Lecture 1 – Cellular Structure of Nervous System

General Comments
The nervous system is broadly divided into two components – the CNS & PNS. The CNS is composed of the brain + spinal cord, whereas the PNS includes all the spinal and cranial nerves travelling to the periphery of the body – innervating numerous structures and organs. The PNS also consists of numerous ganglia – these are collections of neurons (neurons = cell bodies) in a single segment of space – whose processes protrude to innervate the various structures and organs.

There are approximately 100 billion neurons in our body, whereby glial cells make up most of this number. The nervous system is responsible for conveying messages throughout our body. The mechanism within neurons is by electrical conduction, between neurons is by chemical signalling.

Collections of neurons in the PNS are called ganglia – in the CNS– nuclei. Note that the individual neurons in these collections have a similar function; hence the grouping is for the convenience of the body.

Neuron Structure A (Nolte 5th Ed. Pg 2)
All neurons have the same general function – to convey signal to and from one another, and other structures and thus has anatomically specialised areas where this process can occur. The cell body (soma, perikaryon) of a neuron is the protein synthesising part, which supports the metabolic needs of the rest of the cell. Dendrites are receiving ends of a neuron, where signals from neighbouring neurons are transmitted to, and all neurons have an axon which is a single long process that conduct information away from the cell body. Typically, a neuron has 1 axon and numerous dendrites. The polarisation of this arrangement is important in transmitting information. The axon may then split into many collateral branches called axon terminals, that form chemical junctions with the dendrites of other neurons.

Thus, dendrites are referred to as the *input compartment* and axons are the *output compartment.* Notice that all neurons have this basic structure, but neurons may vary in function and size.

Classification of neurons (Nolte Pg 3)
Most neurons are multipolar, meaning they have several dendritic processes and almost always an axon as well. This is the most common type of neuron found in the nervous system. Some neurons are bipolar (i.e.: retina, olfactory), meaning they have one dendritic process and one axon extending from the soma. Other neurons are unipolar (pseudounipolar, i.e.: sensory neurons in cranial/spinal ganglia), meaning they have one process extending from the soma. (Nolte Pg 5, for good diagram on how these come to form).

Neurons can also be classified according to their connections. Sensory neurons receive direct input from external stimuli or via non-neuronal receptors. Motor neurons directly influence muscles, glands or other neurons in the PNS ganglia. Both types reside in the CNS and PNS. Interneurons are by far the most common type of neuron found in the nervous system (technically) and these are confined to the CNS, and are usually are small compared to their counterparts. Projections neurons are those that travel long distances from/to the brain into the spinal cord, to synapse and transmit information from/to neurons of the PNS.

Neuron Structure B (Nolte 5th Ed. Pg 9)
The ultrastructural features of a neuron are similar to those of any other cell in our body. Note that neurons can be have very long extensions from their cell body, so there must be a means of efficient communication between the "brain center" (cell body) and the other parts. Neurons have organelles such as ribosomes, ER, Golgi apparatus BUT the organisation of structures usually reflects the function of the neuron.

Cell body
The cell body (ultra structural view) reflects the protein synthesising nature of a neuron. It has pale staining nuclei (i.e.: indicating active protein synthesis), sometimes a number of nucleioli

(i.e.: indication active ribosomal RNA synthesis), numerous Golgi apparatus, ribosomes, and ER for transport, packaging and protein synthesis. These are all indicative of a very active cell (similar to a glandular secretory cell). Free ribosomes and those attached to ER appear as clumps under light microscopy, these are referred to as Nissl Bodies or Nissl substance. This is present in the cell body and proximal parts of some dendrites.

The Golgi apparatus, and other organelles described above are all embedded within a network of cytoskeletal elements namely: microtubules, neurofilaments, neurofibrils. These are responsible for the structural integrity of the neuron and for movement of organelles along the axon.

Types of synapses
Axo-dendritic – excitatory
Axo-somatic – inhibitory
Axo – axonic – inhibitory

Axonal transport (Nolte 5th Ed. Pg 12)
Axons are too long and tenous to rely on diffusional transport. They use a mechanism called axonal transport for the transportation of organelles, intracellular chemical messengers in both directions. Transport away from the soma is termed anterograde, transport towards the soma is termed retrograde. There are two categories of axonal transport namely: slow & fast. Slow transport is used for the transportation of cytoplasmic proteins, enzymes and other free molecules to the synaptic endings from the soma (few millimetres a day, refer to Pg 14 for dilemma on this matter). Fast transport moves membrane associated components such as organelles, vesicles, lysosomes etc, to and from the cell body at a rate of 400 mm/day. This is done using the microtubules are potential "roads", which have polarity (*plus* end is where new tubulin is added). For anterograde transport – kinesin ATPase is used. For retrograde transport – dynein ATPase is used. Microfilaments are responsible for the movement of the tip of a growing axon.

Methods in Neuroanatomy
Nissl stain is used to visualise RNA (i.e.: ribosomal RNA – hence ribosomes are stained well). Golgi stains work for 1-2% of cells, whereby heavy metals infiltrate the neuronal processes therefore making it easier to visualise.

Glial cells – types and function (Nolte 5th Ed. Pg 22).
PNS
All PNS glial cells are variants of one cell type – called Schwann cells. Satellite cells are flattened out Schwann cells. The satellite cells surround the neuronal cell bodies in PNS ganglia (i.e.: surround whole ganglia and not individual neuronal cell bodies). Schwann cells envelope axons for metabolic support and electrical insulation. Schwann cells are responsible for the myelination of axons. Note that unmyelinated axons are also surrounded by Schwann cell membranes, but myelination is classified as repeated enveloping – forming a sheath. The spaces between these envelopings are called nodes of Ranvier, and the sheaths are called internodes. One Schwann cell can only myelinate one axon, but can (so-called) unmyelinated several axons. Myelination leads to faster conduction called saltatory conduction, whereby electrical impulses jump from one node to another, effectively bypassing the internodes – therefore reaching their destination much faster than usual. This is required in some neurons, for example: for muscular function. Other neurons remain unmyelinated (pain fibres), because speed is not essential (Revise Human Biology).

CNS
Oligodendrocytes: Unlike Schwann cells in the PNS, oligodendrocytes are responsible for the myelination of several axons in the CNS. Also, unlike PNS an unmyelinated axon is not surrounded by an oligodendrocyte (Schwann cell in PNS), directly exposing it to the EC environment. These cells are most prominent in white matter (giving it its white shiny appearance). Multiple sclerosis is caused by breakdown of these myelin sheaths provided in oligodendrocytes, in the CNS (demyelinating disease).

Astrocytes: These are star shaped cells. Two types evident – protoplasmic (grey matter) & fibrous (white matter). Radial glia, the 3rd type – are found during development – and their

function is the guide the growth of axons. Astrocytes have a well developed cytoskeleton, indicating their importance in the structural integrity of CNS tissue and maintenance & regulation of extracellular ionic concentrations. Astrocytes are extremely important in CNS tissue damage, where they proliferate and form gliotic scar tissue (as axons in CNS cannot regrow).

Ependymal cells: The CNS has its embryological origins from a neural tube. The canal of the neural tube, persists in adult hood as the system of ventriles and spinal canal. The epithelial lining of these ventricles are formed by ependymal cells (columnar cells). In some parts, these cells are specialised to produce the CSF (i.e.: choroid plexus – infolding of blood vessels of the pia matter surrounded by ependymal cells).

Microglia: These are the phagocytic cells of the CNS. Their function in a healthy individual is not understood completely, however we know they are activated in the case of CNS injury & proliferate + differentiate into macrophages to clean up the debris and any presenting pathogens. As the pretext suggest (“micro”), these cells are smaller than oligodendrocytes and astrocytes.