TABLE OF CONTENTS

Unit II – Nerve and Muscle

Lecture 1: Histology of the Nervous System

Lecture Summary

- Cells of the NS; Techniques for visualising cells of the NS; Neurons; Neuronal collections; Supporting cells; Miscellaneous cells

Learning Outcomes

1.1 State what neurohistology is

Histology (microscopic anatomy) study of the structure of biological matter at a level below the visibility to the human eye. It uses various microscopal instruments including the light microscope, scanning electron microscope, transmission electron microscope; // **Neurohistology** is the histology of the nervous system;

Morphology = structure, or appearance;

1.2 Neuron; characterisation and examples

A **neuron** is a cell of the human nervous system, grouping to form a large interconnected network. They sense and act on external (somatic) and internal (visceral) environments. Specialised by:

- Extensive processes – communicate over distances, i.e. dendrites, axon
- Excitable membranes – conduct charge
- Contiguous network, synapses, forms network of micro and macro circuits
    - Microcircuit level (cytoarchitecture) within grey matter – local
    - Macrocircuit (part of functional system) level usually between different areas of grey matter – distal

A typical neuron – representative with characteristics shared by most: e.g. cell body, euchromatic nucleus, prominent nucleolus, missile granules, membrane, dendrites, axon hillock (voltage gated ion channels), axon (Golgi type 1 vs. 2 neurons; long vs. short), synapses, etc.

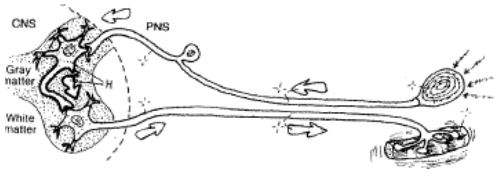
Characterisations –
Histological, or morphological, description/ discussion of central or peripheral neuronal cells:

- Name(e.g. pyramidal, granule, Purkinje); Microscope, Stain
- Cell body size, shape of soma or dendritic tree
- Polarity (unipolar, bipolar, multi polar); Axon length (Golgi 1 or 2)
- Nucleus (size, chromaticity, location, nucleoles); Cytoplasm (e.g. Nissile)
- //General location/ connection (integrative/ intermediary, peripheral motor, sensory, central)
- Specific location of cell body (region, grey matter, cerebral cortex, etc.)
- //Functions

Table 1. Cells of the Nervous System (general function/ location)

Cell.	CNS	PNS
Neuron	Integrative Golgi I (Projection) Golgi II (Interneurons)	Sensory Motor Golgi I (Projection)
Glia/ Supportive	Astrocytes (Protoplasmic, Fibrous) Oligodendrocytes Microglia Ependymal	 Schwann Satellite Perineural
Miscellaneous	Pia/ Arachnoid/ Dura Vessels (Capillaries, Pericytes)	Fibroblast Vessels (Capillaries) Wandering cells (Macrophages, Mast Cells)

PROJECTION NEURONS – Golgi Type I; long axons often extend beyond grey matter of origin *(= pyramidal cell? A neuron with a pyramid-shaped cell body in the grey matter of the cerebral cortex)*
INTERNEURONS – Golgi Type II; short axons usually remain within grey matter where body is located, 90%+ CNS neurons, mostly inhibitory *(a neuron which transmits impulses between other neurons, esp. part of reflex arc)*



1.3 Give an overview of the techniques (microscopes, stains) used to visualise the cells of the nervous system, including examples of how various staining techniques provide different sorts of information

Table 2. Levels of Observation

Level.	Size.	Notes.	Example.
Macroscopic	1 m – 1 mm		Nerve Root; Spinal Nerve; Peripheral Nerve
Light Microscope (Cellular)	1 mm – 1 μm	Utilises light waves and a column of several compound lenses	Nerve Cell; Myelin Sheath; Pacinian Corpuscle
Electron Microscope (Ultrastructure)	1 μm – 1 nm	**Transmission Electron Microscope** (TEM) and **Scanning Electron Microscope** (SEM) - Utilises a beam of electrons and magnetic lenses	Cell Membrane; Synaptic Vesicles; Mitochondria
Molecular	>1 nm		Ion Channels

- **Tissue Fixation** - Chemicals denature protein and other components, stabilise structures
- **Stains** - Molecules differentially attach to tissues and provides contrast e.g. non-specific such as Toluidine Blue, specific to nervous such as silver/ myelin stains, or florescent and injection of dye

1.4 Describe, discuss and draw the morphological characteristics (internal and external levels) of a typical neuron including the synaptic region and correlate the structure with function; Discuss and give examples of the variation in the structure and function of neurons

External Appearance. Typically, body (soma, perikaryon), containing nucleus (karyon) and its processes (neurites). Further divides dendrites, axons, etc. explained 1.2.
Variations. Polarity, cell body size and shape, axonal length, also outlined 1.4.
Schematic Neurons, particularly circuit neurons or populations of similar neurons, O--||---<
Intracellular/ Ultrastructure includes the typical nucleus, nucleolus, ER, ribosomes, mitochondria, Golgi, lysosomes, structural proteins, filaments, tubules and secretory vesicles, but those that typify neurons are high level activity extensive cell processes, large euchromatic nucleus (dispersed DNA), prominent nucleolus (rRNA), extensive ER (Nissl substance, protein synthesis), well developed cytoskeleton and axonal microtubules (rapid transport)

1.5 List the various cell components and their parts that are found in grey matter and white matter in general and give examples of the histological organisation (microcircuits) of neurons in grey and white matter, e.g. the cerebral and cerebella cortex, spinal cord grey matter and the retina

Table 3. Grey and White Matter

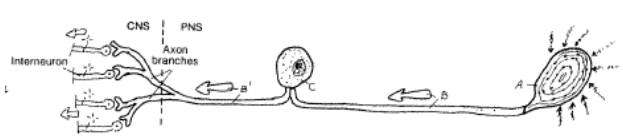
Macroscopic Specimen	Major Components	General Function	Histological Section, Fibre Stain
Grey	Neuronal cell bodies (projection, interneuron), dendrites (projection, interneuron), synapses, interneuron axons, projection neuron proximal, distal, in transit axons, protoplasmic astroglia, many capillaries.	Information Processing	Pale (unless counterstained)
White	Axons (myelinated and unmyelinated), oligodendroglia, fibrous astroglia	Information transfer	Usually dark, often black or green

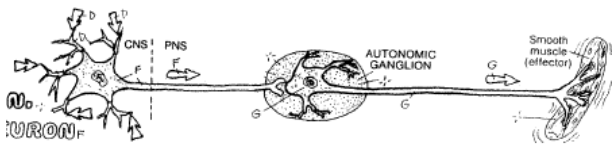
Further levels of morphological organisations within grey matter = spinal cord, cerebellum, cerebral cortex, retina

1.6 Describe, discuss, draw some examples of typical individual neurons/ neuronal collections including:

Table 4. Examples of Morphological Neuronal Classification/ Description

	Polarity	Connections	Axon length	Body Size/ Shape	Location (body)
Somatic Sensory Neuron	Unipolar	Sensory	Long	Large Globular	DRG
Lower Motor Neuron	Multipolar	Motor	Long	Large Fusiform	Ventral Horn
Pyramidal Cell	Multipolar	Intermediary	Long Projection	Large Pyramidal	Cerebral Cortex
Granule Cell	Multipolar	Intermediary	Short Interneuron	Small	Cerebella Cortex





- Cerebral Cortex: Cortical pyramidal neuron

Table 5. Layers of the Cerebral Neocortex

#	Layer	Major Neuronal Cell Type	Major Projection Connections
1	Molecular	few	Within the cortex
2	External Granular	small pyramidal, stellate/ granular	Cortico-Coritcal (in)
3	External Pyramidal	small pyramidal	Corcito-Cortical (in and out)
4	Internal Granular	stellate/ granule	Thalamo-Cortical (in)
5	Internal Pyramidal	large pyramidal	Cortico-Striate/ Cerebellum/ BS/ SC (out)
6	Polymorphic/ Multiform	fusiform	Cortico-Thalamic (out)

- Cerebellar Cortex: Granular neuron/ Purkinje cell

Table 6. Layers of the Cerebellar Cortex

#	Layer	Major Neuronal Cell Type	Major Connections
1	Molecular	few; several types of interneurons and glia	i: climbing fibres, granule cell axon o: Purkinje dendrite
2	Purkinje	Purkinje Cell (projection)	o: deep nuclei
3	Granular	Granular Cell	i: mossy fibres o: axon to molecular

- Retina. Direct pathway: Rod, cone, = PNS/ rest CNS retinal bipolar neuron, Retinal ganglion neuron. Modulating interneurons, horizontal and amacrine cells. Muller cell (glia).

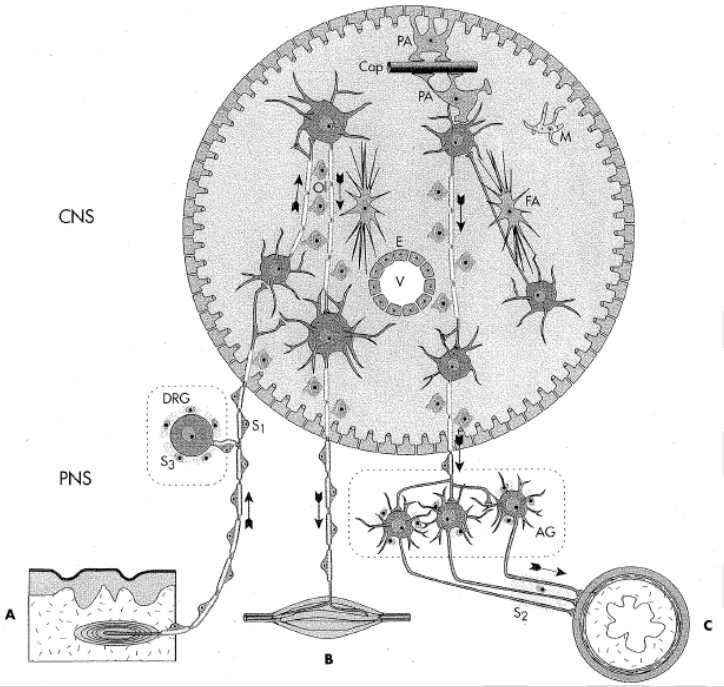
Table 7. Layers of the Retina

#	Layer	Acronym	Major Contents
1	Retinal Pigmented Epithelia	RPE	Cuboid epithelia, junctional complexes, gap junctions
2	Rods/ Cones		120mil:7mil, segmental part of cell, transducers
3	Outer Limiting Membrane	OLM	Zona occludens of the glial (Muller) cells
4	Outer Nuclear Layer	ONM	Nuclei of **rod and cones**
5	Outer Plexiform Layer	OPL	Cell process, synapses, rods, cones, bipolar, horizontal, amacrine cells
6	Inner Nuclear Layer	INL	Cell bodies/ nuclei, **bipolar**, ganglion, amacrine cells, BVs
7	Inner Plexiform Layer	IPL	Cell processes, synapses, bipolar, ganglion, amacrine cells, BVs
8	Ganglion Cell Layer	GCL	Ganglion cell bodies, large 30 micron diameter, large euchromatic nucleus, nucleolus, BVs
9	Ganglion Cell Axons/ Nerve Fibre Layer	GCA/ NFL	Ganglion cell axons, unmyelinated, BVs
10	Inner Limiting Membrane	ILM	Basal lamina of the glial (Muller) cells

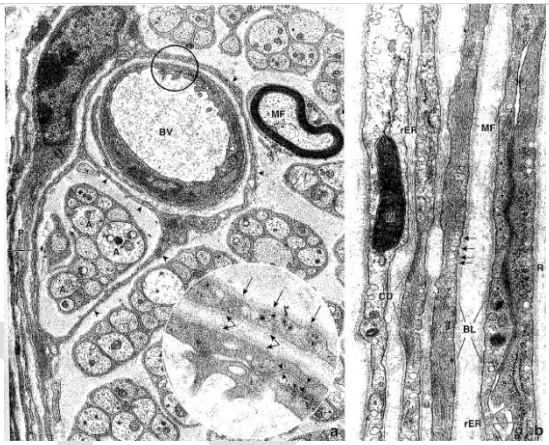
1.7 Describe, discuss and draw the morphological characteristics of the supporting cells (astrocytes, oligodendrocytes, microglia, ependymal, Schwann cells, perineural cells) and other cells (pia, arachnoid, dura, capillaries) of the nervous system and correlate structure and location with function

Spaces, boundaries, junctions and barriers: Fluid filled nervous system has many potential spaces between cells, it mediates passage to mobile cells and molecules, i.e. they manage the microenvironment.
Astrocytes: fibrous (w), protoplasmic (g); medium to small spherical cells with many short processes and end feet; adjacent to capillaries form blood-brain barrier, perivascular glia limitans; adjacent to pial basement lamina/ periphery of CNS form superficial glia limitans; [acts to control the movement of molecules and cells between various spaces] mechanical support, regulation of ion and transmitter content in interstitial space, blood-brain barrier, scar tissue formation;
Oligodendrocytes: small to medium cells with few processes wrapping around axon to form myelin sheath; primarily in white matter; near proximal end of projection neuron axons;
Microglia: small cells with elongated nuclei; pass through cerebral capillary junctions;
Ependymal Cells: cuboidal cells with villi and cilia on luminal surface; line ventricles and spinal canal; lack basal lamina, joined by tight junctions; selective barrier between ventricular/ interstitial space, ventricular/ intravascular space;
Schwann Cells: elongated cells either wrap around or invaginate axon; insulator
Satellite Cells: PNS; small cells that surround neuronal cell bodies in ganglia
Perineural Cells: PNS; flattened cells arranged in layers that surround peripheral nerves and form boundaries of fascicles; tight junction and basal lamina; produce collagen similar to smooth muscle;
Enteric Nervous System: submucosal and muscularis externa

Choroid Plexus: forms from capillary endothelium, pia mater loose CT and ependymal cells; only place in CNS where capillaries have tight junctions; CSF
Arachnoid Villi: located in superior sagittal sinus; most absorption of CSF back into intravascular space; arachnoid invaginates through small holes in dura, two spaces separated by subarachnoid space & arachnoid, endothelium & intravascular space; Meninges
Pia Mater: single layer of flattened cells, basal lamina; loose CT; superficial glia limitans form barrier between CNS interstitial space and subarachnoid space;
Arachnoid: several layers of flattened cells containing tight junctions; extensions form arachnoid trabeculations
Dura Mater: several layers of flattened cells; thicker outer CT; fused with periosteum
BVs: pericytes regulate blood flow, contribute to blood-brain barrier formation, phagocytosis; channels which form in dura, i.e. dural venous sinuses

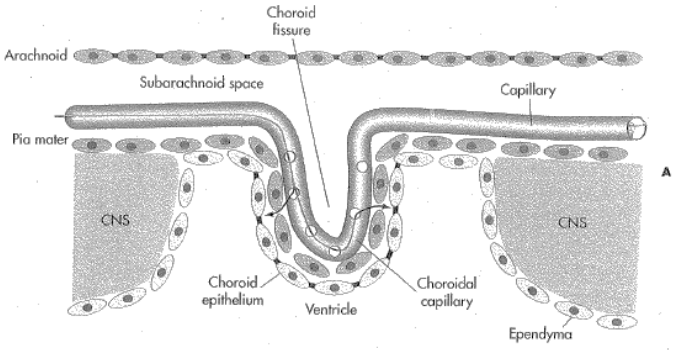


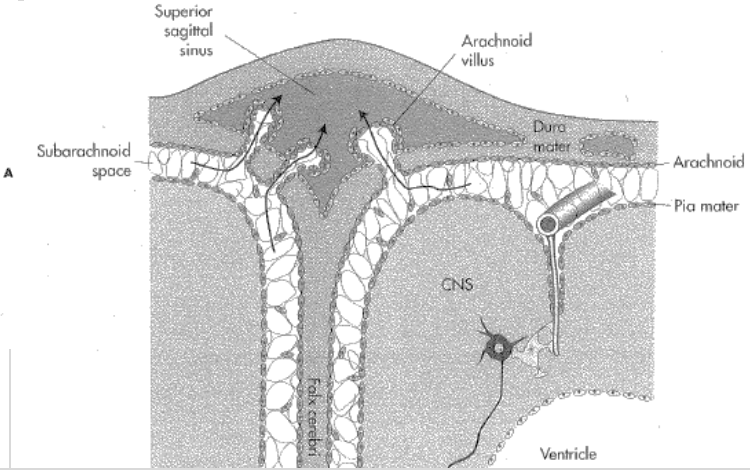
Astrocytes, Oligodendrocytes, Microglia, Ependymal *(Refer to Lecture 6)*



Nerve fibres with four levels of wrapping: Schwann cell; Endoneurium (connective tissue, fibroblasts, capillaries); Perineurium; Epineurium (connective tissue, fibroblasts, adipose cells, small arteries, wandering cells). Collagen fibres of epineurium adjacent to the perineurium are arranged longitudinally in a parallel wavy pattern, which helps protect neurite from damage when stretched or bent.

Cross Section of Typical Nerve





Practical 1: Introduction to Anatomy

With regard to the macroscopic structure of the body, be able to:
(Anatomy = macroscopic structures, observed with the unaided human eye)

I.I Understand what the terms individual characteristics and topographical characteristics mean

In describing and identifying macroscopic structures:

→Understanding **individual** characteristics

It refers to isolated or ex situ specimen, what does it look like, similarities and differences, differentiate structure from other similar structures.

→By **topographical** characteristics

Using an in situ specimen, the physical context as in where it lives, address, neighbours, location, relationships, and may be expanded to involve all structures in a defined region.

I.II Understand the concept of levels of structure and function

Macroscopic structures and their related function may be thought to exist at different levels.

e.g. limb structures, seen overall structure with functions of manipulation, sensation, communication and appearance.

→Sub-regions, shoulder, elbow, hand, etc. relate to another level of function e.g. grasping/ manipulation

→Third level, tissue component e.g. intrinsic hand muscle provides fine movements.

I.III Understand basic anatomical terminology and apply it to identifying, describing and drawing some examples of anatomical structure

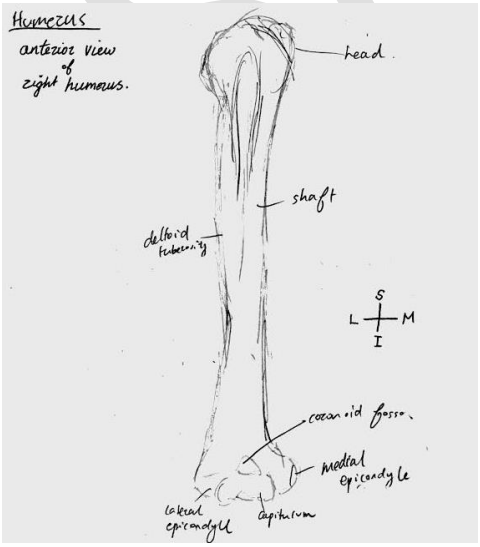
- *Regions* and *Subregions*: head, neck, thorax, abdomen, pelvic, back, upper limb, lower limb, CNS, etc.
- *Anatomical Position*: the particular reference position for defining some anatomical terms
- *Anatomical Planes* and *Sections*: sagittal, para sagittal, coronal/ frontal, horizontal/ transverse
- Terms of *Position* and *Direction*: medial/ lateral, anterior/ posterior, superior/ inferior, dorsal/ ventral, rostral/ caudal, proximal/ distal, superficial/ deep
- Terms Relating to *Movements*: flexion/ extension, abduction/ adduction, rotation, etc.

I.IV Understand the general structure and function of bones, joints, muscles, supply structures and viscera

Bones	Solid structures which transfer force, form joints, allow muscle attachment and offers protection of other internal organs
Joints	Allow and direct movement
Muscles	Control movement and protect some structures
Supply	Nerves activate muscle, glands and sense internal or external environment. Arteries and veins conduct blood to and from other structures. Lymphatics have immunological functions, and return interstitial fluid and large molecules to the blood system.
Viscera	Internal organs, complex structures serving a variety of multiple functions

I.V When drawing macroscopic anatomical structures label the parts clearly and identify the diagram with the name, view, plane, side, etc. of the structure and to be able to include an orientation figure

Activities

(1) 

(3) Biceps Brachii Muscle
Size, medium relative to other muscles
Shape, fusiform Location, brachium
Function, elbow joint flexor

(4) Supply Structures
Nerve, solid with no lumen
Artery, rubbery elastic with lumen
Vein, papery with collapsed lumen (darker)

Lecture 2: Anatomy of the Peripheral Nervous System

Lecture Summary

- Different types of muscles (skeletal, cardiac smooth) and their characteristics

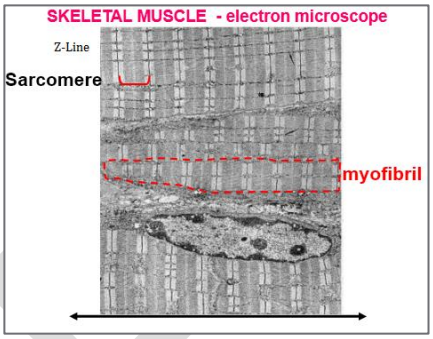
Learning Outcomes

2.1 General terms

Sarcolemma = plasma membrane Sarcoplasmic reticulum = sER Myocyte = muscle cell
Sarcoplasm = cytoplasm Fascicle = bundle

Muscle composed of bundles of **muscle fibres** (cells) arranged in parallel
→ **myofibrils** (in the cytoplasm) → **myofilaments**, Action and Myosin [Electron microscope range]

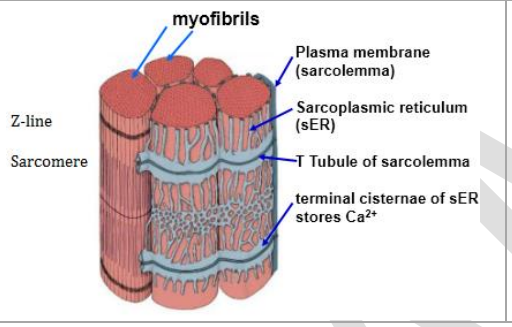
Striated muscle, orderly arrangement of actin and myosin myofilaments = sarcomeres
Smooth muscle, myofilaments not precisely arranged but still present



2.2 Skeletal muscle fibres

- Multiple nuclei located just under the plasma membrane, towards the edges
- Muscle fibres surrounded by connective tissue, arranged in fascicles
- Thin myofilaments of F-actin 6 nm diameter, 1 µm long, Tropomyosin protein, Troponin binds Ca^{2+}
- Thick myofilaments of Myosin II 15 nm diameter, 1.5 µm long, ATP binding sites
- Skeletal muscle fascicles run at different angels, producing x-section and longitudinal sections.
    - Other structures e.g. adipose tissue, capillary, connective tissue, blood vessels, etc. also seen
    - Tapered cells = different sizes/ diameter for cross-sections

Muscle contraction – sarcomere between the Z-lines shortens and bulges, whereas actin and myosin myofilaments remain same length (relaxed = 2-3 μm, contracted = 1 μm)



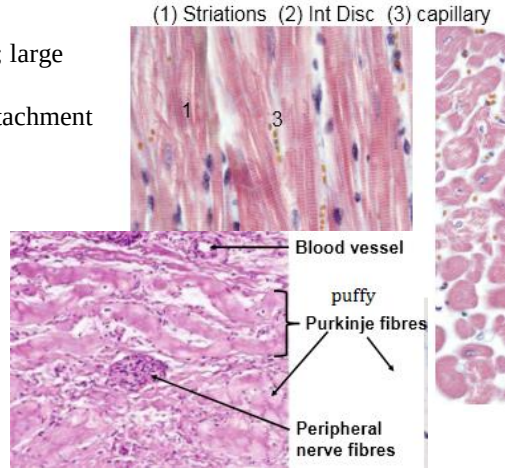
Neuromuscular junction (synapse) between nerve and muscle cell – skeletal muscle innervated by numerous motor neurons; axonal ending with mitochondria, Ach vesicles; folded, convoluted surface to ↑area of contact

Nerve impulse arrives at neuromuscular junction
→ Ach release onto plasma membrane of muscle cell (sarcolemma)
→ Depolarization of plasma membrane (T-tubule)
→ Ca2+ release from sER (terminal cisterna)
→ Energy from mitochondria & glycogen
→ initiates muscle contraction

2.3 Cardiac muscle

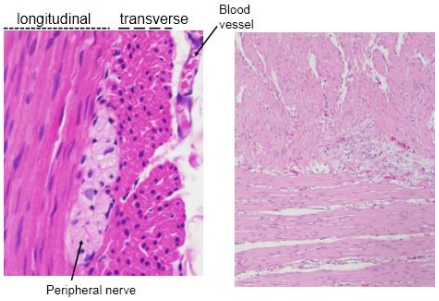
Same myofilaments + arrangement; but single nucleus centrally located; branching fibres; large mitochondria and glycogen surround myofibrils;

- Intercalated discs, esp. important for cardiac muscle to contract at same time. Attachment site between cells end to end
    - Fascia adherens: long area of connection between plasma membrane
    - Desmosomes: spot junction/ folding together
    - Gap junctions: communication ions/ transmitters etc.
- Heartbeat is initiated, locally regulated and coordinated by cardiac conducting cells of the SA node, AV node, Bundle of His, and Purkinje Fibres.
- Purkinje fibres (modified cardiac cells, puffy) are larger than cardiac muscle fibres, myofibrils located at the periphery of cytoplasm, large nucleus, abundant glycogen (pale staining), located in endocardium



2.4 Smooth muscle

- Arranged in bundles or sheets, single central nuclei
- Elongated cells with tapered ends (spindle-shaped)
- 20 µm – 200 µm long
- Interconnected by gap junctions → coordinated contraction
- Myofilaments (actin/myosin) but no myofibrils or sarcomeres thus slower/ less-coordinated



2.5 Tabulated summarisation

Characteristics	**Skeletal**	**Cardiac**	**Smooth**
Cross-striations	Yes	Yes	No
Nuclei	Peripheral	Central	Central
Branching	No	Yes	No
Regeneration	Limited	No	Yes
Cell-Cell junction	Yes (Z.adherens)	Intercalated discs	Gap junctions

	Fatigue – build-up of metabolic products = ↓response to Ca^{2+}; Myofilaments Stretched = pain; Muscular Dystrophy = muscle wasting, actin and Ca^{2+} abnormalities;	High cholesterol levels ↓blood flow = Ischemia/ inadequate O_2; ↓contractile force ; Intracellular Ca^{2+} rise; Cardiac muscle cell death (angina) replaced fibrous;	Severe asthma; Hypertrophy & hyperplasia of airway smooth muscle; ↑contractility and narrowing of airway lumen = inflammation + mucus production;

Lecture 3: The Macroscopic Structure of the Peripheral Nervous System (PNS)

Lecture Summary

- Definition; structural and functional components of the PNS; formation of a peripheral nerve; typical somatic sensory and somatic motor neuron; transducers; structure of the somatic neuromuscular junction; histological structure of a typical peripheral nerve; typical visceral sensory and visceral motor neuron; structure of the visceral (autonomic) neuromuscular junction;

Learning Outcomes

3.1 Define the peripheral nervous system; Sub-classify and describe the PNS according to its attachments.

PNS is part of the nervous system attached to the CNS and which mediates directly with internal/ external environments.

Structural components of the PNS

- **Cranial Nerves**. 12 pairs attached to the brain (mainly brain stem)
- **Spinal Cord Nerves**. 32 pairs attached to the spinal cord; through various structures e.g. plexuses, peripheral nerves, sympathetic trunk, splanchnic nerves, etc.
- Enteric Nervous System. Contains sensory motor and intermediary nerve cells which form plexuses and ganglia in the submucosa and muscularis externa of the gut wall, associated with supporting cells.

3.2 Sub-classify and describe the PNS according to fibre function.

Functional components of the PNS

- **Somatic Sensory System.** CN5,7,9,10, named peripheral nerves; sensory modalities, pain, temperature, coarse/ fine touch, proprioception, etc.
- **Somatic Motor System**. Motor to skeletal muscle, alpha motor neurons to the extrafusal muscle fibres, gamma motor neurons to the intrafusal muscle fibres, in CNs 3-7, 9-12. In the spinal cord, travels in preplexus structures (roots, spinal nerves, rami) and beyond plexus in some named peripheral nerves such as the *phrenic, median, femoral, and tibial nerves*.
- **Special Sensory System.** Carried in/ help form cranial nerves, includes CN1 olfaction, CN2 vision, CN8 hearing, CN8 balance CN7910 taste, etc. sense the external environment
- **Visceral Sensory System**. Innervate viscera, lungs, guts, etc.; detects stretch, ion or gas levels, etc.; distal fibres in ANS of splanchnic nerves; CN such as vagus nerve;
- **Visceral Motor System**. (ANS) motor; internal mileau, homeostasis, para/sympathetic systems; Sympathetic → T1-L2, sympathetic trunk via spinal nerves, ganglia close to CNS, some splanchnic nerves; Parasympathetic → arise from brain stem nuclei travel in CN3,7,9,10, S2-4, or pelvic splanchnic nerves, ganglia more peripheral;

Table 8. STRUCTURAL and FUNCTIONAL components of the PERIPHERAL NERVOUS SYSTEM

Functional Component.	Structures Supplied.	Located in.	Mediates.
Somatic Sensory.	Pain, Temp, Touch, Proprioception from Skin, Muscle Mucosa, etc.	CN/SCN	External Environment.
Somatic Motor.	Skeletal Muscle.	CN/SCN	
Special Sensory.	Smell, Taste, Vision, Hearing, Balance	CN only.	
Visceral Sensory.	Visceral Sensation.	CN/SCN	Internal Environment.
Visceral Motor (ANS).	Smooth/ Cardiac Muscle. Glands.	CN/SCN	

3.3 Discuss, compare and draw the macroscopic formation of a typical cranial and spinal cord peripheral nerve and give examples.

- **Cranial Nerves** – originate from (15-20) cranial nerve nuclei mainly in brainstem; most nuclei associated with one functional type of fibre, but some more; Initially no dorsal/ ventral roots or rami, those with sensory component have ganglia; CNs continue to periphery but no plexuses;

Table 9. Examples of CRANIAL NERVES.

Nerve.	Number	Attachment to Brain	Fibres, Functional Groups.
Olfactory	I	Cerebral hemispheres	Special senses olfaction
Optic	II	Thalamus	Special senses vision
Trigeminal	V	Brainstem, pons	Somatic sensory to face, somatic motor to jaw
Vestibulocochlear	VIII	Brainstem, ponto-medullary junction	Special senses of hearing, balance
Vagus	X	Brainstem, lateral medulla	Somatic motor to larynx, parasympathetic visceral motor to heart, lungs, gut, visceral sensory lungs, gut, etc.

- **Spinal Cord (derived) Peripheral Nerves** – spinal cord segments, rootlets, dorsal/ ventral roots, dorsal root ganglion, spinal nerve, dorsal/ ventral primary rami, white rami communicantes (T1-L2), grey rami communicantes (throughout), plexus, named peripheral nerve, sympathetic trunk prevertebral ganglia, splanchnic nerve.
    - **Peripheral nerves (somatic) –** most larger nerves arise from four major somatic plexuses, supplying skeletal muscle/ skin, with somatic motor and sensory fibres. Also contain sympathetic fibres but referred to as somatic nerves

Table 10. Examples of major PERIPHERAL SOMATIC NERVES

Nerve	Plexus	Structures Supplied
Phrenic	Cervical	Motor to diaphragm. Sensory to pleura, pericardium, peritoneum
Median	Brachial	Motor to forearm and hand muscles. Sensory to skin on hand
Ulna	Brachial	(as above)
Femoral	Lumbar	Motor to anterior thigh muscles. Sensory to skin anterior thigh, medial leg
Tibial	Sacral	Motor to posterior thigh, posterior leg, ventral foot muscles. Sensory to skin on posterior leg and ventral foot.

3.4 Discuss the macroscopic formation of the sympathetic trunk and splanchnic nerves.

- **Sympathetic trunk** is located either side of the vertebral column. It extends from the base of the skull to the coccyx and is composed of fibres and ganglia. It is part of the sympathetic component of the autonomic nervous system, composed. It receives an input via the spinal nerves and white rami communicantes from the thoracic part (T1-L2) of the spinal cord. It send fibres via the grey rami communicantes found throughout length of trunk; somatic peripheral nerves to blood vessels and skin in parietal or wall structures including limbs; and via splanchnic nerves (e.g. thoracic greater splanchnic nerve) to other blood vessels and viscera (e.g. heart, lungs, guts).
- **Parasympathetic**. Fibres arise from sacral segments S2-4, form pelvic splanchnic nerves. They supply the lower gut and several pelvic organs. Some fibres found in CN 3,5, 9,10

3.5 Discuss and compare how the sympathetic and parasympathetic fibres of the visceral motor (autonomic) system are distributed.

Table 11. AUTONOMIC NERVOUS SYSTEM

Component.	Origin.	Preganglionic axon.	Postganglionic axon	Location of Ganglia.	Function.
Sympathetic.	Thoracic Spinal Cord T1-L2	Usually short	Usually long	Away from target structure	Arousal
Parasympathetic.	CN 3, 7, 9, 10 and Sacral Spinal Cord S2-4	Usually long	Usually short	Near to target structure	Vegetative

3.6 Discuss and draw the microscopic structure and course of a typical somatic sensory and somatic motor neuron.

- **Somatic Sensory Neuron**. Large circular cell body, central euchromatic nucleus, prominent nucleolus, located in the dorsal root ganglion or CN sensory ganglion, surrounded by satellite cells. Unipolar (Golgi type I). Process, peripheral, central and connecting piece. The transduction region is located at the distal end of the peripheral process.
- **Somatic Motor Neuron**./ alpha or lower motor neuron. Large cell body, central euchromatic nucleus, prominent nucleolus, multipolar, many dendrites and one long branching axon usually large in diameter, usually myelinated. Cell body located in the ventral horn of spinal cord grey matter or in CN nucleus. Axon + innervated skeletal muscle cell = motor unit.
  Associated with muscles are a group of smaller multipolar neurons called gamma motor neurons, acting on specialised fibres, i.e. muscle spindles.

3.7 Discuss transduction.

Transduction is the process by which a stimulus in the environment is converted to electrical energy in the body in the form of a nerve process action potential.

- *Somatic Nervous System* – peripheral nerve endings of somatic sensory neurons contain ion channels responding differently to tissue damage, temp. or mechanical deformity with production of AP. Some nerve endings have specialised structures around to facilitate this process, e.g. mechanoreceptors such as pacinian corpuscles.
  Information regarding the site of stimulus and modality are encoded by the organisation of the central connections and the intensity of stimulus by frequency of AP.
- *Visceral Sensory Nerve* – concerned with stretch, etc. similar to that of the somatic system
- *Special Senses* – similar but more complex, transducers include rod/ cone cells, hearing and balance hair cells, olfactory cells, neuroepithelial cells in taste buds.

3.8 Describe and draw the microscopic structure of a somatic neuromuscular junction and correlate the ultra-structural components with function.

Excitation-contraction coupling, results in muscle contraction

Structure of somatic neuromuscular junction: (presynaptic region) Schwann cell, nerve ending, mitochondria, synaptic vesicles of ACh, synaptic cleft, basal lamina, (postsynaptic region) subneural clefts, junctional folds of receptors, skeletal muscle cell contents

➔ Further coupling in muscle cells via T-tubules, intracellular reticulum, and contractile proteins.

3.9 Describe, draw and correlate with function the microscopic structure of a typical peripheral nerve as seen in cross section.

A typical peripheral nerve contain both sensory (afferent) and motor (efferent) fibres.

Fibres vary in diameter and in myelination. There is some correlation between fibre size, myelination and functional characteristics of fibre. Medial→Distal:

1. Schwann cells (myelinated surrounds fibres vs. unmyelinated embedded fibres)
2. Endoneurium (loose CT, within fascicle)
3. Perineurium (flat squamous, tight, double, forms fascicles) (made of perineural cells)
4. Epineurium (dense CT by fibroblast)

Refer to Practical 2: Histology of Nerve, for peripheral nerve slide of cross section

3.10 Discuss and draw the microscopic structure and course of a typical visceral sensory and motor neuron and neuromuscular junction

Typical Visceral Sensory Neuron

- Similar/ same as somatic sensory neuron. With peripheral process in a splanchnic or cranial nerve (e.g. CN10), a cell body and a central process. In the spinal cord, this region is located in the dorsal root ganglia and dorsal root.

Typical Visceral Motor Neuron

- Peripheral part of somatic motor system involves one nerve cell body and fibre. Visceral/ autonomic system involves two neurons, pre- and post- ganglionic neuron, both small and multipolar. Preganglionic located either in lateral part of grey matter between dorsal and ventral horns in spinal cord, or in CN nucleus. Sympathetic system involves thoracic and upper lumbar spinal cord segments. Parasympathetic system involved brain stem and sacral segments 2, 3 and 4. The postganglionic cell body is located in a peripheral ganglion. Sympathetic division located in sympathetic trunk or a prevertebral ganglion. Parasympathetic division in particular ganglion near to viscera or in the visceral walls.
- Sympathetic = shorter preganglionic. Parasympathetic = shorter postganglionic. Usually.

Structure of Visceral (Autonomic) Neuromuscular Junction

- Neuromuscular junction also formed between end of postganglionic visceral motor fibre and cardiac/ smooth muscle.
- Smooth muscle neuromuscular junctions, post ganglionic fibre contains a series of regions of increased diameter (=varicosities) which contain vesicles of NT and mitochondria. Some distance away. No clear pre or post synaptic regions on cell membranes
- Postganglionic fibres near glands = similar appearance to those innervating smooth muscle.

Practical 2: Histology of the Nervous System

Learning Outcomes

II.I Define and explain resolution, magnification, contrast and Kohler illumination as it applies to the light microscope

Resolution: ability to tell two objects apart, via illumination, contrast and magnification (LM ~0.2 microns)

Kohler illumination: achieved by adjusting the condenser lens, focusing an even light in the plane of section, minimises scattered and stray light, resulting in better contrast and resolution. Ocular lens magnify and allow for differences between two eyes. Objective lens contributes to resolution and magnification. Iris diaphragm limits stray light entering the field.

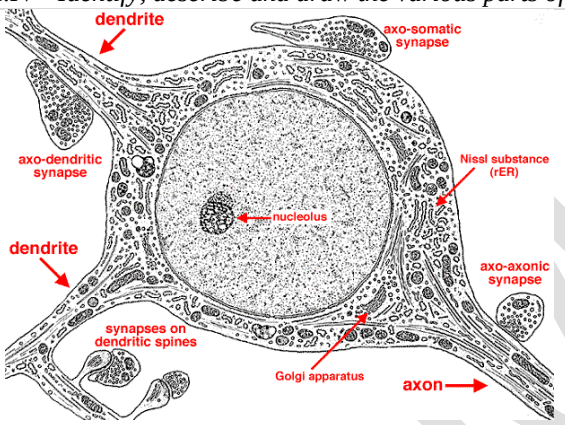
II.II Give an overview of the techniques (microscopes, stains) used to visualise the cells of the nervous system, including examples of how various staining techniques provide different sorts of information

Haematoxylin and Eosin Staining: particularly good for cell numbers and distribution e.g. grey matter, but not good for showing membrane and processes hence in differentiating between neurons/ glial cells.

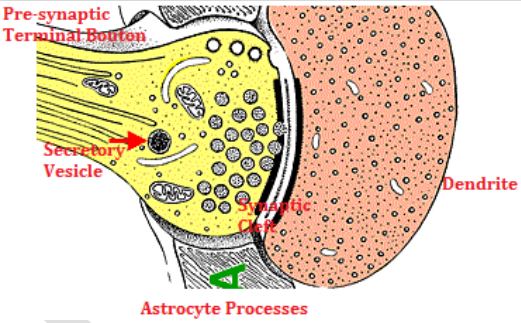
II.III Have some appreciation of the artefacts that are found in light microscope sections of the nervous system and how they might affect interpretation of the tissues in which they are found

Fine black precipitate = formalin-heme pigment formation// polarised light microscopy
Large irregular clumps = tissues not "dezenkerized" prior to staining
Tear/ Holes = insufficient dehydrating

II.IV Identify, describe and draw the various parts of a typical neuron and synapse as seen in the electron microscope



Neuronal Body (4-100 µm). dendrites; nucleus (avg cell ~6 µm); nucleolus; nissl bodies; mitochondria (0.5-1 µm); cell body membrane



Neuronal Axo-dendritic synapse. Axonal membrane; dendritic membrane; pre/post synaptic densities; synaptic cleft (50-100 nm); axonal synaptic vesicles (40 nm); dendritic microtubules; neurofibrils, threads through cytoplasm extending to axon and dendrites

II.V Identify, describe and draw the structure of a typical neuron as seen in the light or fluorescence microscope and examples of particular variations of this structure as seen in various grey matter locations within the CNS; supporting cells of CNS;

Neurons. Specialised charge conducting plasma membranes that form extensive processes, networks and synapses. Cells of the nervous system responsible for production/ transfer of AP and processing information. Morphological differences include polarity, body size, shape, length of axon and grey matter location. E.g. neurons of the spinal cord: interneurons, multipolar neuron with short axon; projection neurons including alpha motor neurons also multipolar neuron but with very long axon, located in ventral horn. Electron dense regions of synapses ~50-100 nm.

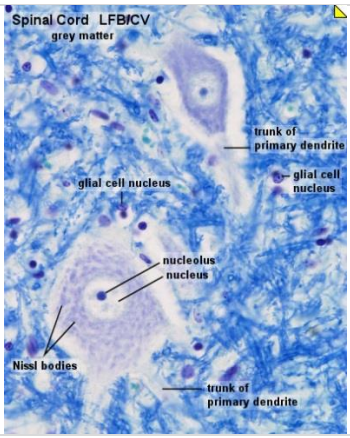
Spinal Cord. Part of CNS, attachment for peripheral nerves via rootlets that run in the subarachnoid space (dorsal rootlets = sensory; ventral rootlets = motor; rootlets → root → spinal nerve). Surrounded by meninges.

Grey matter composition: neuronal cell bodies, dendrites, synapses, proximal axons, glia, mainly astrocytes.

- Dorsal/ Ventral horns (ventral = broader, less extension towards margin)
- Central spinal canal lined with ependymal cells

White matter composition: un/myelinated axons, glia such as oligodendroglia.

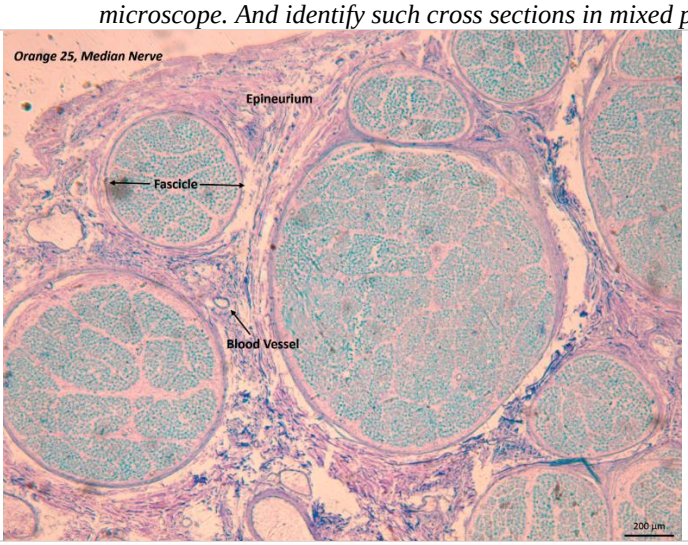
- Dorsal/ Ventral/ Two Lateral funiculi



Cell body (perikaryon 15 - 50 μm)
nucleus (size? 5-15 μm?), nucleolus,
nissl granules (ribosomes), prominent in motor neurons in ventral horn grey matter
proximal cell processes

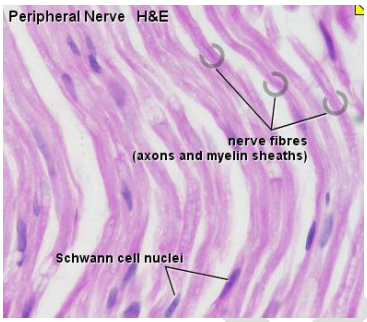
Schematic drawing: multipolar neuron

II.VI Identify, describe and draw the structure of a cross section through a typical peripheral nerve as seen in the light microscope. And identify such cross sections in mixed peripheral tissues; supporting cells of PNS



X-Section of peripheral nerve

fascicles, epineurium, BV
perineural cells, endoneurium, myelinated axons, Schwann cell nuclei, capillaries/ fibroblasts in Endoneurium

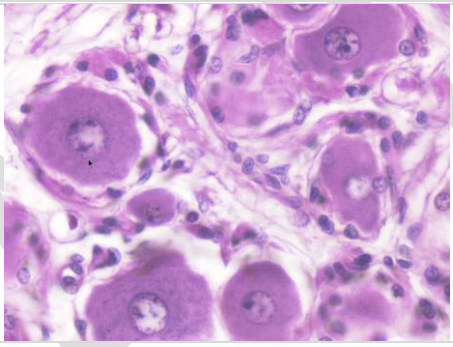
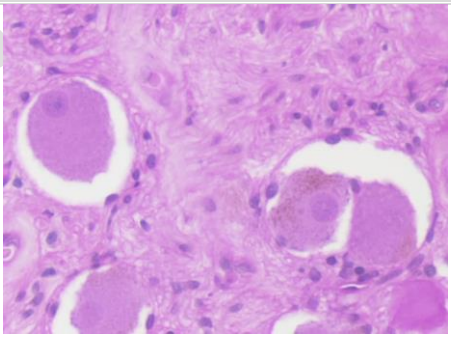


Peripheral nerves: Schwann cells → Endoneurium (loose CT, fibroblast, capillaries) → Perineurium → Epineurium (dense CT, fibroblasts, adipose cells, small arteries, wandering cells)

II.VIIIdentify, describe and draw the distinguishing features and draw the structure of a cross section through a typical sensory and autonomic ganglia as seen in the light microscope

Ganglia = collection of nerve cell bodies

- Somatic Sensory nerve cells: peripheral somatic sensory neurons
- Autonomic Ganglia: contains cell bodies, dendrites and proximal axons of post ganglionic neurons, distal axons of preganglionic neurons, synapses and satellite cells.

Type.	Sensory. (e.g. DRG.)	Autonomic. (e.g. Symp. Trunk.)
Diagram.		
Cells/ Fibres in Ganglia.	somatic sensory fibres// separate	autonomic neurons (cell bodies contained in autonomic ganglia) // mixed
Shape/ Neuronal Nuclei.	large, circular cell body **central** euchromatic nucleus	 **peripheral** euchromatic nucleus
Processes.	unipolar (no dendrites)	bipolar (pre/post ganglion); cell body less tightly packed due to larger # cell processes
Synapses.	none	many
Satellite Cells.	yes; numerous// continuous layer	yes; fewer due to neuronal dendrites occupying space around// incomplete
Intracellular Lipofuschin.	no	yes – brown staining substance, cell by product
Functional System.	Somatic and Visceral Sensory	Visceral Motor (Autonomic)

II.VIII Identify, describe and draw the organisation of neuronal, supporting, and other cells in the spinal cord, cerebellar cortex, cerebral cortex and retina as seen in the light microscope

Cerebellar Cortex: deep → superficial, granular → Purkinje → molecular MPG (many potential grannies? HAHA)

- Granular cells = small (10 µm), multipolar, Golgi II, glutamate
- Purkinje cells = large, multipolar, Golgi I, projection neurons, GABA

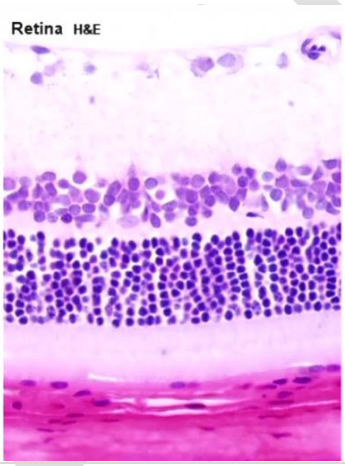
Three layers and underlying white matter, label folia, fissures, meningeal structures; Purkinje and granular cells with processes

Cerebral Cortex: ~6 layers deep → superficial: MGP(GP)P (many exciting granny potentials, intrinsically gained position, polymorphic multiform layer)
polymorphic (multiform) layer → int. pyramidal → int. granular → ext. pyramidal → ext. granular → molecular;
Pyramidal cells are found in most layers, in particular the pyramidal and granular layers
neocortex, radial variation, tangential variation;

- Brodmans Areas: six layers of neocortex studied (i.e. radial variation), types of neuronal cells similar but variation (tangential variation) in their relative proportions in the various layers. Corresponds to particular functional regions on gyri and sulci e.g. 123 primary somatosensory area, 4 primary motor area
- Lamina of Rexed → otherwise homogenous spinal cord grey matter categorised into system of I-X, defined portions of the spinal cord grey columns

Diagram of an astrocyte, oligodendrocyte, microglia, add scale and indicate location of glia limitans

Retina: orbit is ~3 layers, external sclera → middle vascular choroid → inner neural layer/ retina; retina usually has ten layers except at the macular and optic disc, most clearly visible layers through light microscope is (1) pigmented epithelium, outermost layer (4) nuclei and some rods and cones, outer nuclear layer (6) bipolar neurons, inner nuclei layer and (8) ganglion cells. Thought of as a sensory peripheral nerve (rods and cones) with a transducer region attached directly to CNS, retinal ganglion cell is multipolar with long axons → considerable distances, e.g. lateral geniculate nucleus in the thalamus.



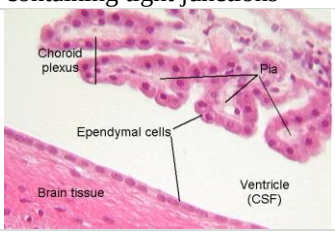
Include sclera, choroid, pigmented epithelium, collections of rods and cones nuclei (outer nuclear layer), bipolar cells (inner nuclear layer), ganglion cells, outer and inner plexiform layers and ganglion cell fibre (axonal) layer

Simple diagram of typical rod, cone, bipolar cell and ganglion cell

II.IX Identify, describe and draw the structure of the pia mater, arachnoid, and dura mater as seen in the light microscope

II.X Identify, describe and draw the structure of capillaries and choroid plexus of the nervous system as seen in the light microscope

Choroid Plexus: in the lateral, third and fourth ventricles, produces CSF, 3 layers, fenestrated capillaries → pia and CT → ependymal cells containing tight junctions



Note irregular folded arrangement

Ependymal cells, CT, capillaries, intravascular/ intraventricular space

II.XI For histological diagrams of the nervous system be able to clearly label them and state the tissue, section and where appropriate the stain, magnification (or provide scale), artefacts present or other helpful and identifying information.
Refer to Lecture 6.