Section A: Dysautonomias

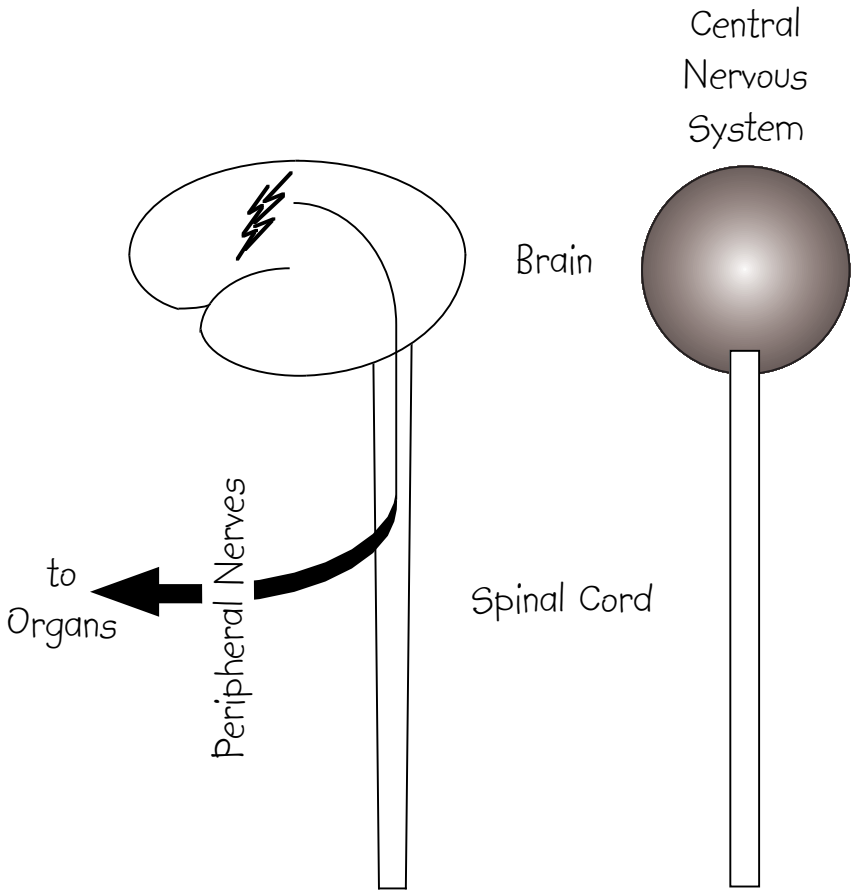
The "Automatic" Nervous System

What is the Autonomic Nervous System?

We all have a nervous system. What exactly makes up this system? What does it do? And what is the "autonomic" part of the nervous system?

This chapter is about your nervous system and how it functions when there is nothing wrong with it. You will need to understand the basics before you can understand the problems that can develop.

Your body has to be able to coordinate many different activities, just to keep you going. Some of these activities are automatic, like breathing and digesting. Some are voluntary, like moving your legs to walk across the room. Your brain uses different parts of the nervous system to regulate these activities.

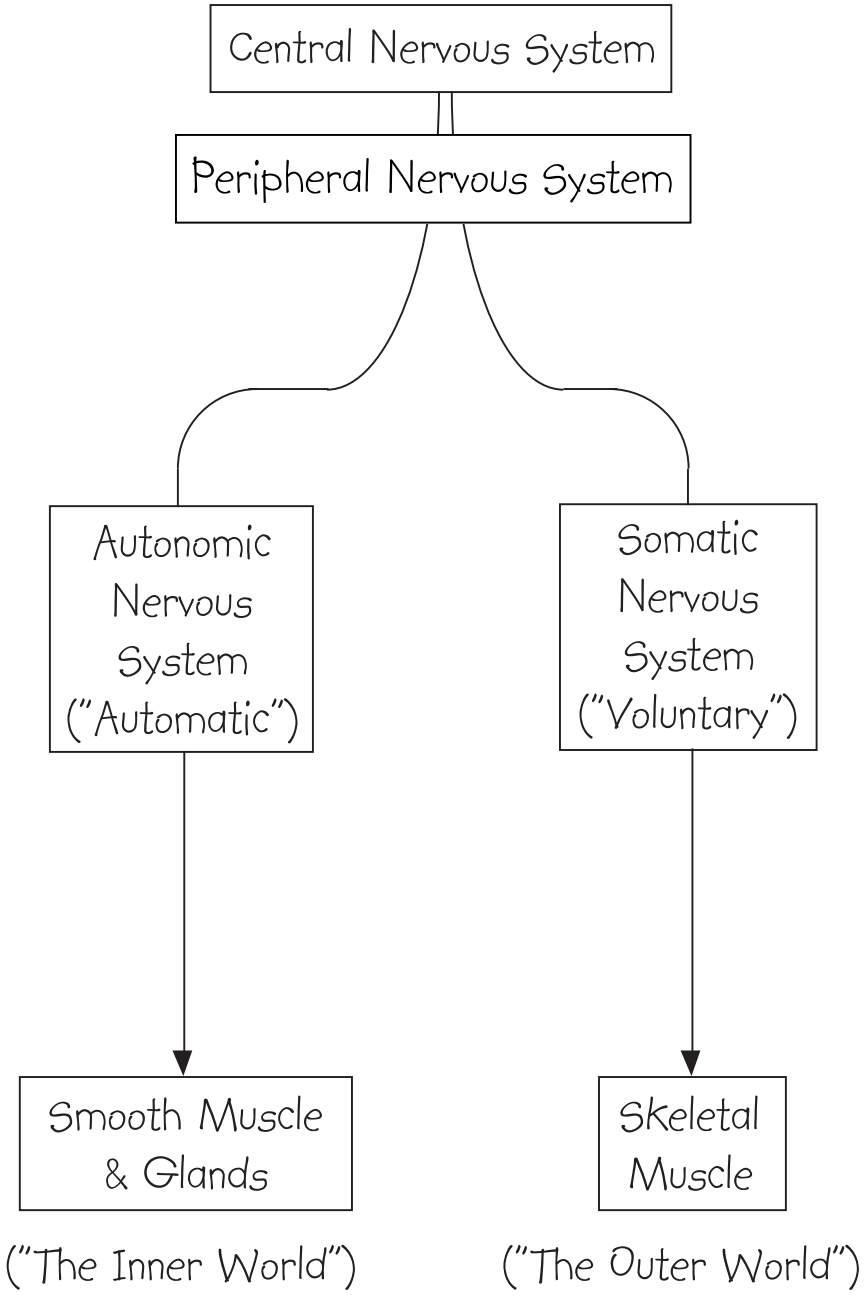


The central nervous system is like a lollipop on a stick. The brain is the candy. The spinal cord is the stick.

The *central nervous system* is made up of the brain and the spinal cord. The brain is like a command and control center. The spinal cord is a rope of nerves that runs from the base of your brain down through your back in your spinal column. The control signals travel from your brain to your limbs and organs by way of the *peripheral nervous system.* The *peripheral nerves* are all the nerves that lie outside the brain and spinal cord.

The *peripheral nervous system* has two main divisions. The first is the *somatic nervous system*, which helps you deal with the "outer world." The second is designed to help you regulate your "inner world," making adjustments to the systems inside your body. This is the *autonomic nervous system.*

We are going to devote the rest of this chapter to explaining the components of the autonomic nervous system and how it works.


Central Nervous System
Peripheral Nervous System
Autonomic Nervous System ("Automatic")
Somatic Nervous System ("Voluntary")
Smooth Muscle & Glands
Skeletal Muscle
("The Inner World")
("The Outer World")

Think of the *autonomic nervous system* as the "automatic nervous system."

The *autonomic nervous system* regulates the "inner world" of the body.

The *autonomic nervous system* is responsible for many of the automatic, usually unconscious processes that keep the body going, such as…

- keeping the right **blood flow to the brain**

- keeping the right **body temperature**

- keeping the right amount of **energy production** and **fuel delivery**

- getting rid of **waste** products

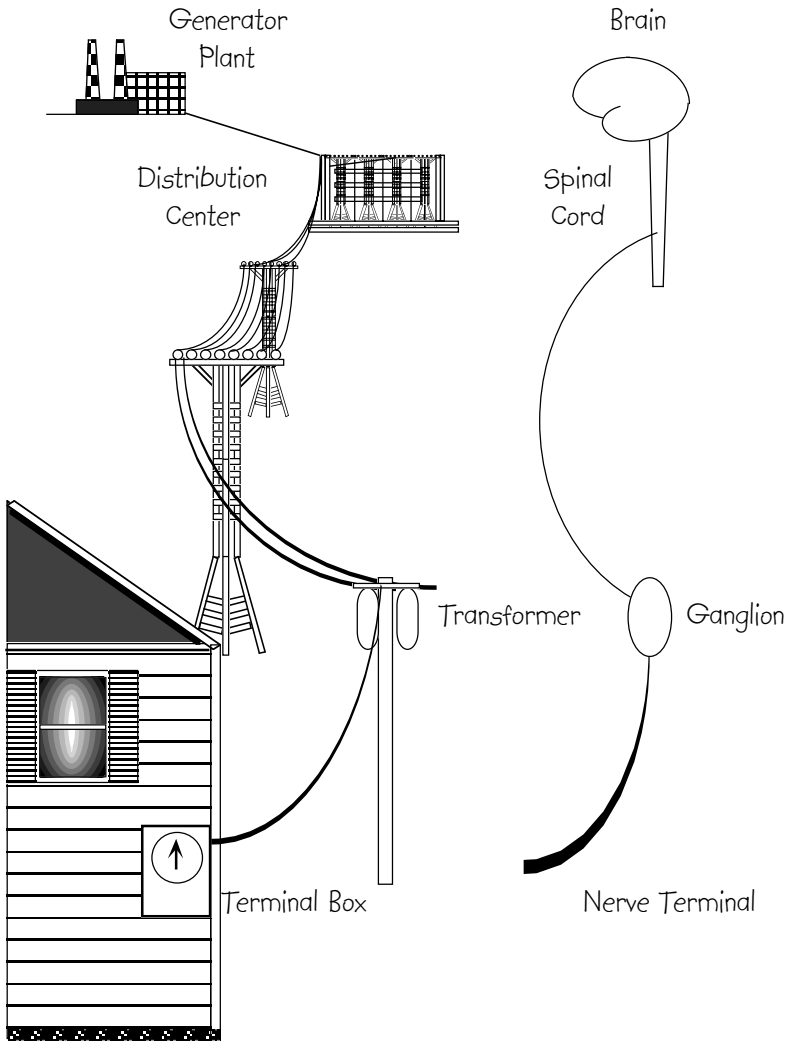
- **warning signs** in dangerous situations, such as fast pulse rate, increased blood pressure, sweating, pallor, and trembling.

By way of the autonomic, or "automatic" nervous system, the brain controls the "inner world."

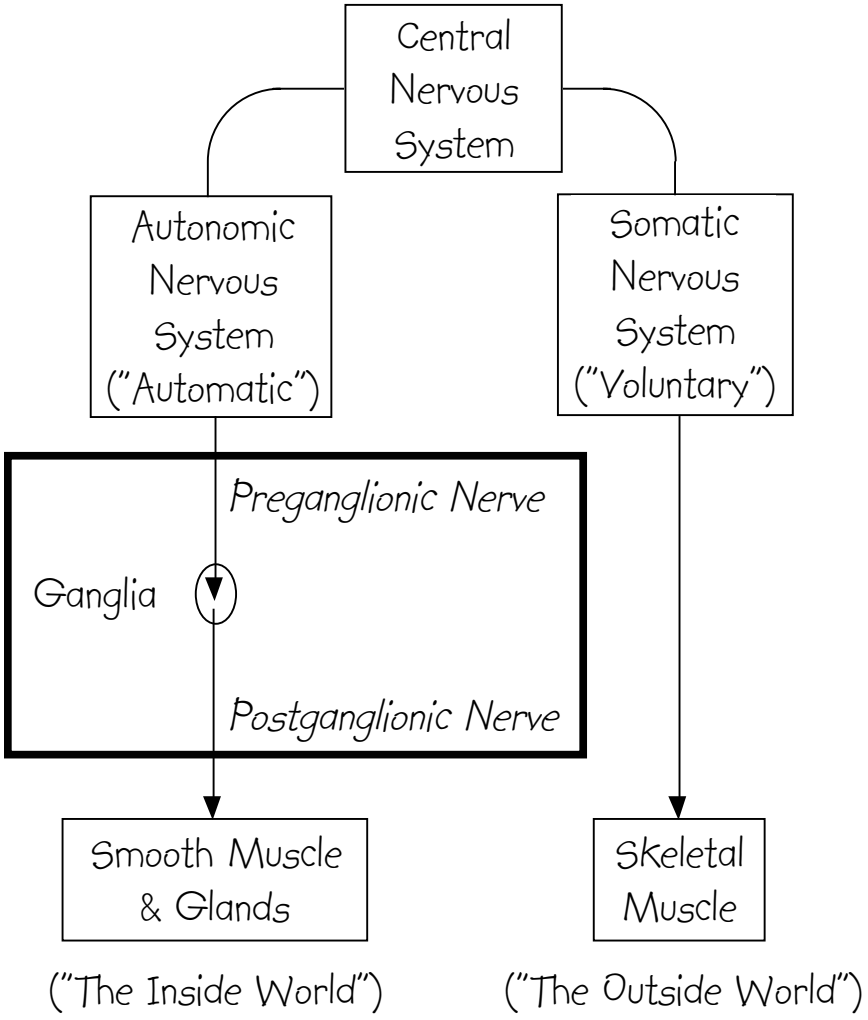
The *autonomic nervous system* is the main way the brain regulates the "inner world." The *somatic nervous system* is the main way the body deals with the "outer world."

The autonomic nervous system sends signals to make changes to the organs in our bodies. These organs are made up of a type of muscle called *smooth muscle.* Smooth muscle is found in organs like your heart and blood vessel walls, and in your glands, such as the thyroid gland, adrenal gland, pancreas, and sweat glands. The *autonomic nervous system* sends signals to the *smooth muscle cells* that cause changes in their muscle tone. All of this happens automatically, all day and night, to keep your body functioning. The target organ of the *somatic nervous system* is skeletal muscle.

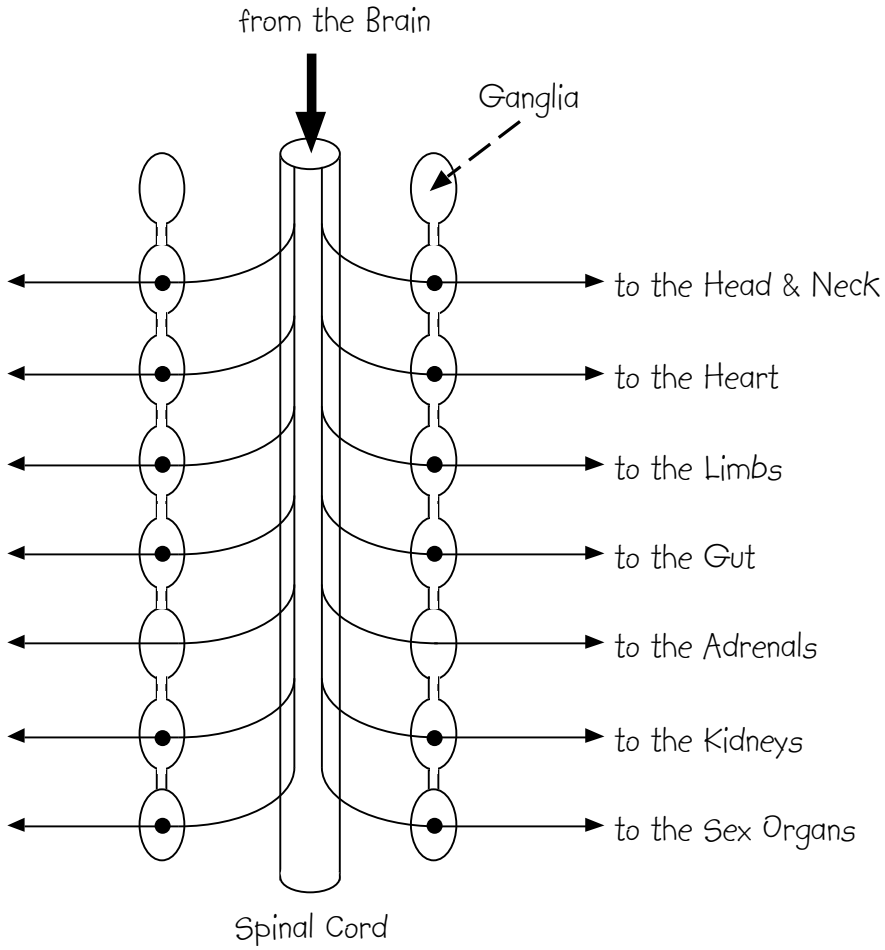
Nerves that go to skeletal muscle to regulate movement come directly from the *central nervous system*, but nerves of the *autonomic nervous system* come indirectly from the *central nervous system*, by way of clumps of cells called *ganglia*. *Ganglia* are like transformers on the utility pole outside your house. The transformer relays the electricity that comes in from the thick trunk lines to the thin cables that go to the house. The *ganglia* are arranged like pearls on a string along each side of the spinal cord.



Ganglia are like transformers that transfer the electricity from the utility pole to the terminal box outside your house.



Ganglia are clumps of cells that relay control signals to the "inner world." Nerves to the ganglia are preganglionic and from the ganglia to the organs postganglionic.



Ganglia are arranged like pearls on a string on each side of the spinal cord.

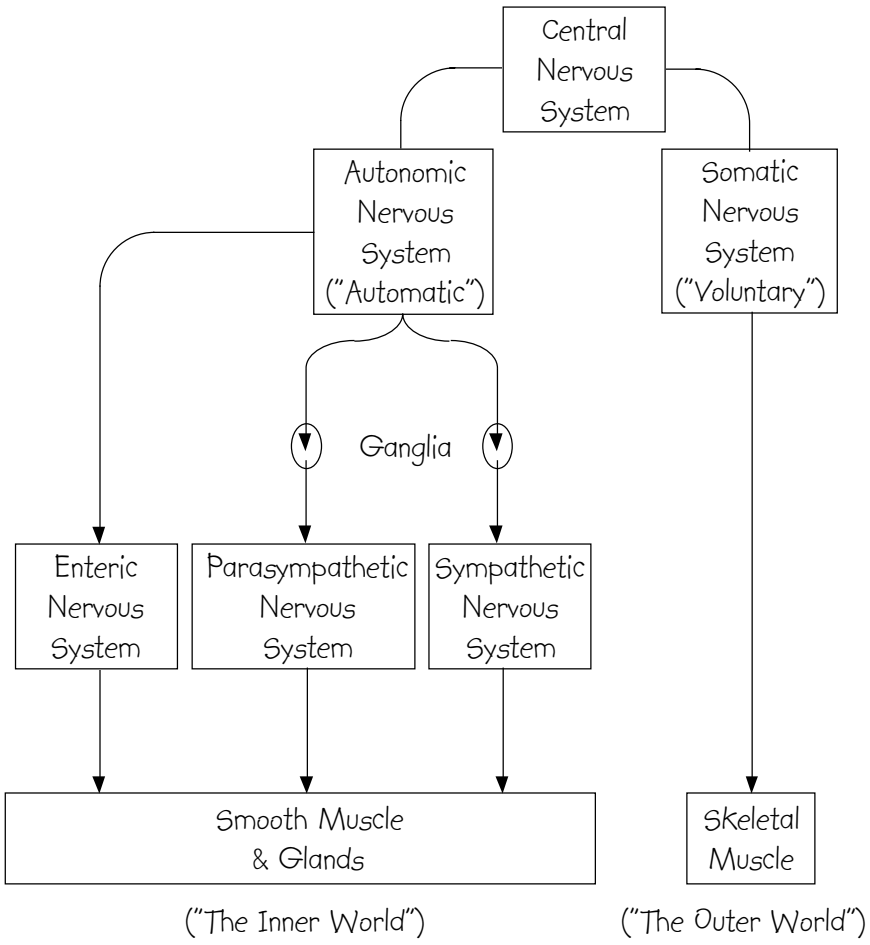
In the *autonomic nervous system,* control signals from the brain and spinal cord go to the *ganglia* (singular *ganglion*) in the *preganglionic nerves,* and nerves from

the *ganglia,* called *postganglionic* nerves, deliver those signals to the *nerve terminals* near or in the target tissues.

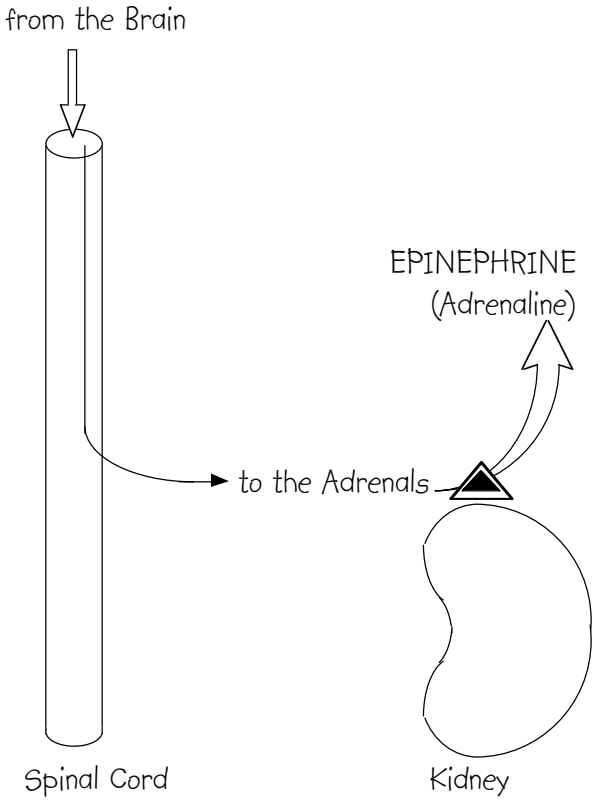
What are the Parts of the Autonomic Nervous System?

As first described a little over a century ago, the *autonomic nervous system* includes the *parasympathetic nervous system* and the *sympathetic nervous system.*

A third part, the relatively less well understood “enteric” nervous system, is in the gastrointestinal tract.



The autonomic nervous system includes the sympathetic, parasympathetic, and enteric nervous systems, which help regulate the "inner world."

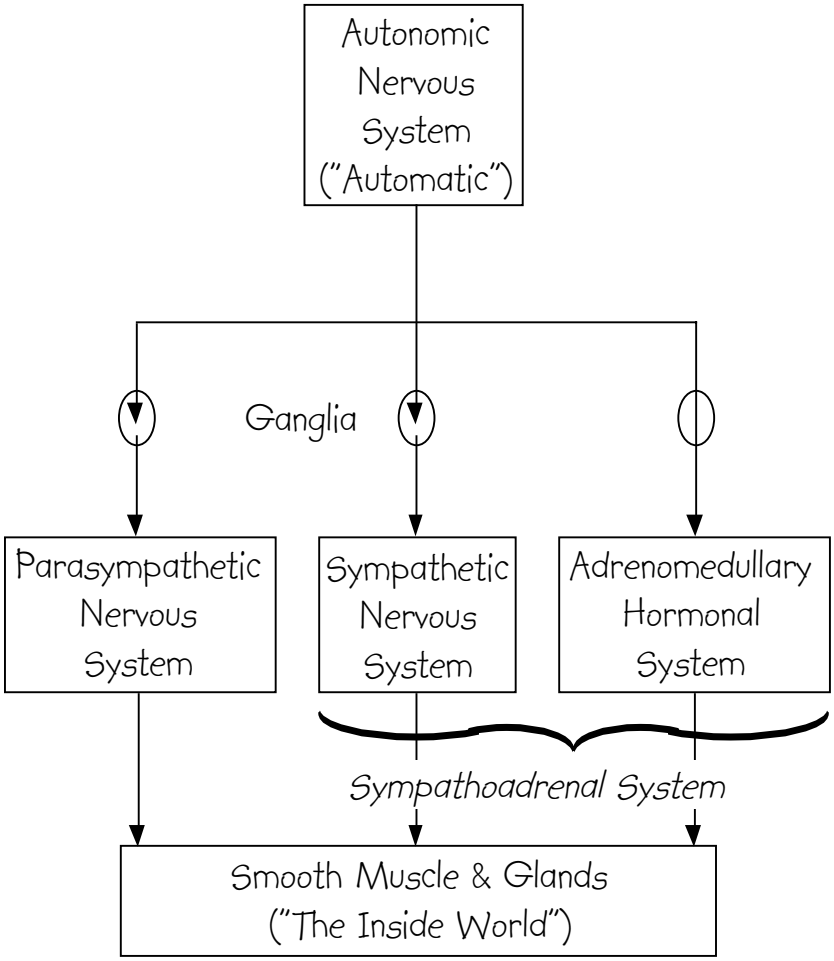


Epinephrine (adrenaline) is released from the adrenal glands, which sit on top of the kidneys.

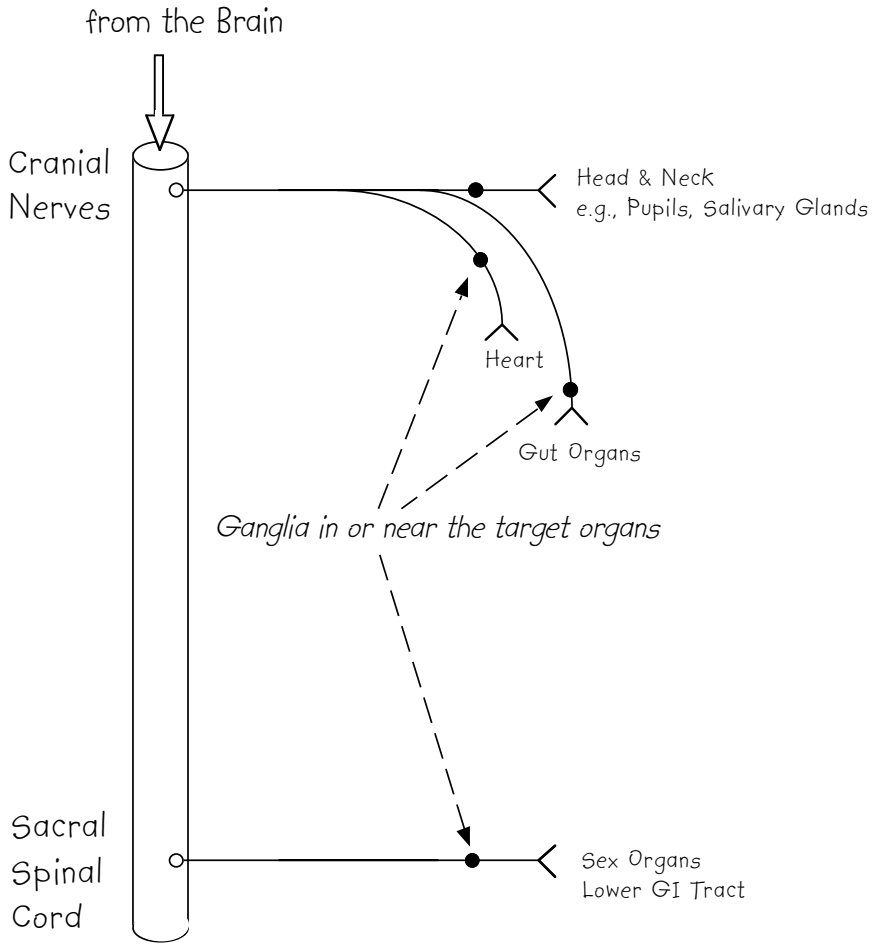
Also about a century ago, the *hormone, adrenaline (epinephrine),* was discovered. *Adrenaline* is released into the bloodstream from the *medulla* (from the Latin word for "marrow") of the *adrenal glands,* which sit at the tops of the *kidneys.*

With these discoveries, scientists began to understand more about the *autonomic nervous system* and what roles it plays in our daily lives. The combination of the *sympathetic nervous system* and *adrenal glands* came to be understood as a single "emergency" system for the body. This emergency system was called the *"sympathoadrenal"* system, or *"sympathico-adrenal"* system. You may have heard of the "fight-or-flight" response that you experience in distressing situations. The *sympathoadrenal system* would help you to survive emergencies, by adjusting several body processes to enhance your ability to protect yourself (fight) or to escape (flight).

The *parasympathetic nervous system* in many ways acts like the opposite of an emergency system. "Vegetative" behaviors, activities that increase instead of use up energy, are associated with increased activity of this system. Examples of this are sleeping, eating, digesting, and excreting waste.



Scientists have thought the sympathetic nervous system and adrenal medulla are a single "emergency" system, the "sympathoadrenal system."

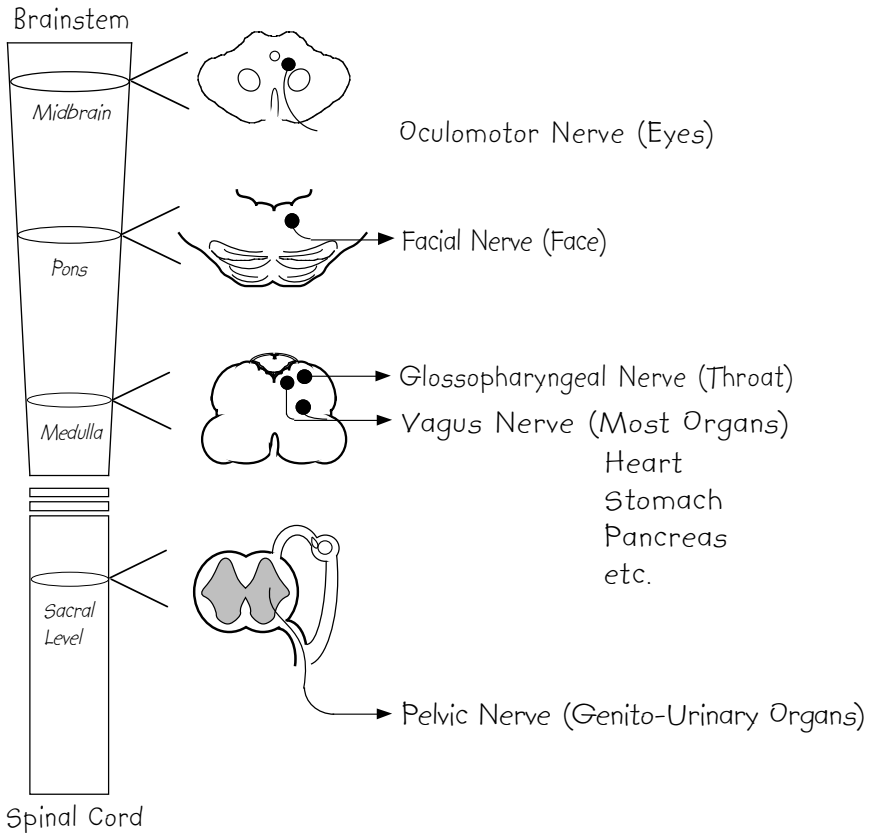


The parasympathetic nervous system has two parts, at opposite ends of the nervous system.

The upper part of the *parasympathetic nervous system* is the nerves that come from a portion of your brain called the *brainstem.* The *brainstem* connects the brain to the spinal cord. Most of the nerves of the *parasympathetic nervous system* come from the *brainstem.* These nerves travel to many parts of your body, including the eyes, face, tongue, heart, and most of the gastrointestinal system.

The nerves that come from the brainstem are called the *cranial nerves* (the word, "cranial," refers to the skull). The parasympathetic nerve fibers travel in major *cranial nerves* that have specific names. The *oculomotor nerve* connects to the eye, the *facial nerve* to the face, the *glossopharyngeal nerve* to the tongue and muscles involved with swallowing and talking, and the *vagus nerve* to the heart and most of the abdominal organs. You may have heard your doctor talk about some of these nerves, especially the *vagus nerve*.

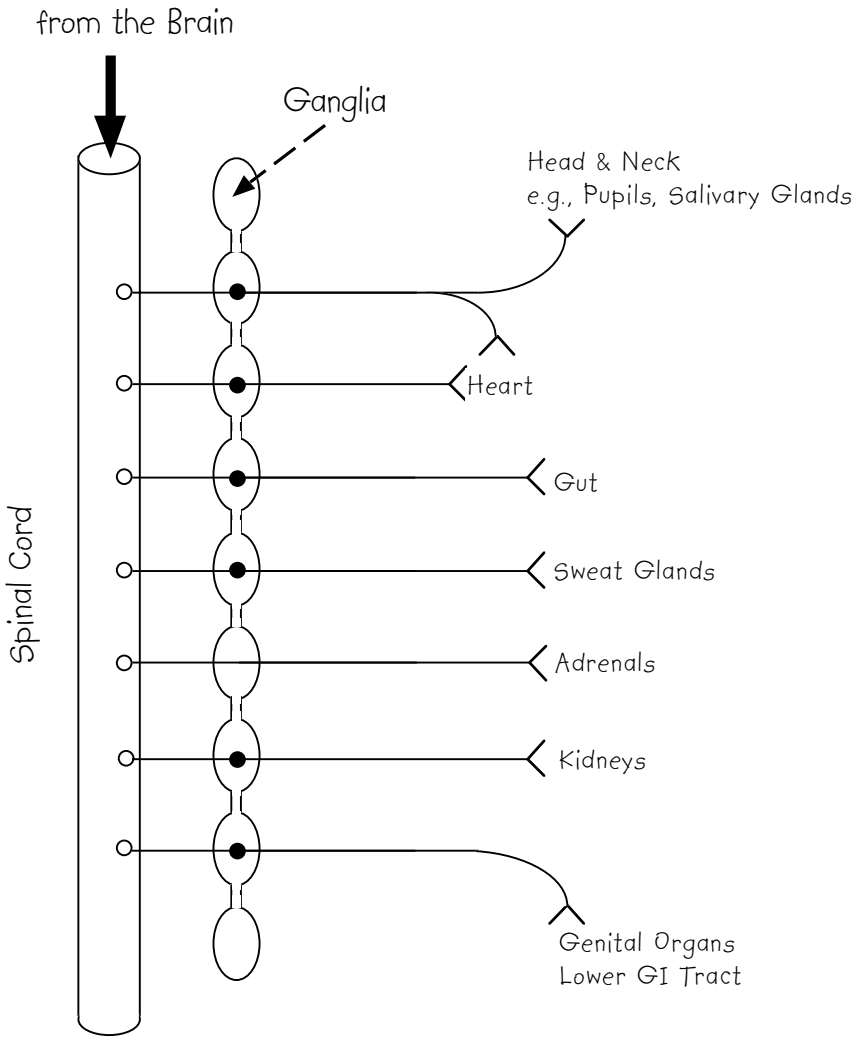
The lower part of your *parasympathetic nervous system* is the group of nerves that travel from the bottom level of the spinal cord, which is called the sacral spinal cord. These nerves travel to the genital organs, urinary bladder, and lower gastrointestinal tract.



Parasympathetic nerves come from the brainstem and from the bottom of the spinal cord. Scientists have thought that the parasympathetic nervous system regulates "vegetative" body functions.

The nerves of the *sympathetic nervous system* come from the spinal cord at the levels of the chest and upper abdomen *(thoracolumbar spinal cord).* The *sympathetic nerves* to most organs are *postganglionic,* coming from cell bodies in the *ganglia.* Remember that the *ganglia* are the clusters of nerve cells like a transformer on the utility pole that supplies the electricity to your house. From the prefix, “post” meaning “after,” the *postganglionic nerves* come from the *ganglia,* like the electric line that comes from the utility pole to your house.

You also have sympathetic nerves that travel to your *adrenal glands* (the glands that sit on top of your kidneys and release the hormone *adrenaline*). These nerves are called *preganglionic,* from the prefix, “pre”, meaning before, the *preganglionic*nerves come from cell bodies in your spinal cord and then pass through the *ganglia.* It is like a direct wiring connection from the electrical distribution center to the terminal box on your house. Most of the *sympathetic nerves* to the *adrenal medulla* are *preganglionic,* coming from cell bodies in the *spinal cord* and passing through the *ganglia.*



The sympathetic nerves come from ganglia attached to the spinal cord at the levels of the chest and upper abdomen.

How Does the Autonomic Nervous System Work?

The *autonomic nervous system* works by releasing messenger chemicals inside the body. These chemicals act on *receptors* on target cells, such as heart muscle cells, and this changes body functions.

For example, when you exercise on a hot day, activation of a part of the *autonomic nervous system* releases *acetylcholine,* a chemical messenger, from the nerve terminals, activating *receptors* on the cells of sweat glands. Activation of the *receptors* causes the glands to release sweat.

There are two types of chemical messengers that can be released in your body. The first type is a messenger that is released directly from the nerves in body organs. Chemicals released from nerve terminals in body organs are called *neurotransmitters.*

The second type of messenger is released directly into the bloodstream. This type of messenger is called a *hormone.* One famous *hormone* is *adrenaline*, released into the bloodstream by the *adrenal gland*, the gland that sits on top of each kidney. Chemicals released into the bloodstream are called *hormones*.

A Quick Review

Now is a good time for us to review the information so far. It can be a bit confusing, because of the several "nervous systems."

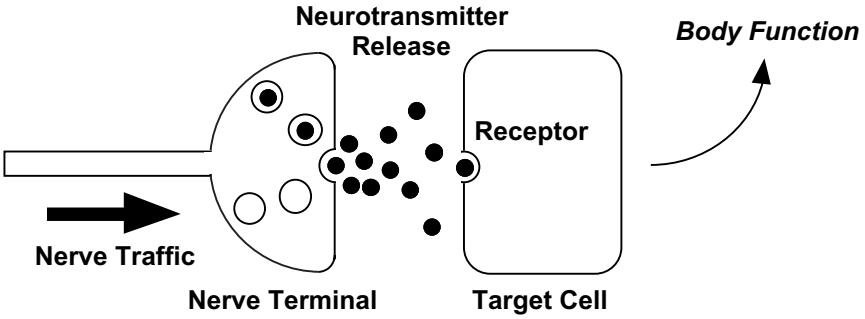
Remember, you have a *central nervous system* (your brain and spinal cord) and a *peripheral nervous system* (the rest of your nerves). Your *peripheral nervous system* has two divisions, the *somatic nervous system* and the *autonomic nervous system.* The *somatic nervous system* is concerned with the "outer world," and the nerves in this system travel to skeletal muscle.Your *autonomic nervous system* is concerned with the "inner world" of your body, and it usually works automatically, so that you can think of the *autonomic nervous system* as the "automatic nervous system."

The control signals of the *autonomic nervous system* travel indirectly from your *central nervous system* through *ganglia* (clusters of nerve cells) to *smooth muscle*, found in areas like your blood vessels, heart, and glands throughout your body. Nerves coming from the *ganglia* are called *postganglionic.* Some nerves, such as those to the adrenal glands, pass through the *ganglia* without relaying within the *ganglia,* so that there is a direct connection from the *central nervous system* to the target organs, and these nerves are called *preganglionic.*

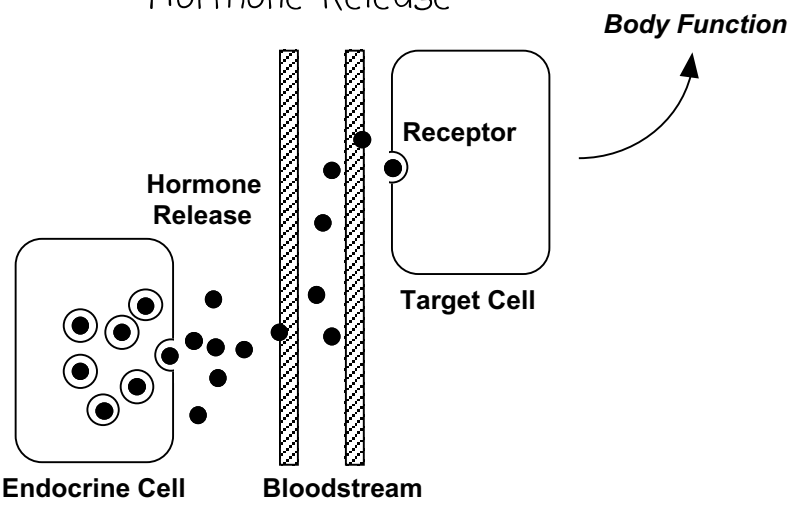
You have also learned that there are two divisions of the *autonomic nervous system*, called the *sympathetic nervous system* and the *parasympathetic nervous system.*

And you have learned that the *autonomic nervous system* works by releasing chemical messengers that act on *receptors* located in organs throughout the body. These messengers either come from nerves *(neurotransmitters)* in body organs or are released into the bloodstream *(hormones).* The *adrenal glands* located on the tops of the kidneys are where the *hormone adrenaline* is released. The *adrenal glands,* combined with the *sympathetic nervous system*, has been called the *"sympathoadrenal system,"* which can function as an emergency system to help protect you in "fight-or-flight" situations.

Chemical Neurotransmission



Hormone Release



The autonomic nervous system releases chemical messengers and hormones.

What are the Chemical Messengers of the Autonomic Nervous System?

There are two main chemical messengers *(neurotransmitters)* of the *autonomic nervous system* and one main *hormone*. *Acetylcholine* and *norepinephrine* (also called *noradrenaline)* are the *neurotransmitters. Adrenaline* (also called *epinephrine)* is the *hormone* (remember that this is the *hormone* released from the *adrenal glands).*

These chemical messengers are used differently by your autonomic nervous system. Acetylcholine (ACh) is the neurotransmitter that is used by the parasympathetic nervous system.

Norepinephrine (NE, noradrenaline) is the main neurotransmitter used by the sympathetic nervous system. Epinephrine (EPI, adrenaline) is the hormone used by the adrenomedullary hormonal system. (The adrenal medulla is the center part of the adrenal gland. It is surrounded by the adrenal cortex, which releases other hormones.)

Acetylcholine is the main chemical messenger that relays control signals from the *preganglionic* to the *postganglionic* cells in the *ganglia. Acetylcholine* does so by binding to a specific type of receptor called a *nicotinic receptor*. As the name suggests, *nicotine* stimulates transmission of signals within the *ganglia*.

Acetylcholine is important for "vegetative" activities, like eating, digesting, sweating, and getting rid of waste.

Acetylcholine is also used to help signal the release of *epinephrine (adrenaline)* from the *adrenal gland*. The *sympathetic nerves* that trigger the release of *adrenaline* pass through the *ganglia* and directly supply the cells in the *adrenal gland* that produce and release *adrenaline*. *Acetylcholine* is released from the *sympathetic nerve terminals* in the center of the *adrenal gland*, which is

called the *adrenal medulla*. The *acetylcholine* then binds to *nicotinic receptors* on these cells, which stimulates them to release *adrenaline* into the bloodstream. The bloodstream delivers the *adrenaline* to organs throughout the body. This is how *adrenaline* is able to produce so many different effects in the body.

The bloodstream delivers adrenaline throughout the body.

We all know that cigarettes contain *nicotine.* The acute effects of *nicotine* in the body, such as fast pulse rate, increased blood pressure, sweating, and increased production of saliva, result from the release of *epinephrine* and from the increased transmission of nerve signals in *ganglia* supplying the *sympathetic nervous system* and *parasympathetic nervous system*.

The effects of nicotine in the body result from increased release of adrenaline into the bloodstream and from increased transmission of nerve impulses through the ganglia.
Norepinephrine is the main chemical messenger, or neurotransmitter, of the sympathetic nervous system.

As a *neurotransmitter*, *norepinephrine* released from *sympathetic nerve terminals* acts locally on nearby cells. For instance, *norepinephrine* released from *sympathetic nerve terminals* in the heart acts on heart muscle cells. A small amount of released *norepinephrine* makes its way into the bloodstream, but usually the amount is too small for *norepinephrine* to produce effects as a *hormone.* Nevertheless, specialized laboratories can measure the amount of *norepinephrine* in the bloodstream, and this can provide an index of the activity of the *sympathetic nervous system.* The chapter about testing goes into detail about the source and meaning of *plasma norepinephrine* levels.

Although the main chemical messenger of the *sympathetic nervous system* is *norepinephrine (noradrenaline),* an exception to this rule is in the sweat glands, where *sympathetic nerves* release *acetylcholine* as the signal for sweating. This means that *sympathetic cholinergic nerves* cause changes in sweating such as in response to changes in environmental temperature.

Norepinephrine (noradrenaline) and epinephrine (adrenaline) are in a chemical family called catecholamines.

Catecholamines are a small family of body chemicals whose members are *norepinephrine, epinephrine,* and *dopamine. Norepinephrine* and *epinephrine* are key chemical messengers of the *autonomic nervous system.*

Dopamine is an important chemical messenger in the brain that helps to regulate movement and mood. Suprisingly, most of the *dopamine* made in the body is produced outside the brain, and the functions of *dopamine* outside the brain are still poorly understood.

You may have heard your physician talk about testing your *catecholamine* levels. This is done to help determine how your *autonomic nervous system* is working. We will talk more about this in the chapter about autonomic function testing.

What are the Functions of the Different Parts of the Autonomic Nervous System?

The *parasympathetic nervous system* regulates what are known as "vegetative" processes. These include body functions like digestion and urination. Remember that *acetylcholine* is the *neurotransmitter* used by the *parasympathetic nervous system.* *Acetylcholine* released from *parasympathetic nerves* acts to stimulate the gut, increase urinary bladder contractions, increase salivation, and decrease the pulse rate.

The parasympathetic nervous system regulates "vegetative" processes. The sympathetic nervous system keeps body numbers like temperature and blood pressure in check. The adrenomedullary hormonal system regulates "emergency" processes such as in distress.

The *sympathetic nervous system* regulates unconscious "housekeeping" processes, such as tightening blood vessels when you stand up and increasing the rate and force of the heartbeat when you exercise. When you are exposed to cold, *norepinephrine* released from *sympathetic nerves* in the skin causes pallor, goosebumps, and hair standing out. The *sympathetic nervous system* therefore helps keep body numbers like temperature and blood pressure in check.

When you are exposed to heat, eat spicy foods, or experience *distress*, *acetylcholine* released from *sympathetic nerves* in the skin stimulates production of sweat.

The *adrenomedullary hormonal system* plays a key role in "emergencies" and *"distress,"* when all organs of the body are threatened, such as by low blood sugar *(hypoglycemia),* low blood temperature *(hypothermia),* choking *(asphyxiation),* shock, and fear. *Adrenaline* increases blood *glucose* levels, increases pulse rate and blood pressure, stimulates metabolism, quiets the gut, and dilates blood vessels in skeletal muscle.

Psychologists and researchers have differed about the meanings of *"stress"* and *"distress"* as medical scientific ideas. For the purposes of this book, *"stress"* is a condition where the brain senses a challenge to physical or mental stability that leads to altered activity of systems to meet that challenge; and *"distress"* is a form of *stress* where there is a sense that you can't cope with the situation, you want to avoid or escape it, you show built-in, instinctively communicated signs, and the *adrenal gland* is activated. According to these definitions, neither *stress* nor *distress* is necessarily harmful or causes disease.

The Sympathetic Norepinephrine System and the Parasympathetic Acetylcholine System usually antagonize each other…

Sympathetic	**Parasympathetic**
≠ Pulse rate	Pulse rate
Gut tone	≠ Gut tone
Bladder tone	≠ Bladder tone
Dilated pupils	Constricted pupils

…but not always…

Sympathetic	**Parasympathetic**
≠ Saliva (thick)	≠ Saliva (mucus)
Ejaculation	Erection

The Sympathetic Norepinephrine System and the Adrenomedullary Hormonal System usually work together,

	SNS	AHS
Pulse rate	≠	≠
Systolic blood pressure	≠	≠
Gut tone		
Sweating	≠	≠
Dilated pupils	≠	≠

…but not always…

	SNS	AHS
Periph. resistance	≠	
Skeletal m. blood flow		≠
Fainting		≠

Parasympathetic Acetylcholine Effects

- Decreased pulse rate
- Increased salivation (watery)
- Stimulation of the gut
- Stimulation of the urinary bladder
- Penile erection
- Constriction of the pupils

Sympathetic Norepinephrine Effects

- Tightens blood vessels
- Increased pulse rate
- Increased force of heartbeat

(Increased blood pressure)

- Relaxation of the gut
- Emotional sweating
- Goosebumps and hair standing out
- Salt retention by the kidneys
- Increased salivation (mucus)
- Dilation of the pupils

Sympathetic Acetycholine Effects

- Sweating from altered temperature
- Sweating from eating spicy foods

Adrenomedullary Hormonal Effects

- Increased pulse rate
- Increased force of heartbeat
- Constriction of skin blood vessels (pallor)
- Dilation of the pupils
- Relaxation of the gut
- Increased blood sugar
- Decreased serum potassium level
- Increased respiration
- Emotional sweating
- Anti-fatigue effect
- Increased emotional intensity

Summing Up

You now have a basic understanding of your *autonomic nervous system.* It plays a critical role both in emergencies and in our daily activities, working to keep us going and helping our bodies make adjustments throughout the day.

Much of what you have learned may seem a bit complicated, but if you remember the basics, this will help you understand what can happen in your body if the *autonomic nervous system* is not working like it should.

You will probably need to refer back to this chapter for review as you continue to learn about the disorders and testing of the *autonomic nervous system* and the treatments of *dysautonomias* in the following chapters.