The Neuron

by Richard H. Hall, 1998

External Structure

A **neuron** can be defined as a nerve cell. The neuron is often thought of as the "building block" of the nervous system, and for good reason. The neuron is the fundamental unit which makes up a nerve pathway, neural firing (neurotransmitter release) takes place at the level of the neuron, and many aspects of the physiology-behavior relationship can be explained in terms of activity at the neuronal level. Therefore, we will begin our discussion of the nervous system with a description of the external structure of the neuron.

In a general sense you can think of the neuron as a miniature self-contained information processor. It receives inputs, processes information, and generates outputs. The structure most associated with receiving is the **dendrite**, the structure most associated with processing is the **cell body** (also called **soma**), and the process most associated with the output is the **axon**, more specifically the **terminal buttons** (see Figure 1). If we move to a slightly more detailed level we will find that neural signals most often are received by specialized areas on the dendrites called dendridic spines. As for the cell body, the "processing" actually occurs in the **nucleus**, within the cell body. Continuing our analogy of the nerve cell as an independent information processor, we can think of the nucleus as the "brain" of the cell, where many important cellular activities are initiated, as we'll discuss in the internal structure section below. Also, it's important to note that a general characteristic of the terminal buttons is that they contain the chemical messengers, **neurotransmitters,** which we will talk about in much more detail in subsequent modules. These chemical messengers are responsible for communication among neurons.

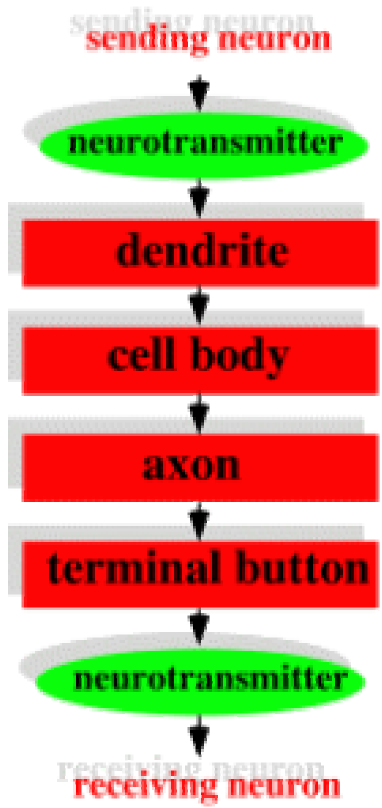

Figure 1. Neuron Structure and Typical Signal Direction

Three other important neuronal structures that will play an important role in future discussions are the neuronal membrane, the synapse, and the myelin sheath. The **membrane,** which surrounds the nerve cell, is made up of a double layer of lipid and contains protein molecules that play many important roles in transporting and blocking substances from coming in and out of the cell. The **synapse** is the very small space or gap between adjacent neurons, and, as we will see, many important processes occur in this tiny gap. Finally, the **myelin sheath** consists of a fatty sheath that is wrapped around the axons of many neurons. The "wrapping" is interrupted by small spaces called **nodes of Ranvier**. The main function of the myelin sheath is to speed the neural signal.

Internal Structure

(Figure 2 is a concept map of the following discussion of internal neuronal structures). As I mentioned above the nucleus includes many important structures, and perhaps most important are the **chromosomes**, which are made up of strands of **deoxyribonucleic acid (DNA)**, which are made up of **genes**. These genes contain "programs" or "blue prints" for the direction of protein synthesis, which is the creation of structures that carry out the cell's work. This process begins when the gene communicates with a complex molecule called **messenger ribonucleic acid (mRNA)**. Then the mRNA molecule carries the message to structures outside the nucleus called **ribosomes** which are the sites where these proteins are synthesized/built. The ribosomes are sometimes independent free-floating structures in the cytoplasm of the cell (outside the nucleus), and sometimes connected to larger structures called **endoplasmic reticulum**. In the former case the ribosomes create proteins which are used inside the cell, and in the latter case they create proteins which are used in the cell membrane or transferred out of the cell.

The materials that are transported out of the cell, are usually packaged by a sort of cellular "packaging plant" called the **Golgi apparatus**. The Golgi apparatus packages the products of protein synthesis and the products are then transferred to the cell membrane where the package merges with the membrane and it's contents are released outside the cell in a process referred to as **exocytosis**. The most important type of exocytosis in neural communication occurs in the terminal buttons, often with packages of neurotransmitter that have been created in the Golgi apparatus. These products are transferred down the axon on structures called **microtubules**, by fascinating protein molecules called **kinesin**. These molecules "carry" the packages and "walk" down the microtubules in a process known as **axoplasmic transport**.

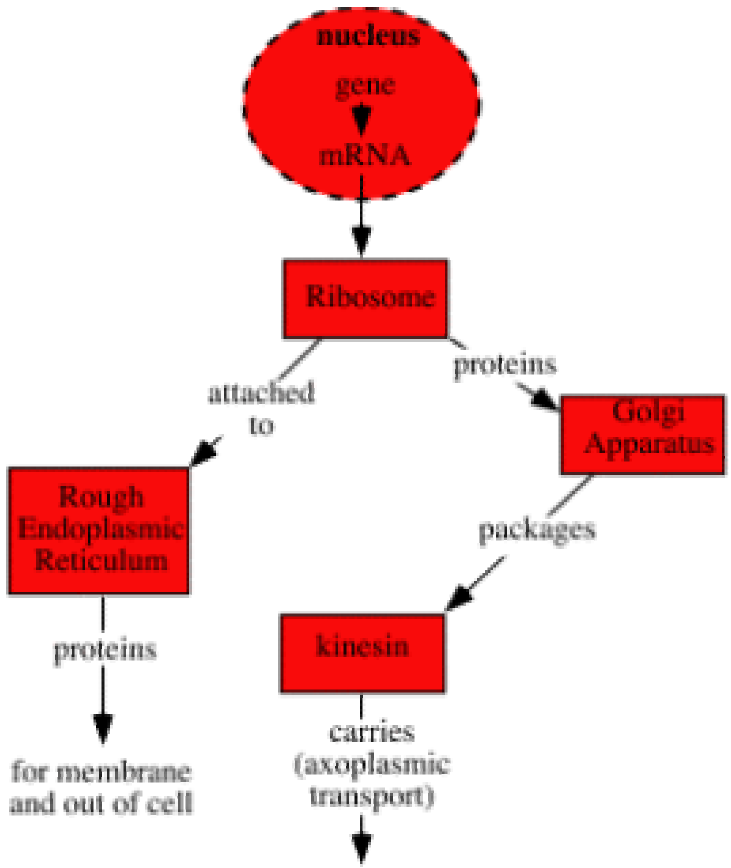

Figure 2. Neuronal Internal Structures

Types

The simplest way to classify neurons is based on their function (see Figure 3). Neurons that carry messages from the "outside world", the sensory receptors, to the spinal cord and brain are called **sensory neurons**. Those the carry the messages to the "outside world" in order to control the movement of muscles and activities of glands are called **motor neurons**. (Note that I am using the term "outside world" figuratively in that messages also come "in" from internal organs such as the stomach, and messages often go out to internal organs such as the heart). The large group of neurons which do not form connections with sensory receptors or muscles or glands, but just with other neurons, are called **interneurons**.

Neurons come in many shapes, but the "typical" neuron has multiple dendridic projections and one axon from the soma. This is called a **multipolar neuron**, but there are also neurons that have only one dendridic projection and these are called **bipolar**, and some that only have one projection that includes both the dendrite and axon and these are called **unipolar**. To some extent the shape represents the function in that unipolar and bipolar neurons are more typically sensory neurons, while multipolar neurons are more typically motor or interneurons.

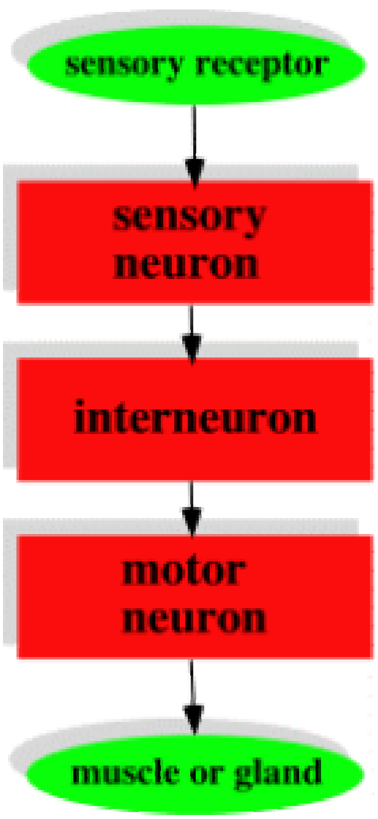

Figure 3. Relationship Among Different Types of Neurons

Supporting Cells

Although neurons are typically defined as nerve cells, they are not actually the only cells in the nervous system. In fact, they are supported by a large number of other cells apply named supporting cells. While the neurons are important for carrying the neural message, the supporting cells are important for insuring that the neurons carry out this process. In fact, without supporting cells communication among neurons would be impossible.

There are many types of supporting cells in the nervous system, and their properties differ somewhat between the central and peripheral nervous system, which we will touch on below. One of the major functions of supporting cells is to transfer nutrients in the blood from the capillaries surrounding the nervous system to the nerve cells, so, in some sense, they serve to "feed" the nerve cells. They also provide a structure for guiding and directing the neural signal. Supporting cells also serve the function of "consuming" damaged tissue in a process known as **phagocytosis**. Not only do they clean up the damaged tissue, but they also fill the space that is left in order to maintain the structure of the system. A central function supporting cells carry out is that they provide the "fatty sheaths" called myelin sheaths referred to in the first section above.

One of the most important functions of the supporting cells is to aid in the regrowth of nerve cells that have not been damaged too much to regrow. First, the cells secrete a substance referred to as nerve growth factor, and second they provide a structure, a sort of tube, to guide the growth of neuronal projections. Without such structures the new projections simply wither and die. Interestingly enough, this is one of the basic differences between cells in the central nervous system (CNS) (the brain and spinal cord) and the peripheral nervous system (PNS) (nervous system outside of the spinal cord and brain). Supporting cells in the PNS provide the structural guides I described, while cells in the CNS do not. As a result damaged PNS neurons are much more likely to regrow after damage than CNS cells, not due to the nature of neurons in the PNS versus CNS, but due to the nature of differences between supporting cells in the two systems.