In this module, we will consider how sympathetic innervation reaches various structures and regions within the body, and we will look at the general scheme of the parasympathetic nervous system.

Postsynaptic sympathetic fibers need to reach the neck, body wall and limbs to provide sympathetic innervation to the peripheral blood vessels, arrector pili muscles, and sweat glands in these areas. Remember that the sympathetic nervous system acts to constrict peripheral blood vessels, increase secretion from sweat glands and contract the arrector pili muscles. These are all responses that promote survival in times of distress.

To reach these structures in the neck, body wall and limbs, postsynaptic fibers exit the sympathetic trunk via gray rami communicantes, then enter the spinal nerves to be passed to the ventral primary rami and dorsal primary rami for distribution to the periphery.
Postsynaptic sympathetic fibers to the neck travel via gray rami to reach ventral primary rami. However, the sympathetic chain ends below the base of the skull as the **superior cervical ganglion**. So, the cell bodies of the postsynaptic sympathetic fibers to the head are all located in the two (right and left) superior cervical ganglia. Presynaptic sympathetic fibers must ascend through the sympathetic trunk to reach the superior cervical ganglion where they synapse. The postsynaptic sympathetic fibers leave the sympathetic trunk via **external** and **internal carotid nerves** that travel to the carotid arteries. These postsynaptic fibers form **perivascular plexuses** and are distributed to the structures of the head along with the branches of the external and internal carotid arteries. The blood vessels, sweat glands and arrector pili muscles of the head, as well as certain muscles associated with the eye, receive sympathetic innervation. Sympathetic innervation in the head, as with the rest of the body, leads to constriction of the peripheral blood vessels, increase in sweat gland secretion, and contraction of the arrector pili muscles. Sympathetic innervation to the eye results in dilation of the pupil and elevation of the upper eyelid.
Within the thorax, the sympathetic nervous system innervates the heart, trachea, bronchi, lungs and esophagus. To reach these organs, the postsynaptic sympathetic fibers exit the sympathetic trunk as cervical cardiac branches and thoracic visceral nerves (the thoracic visceral nerves could not be called thoracic splanchnic nerves, because that name is used for another type of sympathetic visceral branch, which you will see soon). These nerves enter the cardiac, pulmonary, and esophageal plexuses to innervate their target organs. Sympathetic innervation to the heart increases heart rate and strength of contraction, as well as dilates the coronary vessels. Sympathetic innervation to the trachea and lungs leads to bronchodilation and reduced secretions, maximizing air exchange. Sympathetic innervation to the esophagus decreases peristalsis and limits the blood flow in order to preserve blood for the skeletal muscles.
Presynaptic sympathetic fibers reach the prevertebral ganglia in the abdomen by way of splanchnic nerves: the greater, lesser, least thoracic splanchnic nerves and the lumbar splanchnic nerves. Sacral splanchnic nerves, predominantly postsynaptic, enter pelvic autonomic plexi to reach pelvic viscera. You will encounter the words "splanchnic" or "visceral" in many contexts. "Splanch" is a Greek word meaning "organ" in English or "viscera" in Latin. The thoracic and lumbar splanchnic nerves enter the prevertebral ganglia, located on the major branches of the abdominal aorta: the celiac, aorticorenal, superior mesenteric and inferior mesenteric ganglia. Within these ganglia, all the presynaptic sympathetic fibers synapse (except those going to the suprarenal gland). Some fibers from these splanchnic nerves may enter a more superior ganglion and pass through it to a more inferior ganglion before synapsing. The postsynaptic sympathetic fibers leaving these ganglia form perivascular plexuses along the branches of the aorta and ride these vessels to their destinations in abdominal organs. Sympathetic innervation to the digestive tract decreases peristalsis and blood flow to allow other structures to receive more blood, as well as contracts the internal anal sphincter to prevent defecation. Sympathetic innervation to the liver and gallbladder promotes the breakdown of stored glycogen to provide more energy to the body. Sympathetic innervation to the urinary tract results in slowed urine production and contraction of the internal sphincter of the bladder to prevent urination.
The suprarenal gland (also known as the adrenal gland) is unique in its innervation and function. The cells in the medulla of the suprarenal gland behave like a collection of postsynaptic sympathetic neurons in that they release norepinephrine upon stimulation by a presynaptic sympathetic nerve. Presynaptic sympathetic fibers to the suprarenal medulla pass from the greater thoracic splanchnic nerves through the celiac ganglia without synapsing and terminate on the medullary cells. In response to the presynaptic signal, the suprarenal medullary cells release norepinephrine and epinephrine (a related chemical) into the blood stream. In contrast to postsynaptic sympathetic neurons that release norepinephrine onto specific organs resulting in a change of function within that organ, the cells of the suprarenal medulla secrete norepinephrine and epinephrine into the blood stream producing a systemic, or whole-body, fight or flight response.
In addition to the splanchnic nerves we have discussed, it is important to keep in mind that there are **gray rami communicantes** to ALL spinal nerves. These gray rami communicantes result in autonomic sympathetic fibers being incorporated into essentially all the branches of all the spinal nerves. Therefore, the sympathetic nervous system reaches virtually every part of the body. It is easy to become confused by gray and white rami communicantes. Remember that **white rami communicantes** carry presynaptic sympathetic fibers from the ventral primary rami to the sympathetic trunk and exist only between spinal cord segments T1 and L2. Gray rami communicantes carry postsynaptic sympathetic fibers from the sympathetic trunk to all spinal nerves. In spinal cord segments T1-L2 the sympathetic trunk is attached to the spinal nerve by two short branches, the white and gray rami communicantes. Above T1 and below L2, the sympathetic trunk is attached to the spinal nerve (actually, its ventral primary ramus) only by gray rami communicantes. There are NO white rami in the neck or below L2.
We will now turn our attention from the sympathetic division of the ANS to the parasympathetic portion. The **parasympathetic division** of the ANS is sometimes called the craniosacral outflow because the cell bodies of presynaptic parasympathetic neurons are located in the brainstem (nuclei of cranial nerves III, VII, IX, and X) and in the lateral horn of spinal cord segments S2, S3, and S4. In spinal cord segments T1-L2 the lateral horn is home to the cell bodies of presynaptic sympathetic neurons. The lateral horn is absent from L3-S1, but reappears in segments S2, S3 and S4 to house the cell bodies of presynaptic parasympathetic fibers. In general, when "the lateral horn" is mentioned, it refers to the T1-L2 sympathetic lateral horns, but don't get confused by the presence of a parasympathetic lateral horn in segments S2, S3 and S4.

The parasympathetic system is much more limited in its distribution as compared to the sympathetic nervous system. The parasympathetic system distributes fibers to viscera of the head, thorax, abdomen, and pelvis. The parasympathetic nervous system does NOT reach the body wall, and NO parasympathetic innervation reaches the limbs. It is particularly important to note that the parasympathetic nervous system does not innervate peripheral blood vessels.
Another important difference between the sympathetic and parasympathetic nervous systems is that the presynaptic parasympathetic fibers synapse with terminal ganglion cells that are located individually in or near the wall of the target organ. (This is in contrast to the sympathetic nervous system, in which presynaptic sympathetic fibers synapse in ganglia relatively further away from the target organ.) The exception to this pattern of parasympathetic innervation are 4 pairs of parasympathetic ganglia that occur in the head, although even in the head, these parasympathetic ganglia are relatively close to their targets. So, except for these four pairs of macroscopic ganglia in the head, presynaptic parasympathetic axons travel directly to terminal ganglia (micro-ganglia) within the walls of the target organ.
The presynaptic fibers of the parasympathetic nervous system reach the locations where they synapse by one of three pathways.

1. Most commonly, presynaptic parasympathetic axons travel with their nerves of origin (or in branches that travel into the thorax) directly to ganglia.
2. In the head, some presynaptic parasympathetic axons join the course of an unrelated nerve to arrive at their postsynaptic parasympathetic neuron cell body. In this case, the parasympathetic fibers and unrelated nerve look like one structure and cannot be distinguished.
3. Finally, in the abdomen, presynaptic parasympathetic neurons pass through a sympathetic ganglion without synapsing and join a perivascular plexus to form a combined autonomic nerve plexus. They then synapse on cells within the organ wall, like good parasympathetic fibers should.
The cranial segment of the parasympathetic nervous system consists of presynaptic cell bodies in the brainstem and parasympathetic fibers exiting the brainstem in cranial nerves III (oculomotor), VII (facial), IX (glossopharyngeal), and X (vagus). Cranial nerves III, VII, and IX provide parasympathetic innervation to the lacrimal, nasal, palatine and pharyngeal glands; the ciliary muscle of the lens and the sphincter pupillae muscle of the iris; and the parotid, sublingual, and submandibular glands. In general, the parasympathetic nervous system promotes secretion from these glands, causes the pupil of the eye to constrict, and the lens to thicken to accommodate for near vision. The presynaptic parasympathetic fibers from these three cranial nerves synapse in four parasympathetic ganglia. Parasympathetic fibers from cranial nerve III synapse in the ciliary ganglion. Parasympathetic fibers from cranial nerve VII synapse in the pterygopalatine and submandibular ganglia, and parasympathetic fibers from cranial nerve IX synapse in the otic ganglion. You will learn more about these four ganglia in other modules, but remember that they are parasympathetic ganglia!

Cranial nerve X, the vagus nerve, plays a very important role in the parasympathetic nervous system. It provides parasympathetic innervation to all the thoracic viscera via cardiac branches, and to the GI tract from the esophagus to the left colic flexure of the colon, including the pancreas, spleen, liver and gallbladder. In general, parasympathetic innervation to the digestive tract stimulates peristalsis and the secretion of digestive juices. Parasympathetic innervation to the gallbladder causes it to empty. Presynaptic parasympathetic fibers from the vagus nerve synapse in individual cell bodies located on or in the wall of the effector organ, and reach organs in the abdomen via combined autonomic perivascular plexuses. You will learn more about the vagus nerve in other modules.
The sacral component of the parasympathetic nervous system includes the cell bodies of presynaptic parasympathetic nerves in the lateral horns of spinal cord segments S2, S3 and S4. These fibers exit the spinal cord via the ventral roots of segments S2, S3 and S4, pass through the spinal nerve, and then enter the ventral primary rami. **Pelvic splanchnic nerves**, containing presynaptic parasympathetic fibers, branch from the ventral primary rami shortly after dorsal and ventral primary rami branch. (Here is another type of splanchnic nerve, so we have now encountered splanchnic nerves that are presynaptic, postsynaptic, sympathetic and parasympathetic. So, don't learn these nerves as simply splanchnic!) The pelvic splanchnic nerves provide parasympathetic innervation to the descending and sigmoid colon, the rectum, and pelvic viscera via the inferior hypogastric plexus. Parasympathetic innervation to the colon and rectum increases peristalsis, and inhibits the internal anal sphincter to allow for defecation. Parasympathetic innervation to the bladder inhibits contraction of the internal sphincter of the bladder and contracts the detrusor muscle of the bladder wall allowing for urination. The postganglionic cell bodies for the pelvic splanchnics are in microscopic **terminal ganglia** that sit on or in the wall of the target organ.
One point that is worth mentioning when discussing the autonomic nervous system is the fact that visceral efferent fibers are accompanied by **visceral afferent fibers**. These afferent fibers provide information to the central nervous system about the internal environment including blood pressure and blood oxygen and carbon dioxide levels. This information gets integrated in the CNS, which generates visceral reflexes such as changing heart rate to maintain homeostasis.

In general, we are unaware of visceral sensations. When we are aware, the sensations are usually poorly localized and vague, such as the sensation of nausea. There are, however, certain stimuli, especially pathological conditions, that evoke true pain. For the most part, unconscious sensation is carried on afferent fibers accompanying parasympathetic fibers, and visceral pain is carried on afferent fibers accompanying sympathetic fibers. These visceral pain fibers travel through dorsal roots, as do other sensory fibers, and this is the cause of **referred pain**, such as the pain of a heart attack felt down the left upper limb.
To review, the autonomic nervous system is divided into sympathetic and parasympathetic components. The sympathetic nervous system prepares the body for stress and is called the "fight or flight" system. The parasympathetic system prepares the body for rest and is called the "rest and digest" or "vegetative" system.

Sympathetic presynaptic nerve cell bodies are located in the lateral horn of spinal cord segments T1-L2. Sympathetic postsynaptic cell bodies are in ganglia, either sympathetic chain ganglia or
prevertebral ganglia. Sympathetic presynaptic fibers get to the sympathetic chain via white rami communicantes and either synapse at the level they enter, ascend or descend to synapse, or leave the sympathetic trunk without synapsing as a splanchnic nerve to go to a prevertebral ganglion. Sympathetic postsynaptic fibers may enter the spinal nerves via gray rami communicantes to be distributed with dorsal and ventral primary rami, may form perivascular plexuses to be distributed with blood vessels, or may travel to the target organ directly. The sympathetic nervous system provides sympathetic innervation to essentially every part of the body.

Parasympathetic presynaptic cell bodies are located in the brainstem and the lateral horns of spinal cord segments S2, S3, and S4 and leave the CNS in cranial nerves III, VII, IX and X, and in pelvic splanchnic nerves arising from the ventral primary rami of spinal nerves S2, S3, and S4. The parasympathetic postsynaptic cell bodies are located in four pairs of ganglia in the head (associated with cranial nerves III, VII and IX), and otherwise in microscopic ganglia either on or in the wall of the target organ. The distribution of the parasympathetic nervous system is more limited than the sympathetic nervous system, with cranial nerves III, VII and IX supplying smooth muscle and glands of the head, the vagus nerve supplying the visceral organs up to the left colic flexure, and the pelvic splanchnics supplying the descending and sigmoid colon, rectum and pelvic viscera. With the exception of the external genitalia, the parasympathetic nervous system does not reach the body wall.

The autonomic nervous system allows us to go about our daily business without having to think about the mechanics of our organs. Our hearts beat, our intestines digest, our blood vessels change diameter, and we adapt appropriately to any situation, all without our having to think about it. We should all stop and thank our autonomic nervous systems, for letting us concentrate on our studies in medical school.