Chapter 2

Basic Anatomy and a Little Physiology

The nervous system can be considered to consist of two parts: the central nervous system and the peripheral nervous system. A third component, the autonomic nervous system, features little if at all in the clinical application of electrophysiological testing. This and its complexity might permit us the notion that it should be enjoyed rather than understood.

The function of the individual elements, the neurons, of both parts of the nervous system is to transmit information from one site to another. Each neuron comprises a cell body, the soma, bearing an extrusion, the axon, which is usually of such impressive length that when referred to as a 'nerve' it is easy to overlook the fact that it is merely a conduit between the soma and its destination. Sensory neurons in the peripheral nervous system have two such axons and are therefore called bipolar cells.

The transmission of information may take place between sensory receptors and a neuron, between neurons or between a neuron and a muscle. The axon terminals from one neuron connect to the soma of another neuron at junctions called synapses. These are mainly located on dendrites, which are also extrusions of the soma but much shorter than the axon. A motor nerve connects to muscle fibres at the neuromuscular junction.

The brain and spinal cord comprise the central nervous system. Within this system, areas containing the cell bodies of nerves appear darker and are referred to as grey matter. At the base of the brain is a stalk-like structure, the brain stem, which forms a continuation of the spinal cord.

Grey matter in the brain is located over the surface, forming the cerebral cortex, or in clusters such as the thalamus and basal ganglia buried within the substance of the hemispheres. The grey matter in the spinal cord is deeply situated. It is roughly H-shaped having two ventral, or anterior, horns and two dorsal, or posterior, horns.

The interconnecting nerves between the cell bodies in the central nervous system are bundled into tracts known as white matter. They are sheathed in myelin which, containing lipids, imparts their lighter appearance. This insulates them from one another thus preventing unwanted 'cross-talk' between adjacent nerves. As we shall see in Chapter 4, 'Peripheral Nerve Function', the presence of myelin also increases the conduction velocity along the nerve.

Nerves supplying the limbs and trunk form the peripheral nervous system. The nerves to the head and neck have complex and individual anatomies and so rather than being thought of as a system, they are referred to by their individual cranial nerve names.

The majority of peripheral nerves are unmyelinated but in those that are, the myelin is applied in multiple, short segments.

Nerves carrying impulses into the central nervous system are called afferent or sensory nerves whilst those carrying impulses from the central nervous system to muscles are called

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efferent or motor nerves. Most but not all peripheral nerves contain some of both types of nerve and are therefore called mixed nerves.

Motor System

The motor nerves which supply the limbs and trunk arise in the cerebral cortex and then run through the part of the brain stem known as the medulla and thence down into the spinal cord where they form a synaptic link with the anterior horn cells in the ventral grey matter. Most of these fibres cross to the other side as they pass through the region of the medulla known as the pyramids to form the pyramidal or lateral corticospinal tract. The remainder form the anterior corticospinal tract.

The spinal cord, although a continuous structure, can be thought of as a sequential series of segments. The motor outflow from a given segment supplies a series of muscles, the myotome. The anterior horn cell pool of motor neurones supplying the myotome receives connections from the pyramidal tract and from the anterior corticospinal tract after it has decussated (crossed sides) at that level.

The nerves issuing from the anterior horn cells destined for the limbs and trunk exit from the spinal cord via the ventral nerve roots and then negotiate plexuses where sensory and motor nerves arising from different segmental levels in the spinal cord combine. Each paraspinal muscle receives its nerve supply from the dorsal ramus which arises just distal to the point where the dorsal and ventral roots at that segmental level merge.

The anterior horn cell, its peripheral nerve and all the muscles fibres it innervates is called a motor unit. The size of the motor unit is proportional to the number of muscle fibres it contains.

Sensory System

Sensory neurons within the peripheral nervous system are located in the dorsal root ganglia just outside the spinal cord. They differ from motor neurons in having not one but two extruded nerve fibres, hence the name bipolar cells. The peripheral, distal fibre brings in impulses from the limbs or trunk. It also participates with the motor nerves in the formation of plexuses. The centrally projecting fibre from the dorsal root ganglion runs into the spinal cord via the dorsal root and then follows one of two main pathways.

Nerves carrying pain, temperature and deep touch sensations cross the midline and form synapses in the posterior horns of the spinal grey matter. From here the lateral spinothalamic tracts relay signals to the cerebral cortex after making further synaptic connections in the thalamus.

Nerves carrying light touch and proprioceptive sensations do not cross the midline at this stage. They enter tracts called the dorsal columns which synapse in the cuneate and gracile nuclei located in the medulla. They then cross the midline in the medial lemniscus tract to the thalamus. Here they also engage in further synaptic activity before their onward journey to the cerebral cortex.

There is an exception to this general trend of relays mediated via multiple synapses. Nerves from the intrafusal muscle spindles, which signal information about its length, form a monosynaptic link with the anterior horn cells supplying the force-producing extrafusal fibres of the same muscle. This will be discussed further when we consider the H-reflex in Chapter 17, ‘Other Techniques: F-waves and H-reflexes’. The intrafusal and extrafusal muscle fibres are discussed more fully in Chapter 6, ‘Muscle’.

Soma, Axon Hillock and Initial Segment

We are now in a position to consider how an impulse from the spinal cord begins its journey to a muscle.

As we have seen, the soma – in this case, the anterior horn cell – has numerous small projections called dendrites and a long, extruded portion, the axon, which forms the peripheral motor nerve fibre. The activity in the connections between the axon terminals from other nerves and these anterior horn cell dendrites determines the activity of the soma and hence its nerve.

Neurotransmitters cross the junctions between these connection, the synapses, and induce either an excitatory or inhibitory potential in the soma. These are known as excitatory post-synaptic potentials (EPSPs) or inhibitory post-synaptic potentials (IPSPs), respectively. A single EPSP is insufficient to generate a so-called action potential in the axon, that is to say, a potential that will be propagated down the nerve. Both EPSPs and IPSPs may be augmented by spatial and/or temporal summation. In spatial summation, the effects of activity in multiple dendrites are summed. In temporal summation, the effects of repeated activity at a single dendrite are summed. The algebraic summations of the EPSPs and IPSPs then determine if the soma has been sufficiently depolarised to generate an action potential. If so, the soma is said to fire. How is this achieved? The currents from these potentials are routed to a bulge in the soma called the axon hillock from which the axon itself arises. The axon hillock and the so-called initial segment of the axon leading from it are both especially sensitive to depolarisation as they contain very high concentrations of sodium channels which facilitate the entry of sodium ions.

In this way, the soma weighs the evidence of incoming signals in determining whether or not to fire. When it does decide to do so, the physiology of the peripheral nerve means that there is no going back in either sense of the term. This relates to something called the absolute refractory period which, together with further details of the depolarisation process, will be described in Chapter 4, 'Peripheral Nerve Function'.