The **motor** or efferent branch of the peripheral nervous system is divided into a **somatic division** and an **autonomic division**.

The **ANS** contains motor neurons that innervate **smooth muscle**, **cardiac muscle**, and **glands**. The ANS is responsible for adjusting heart rate and contractile force, controlling digestive secretions, urination, defecation and other body activities. The ANS is divided into a **sympathetic division** (the “fight or flight” division) and a **parasympathetic division** (the “rest and digest” division).

There are several differences between the ANS and the **somatic nervous system**.

The ANS is **involuntary**. This is in sharp contrast to the motor neurons of the somatic nervous system which innervate **skeletal muscles** and are mostly under **voluntary** control.

Another difference between the SNS and ANS is the pathway between CNS and effector. Somatic motor neurons have their cell bodies in the CNS and their myelinated axons extend all the way to the effector (skeletal muscle tissue) via **spinal nerves** or **cranial nerves**. The ANS has a 2-neuron chain linking the CNS and the effector. The 1st neuron in this path is known as the **preganglionic neuron** and its cell body resides in the CNS. The axon of the preganglionic neuron is lightly myelinated and is known as the **preganglionic axon**. It exits the CNS via a spinal or cranial nerve and synapses upon the dendrites or cell body of the 2nd motor neuron, the **ganglionic neuron** in an **autonomic ganglion**. The axon of the ganglionic neuron is unmyelinated and is the **postganglionic axon**. It extends to the effector organ.

All somatic neurons release **acetylcholine (ACh)** as their neurotransmitter. ACh always has an excitatory effect on the skeletal muscle and causes muscle contraction. The autonomic preganglionic neurons always release ACh as their neurotransmitter. Most sympathetic postganglionic neurons release **norepinephrine (NE)** as their neurotransmitter. Parasympathetic postganglionic neurons release **ACh** as their neurotransmitter. The effect of the postganglionic neurotransmitters can be excitatory or inhibitory. It depends on the receptor on the target tissue.

The 2 divisions of the ANS (sympathetic and parasympathetic) usually innervate the same organs but have opposing (antagonistic) effects. This is known as **dual innervation** and allows each division to “check” the other and to keep body activities in homeostasis.

Functions of the parasympathetic division include stimulating digestive activity, lowering heart rate, constricting the pupils, and accommodation of the lens of the eye. The parasympathetic division is sometimes referred to as the **D division** since it promotes digestion, defecation, and diuresis (urination).

The sympathetic division dominates during stressful events. Some of the general roles of the sympathetic division include raising heart rate, raising blood pressure, shunting blood to skeletal muscles and the skin, dilation of airways, release of glucose by the liver, and dilation of the pupils. The sympathetic division is sometimes referred to as the **E division** since it is “turned on” when someone is exercising, excited, embarrassed, or in an emergency.

There are anatomical differences between the divisions of the ANS as well. Parasympathetic fibers emerge from the brain and the sacral spinal cord and thus the parasympathetic division is referred to as the
craniosacral division. Sympathetic fibers emerge from the thoracolumbar region of the spinal cord and thus the sympathetic division is referred to as the thoracolumbar division. The parasympathetic division has long preganglionic axons and short postganglionic axons whereas the sympathetic division has short preganglionic axons and long postganglionic axons. The parasympathetic ganglia are located within the visceral effector organs while the sympathetic ganglia are found adjacent to the spinal cord.

Parasympathetic nerve fibers emerge from the brainstem and from the sacral spinal cord. The cranial nerves that carry parasympathetic motor fibers are the oculomotor (CN III), facial (CN VII), glossopharyngeal (CN IX), and vagus (CN X). Cranial nerves III, VII, and IX supply the parasympathetic output to the head. The vagus nerve supplies the parasympathetic output to organs of the thorax (heart and lungs) and the abdomen (stomach, pancreas, liver, gallbladder, kidneys, small intestine, and the proximal ⅔ of the large intestine). The distal ⅔ of the large intestine, the urinary bladder, and the genitalia (penis/clitoris, vagina) are served by the parasympathetic outflow from the sacral spinal cord.

Sympathetic fibers innervate more organs and the path of the fibers to the effector organs is complex. The sympathetic division innervates the viscera of the thorax and the viscera of the abdomen. But, it also serves the sweat glands and arrector pili muscles found in the dermis of the skin. Furthermore, it serves the smooth muscle found in every artery and vein.

The sympathetic preganglionic neurons have their cell bodies in the lateral horns of spinal segments T1 to L2. The axons of these neurons exit the spinal cord via the ventral roots. An axon travels a short way within a spinal nerve before entering its ventral ramus and then it will enter a white ramus communicans.

Once in the white ramus communicans, there are several different pathways that can occur. The preganglionic axon can enter a neighboring sympathetic trunk ganglion. (The sympathetic trunk ganglia are oriented like beads on a string on each side of the spinal cord. B/c of their location, these ganglia are also known as paravertebral ganglia.) Within the trunk ganglion, the preganglionic axon can synapse with a ganglionic neuron. The axon of the ganglionic neuron (i.e. the postganglionic axon) will leave a sympathetic trunk ganglion via a gray ramus communicans which will rejoin either a ventral ramus or a dorsal ramus of a spinal nerve. The axon will then continue to an effector in the skin of the neck, torso, and limbs. A preganglionic axon might alternatively pass through the trunk ganglionic and ascend or descend to a different ganglion at a different level of the spinal cord and synapse with a ganglionic neuron there. These are examples of the sympathetic spinal nerve pathway.

The postganglionic sympathetic nerve pathway is utilized by sympathetic neurons extending from the spinal cord to the organs of the thoracic cavity (heart, lungs, esophagus, etc). In this case, the preganglionic axon enters the sympathetic trunk ganglion via a white ramus communicans and synapses with the ganglionic neuron there. But then the ganglionic axon does not exit the ganglion via a gray ramus communicans. Instead it exits via nerves that travel directly to the effector. In this case the

The splanchnic nerve pathway is utilized by sympathetic neurons going from the spinal cord to the viscera of the abdomen and pelvis. In this case the preganglionic axon enters the trunk ganglion via a white ramus communicans, but it passes directly through it without synapsing. The preganglionic axon then extends into one of the prevertebral ganglia (these are generally found just anterior to the aorta).
There the preganglionic axon synapses with the ganglionic neuron. The ganglionic axon then extends to the effector.

Some thoracic and lumbar preganglionic axons enter the trunk ganglion via a white ramus communicans, extend through it without synapsing, and continue all the way to the adrenal medulla (the interior of the adrenal glands that sit atop each kidney) and synapse within hormone-releasing cells there. These cells release the fight-or-flight-hormone epinephrine (a.k.a. adrenaline) into the bloodstream.

Recall that all autonomic preganglionic axons release the neurotransmitter acetylcholine (ACh) onto the ganglionic neuron. The neurotransmitter released by the postganglionic axon differs between the sympathetic and parasympathetic divisions. Parasympathetic postganglionic axons release ACh, whereas sympathetic postganglionic axons release norepinephrine (NE). Axons that release ACh are said to be cholinergic. Axons that release NE are said to be adrenergic. The response to ACh and NE depends on the type of receptor found on the target cell.

**Cholinergic receptors** bind to and respond to ACh. There are 2 main types of cholinergic receptors: nicotinic receptors and muscarinic receptors. Nicotinic receptors are found on skeletal muscle cells, sympathetic ganglionic neurons, parasympathetic ganglionic neurons, and the hormone-producing cells of the adrenal medulla. The binding of ACh to a nicotinic receptor results in the opening of an ion channel and the generation of an excitatory graded potential. Muscarinic receptors are found on all cells innervated by parasympathetic postganglionic axons. The binding of ACh to a muscarinic receptor can be excitatory or inhibitory depending on what subtype of muscarinic receptor is present. In most cases the binding of ACh by a muscarinic receptor produces an excitatory response. This is true for organs such as: salivary glands, stomach, intestines, pancreas, liver, gallbladder and the urinary bladder. The binding of ACh will stimulate secretion and/or smooth muscle activity in these organs. The heart on the other hand is inhibited (i.e. heart rate decreases) by the binding of ACh to muscarinic receptors on cardiac muscle cells. Remember that ACh will be released by parasympathetic postganglionic axons when you are “resting and digesting.”

**Adrenergic receptors** bind to and respond to NE (and usually to epinephrine). There are 2 main types of adrenergic receptors: alpha receptors and beta receptors. The response of these receptors to NE depends greatly on the subtype of receptor. Remembering that NE is released during the “fight or flight” response is helpful in predicting the effect of NE on different organs. NE (and or epinephrine) will cause:

- Heart rate and force of contraction to increase
- BP to increase
- Inhibition of gastrointestinal secretion and smooth muscle activity
- Airway dilation
- Constriction of visceral blood vessels
- Dilation of blood vessels serving the skin and skeletal muscles
- Inhibition of the urinary reflex
- Sweating
- Release of glucose into the blood by the liver.

The sympathetic and parasympathetic divisions differ in the spread and the duration of their effects. There is a typically a 1-1 relationship between parasympathetic preganglionic neurons and ganglionic neurons. However, sympathetic preganglionic neurons will branch profusely and synapse with multiple ganglionic neurons. This (coupled with the release of epinephrine into the bloodstream during the sympathetic response) means that the sympathetic response is much more widespread and the parasympathetic response is much more local. ACh is quickly broken down by the enzyme acetylcholinesterase, which is found in the synaptic cleft of cholinergic synapses. NE has to be actively reabsorbed from the synaptic cleft by the postganglionic neuron. This will take longer than the breakdown of ACh. Similarly, it takes a while before the epinephrine is removed from the circulation by the liver. Thus the duration of the effect of the sympathetic division is longer than that of the parasympathetic division.

We’ve noted that the sympathetic and parasympathetic divisions are antagonistic to one another. An exception to this occurs in the genitalia. Penile erection is caused by parasympathetic stimulation of the penis and ejaculation is caused by a subsequent sympathetic stimulation of the penis and associated reproductive glands and ducts.