15. Nervous System: Autonomic Nervous System

I. Comparison of the Somatic and Autonomic Nervous Systems

The somatic nervous system is fairly straightforward. It consists of somatic motor neurons with bodies located in the brain or spinal cord and axons that extend through cranial or spinal nerves. The axons of somatic motor neurons synapse with skeletal muscles. All somatic motor neurons release the neurotransmitter acetylcholine (ACh) from their synaptic knobs. ACh is always excitatory at synapses with skeletal muscle fibers; a synapse between a motor neuron and a muscle fiber is called a neuromuscular junction. Thus, whenever the CNS decides to activate a skeletal muscle, it simply sends commands through somatic motor neurons, which stimulate contraction of the particular skeletal muscle. See Figure 15.1 for an overview.

Somatic motor neurons can be activated consciously. However, they can also be activated unconsciously to maintain posture, breathe, carry out a reflex, etc.

The autonomic nervous system (ANS) consists of visceral motor neurons, which carry motor commands to glands, smooth muscle, and the heart. In so doing, the ANS is involved in maintaining blood pressure, water and salt balance, dissolved gas concentration, digestion, etc. Be aware that the ANS does not control any of these functions; control is accomplished by various parts of the CNS, such as the hypothalamus.

In the somatic nervous system, motor neuron bodies originate in the CNS and their axons extend all the way to their effectors. In contrast, the ANS makes use of pairs of visceral motor neurons (Fig. 15.2). The body of the first visceral motor neuron lies in the CNS, and the body of the second visceral motor neuron lies in an autonomic ganglion (e.g., the sympathetic trunk ganglia).

Visceral motor neurons that originate in the CNS are called preganglionic neurons. Axons of preganglionic neurons, which are called preganglionic axons (or fibers), synapse with ganglionic neurons in the autonomic ganglia. Axons of the ganglionic neurons, which are called postganglionic axons (or fibers), extend to effectors. Preganglionic axons are thin and lightly myelinated, and postganglionic axons are generally thinner and unmyelinated. How do the conduction velocities of these axons compare with conduction velocities of somatic motor neuron axons?

All preganglionic axons of the ANS release ACh. The effect of ACh on the ganglionic neuron is always excitatory.

Postganglionic axons of the parasympathetic division of the ANS also release ACh, but it may be either stimulatory or inhibitory. This depends upon the type of ACh receptor present on the effector.

Postganglionic axons of the sympathetic division of the ANS generally release norepinephrine (NE), which may also be either stimulatory or inhibitory depending upon the type of receptor present on the effector. Be aware that some sympathetic postganglionic axons release ACh.
II. Divisions of the Autonomic Nervous System

Functional differences
The autonomic nervous system is divided into the sympathetic and parasympathetic divisions. The two divisions often innervate the same effectors, but they generally have opposing effects.

The parasympathetic division maintains the body during “normal,” non-stressful situations. Your text refers to it as the “resting and digesting system.” It reduces the activities of some organs (e.g., the heart) and generally elevates activity of the digestive system.

The sympathetic division generally prepares the body for action in what is often called the “fight-or-flight” response. Activities of various effectors (e.g., sweat glands and the heart) increase, and activity of the digestive system is reduced. Although specific sympathetic effectors can be activated independently, in a crisis the entire division is generally activated.

Anatomic differences
Although the sympathetic and parasympathetic divisions share many effectors and work together to maintain homeostasis, their anatomical pathways are separate: their motor pathways originate in different regions of the CNS, and they use different ganglia (Fig. 15.3).

Parasympathetic axons originate from cranial nerves III, VII, IX, and X as well as sacral spinal nerves. The term craniosacral control is often used in reference to the parasympathetic division. Ganglia used by the parasympathetic division are located in or near the target organs, and preganglionic axons travel more or less directly to the ganglia. Therefore, the preganglionic axons are long and the postganglionic axons are short.

Sympathetic axons originate from the thoracic and lumbar regions. The term thoracolumbar control is often used in reference to the sympathetic division. The bodies of these neurons are located in the lateral horns of the spinal cord. Ganglia used by the sympathetic division are located near the spinal cord. Therefore the preganglionic axons are generally short and the postganglionic axons are generally long.

III. Parasympathetic Division

This section of the text reinforces the concept of craniosacral control. Although you do not need to memorize specific pathways, you should understand the general point illustrated by Fig. 15.5. Notice that the vagus nerve is responsible for carrying parasympathetic motor commands to the majority of organs in the ventral body cavity.
IV. Sympathetic Division

This section of the text reinforces the concept of thoracolumbar control. Although you do not need to memorize specific pathways, you should understand the general point illustrated by Fig. 15.6. Notice that all preganglionic axons of the sympathetic enter the **sympathetic trunk**. Many of these axons form synapses with ganglionic neurons in the sympathetic trunk ganglia. Some preganglionic axons pass through the sympathetic trunk via nerves called **splanchnic nerves** to make synapses with ganglionic neurons in other ganglia, such as the **prevertebral ganglia**. Preganglionic axons that send sympathetic commands to the **adrenal medulla** travel directly to the adrenal medulla. These preganglionic axons do not synapse with ganglionic neurons. Rather, they stimulate the adrenal gland directly and both norepinephrine and epinephrine are released into the blood. What is the significance of releasing these chemicals into the blood?

V. Comparison of Neurotransmitters and Receptors of the Two Divisions

Refer to Figure 15.9.

Neurons that release acetylcholine are called **cholinergic neurons**. Somatic motor neurons, all preganglionic visceral motor neurons, and parasympathetic postganglionic neurons are all cholinergic. The sympathetic postganglionic neurons that innervate sweat glands are also cholinergic. Cholinergic neurons can have different effects on their targets because there are different receptors for acetylcholine. **Nicotinic receptors** are found on the motor end plates of skeletal muscle fibers, all ganglionic neurons, and hormone-producing cells of the adrenal medulla. Nicotinic receptors are always excitatory, depolarizing the postsynaptic cell. **Muscarinic receptors** are found on all effectors targeted by parasympathetic postganglionic neurons, and on sweat glands. Muscarinic receptors are generally excitatory, but there are exceptions; muscarinic receptors on cardiac muscle are inhibitory.

Neurons that release norepinephrine are called **adrenergic neurons**. Most sympathetic postganglionic neurons are adrenergic. Adrenergic neurons can have different effects on their targets because there are different receptors for norepinephrine. **Alpha receptors** are found in blood vessels that serve the skin, abdominal organs, kidneys, and salivary glands. Binding of NE to these alpha receptors causes vasoconstriction. **Beta receptors** are found in bronchioles of the lungs and blood vessels that serve the heart and skeletal muscles. Binding of NE to these beta receptors causes dilation. Beta receptors on cardiac muscle cause increases in heart rate and strength of contraction. Beta receptors associated with smooth muscle of the digestive tract are inhibitory.

The sympathetic division of the ANS tends to have widespread effects throughout the body. One reason for this is stimulation of the adrenal medulla by the sympathetic. When stimulated, the adrenal medulla releases epinephrine and norepinephrine into the bloodstream. Thus, these two chemicals travel throughout the body. Why does a widespread sympathetic response throughout the body make sense?
VI. Interactions Between the Parasympathetic and Sympathetic Divisions

As mentioned previously, the parasympathetic and sympathetic divisions often innervate the same effectors, but they generally have opposing effects. This system by which the two divisions work together by counteracting each other is referred to as dual innervation. As an example, the sympathetic division dilates bronchioles in the lungs, and the parasympathetic division constricts bronchioles. However, some effectors of the ANS are innervated by only by the sympathetic system (e.g., the arrector pili muscles, sweat glands, liver, and kidneys).

For a good overview of the effects of the sympathetic and parasympathetic divisions of the ANS, you should review Table 15.5 and Figure 15.11 in your textbook. You do not need to memorize all of the information in this table, but reviewing it should help you to understand the ANS.

In addition to its effects on specific organs (e.g., heart, lungs, sweat glands), the sympathetic division affects metabolism throughout the body. For example, sympathetic stimulation causes (1) increased metabolic activity of cells, (2) increased blood glucose levels, and (3) mobilization of fats from adipose tissue into the bloodstream.