Lecture 13 – Sensory Receptors and the Peripheral Nervous System

Gross organisation of the peripheral nervous system (Moore pp 41-45, Fig 1.26-1.29)
The peripheral nervous system is everything outside the central nervous system. The peripheral nervous system includes the spinal nerves + cranial nerves, and all the branches that arise from these nerves. The gross organisation arises from the spinal cord:

- You have dorsal and ventral roots (sensory, motor → respectively)
- These combine at some stage to form a spinal nerve
- Upon formation of a mixed spinal nerve, it splits into a dorsal primary ramus and a ventral primary ramus
- Dorsal ramus supplies posterior aspect of the body, ventral ramus supplies the much larger anterior aspect of the body
- Viscerals arise from anterior ramus, white ramus communicans, paravertebral ganglion, gray ramus communicans and visceral nerves
- The ventral primary ramus of spinal nerve becomes the somatic pathway (includes general sensation)

Peripheral nerve (Moore pp 42)
Here are some general concepts:

- A peripheral nerve has an analogous structure to the meninges of the spinal cord. It contains three connective tissue coverings namely: endoneurium (covers individual nerve fibres + neurolemma), perineurium (covers bundles of nerve fibres – fascicle), epineurium (thick sheath covering all the bundles – your outer coating). A peripheral nerve can be sensory or motor in function, or both. A motor unit is composed of a nerve fibre and all the muscle fibres it innervates. The smaller the motor units, the finer movements it accounts for.

General classification of receptors (Nolte 5th Ed pp 198)
Receptors are classified in different ways and one way is the following:

- **Interoceptors:** respond to stimuli within the body (i.e.: BP, gastric juice, pH etc)
- **Proprioceptors:** respond to movement of parts of the body (i.e.: muscle spindle)
- **Exteroceptors:** respond to stimuli outside the body (i.e.: touch, hearing, vision, pain)
    - ***Teloreceptors:*** respond to stimuli that is separate from the body (i.e.: vision, hearing etc)
    - ***Contact receptors:*** respond to stimuli that are in contact with the body (i.e.: tactile, pain)

Note that the main function of receptors is to bring information to the brain. The brain processes the information, and responds accordingly.

Properties of receptors (Nolte 5th Ed pp 198, Fig 9-1)
We know that receptors can send information higher centres about the nature of the stimulus (i.e.: pain, vibration, light tough, pressure etc), but some receptors also can send information regarding where the sensation is picked up. This is called a **receptive field**. A receptive field is a particular location in the periphery where application of an adequate stimulus will cause that receptor to be activated. Another property of a receptor includes the **intensity/duration** property (Fig 9-2). That is, a particular receptor may be sensitive to the intensity and duration of a stimulus. Thus, a larger stimulus will produce a larger receptor potential, whereas a longer stimulus will produce a longer receptor potential.

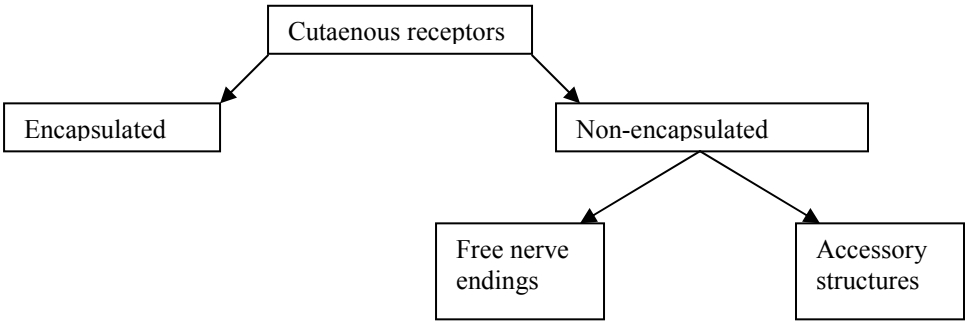
Transduction (Nolte 5th Ed pp 199)
Sensory receptors will convert the stimulus into an electrical signal so it can be interpreted by the nervous system. This is called transduction. Transduction almost always involves opening and closing of ion channels, which in turn produce receptor potentials. The mediation of ion channel opening/closing can be done directly by the stimulus → stimulus-gated-ion-channel (e.g.:

somatosensory receptors, vestibular/auditory, taste, visceroreceptors), or indirectly by way of a G-protein-coupled mechanism (e.g.: photoreceptors, olfactory, some taste, some nociceptors, some visceroreceptors). When stimulated, they can produce a depolarising (i.e.: somatosensory receptors) or a hyperpolarising (e.g.: photoreceptors) receptor potential depending on which type of receptor they are. Vestibular and auditory receptors can do both depending on the type of stimulus.

Note that not all receptive potential will produce an action potential (i.e.: threshold must be reached). This is because some sensory neurons are small, so the receptive potential is big enough to be transmitted to 2^0 neurons, but others are large → capable of producing AP.

Adaptation (Nolte 5th Ed pp 199)
Adaptation is when a sensory receptor gets less sensitive to a stimulus during the course of a maintained stimulus. This could mean that less and less receptor potentials are generated with time, or the number of AP generated given a receptor potential is decreasing. Adapt quickly → rapidly adapting (i.e.: Pacinian corpuscles), adapt slowly → slowly adapting (i.e.: receptors for static position). Note that nociceptors (i.e.: pain etc) does not adapt at all, and may even get sensitive if stimulus is prolonged.

Types of cutaneous receptors (Nolte 5th Ed pp 201)



Non-encapsulated receptors
Free nerve endings are usually associated with pain (nociception), temperature, touch (hair receptors). Some nociceptors can preferentially detect a particular stimuli (i.e.: mechanical, thermal, chemical etc). These are called polymodal nociceptors. Some nociceptos are small and thinly myelinated, whereas others are even thinner and unmyelinated. Functional significance → When you hit yourself with a hammer → you perceive an immediate sharp pain (mediated by small myelinated fibres – Aδ fibres) followed by an aching longer lasting pain (mediated by small unmyelinated fibres – C fibres).

Another type of non-encapsulated receptor (but contains an accessory structure) is the Merkel ending. Structurally, the ending of the nerve fibre expands like a disc, which is inserted into a specialised cell → Merkel cell. A single nerve fibre usually branches to give several nerve endings → innervating several Merkel cells. These receptors are associated with touch + 2 point discrimination and are found in the basal layer of the epidermis. Note that the density of Merkel endings is increased as you move more peripherally.

Another type of non-encapsulated receptor is the hair receptor. The sensory nerve ending wraps around the base of the hair follicle, so mechanical disturbance is felt by the nerve ending, distorting the mechanically sensitive channels – therefore firing off a potential.

Axon reflex (Nolte 5th Ed pp 208 Fig 9-12)
An axon reflex produces flare and oedema in response to tissue injury. An example would be localised skin injury. The nociceptors pick up the signal, and send afferent signals to the spinal cord which is then interpreted by the CNS. The neurotransmitters involved are glutamate and

others. The neurotransmitters bind to 2^0 order neurons in the CNS. Unlike other afferents, nociceptors also send signals back peripheral to the nerve endings which cause release of the same neurotransmitters. Hence action potentials initiated by pain sends a central + peripheral stimulus. The neuropeptides released peripherally cause localised vasodilation (flare), ↑ capillary permeability, therefore causing oedema. Infiltration of wound healing cells also occurs due to the ↑ capillary permeability. The peripheral signalling by the nerve fibre is the only example of a reflex, which doesn't have a synapse.

Encapsulated receptors (Nolte 5th Ed pp 205)
The layers of encapsulation on encapsulated receptors serves some function. This includes: acting as a filter to modify sensory input. Examples of such receptors include: Meissner's corpuscles + Pacinian corpuscles. Meissner's corpuscles are in the dermal papillae of hairless skin. The capsule is thin, underneath you find stacks of epithelial cells arranged perpendicularly to the nerve fibre. These are rapidly adapting receptors, and are involved in light tough + 2 – point discrimination. Pacinian corpuscles, on the other hand, are found in the hypodermis and other connective tissue sites → concentric layers of epithelial cells, with fluid spaces between concentric layers. These are rapidly adapting receptors because inner capsular layers are not mechanically disturbed as their outer counterparts (i.e.: think of balloon within balloon, and nerve ending in the centre).

Receptors in muscles (Nolte 5th Ed pp 210)
The main fn of eeceptors in muscles detect muscle status and proprioception (limb position). The various types include: muscle spindle & golgi tendon organ.

Muscle spindle (Nolte 5th Ed pp 210)
Muscle spindles are stretch receptors distributed throughout each striated muscle in the body, have a capsule surrounding the middle third. The small muscle fibres located within the larger muscle fibres are called intrafusal fibres, the latter → extrafusal fibres. The intrafusal fibres are attached to the extrafusal fibres so when the extrafusal fibres are stretched, so are the intrafusal fibres. Note that the intrafusal fibres have few myofilaments, so contractile function is low. The central region of the intrafusal fibres has numerous sensory nerve endings. So what happens?

- Muscle stretched → intrafusal fibres stretched → mechanical distorting of the sensory nerve endings → mechanical sensitive channels opened → impulse given off to spinal cord via afferent limb of reflex arc.

Some specialisation of muscle spindles:

- Two types of intrafusal fibres: nuclear chain fibres (central region which contains nuclei is thin because nuclei arranged in single file), nuclear bag fibres (nuclei arranged several adjacent to each other – central portion is expanded).
- Two types of sensory innervation:
    - Ia – primary ending (annulospiral): large nerve fibre branches to surround (spiral) central region of each intrafusal fibre → detect onset of stretch but discharge slowly when stretch is maintained.
    - II – secondary ending (flower-spray): small fibres that branch and innervate mainly nuclear bag fibres → less sensitive to onset of stretch but discharge fast when stretch is maintained.
- Also receive motor innervation. Large nerve fibres supplying extrafusal fibres are called alpha motor neurons, whereas small nerve fibres supplying contractile portion (i.e.: extremities) of intrafusal fibres are called gamma motor neurons (fusimotor) → regulate sensitivity of muscle spindle (read pp 212 → excellent!)

Golgi tendon organ (Nolte 5th Ed pp 212)
These detect muscle tension, adjusting the force of muscle contraction. They are composed of interwoven collagen bundles surrounded by a thin capsule. Sensory fibres (Type Ib) enter the capsule, branch into fine processes and receptors terminate between collage bundles. Tension

along the tendons squeezes the collagen bundles, which squeezes these receptors, mechanical distortion → potentials generated by mechanically sensitive channels.

Classification of Peripheral nerve fibres (Nolte 5th Ed pp 220, Table 9.3)
Classification is based on conduction speeds. A fibres are really fast, i.e.: Aα (efferent to extrafusal fibres), Aγ (efferents to intrafusal fibres), Aδ (sharp pain). B fibres are still fast but not that fast → myelinated visceral motor/sensory fibres. C fibres are really slow – unmyelinated fibres (i.e.: slow pain, dull pain).

Classification also includes axonal diameter measurements. Large fibres → 180m/sec, small → 1m/sec.