rd week as a slipper-shaped plate of thickened ectoderm, called the Neural Plate. This is located in the mid-dorsal region in front of the primitive pit. The neural folds appear as longitudinal elevations which meet and fuse in the midline forming the Neural Tube. Fusion of this tube starts in the cervical region and extends both cephalically and caudally. The open end of the tube at the cephalic end is called the **Cranial Neuropore** and at the caudal end the **Caudal Neuropore**. Fusion at these extreme ends occurs two weeks later.

Organisation of the Spinal Cord

The spinal cord forms the caudal end of the central nervous system and is characterised by the **Basal Plate** containing the motor neurons; the **Alar Plate** containing the sensory neurons; and a '**Floor**' and a '**Roof Plate**' as connecting plates between the anterior and posterior sides. In addition to the above plates (future **horns**) a group of neurons accumulates between them resulting in the formation of a small **intermediate horn**. This horn contains mainly neurons of the **sympathetic** portion of the autonomic nervous system and is therefore only present between T1-L3 segments.

Cells of the Neural Tube Wall

Neuroblasts or primitive nerve cells arise by division of the **neuroepithelial cells** which are located on the walls of the neural tube and migrate to their designated regions. Neuroblasts differentiate into the primary nerve cells (**neurons**) and supporting cells (**glia**).

1. **Neuroblasts** form all neurons within the brain and spinal cord, including the preganglionic sympathetic and preganglionic neurons.
2. **Gliaoblasts** develop the supporting cells within the CNS.
 - a. **Astrocytes** surround capillaries
 - b. **Oligodendrocytes** produce myelin (within the CNS)
 - c. **Ependymocytes** line the ventricles and central canal
 - d. **Tanycytes** line the 3rd ventricle and transport substances from the cerebrospinal fluid (CSF) to phagocytic cells of the CNS, are derived from monocytes. the hypothalamic portal system.
 - e. **Choroid plexus** cells produce CSF. The tight junctions between them form the blood-CSF barrier.
 - f. **Microglia**, phagocytic cells of the CNS, are derived from monocytes.
 - g. **Schwann** cells, myelin-producing cells (for peripheral nerves)

Positional Changes of the Spinal Cord

At week 8 of development, the Spinal Cord extends the entire length of the bony vertebral canal. By the time of birth the **conus medullaris** extends to the L3 vertebra and in the adult the conus extends to the L1 vertebra. This relative change in position of the spinal cord is not caused by movement or shrinkage of the spinal cord but by the continued growth of the spine.

Primary Vesicles of the Neural Tube

When the neural tube is formed the cephalic portion develops into 3 enlarged areas called **vesicles**.

1. **Forebrain vesicle (prosencephalon)**
2. **Midbrain vesicle (mesencephalon)**
3. **Hindbrain vesicle (rhombencephalon)**

These vesicles are fluid-filled enlargements that developed by the 4th week of gestation. Further development of the vesicles by undergoing flexures results in the formation of **5 secondary vesicles**.

1. The **forebrain vesicle (prosencephalon)** divides into:
 - a. **Telenencephalon** (anteriorly) → cerebral hemispheres & basal ganglia
 - b. **Diencephalon** (posteriorly) → thalamus, hypothalamus & pineal gland
2. The **midbrain vesicle (mesencephalon)** remains unchanged → midbrain
3. The **hindbrain vesicle (rhombencephalon)** divides into:
 - a. **Metencephalon** (anteriorly) → **pons & cerebellum**
 - b. **Myelencephalon** (posteriorly) → **medulla oblongata**

The area of the neural tube inferior to the **myelencephalon** gives rise to the spinal cord.

The cavities within the vesicles develop into the **ventricles** of the brain which are filled with the **cerebrospinal fluid**.

The Hypophysis Cerebri

The pituitary gland or **hypophysis cerebri** is developed in two portions.

- a. The **adenohypophysis** develops from an evagination of ectoderm from the roof of the primitive mouth.
- b. The **neurohypophysis** develops from an evagination of neuroectoderm from the diencephalon.



CLINICAL NOTES

Spina bifida occulta

In this form there is only a defect of the vertebral arches. The posterior portion of the arches especially the laminae fail to fully develop or fuse.

Spina bifida with meningocele (operata)

This occurs when the meninges project through a vertebral defect.

Spino bifida with meningomyelocele

This occurs when the meninges and spinal cord project through a vertebral defect.

Spino bifida with myeloschisis

This occurs when the neural tube fails to close resulting in an open neural tube on the surface of the back. As a result the new born infant is paralysed distal to the lesion.

- 📖 Anencephaly
- 📖 Arnold-Chiari malformation (cerebellar herniation)
- 📖 Dandy-Walker syndrome (congenital hydrocephalus)
- 📖 Hydrocephalus (acquired)
- 📖 Foetal alcohol syndrome

SELF ASSESSMENT QUESTIONS



1. From which germ layer is the neural tube derived
2. What is the function of the neural tube?
3. Where in the spinal cord are the bodies of lower motor neurones located. State this for both sensory and motor neurones.
4. What is the principal function of the following types of neuronal cells: Neuroblasts, Glaioblasts, Astrocydes, Oligodedrocydes, Ependymocytes, Tancytes, Choroid plexus cells, Microglia, Schawnn cells.
5. At what spinal level is the conus medullaris located in the adult.
6. List the parts of the brain derived from Forebrain, Midbrain and Hindbrain
7. What do you understand by the term spina bifida and how is it caused. List the different variants of this congenital disorder.

Please refer to your labelling supplement handbook and label any images associated with the above chapter.



The embryonic development of the special Senses The Ear and Eye

Objectives:

1. To have a basic understanding of the development of the ear
2. To have a basic understanding of the development of the eye
4. To know the congenital malformations affecting the ears and causative factors
5. To know the congenital malformations affecting the eyes and causative factors



Development of the Ears

Although in the adult the ear forms one anatomical unit serving both hearing and equilibrium in the embryo it develops from three distinctly different parts:

- a. **The External ear.** It serves as a sound-collecting organ
- b. **The Middle ear.** It functions as a sound conductor from the external to the internal ear.
- c. **The Inner ear.** It converts the sound waves into nerve impulses and registers changes in equilibrium.

Therefore, the ear consists of three parts which are of different origin but function as one unit.

The internal ear originates from the **otic vesicle** which in the 4th week of development splits off from the surface ectoderm. This otic vesicle divides into a ventral component which gives rise to the **sacculle and cochlear duct**, and a dorsal component which gives rise to **utricle, semicircular canals, and endolymphatic duct**.

The epithelial structures so formed are known collectively as the **membranous labyrinth**. With exception of the cochlear duct, from which will develop the **organ of corti**, all structures derived from the membranous labyrinth are involved with equilibrium.

1. The **middle ear**, consisting of the **tympanic cavity** and **auditory tube**, is lined with epithelium of endodermal origin as is derived from the 1st pharyngeal pouch. The auditory tube maintains contact between the tympanic cavity and nasopharynx. The **ossicles**, which transfer sound vibrations from the tympanic membrane to the oval window, are derived from the 1st (**malleus and incus**) and 2nd (**stapes**) pharyngeal arches.
2. The **external auditory meatus** develops from the 1st pharyngeal cleft and is separated from the tympanic cavity by the tympanic membrane. The eardrum consists of (a) an ectodermal epithelial lining, (b) an intermediate layer of mesenchyme, and (c) an endodermal lining from the 1st pharyngeal pouch.
3. The **auricle** develops from mesenchyme of the 1st and 2nd pharyngeal arches.

Development of the eyes

The eyes begin to develop around day-22 as a pair of optic vesicles on each side of the forebrain. The optic vesicles which are outpocketings of the forebrain, contact the **surface ectoderm** and induce changes necessary for the **lens formation**. When the optic vesicle begins to invaginate to form the **pigment and neural layer of the retina**, the **lens placode invaginates to form the lens vesicle**.

Through a groove at the inferior aspect of the optic vesicle, the **choroid fissure**, the hyaloid artery (which later becomes the central artery of the retina) enters the eye. Nerve fibres of the eye also occupy this groove to reach the optic areas of the brain. The cornea is formed (from outside to inside) by (i) a layer of surface ectoderm, (ii) the stroma which is continuous with the sclera, and (iii) an epithelial layer bordering the anterior chamber.

CLINICAL NOTES



1. Congenital deafness although once believed to be hereditary, is now known that environmental factors may likewise interfere with normal development of the internal and middle ear.
 - Rubella virus affecting the embryo in the 7th and 8th weeks, will cause severe damage to the organ of Corti
 - Other factors are: Poliomyelitis, erythroblastosis fetalis, diabetes, hypothyroidism and toxoplasmosis.

- Chromosomally determined syndromes
- Abnormalities of the 1st arch

The above conditions may cause a variety of defects associated with deaf-mutism ie:

Abnormal development of membranous and bony labyrinths, auditory ossicles and eardrum. In extreme cases the tympanic cavity and external meatus may be absent.

Congenital Malformations of the Eye

 **Coloboma Iridis**

 **Congenital Cataract**

 **Microphthalmia**

 **Anophthalmia**

SELF ASSESSMENT QUESTIONS

1. Describe the structure and function of:

- a. External ear
- b. Middle ear
- c. Inner ear



2. From which part of the brain does the eye receive contribution?

3. List agents or factors which may lead to congenital anomalies of the ears.

4. List agents or factors which may lead to congenital anomalies of the eyes.

Please refer to your labelling supplement handbook and label any images associated with the above chapter.



SECTION-B

Anatomy and physiology of the nervous system & special senses



Overview of the Nervous System

Learning Outcomes:

The student should be able to:

- Arrange the nervous system into functional categories
- Name the various parts of the brain and their functions
- Identify the lobes of the brain
- Describe the coverings of the brain.
- Determine the origin and the functions, of the cerebrospinal fluid
- Describe the concept of the blood brain barrier
- Give a brief overview of the anatomy of the spinal cord
- The names and numbers of the Cranial Nerves. e.g. cranial nerve II is the Optic nerve.
- Sensory or Mixed
- The branches and function of each cranial nerve.

The spinal cord

- Spinal cord anatomy – internal and external anatomy.
- The sensory and motor tracts
- Reflexes – Just read the introductory paragraphs and the reflex arcs.
- Dermatomes
- Sensation
- The nature of sensory receptors
- Somatic sensations
- Somatic ascending sensory pathways
- 1) Posterior column –medial lemniscus pathway.
- 2) Anterolateral Spinothalamic pathway
- Motor Pathways
- 1) Pyramidal tract
- 2) Extrapyrarnidal tract
- Comparisons between somatic and autonomic systems
- Anatomy of autonomic motor pathways
 - The sympathetic division
 - The parasympathetic division
- The physiological effects of the autonomic nervous system

The nervous system is one of the most complicated systems to study, but also one of the most widespread and important to know.

Map of the Nervous System:

The nervous system is basically divided into two systems:

- 1) **The Central Nervous System (CNS)** – Brain and Spinal Cord only.
- 2) **The Peripheral Nervous System (PNS)** - all nervous tissue outside of the CNS, including the 12 pairs of cranial nerves, and multiple spinal nerves.

The PNS is subdivided into:

2a) Somatic nervous system (SNS)– involved in the affecting of skeletal or voluntary muscle. This system is composed of

- **Sensory neurons** – convey impulses from somatic (body) and special sensory receptors in the head, body wall, and limbs towards the CNS.
- **Motor neurons** – convey impulses from the CNS to the skeletal muscles only

2b) Autonomic nervous system (ANS)– involved in effecting smooth & cardiac muscle, & the glands. This system is divided into:

- **Sensory neurons** – convey information from autonomic sensory receptors in the visceral organs and walls of the viscera, to the CNS.
- **Motor neurons** – convey impulses from the CNS to the smooth muscle, cardiac muscle, and glands.

The motor portion of the Autonomic Nervous System is further divided into:

- **The Sympathetic division** (fight or flight)
- **The Parasympathetic division** (rest & digest)

The Brain

The brain is primarily divided into the **brain stem**, the **cerebellum**, the **diencephalon**, and the **cerebrum**.

Brain stem

This division of the brain, is sub-divided into the **Medulla oblongata**, the **Pons**, and the **Midbrain** (also called the **Mesencephalon**).

Medulla oblongata

- It is the continuation of the spinal cord into the brain, and is most inferior part of the brain stem.
- It consists of ascending sensory tracts and descending motor tracts.
- Has two bulges on anterior aspect, termed pyramids.

- Decussation (crossing over) of 90% descending motor tracts occurs at the pyramids (10% do not decussate). Hence right side of the brain controls left side of the body and vice versa.
- It contains the nuclei of 5 cranial nerves:
 - Vestibulocochlear (VIII)
 - Glossopharyngeal (IX)
 - Vagus (X)
 - Accessory (XI)
 - Hypoglossal (XII)

Functions

- Relays motor and sensory impulses between brain and spinal cord
- Regulates certain autonomic functions: heart rate, vaso-diameter (and therefore blood pressure), basic respiration rate, and reflexes for vomiting, sneezing and coughing.

Pons

- It lies superior to medulla, and connects parts of the brain by transverse and longitudinal tracts
- It contains the nuclei of 4 cranial nerves
 - Trigeminal (V)
 - Abducens (VI)
 - Facial (VII)
 - Vestibulocochlear (VIII)

Functions

- Relays impulses from one side of the cerebellum to the other and between medulla and mid-brain

Midbrain

- Extends from Pons to Diencephalon
- Reflex centres for visual and auditory stimuli.
- Muscular coordination.
- It contains the nuclei of 2 cranial nerves:
 - Oculomotor (III)
 - Trochlear (IV)

Functions:

- Relays motor impulses from cortex to pons and sensory impulses from spinal cord to thalamus

Cerebellum

- The cerebellum lies posterior to the brain stem. It is separated from the cerebrum by transverse fissure tentorium cerebelli
- Attached to the brain stem by 3 paired cerebellar peduncles
- The vermis separates the cerebellar hemispheres
- Grey matter: Cerebellar cortex (folia) and cerebellar nuclei

- White matter: Arbor vitae

Functions:

- Co-ordinates skilled movement, posture and balance

Diencephalon

- The Diencephalon lies superior to the brain stem and extends from brain stem to cerebrum. It surrounds the 3rd ventricle.
- The Diencephalon is sub-divided into
 - Thalamus
 - Hypothalamus
 - Epithalamus
 - Subthalamus

Thalamus

- Nuclei of grey matter, with a mass of grey matter (the intermediate mass) as a bridge across the ventricle to join right and left sides.
- Relays sensory impulses from the spinal cord, brain stem, cerebellum and cerebrum to the cerebral cortex.
- **Perceives - pain, temperature, touch and pressure**
- Plays a role in cognition.

Hypothalamus

- located inferior to the thalamus.
- Made up of nuclei in 4 major regions:
 1. **Mammillary bodies** – relays reflexes for sense of smell
 2. **Tuberal region** – the infundibulum connects to the Pituitary gland
 3. **Supraoptic region** – superior to the optic chiasm. Axons from these nuclei make up the hypothalamohypophyseal tract, which extends through the infundibulum.
 4. **Preoptic region** – anterior to the supraoptic region.

Functions of hypothalamus

- Controls the ANS through axons, which extend from the hypothalamus to the sympathetic and parasympathetic nuclei in the brains stem and spinal cord.
- Regulates emotional behavior, eating and drinking, body temperature, circadian rhythms and states of consciousness.
- **Control of pituitary gland:**
 - Hypothalamic regulating hormones released into the capillary network of the median eminence, and carried to the anterior pituitary gland to influence it's secretions of hormones.
 - Axons from the paraventricular and supraoptic nuclei descend via the infundibulum to the posterior pituitary gland – to manufacture oxytocin or ADH. These hormones are stored and released by the pituitary gland.

Epithalamus:

- Superior and posterior to thalamus.
- Made up of the pineal gland – this protrudes from the 3rd ventricle and secretes melatonin.
- The habenular nuclei – emotional responses to olfaction.

Subthalamus:

- Inferior to thalamus.
- Made up of motor tracts connected to areas of the cerebrum – works with the basal ganglia, cerebellum and cerebrum to control body movement.

Cerebrum

- Covers the diencephalon and fills most of the cranium.
- This is the largest and most recently evolved part of the human brain. The cerebral cortex is made up of grey matter, whilst the interior of the brain is primarily made up of white matter – with some nuclei of grey matter.

Grey matter is made up of neuronal cell bodies, and is involved in generating action potentials.

White matter is made up of dendrites and axons, and is concerned with the conduction of these impulses.

Bodies of White matter in the cerebrum:

Function to transmit impulses between areas in the brain

- **Association fibres – same side.** Between gyri of same hemisphere
- **Commissural fibres – left and right.** Between gyri in one hemisphere to corresponding gyri in the other hemisphere. e.g. Corpus callosum,
- **Projection fibres – up and down.** Ascending and descending tracts from cerebrum to spinal cord and visa versa. e.g. the internal capsule and corona radiata

Bodies of grey matter in the cerebrum:

Basal Ganglia: pairs of grey matter nuclei on opposite sides of the cerebrum.

Provide impulses to and from the cerebral cortex, thalamus, and hypothalamus.

Functions: coordinates gross, autonomic muscle movement, and regulates muscle tone

Limbic System

- Surrounds the brainstem and corpus callosum.
- Includes the olfactory bulbs.
- Plays a role in emotional behavior.

The brain is divided into the right and left hemispheres by the longitudinal fissure. The central sulcus separates the frontal lobes from the parietal lobes of the brain.

The lateral fissure divides off the temporal lobes, and the occipital lobe is separated by the parietooccipital sulcus from the parietal lobes.

Meninges

The brain and spinal cord are covered by the meninges – membranes covering and protecting the CNS, of which there are three layers.

The Dura mater – is the outer meninx (singular – meninx - plural)

This tough outer layer is made up of dense fibrous tissue. In the spinal cord, it is a single layer, but over the brain it involutes to become a double layer – made up of an outer periosteal layer, and an inner meningeal layer.

Between the two layers is a potential space, which is realized when the meningeal layer descends between the two hemispheres in the longitudinal fissure – to form the falx cerebri. Within this space created between the layers, flows superior sagittal sinus – a venous sinus involved in the re-absorption of cerebrospinal fluid. The dura mater follows the contours of the brain loosely, and terminates at the coccyx.

The Arachnoid mater – this delicate middle layer is a web-like (hence 'arachnoid' or 'spider-like') transparent membrane made up of elastic and collagenous fibres, and covered internally by a layer of cuboidal epithelium. It is closely adherent to the dura mater except for a thin film of fluid in the sub-dural space. Arachnoid villi or granulations push into the sagittal sinus to allow the cerebrospinal fluid to be reabsorbed into the blood. The arachnoid mater continues to envelope the spinal cord and merges with the dura mater at the level of the 2nd sacral vertebra.

Between the arachnoid and the pia is the subarachnoid space, into which the arachnoid sends fibrous thread – the trabeculae, which connect these two membranes. The subarachnoid space contains the cerebrospinal fluid.

The Pia mater:

A highly vascular membrane of loose fibrous connective tissue, adhering intimately with the brain and following it into all its fissures and sulci.

It functions to support blood vessels reaching the brain and spinal cord. The pia mater continues to invest the spinal cord, and terminates with the dura mater at the coccyx.

The ventricles of the brain, and Cerebrospinal fluid

The ventricles are four cavities involved in producing and containing the cerebrospinal fluid (CSF). This is a clear viscous fluid similar in chemical composition to lymph.

Cerebrospinal fluid is formed from blood plasma, by ependymal cells in the capillaries of the choroid plexuses of the ventricles. The fluid circulates through the

ventricles, around the brain and spinal cord within the sub-arachnoid space. It is reabsorbed into the superior sagittal sinus of the dura mater of the brain by the arachnoid villi.

Functions of CSF:

- **Mechanical protection.** Shock absorbing medium. The brain 'floats' in the cranial cavity. Maintains a uniform pressure around the brain.
- **Chemical protection.** Optimal ionic medium for neuronal signal conduction.
- **Circulation.** Exchange of nutrients and waste products between blood and nervous tissue.
- **Brain and spinal cord is kept moist.** For an interchange of substances between the CSF and the neurons.

The Blood-Brain Barrier

Blood enters the brain via the cerebral arteries forming the circle of Willis at the base of the brain.

The blood-brain barrier protects brain tissue from harmful substances and pathogens.

It is made up of:

- Tight junctions of the endothelial cells of the brain capillaries
- Surrounded by a continuous basement membrane
- An outer layer of foot processes of astrocytes (neuroglia), which selectively allow certain substances to pass from the blood to the brain tissue. Some water-soluble solutes, such as glucose are able to cross the BBB. Other ions and substances cross more slowly, whilst some substances cannot pass at all, for example - antibiotics and proteins. On the other hand, all lipid soluble substances, such as oxygen, carbon dioxide and anesthetics are able to cross.

The Spinal Cord:

The spinal cord is a cylindrical cord of grey and white matter, extending inferiorly from the medulla oblongata to the level of the 1st lumbar vertebra. It is housed within the protective coverings of the bony vertebral column, the tough meninges, and the cushion-like cerebrospinal fluid.

31 pairs of spinal nerves extend from the cord (the CNS) at regular intervals.

Spinal nerves are named according to their vertebral location. So there are:

- 8 pairs of **cervical** nerves – C1-C8
- 12 pairs of **thoracic** nerves – T1-T12
- 5 pairs of **lumbar** nerves – L1-L5
- 5 pairs of **sacral** nerves – S1-S5
- 1 pair of **coccygeal** nerves

The spinal nerves are the routes of communication between the peripheral nervous system innervating the rest of the body, and the CNS.

Two bundles of axons connect the spinal root to the spinal cord, and are referred to as the spinal roots.

The posterior/dorsal root carries sensory (afferent) fibres towards the CNS.

The anterior/ventral root carries motor (efferent) fibres away from the CNS towards the effector organs.

These roots converge together a short distance after leaving the cord, and continue on as mixed spinal nerves.

The internal anatomy of the spinal cord:

When the spinal cord is examined in its transverse section, it is described as having the grey matter shaped roughly like the letter 'H', which is surrounded by white matter.

The grey matter consists mainly of nerve cell bodies and neuroglia.

The grey commissure is the cross bar of the H. Contains the central canal, which is continuous with the 4th ventricle, and contains the CSF.

The grey matter on each side of the spinal cord is subdivided into areas called 'horns':

Anterior grey horns made up of cell bodies of somatic motor neurons, providing outgoing nerve impulses from the brain for contraction of skeletal muscles.

Posterior grey horns made up of sensory nuclei, which receive incoming sensory input from sensory nerves.

Lateral grey horns present in thoracic, upper lumbar and sacral segments of the cord.

Made up of motor and sensory cell bodies of the ANS – regulating smooth muscle, cardiac muscle and glands.

The white matter is made up of tracts of sensory and motor axons ascending and descending the cord, and exiting & entering at various levels of the vertebral column.

(Rather like an elevator system in a multi-story building, with messengers, whizzing up and down carrying information to and from headquarters - at the top story)

The white matter is divided into regions by the horns of the grey matter.

- Anterior white columns
- Posterior white columns
- Lateral white columns

These columns represent the routes by which sensory and motor axons ascend and descend the cord.

Two grooves divide the white matter into right and left sides. The anterior median fissure is a deep wide groove. The posterior median sulcus is a shallower, narrower groove.

The white matter is made up of bundles of myelinated and unmyelinated axons of sensory neurons, interneurons and motor neurons, which are called tracts.

- Ascending tracts are sensory.
- Descending tracts are motor.

The white commissure is found anterior to the grey commissure, and links the white matter from the left and right sides.

Sensory Tracts of the spinal cord:

Spinothalamic Tract

Pain and temperature Sensory neurons enter at posterior horn, synapses with 2nd order neuron and crosses to contra-lateral side, entering the lateral funiculus, ascends to thalamus, synapses with 3rd order neuron, transverse the internal capsule and corona radiata to cortex.

Posterior columns Tract:

Touch, pressure, vibration, proprioception Sensory neurons enter the posterior horn cells, ascend the posterior funiculus of white matter to the medulla. Synapse with 2nd order Neurons decussate and ascend to the thalamus. Synapse with 3rd order neurons, and ascend to sensory cortex, via the thalamocortical tract.

Motor Tracts of the spinal cord:

Pyramidal Tracts:

Voluntary skilled/fine movement. Cerebral cortex, axons descend via the corona radiata, the cerebral peduncles and the pons as the corticospinal tract. 90% decussate in the pyramids of the medulla to form the lateral corticospinal tract synapse with the anterior horn neurons to innervate skeletal muscle.

Extrapyramidal System:

Muscle tone, posture and balance.

Collective inputs from the cerebral cortex, basal nuclei, cerebellum and thalamus descend to the lower motor neurons via tracts which do NOT transverse the medullary pyramids.

There may be thousand of synapses with interneurons, but the anterior horn motor neuron is considered the 'final common pathway' for the expression of muscle co-ordination.

The Peripheral Nervous System:

Peripheral Nervous System

Somatic nervous system

- Voluntary action of skeletal muscle
- Sensory neurons convey information from somatic and special sensory receptors, to the central nervous system
- Motor neurons from the central nervous system, conducting impulses to the skeletal muscles.

Autonomic nervous system

- Involuntary action of Smooth muscle
- Sensory neurons convey information from autonomic sensory receptors to the central nervous system.
- Motor neurons from the central nervous system conduct impulses to the smooth muscle, cardiac muscle, glands and adipose tissue.
- Divided into the sympathetic nervous system and the parasympathetic nervous system.

Enteric nervous system

- Responds to chemical changes in GI tract and stretch receptors.
- Governs smooth muscle contraction, and glandular secretion.

Cranial nerves

The Autonomic nervous system

- Regulates activity of smooth muscle in the viscera and blood vessels, certain glands, and cardiac muscle. It is influenced by the somatic N/S, special senses and limbic system, but is regulated mainly by the hypothalamus and the brainstem.

The motor portion is divided into the sympathetic and parasympathetic nervous systems:

Sympathetic Division: FIGHT OR FLIGHT

- The preganglionic neurons have their cell bodies in the lateral grey horns of T1-L2 of the spinal cord. Thorocolumbar division.
- The axons leave the spinal cord via the anterior roots, join the spinal nerves for a short distance, entering the sympathetic chain of ganglia via the white communicating rami.
- Sympathetic ganglia are divided into two groups:
 - 1) Sympathetic trunk ganglia – in a vertical row on either side of the spinal column, from the base of the skull to the coccyx.
Postganglionic fibres innervates organs above the diaphragm
 - 2) Prevertebral ganglia – lie anterior to the spinal column, close to the large abdominal arteries. Postganglionic fibres innervate organs below the diaphragm.
- Once the preganglionic fibres have entered the ganglionic chain, they may take four courses:
 - 1) Synapse with the postganglionic neuron at the same level in the chain.
 - 2) Ascend and synapse at a high level
 - 3) Descend and synapse at a lower level
 - 4) Pass straight through the chain, forming a splanchnic nerve, which synapses with prevertebral ganglia. These preganglionic axons terminate in the celiac, superior mesenteric or inferior mesenteric ganglia – near to the abdominal viscera.
- The postganglionic neuron leaves the sympathetic ganglionic chain via the grey communicating rami to merge with a spinal nerve.

Parasympathetic Division: REST AND DIGEST

- These preganglionic cell bodies lie in the nuclei of the 4 cranial nerves – CN III, VII, IX, X.
- Plus in the lateral grey horns of S2-S4 of the spinal cord. Cranialsacral division.
- Parasympathetic ganglia: located close to or in the wall of visceral organs – known as terminal or intramural ganglia. Preganglionic fibres are long, extending from the CNS to the ganglia in or near to the walls of the organs.
- The preganglionic neurons leave the brainstem with their cranial nerve, and synapse at one of the cranial ganglia. The postganglionic neurons are short and terminate in the area of the head – e.g. affecting the nasal, optic and oral cavities.
- The preganglionic axons associated with the Vagus nerve are very long, and descend down the oesophagus to the descending colon. The ganglia are in the muscular walls of the organs that they supply – affect the smooth muscle and glands.
- The Sacral division of preganglionic neurons are located in the lateral horns of S2, 3, 4, and leave the cord via the anterior rami to form the pelvic splanchnic nerves. These splanchnic nerves synapse with postganglionic neurons in intramural ganglia in the walls of the organs supplied.

The Cranial Nerves.

- Sensory or mixed motor and sensory.
- May be part of the autonomic or somatic nervous systems

Special senses

- Accessory structures of the eye
- The lacrimal apparatus
- Anatomy of the eyeball
- The interior of the eyeball
- Brain pathway and visual fields
- Anatomy of the ear The physiology of hearing
- The physiology of equilibrium

The Special Senses:

The Eye:

Accessory Structures of the Eye:

1) The Lacrimal Apparatus:

- The lacrimal glands are found on the lateral superior aspect of each eye. It is the size and shape of an almond.
- Secretes lacrimal fluid (tears) into 6-12 excretory lacrimal ducts which empty tears onto the surface of the conjunctiva of the upper lid. Tears pass medially over the surface of the eyeball and enter two lacrimal puncta. These openings lead into the lacrimal canals and from there into the lacrimal sac, and then into the nasolacrimal duct, and finally into the nasal cavity.
- Lacrimal fluid consists of salts, mucus and lysozyme (a bactericidal enzyme). The fluid protects, cleans, lubricates and moistens the eyeball. Each gland produces about 1ml per day.

2) Extrinsic Muscles:

- Innervation from cranial nerves III, IV, VI
- Superior rectus, inferior rectus, lateral rectus, medial rectus, superior oblique and inferior oblique.

Anatomy of the Eyeball:

- The adult eyeball is approximately 2.5cm and fits into the eye socket with only 1/6th exposed to the elements.
- Made up of 3 layers:
 - 1) Fibrous tunic
 - 2) Vascular tunic
 - 3) Nervous tunic (Retina)

Fibrous Tunic:

- The outer avascular coat
- Makes up the anterior cornea and posterior sclera.

The cornea:

Transparent coat that covers the coloured iris.

Curved, therefore helps to focus light onto the retina.

Made up of 3 layers:

- 1) The outer surface consists of non-keratinized stratified squamous epithelium.
- 2) The middle coat consists of collagen fibres and fibroblasts
- 3) Inner surface is simple squamous epithelium.

The sclera:

Dense connective tissue made up of collagen fibres and fibroblasts.

Covers the entire eyeball, except the cornea –

Gives shape and form, and protects the inner parts of the eye.

At the junction of the sclera and cornea is an opening – scleral venous sinus (canal of Schlemm).

Vascular Tunic:

- The vascular tunic or uvea is the middle layer of the eyeball.

- Consists of three layers:
 - 1) Choroid – Highly vascular
 - Pigmented to absorb light
 - Lines the internal surface of the sclera.
 - Provides nutrients to the posterior surface of the retina.
 - Expand to become the ciliary body at the edge of the retina.
 - 2) The Ciliary body –
 - Extends from the anterior margin of the retina to the point posterior to the junction of the sclera and cornea.
 - Consists of the ciliary process and ciliary muscle.

The ciliary process – folds on the internal surface of the ciliary body.
 Contains blood capillaries which secrete aqueous humour.
 Attach to suspensory ligaments, which connect to the lens.

The ciliary muscle – circular band of smooth muscle that alters the shape of the lens to adapt for vision.
 The ciliary muscle contracts, pulls the ciliary body, which pulls the suspensory ligament and alters the shape of the lens.

- 3) The Iris The coloured part of the uvea is suspended between the cornea and lens, and is attached at the outer margin to the ciliary process. Consists of circular and radial smooth muscle fibres. Regulates light entering the pupil.

The Nervous Tunic/The Retina:

- The inner coat of the eyeball lines the posterior $\frac{3}{4}$ of the eyeball, and is the source of the visual pathway.
- Lies over the Choroid.
- Blood vessels are exposed, and we can use an ophthalmoscope to observe the state of the micro-vessels – in diseases such as diabetes, or hypertension.

It is composed of two layers:

- 1) Inner layer is made up of a neural portion.
 - 2) Outer layer is pigmented epithelium, and a non-visual area.
- The neural portion is a multi-layered out-growth of the brain which processes visual data before transmitting nerve impulses to the thalamus.
 The pigment epithelium is a sheet of melanin containing epithelial cells lying between the choroid and the neural portion of the retina. Melanin absorbs stray light, preventing scattering and keeping the image clear.

There are 3 layers of retinal neurons

- 1) The photoreceptor layer:

Dendrites of the photoreceptors form rods and cones

2) The bipolar cell layer:

3) The ganglion cell layer:

In between these neuronal layers, lie 2 synaptic layers.

Rods – 12 million in each retina

Low light threshold – used to see in dim light

Do not provide colour vision.

Loss of rods gives a person night blindness.

Cones - 6 million cones in each retina

Stimulated by brighter light

Gives colour vision – loss of cones results in legal blindness.

The optic disc – is the site where the optic nerve leaves the eyeball, and the central retinal vein and artery enter and exit.

The macula lutea – is a flat yellow spot in the direct centre of the posterior portion of the retina. In the centre of this spot is the central fovea – a small depression, which contains only cones. The layers of bipolar and ganglion cells, which scatter light do not cover the cones here, thus resulting in an area of highest visual acuity.

The Lens:

- The lens is a completely transparent body of proteins (called crystallins) arranged in circular layers.
- It is found posterior to the pupil, iris and cornea.
- Held in position by suspensory ligaments, which are attached to the ciliary (intrinsic) muscle and process.
- The ciliary muscle adjusts the lens so that the light rays are focused onto the retina.

The Interior of the Eyeball:

The interior is divided by the lens into two cavities:

1) The Anterior cavity – which is divided into:

1a) Anterior chamber

1b) Posterior chamber.

2) The Vitreous chamber

1) The Anterior cavity:

1a) The Anterior chamber:

This is the space anterior to the lens and iris, and posterior to the cornea.

Filled with aqueous humor – a watery fluid. The fluid is filtered from the blood capillaries in the ciliary processes, and constantly being replaced. It is used to nourish the lens and cornea.

The aqueous humor flows into the posterior chamber, then forward between the iris and lens through the pupil into the anterior chamber, where it drains into the canal of Schlemm, and from there into the blood stream.

1b) The Posterior chamber:

It is located posterior to the iris, and anterior to the suspensory ligaments and the lens.

Intra-ocular pressure maintained by aqueous humor, and to a lesser degree, the vitreous body – to maintain shape of the eye, and visual acuity.

2) The Vitreous Chamber/Posterior cavity:

It is situated between the lens and the retina.

Within the vitreous chamber is the vitreous body – a jellylike substance, which

a) contributes to intraocular pressure

b) holds the retina evenly against the choroid for a clear image.

The vitreous humor is formed in the embryonic stage and never replaced.

The vitreous body contains phagocytic cells, which remove debris.

The Visual Pathway:

The eye's vision is called the visual field. The visual field of each eye is divided into the nasal and temporal half.

- Axons of all retinal ganglion cells in one eye exit the eyeball at the optic disc and form the optic nerve on that side.
- At the optic chiasm, nerve fibres from the temporal half of each retina continue directly to the lateral geniculate nucleus of the thalamus **ON THE SAME SIDE.**
- Nerve fibres from the nasal half of each retina cross and continue to **THE OPPOSITE** thalamic nuclei.
- Therefore each optic tract consists of crossed and uncrossed axons that project from the optic chiasm to the thalamus on one side.
- The axons of the thalamic neurons form the optic radiation and project onto the visual cortex of the same side.

The Ear:

The ear is divided into three components:

- 1) The external ear: channels sound waves towards the middle ear.
- 2) The middle ear: This changes and conveys these stimuli towards the oval window of the inner ear.
- 3) The inner ear: This houses the receptors for hearing and balance.

The External Ear:

Comprises of:

- The auricle or pinna – made up of hyaline cartilage. The rim is called the helix and the inferior portion is the lobule. It is attached to the scalp by ligaments and muscle.

- The auditory canal – is a tube about 2.5cm long lying within the temporal bone leading from the auricle to the ear-drum (tympanic membrane). Within the canal are a few hairs and sebaceous glands called ceruminous glands – which secrete cerumen. This is used to prevent dust and foreign objects from entering the ear.
- The tympanic membrane is a thin semitransparent partition between the external and middle ear. It is covered by an epidermis and lined by simple cuboidal epithelial layers. Intermediate layers include connective tissue made up of collagen, elastic fibres and fibroblasts.

The Middle Ear:

- This is a small cavity in the temporal bone bounded by the tympanic membrane, and from the inner ear by the oval and round windows.
- Contains the three smallest bones in the body – the auditory ossicles (malleus, incus and stapes). These are the smallest bones in the body, and are connected to each other by tiny synovial joints. The handle of the malleus (hammer) is attached to the tympanic membrane, and the head articulates with the body of the incus (anvil). The incus articulates with the head of the stapes (stirrup), which fits into the oval window.
- Below the oval window is the round window – which is enclosed by a secondary tympanic membrane.
- There are two very tiny muscles – the tensor tympani muscle – which is innervated by the mandibular branch of the Trigeminal Cranial Nerve. It limits movement and increases tension on the tympanic membrane to prevent damage from loud noises.
The stapedius muscle is innervated by the facial nerve – and dampens the large vibrations of the stapes caused by loud noises.
- The middle ear contains the auditory canal. This is made up of bone and hyaline cartilage and connects the middle ear to the nasopharynx. Normally, it is closed, by yawning and swallowing opens it – and this equalizes the air pressure in the middle ear with atmospheric pressure.

The Inner Ear:

It is also called the labyrinth. It consists of two main divisions an outer bony labyrinth, which encloses an inner membranous labyrinth.

The bony labyrinth: is a series of cavities in the temporal bone divided into

- 1) The semicircular canals
- 2) The vestibule
- 3) The cochlear

The bony labyrinth is lined with periosteum and contains perilymph, which surrounds the membranous labyrinth.

The membranous labyrinth fits within the bony labyrinth, and is lined with epithelium and contains endolymph.

The vestibule is the oval central portion of the bony labyrinth. The membranous labyrinth in the vestibule consists of two sacs called the utricle and the saccule – which are connected by a small duct.

The semi-circular canals, each lie at right angles to each other. At the end of each of these canals, is a swollen ampulla.

Within the bony semi-circular canals lie the membranous semicircular ducts – which communicate within the utricle of the vestibule.

The vestibular branch of the vestibulocochlear (VIII) nerve consists of the ampullary, utricular and saccular nerve. These nerves have both sensory and motor divisions, which synapse with receptors for equilibrium. The cell bodies are located in the vestibular ganglia.

The cochlea is a bony spiral canal resembling a 'snail shell'. The cochlear is divided into three channels. It is divided by a Y-shaped partition – the stem of the Y is a bony shelf, with the other two arms being made up of membranous labyrinth.

- 1) The channel above the bony partition is the scala vestibuli – which ends at the oval window.
- 2) The channel below is the scala tympani, which ends at the round window. Both scala contain perilymph, and are separated except at the apex of the cochlea – the helicotrema.
- 3) The third channel is the scala media (cochlear duct). The vestibular membrane separates the cochlear duct from the scala vestibuli and the basilar membrane separates the cochlear duct from the scala tympani.

The spiral organ rests on the basilar membrane and is made up of a coiled sheet of epithelial cells. The cells include supporting cells, and about 16000 hair cells – which are the receptors for hearing.

There are two groups of hair cells.

- 1) The inner hair cells – are arranged in a single row and extend the length of the cochlea.
- 2) The outer hair cells – are arranged in three rows.

At the apical tip of each hair cell is a hair bundle, consisting of 30-100 stereocilia (microvilli) – which extend into the endolymph of the cochlear duct. At their basal ends, hair cells synapse with sensory and motor neurons from the cochlear branch of the vestibulocochlear (VIII) nerve.

Projecting over and in contact with the hair cells of the spiral organ is the tectorial membrane – a flexible gelatinous membrane.

Hearing:

The auricle and auditory canal directs sound waves to the tympanic membrane.

As sound strikes the tympanic membrane, the sound waves are converted into mechanical energy through the vibration of the membrane.

The vibrating tympanic membrane causes the attached malleus to vibrate, and this vibration is transmitted to the oval window via the auditory ossicles. The vibration of the oval window causes the perilymph to produce fluid waves in the scala vestibuli. These waves continue round to the scala tympani and eventually dampened down at the round window. These waves cause the basilar membrane to vibrate, moving the hair cells of the spiral organ against the tectorial membrane. Bending of the stereocilia cause impulses in the cochlear nerve fibres.

The membranous semi-circular ducts:

Lie at right angles to each other in three planes. This positioning permits detection of rotational, acceleration or deceleration. In the ampulla, the dilated portion of each duct is a small elevation – the crista. The crista is made up of a group of hair cells and supporting cells, covered by a gelatinous material – the cupula.

When the head moves, the attached membranous semicircular ducts and hair cells move with it. The endolymph lags behind. As the hair cells drag the fluid along, the hair bundles bend, producing receptor potentials which propagate impulses along the vestibular branch of the vestibulocochlear nerve (VIII).

Chapter-9

Self-Assessment Questions

Question 1:

Describe the reflex arc.

Question 2:

- a) Define a dermatome.
- b) Why is it useful to know the distribution of dermatomes?

Question 3:

The hypothalamus is located slightly remote from the pituitary gland, and yet it has hormonal control over the gland. What are the two routes of hormonal transport from the hypothalamus to the pituitary gland?

Question 4:

Draw a diagram to illustrate the distribution of the three branches of the trigeminal nerve, over the face.

Question 5:

The eye:

- a) Which structure of the eye changes shape to facilitate clear vision?
- b) Name all the structures, which contribute to its changing shape.

Question 6:

- a) Name the three auditory ossicles.
- b) Where specifically are these bones found?

Question 7:

- a) Name the three divisions of the bony labyrinth.
- b) What is the name of the fluid, which fills the bony labyrinth?
- c) Name the three channels of the cochlea
- d) What is the name of the fluid, which fills the cochlear duct?

Question 8:

Describe the four possible routes which a preganglionic sympathetic nervous axon might take having entered the sympathetic ganglionic chain

Question 9:

Which division of the autonomic nervous system does the vagus nerve belong to?

Please refer to your labelling supplement handbook and label any images associated with the above chapter.

