Chapter Ten

Peripheral Nervous System

Okay... Let's start this week off with a little review:

The main functions of the nervous system are to perceive what is going on inside and outside our bodies; to integrate these signals to other areas of the body; and, to manage the responses of the organ systems to these signals.

The signals we receive and the responses they trigger are sent as electrochemical nerve impulses along bundles of individual nerve cells called nerves.

Many of these signals are sent directly to a central nervous system which consists of two organs: the brain and spinal cord.

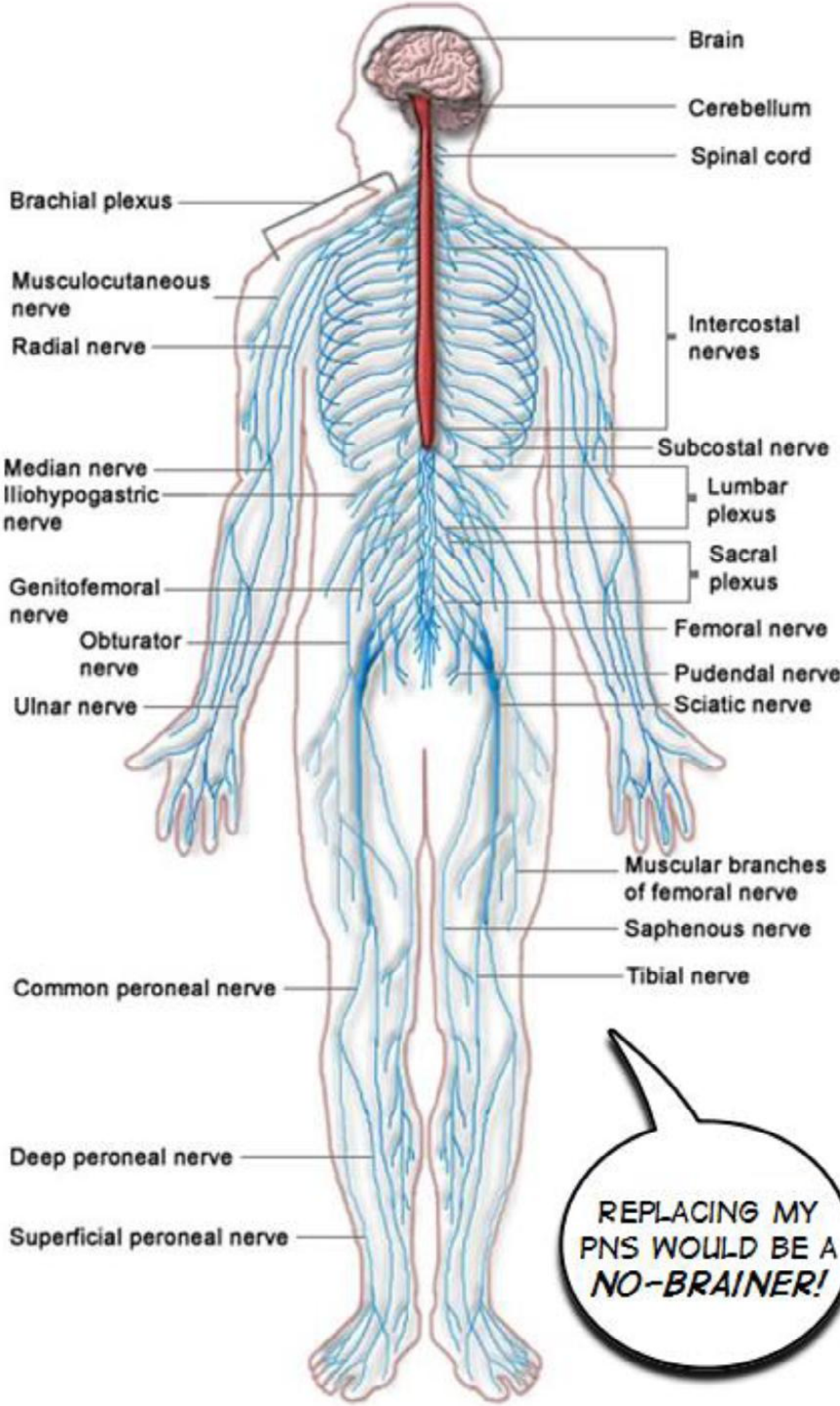
Now it's time to study the pathways of nerves attached to the central nervous system which send these signals. These large areas of efferent nerves make up the second division of the nervous system known as the...

Peripheral Nervous System (PNS)

All communication from the central nervous system to the rest of the body is accomplished through the peripheral nervous system. And, as you have learned before, specialized nerves allow this communication to exist:

Sensory (or afferent) nerves send information from the body TOWARD the central nervous system; and motor (or efferent) nerves send information AWAY from the central nervous system.

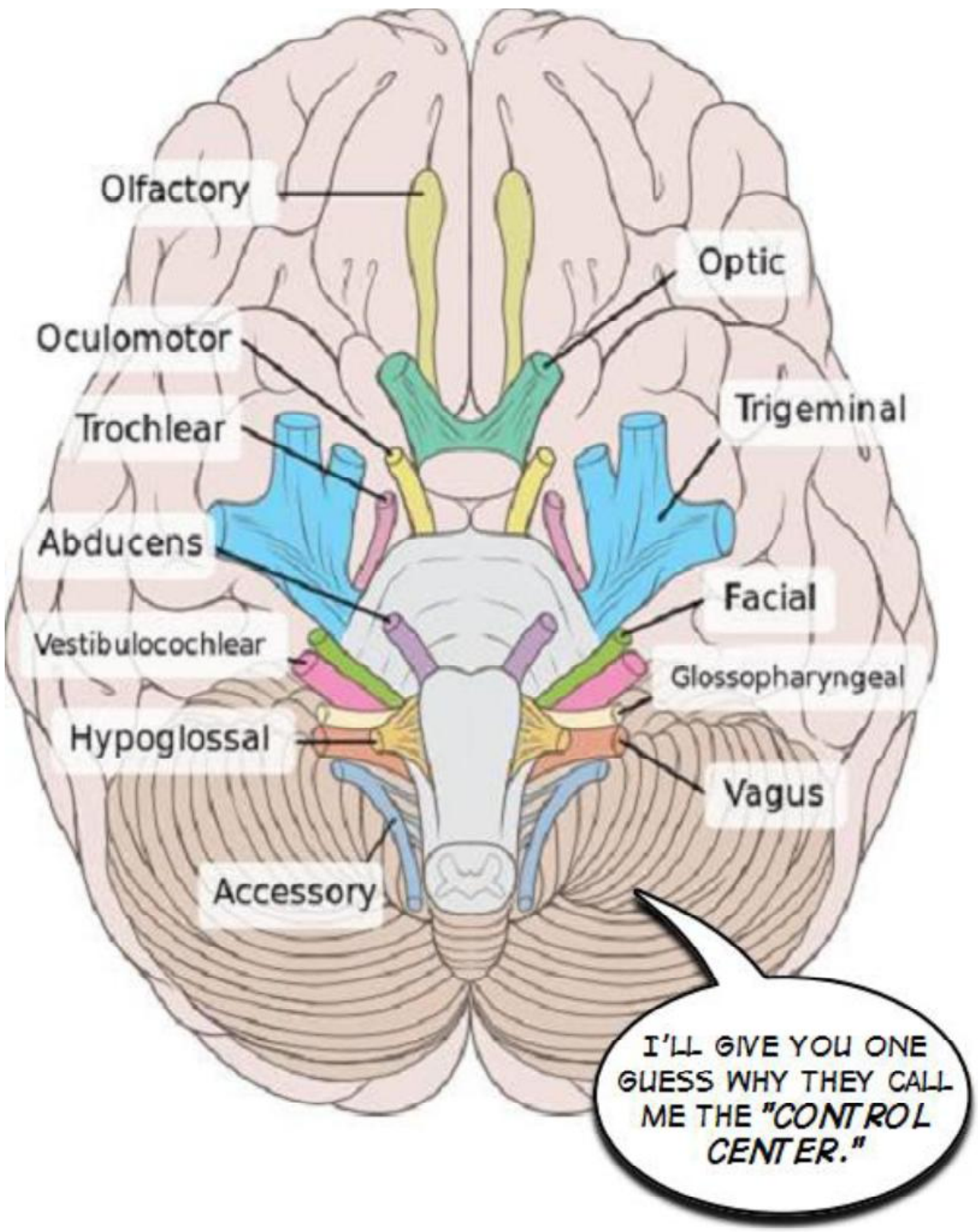
If you were to place all of the nerves within the PNS end-to-end in your body, it would stretch for approximately 93,000 miles (150,000 kilometers) in length! Impressive? That distance measures approximately four times around the planet!


Brain
Cerebellum
Spinal cord
Brachial plexus
Musculocutaneous nerve
Radial nerve
Intercostal nerves
Subcostal nerve
Median nerve
Iliohypogastric nerve
Lumbar plexus
Sacral plexus
Genitofemoral nerve
Obturator nerve
Femoral nerve
Pudendal nerve
Ulnar nerve
Sciatic nerve
Muscular branches of femoral nerve
Saphenous nerve
Common peroneal nerve
Tibial nerve
Deep peroneal nerve
Superficial peroneal nerve
REPLACING MY PNS WOULD BE A *NO-BRAINER!*

The peripheral nervous system has been divided into two subdivisions:

Somatic Nervous System and Autonomic Nervous System

You briefly read last week of the thirty-one pairs of spinal nerves attached to the sides of the spinal cord and 12 pairs of cranial nerves attached to the brain. All of these cranial and spinal nerves make up the **somatic nervous system**. These nerves connect the brain and spinal cord to structures such as the skin and the skeletal muscles.



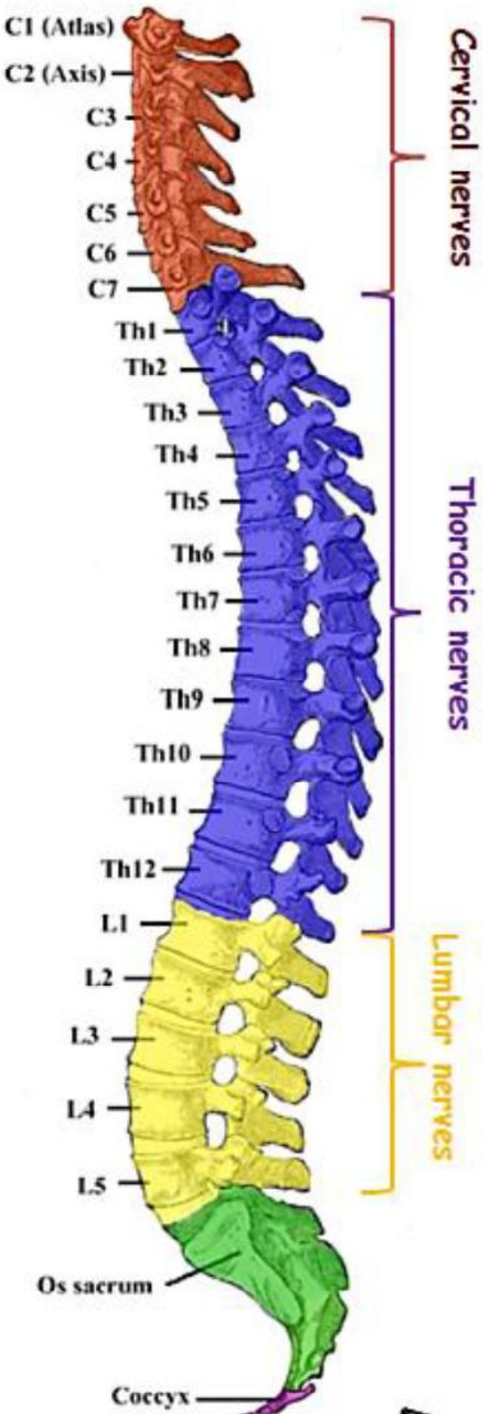
The cranial nerves are connected directly to the brain and are identified by both Roman numerals and their function. As you will notice in the chart below, these nerves are attached to movements and sensations in and around the head.

Cranial nerves and their function:

Name of Cranial Nerve	Function
I Olfactory	Smell
II Optic	Vision
III Oculomotor	Movement of the eye, eyelid, pupil, and lens
IV Trochlear	Movement (rotation) of the eye
V Trigeminal	Sensations to the face, including scalp, forehead, cheeks, upper lip, tongue, and lower jaw; regulates the act of chewing
VI Abducens	Movement (abduction) of the eye
VII Facial	Facial expressions, taste, secretion of tears and saliva
VIII Vestibulocochlear	Hearing and balance of the body
IX Glossopharyngeal	Taste, swallowing and secretion of saliva
X Vagus	Swallowing, coughing, voice production; monitors blood pressure and oxygen and carbon dioxide levels in blood
XI Spinal Accessory	Voice production; movement of head and shoulders
XII Hypoglossal	Movement of tongue during speech and swallowing

The somatic nervous system also contains thirty-one pairs of spinal nerves as well. These nerves are connected directly to the spinal cord. In addition, spinal nerves are identified by the nearest individual vertebrae to which their attachment is located along the spinal cord. For example, the cervical nerves attach to the spinal cord alongside the first two vertebrae, C1 and C2.

Spinal nerves - location and function:



Location	Function
C1-C6	Flexes neck
C1-Th1	Extends neck
C3, C4, C5	Moves diaphragm (mostly C4)
C5, C6	Shoulder movement, raise arm (deltoid); flexion of elbow (biceps); C6 externally rotates the arm
C6, C7	Extends elbow (triceps) and wrist
C7, Th1	Flexes wrist
C7, Th1	Moves small muscles of the hand
Th1 -Th6	Intercostals and trunk above the waist
Th7-L1	Abdominal muscles
L1, L2, L3, L4	Thigh flexion
L2, L3, L4	Thigh adduction
L4, L5, S1	Thigh abduction
L5, S1, S2	Extension of leg at the hip (gluteus maximus)
L2, L3, L4	Extension of leg at the knee (quadriceps)
L4, L5, S1, S2	Flexion of leg at the knee (hamstrings)
L4, L5, S1	Flexion of foot
L4, L5, S1	Extension of toes
L5, S1, S2	Flexion of foot
L5, S1, S2	Flexion of toes

WHAT? DID YOU THINK EVERYTHING YOU LEARNED IN *CHAPTER FIVE* WASN'T COMING BACK? HA!

The somatic nervous system uses all of these cranial and spinal nerves to connect the body to the central nervous system. However, as you learned in the last chapter, there are some occasions where the CNS is not a part of a nerve impulse at all. In these cases, a second division of the peripheral nervous system does all the work. This system is known as the...

Autonomic Nervous System

The **autonomic nervous system** is responsible for all of the <u>involuntary</u> activity in the body. If you remember from previous chapters on muscles and tissues, an involuntary action takes place without any help from the CNS. Specifically, these actions take place within smooth and cardiac muscle tissue.

The autonomic nervous system is broken down into three divisions:

Sympathetic nervous system
Parasympathetic nervous system
Enteric nervous system

The **sympathetic nervous system** is often called the "fight or flight" system because it usually increases your alertness, increases your heart rate, and generally prepares your body to deal with emergencies. On the other side, the **parasympathetic nervous system** helps your body to conserve energy and tends to slow your heart rate.

The **enteric nervous system** is localized solely within the smooth muscle tissue of the digestive system.

Even though both the somatic and autonomic subdivisions of the peripheral nervous system are responsible for transmitting nerve impulses throughout the body, there is one very important difference I hope you will remember:

The **somatic nervous system** works with voluntary muscles such as skeletal muscles while the **autonomic nervous system** deals with involuntary muscles such as cardiac and smooth muscles.

Much like the rule concerning opposing muscles causing flexion and extension, the autonomic nervous system has a similar rule:

The sympathetic and parasympathetic systems typically have opposing actions.

But why do we need two systems opposing each other in the human body? The answer to this question can be found with our old friend...

Homeostasis

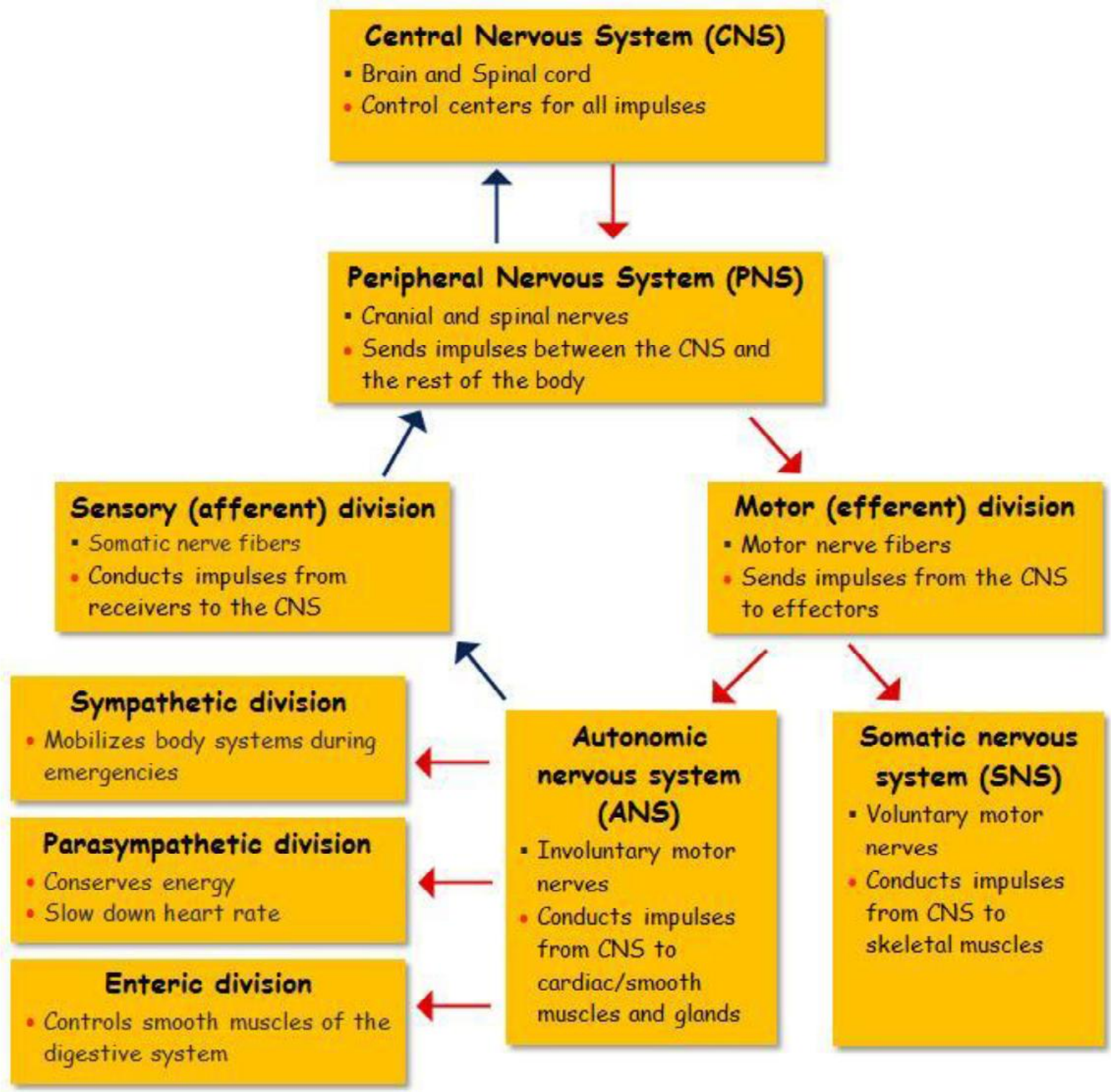
Looking back to our analogy of the aquarium in Chapter One, our bodies will act in a certain way until an opposing action brings it back to a balanced level. This can be felt when the sympathetic system makes your heart race when you are frightened.

But your heart doesn't continue to race, does it?

Hopefully not! It is the parasympathetic system which slows it down to a safe and comfortable rate. The same can be said of your lungs as the sympathetic system relaxes your lungs allowing air to flow into your body while the parasympathetic contracts the lungs and forces air out of your body. There are plenty of these involuntary actions within the human body that take place without any help whatsoever from the CNS:

Digestion of your food, Production of tears, Goosebumps, Sweating, ...and many more!

With all of these "nervous systems" floating around, your head may be spinning. On the following page you will find a flow chart that may help you separate all of the different divisions within the nervous system.



Naturally, we could spend months studying each of these individual systems; however, we have to stop here. Next week, we are going to take a look as some of our special senses. See you next week!

Match the following vocabulary terms with their correct definition:

enteric nervous system	**glossopharyngeal nerve**
autonomic nervous system	**hypoglossal nerve**
somatic nervous system	**lumbar nerves**
spinal accessory nerve	**oculomotor nerve**
sympathetic nervous system	**olfactory nerve**
vestibulocochlear nerve	**optic nerve**
parasympathetic nervous system	**thoracic nerves**
sacral and coccygeal nerves	**trigeminal nerve**
abducens nerve	**trochlear nerve**
cervical nerves	**vagus nerve**
facial nerve	

1)	______________	cranial nerve; responsible for the function of facial expressions, taste, secretion of tears and saliva
2)	______________	cranial nerve; responsible for the function of hearing and balance of the body
3)	______________	cranial nerve; responsible for the function of smell
4)	______________	cranial nerve; responsible for the function of swallowing, coughing, and voice production; also monitors blood pressure and oxygen and carbon dioxide levels in blood
5)	______________	cranial nerve; responsible for the function of taste, swallowing and secretion of saliva
6)	______________	cranial nerve; responsible for the function of vision
7)	______________	cranial nerve; responsible for the function of voice production; movement of head and shoulders
8)	______________	cranial nerve; responsible for the movement of tongue

9) ______________ cranial nerve; responsible for the abduction of the eye

10) ______________ cranial nerve; responsible for the rotation of the eye

11) ______________ cranial nerve; responsible for the movements of the eye, eyelid, pupil, and lens

12) ______________ cranial nerve; responsible for the sensations to the face and regulates the act of chewing

13) ______________ helps the body to conserve energy and tends to slow the heart rate

14) ______________ known as the "fight or flight" system because it usually increases the alertness and generally prepares the body to deal with emergencies

15) ______________ localized solely within the smooth muscle tissue of the digestive system

16) ______________ nerves which connect the brain and spinal cord to structures such as the skin and the skeletal muscles; works with voluntary muscles only

17) ______________ responsible for all of the involuntary body activity

18) ______________ spinal nerve; responsible for functions pertaining to the head, neck, and shoulders

19) ______________ spinal nerve; responsible for functions pertaining to the hips, tail bone, buttocks, rectum, anus, and sex organs

20) ______________ spinal nerve; responsible for functions pertaining to tissues found between the shoulders and intestines

21) ______________ spinal nerve; responsible for tissues found within the lower abdomen and all lower extremities

Choose the correct answer from the following questions:

1) **Preparing the body for the "fight-or-flight" response during threatening situations is the role of the:**
   A) sympathetic nervous system
   B) somatic nervous system
   C) enteric nervous system
   D) afferent nervous system
   E) parasympathetic nervous system

2) **Which one of these muscle types is NOT directly controlled by the autonomic nervous system:**
   A) smooth muscle
   B) cardiac muscle
   C) skeletal muscle

3) **The cranial nerve that contains sensory fibers that are involved in hearing is:**
   A) cranial nerve VIII
   B) cranial nerve II
   C) cranial nerve IX
   D) cranial nerve III
   E) cranial nerve V

4) **The peripheral nervous system consists of:**
   A) the spinal and cranial nerves
   B) the brain and spinal cord
   C) spinal nerves only
   D) cranial nerves only
   E) the brain only

5) **The sympathetic and parasympathetic nervous systems are subdivisions of the:**
   A) autonomic nervous system
   B) voluntary nervous system
   C) somatic nervous system
   D) central nervous system
   E) peripheral nervous system

6) **The effects of the sympathetic nervous system are essentially opposite of the:**
   A) autonomic nervous system
   B) enteric nervous system
   C) central nervous system
   D) parasympathetic nervous system

Application Question:

Lindsay was watching a scary late-night horror movie when she heard a door slam and a cat's yowl. The hair rose on her arms and she was covered with goose bumps. Based upon your knowledge from this chapter, which section and subsection of the human nervous system do you believe is associated with the development of goose bumps because of Lindsay's situation? What evidence can you use to defend your idea?

Chapter Eleven

Sense Organs

In the past three chapters, we have explored the pathways of electrochemical signals through specialized cells known as neurons. In addition, we have also spent some time looking at the central nervous system and how it regulates our responses to various stimuli to our bodies.

This week, we will be fine-tuning our look at the peripheral nervous system by studying the very important and specialized functions which make up our...

Senses

Our senses can be broken down into two separate groups based upon their location in the body:

Special senses

These senses include our sense of smell, hearing, vision, taste, and balance and are produced by very specific organs found only in certain areas of the body.

General senses

These senses can generally be found throughout our body as they are associated with our skin. These senses include touch, pressure, pain, and temperature.

All of these senses require some form of sensory receptor (as you learned back in Chapter 3) which can detect changes in the environment and trigger a nerve impulse within the body. These receptors can be in the form of specialized neurons or other types of specialized cells which respond to particular stimulus.

The five different variations of sensory receptors listed below each responds to a different type of stimulus:

Name of sensory receptor	Responds to....
Chemoreceptors	...chemical compounds such as odor molecules
Photoreceptors	...light
Thermoreceptors	...changes in temperature
Mechanoreceptors	...changes in pressure or movement
Pain receptors	...stimuli that result in the sensation of pain

We could spend an entire week on each of these receptors. However, for the remainder of this chapter, let's focus more on four of our specialized senses:

Smell, Taste, Hearing, and Vision

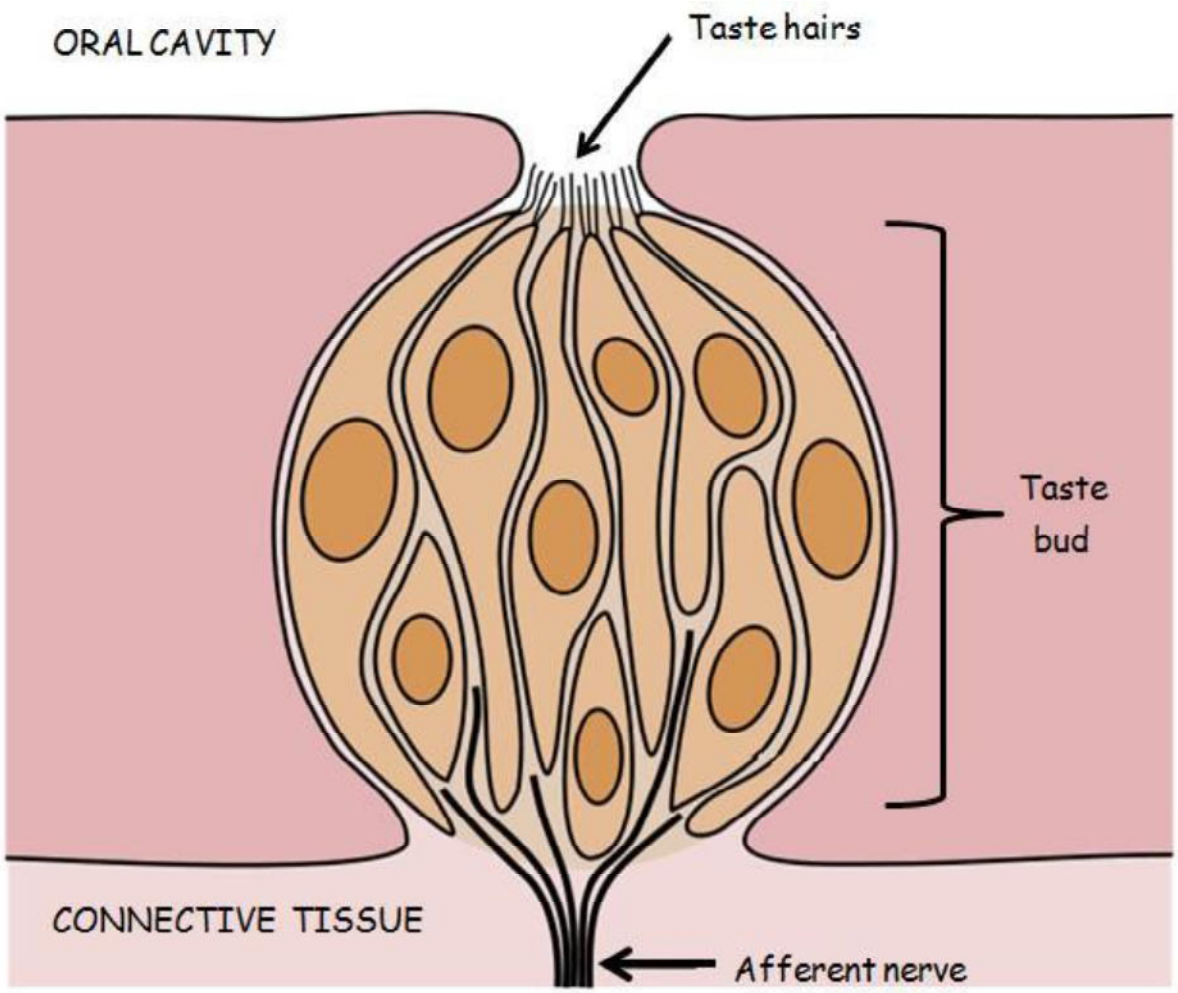
Smell

Chemoreceptors are responsible for our ability to detect different odors in the environment. These sensory receptors are specialized neurons as they do not contain dendrites but branches of fingerlike projections from the cell body called **cilia**. Each cilia contains one of nearly 4000 different "locks" which can only be opened by a specific "key" found on a particular molecule that has been inhaled.

When the individual key (which is attached to the outer surface of the inhaled object) finds its lock on a particular cilia, a nerve impulse is generated from its chemoreceptor towards the CNS. It is the brain which can identify which particular chemical is being smelled and can act accordingly.

Taste

Much like our sense of smell, our ability to taste is very specialized as well. This is due to bundles of specialized cells known as **taste buds** located on the superior surface of visible "bumps" mushroom-shaped projections on your tongue known as **papillae**. An adult has nearly 10,000 taste buds on the surface of the papillae. Individual cells within the taste buds contain specialized structures called **taste hairs** that act very similarly as the chemoreceptors found on cilia. Each taste hair is able to detect specific molecules using the same "lock and key" method. Once detected, a nerve impulse is sent to the brain for the sensation to be identified.



Generally speaking, our taste buds can detect four major types of taste sensations: sweet, sour, salty, and bitter. However, other sensations have also been identified such as metallic, **alkaline** (non-acidic compounds such as those in garlic, raw spinach, and broccoli), and **umami** (which is a flavor associated with a particular chemical called monosodium glutamate otherwise known as MSG).

All taste buds are able to detect each of the four basic taste sensations; however, most taste buds are more sensitive to only one type of taste sensation and can be found in clusters on particular areas of the tongue:

Taste Sensation	Area of the Tongue
Sweet	Tip of the tongue
Sour	Sides of the tongue
Salty	Tip and front edges of the tongue
Bitter	Back of the tongue

Hearing

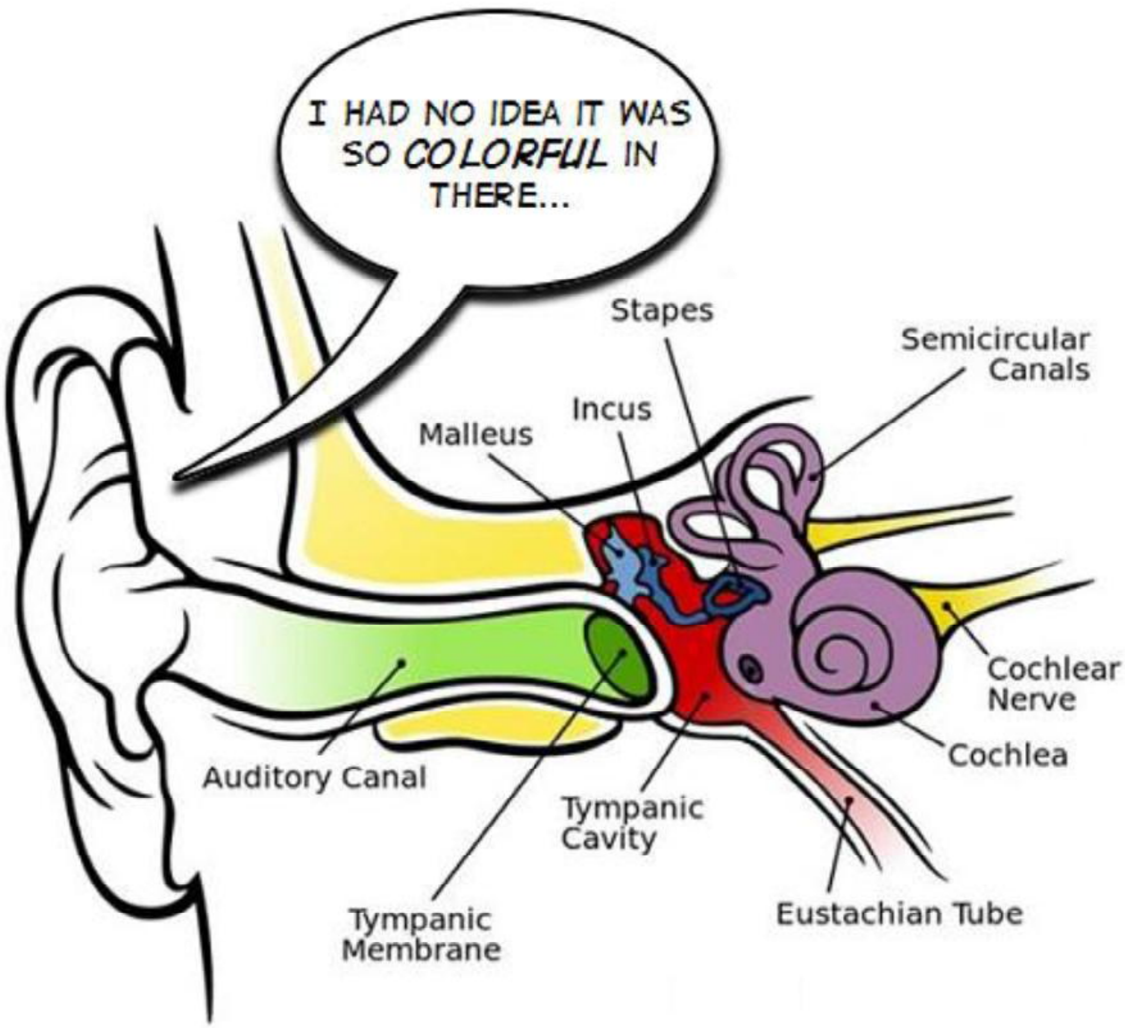
Our ears are more than just a place to hold onto our glasses. Before you explore the physiology of how we hear sounds, you need to understand the anatomy of the three major parts of the ear:

the **External ear, Middle ear,** and **Inner ear**

The **external ear** is the visible part of the ear and is made up of a funnel-shaped structure called the **pinna** attached to a 1 inch (2.5 cm) tube called the **auditory canal** which ends at the **eardrum** (**tympanic membrane**).

The **middle ear** (**tympanic cavity**) is a small, air-filled space within the skull which contains the tympanic membrane and three small bones called **auditory ossicles**.

The auditory ossicles are known as the **malleus** (hammer), **incus** (anvil), and **stapes** (stirrup).



The middle ear is connected to the throat by another structure known as the **Eustachian tube**. This tube is very important as it maintains equal amounts of air pressure on both sides of the eardrum. When our bodies experience an increase in air pressure, the eardrum is pushed inward and causes a decrease in hearing; however, as more air is allowed to pass through the Eustachian tube, the air pressure inside the tympanic cavity can increase as well. This results in our eardrum being forced back to its normal position. In this instance, we experience the "popping" of our ears.

The **inner ear** is the last stop on our journey through the anatomy of the ear. Within this area, our sense of hearing is created by a spiral-shaped fluid-filled chamber called the **cochlea**. Mechanoreceptors line the walls of the cochlea and react to stimuli from the middle ear to transmit nerve impulses to the CNS.

How do our ears sense sound?

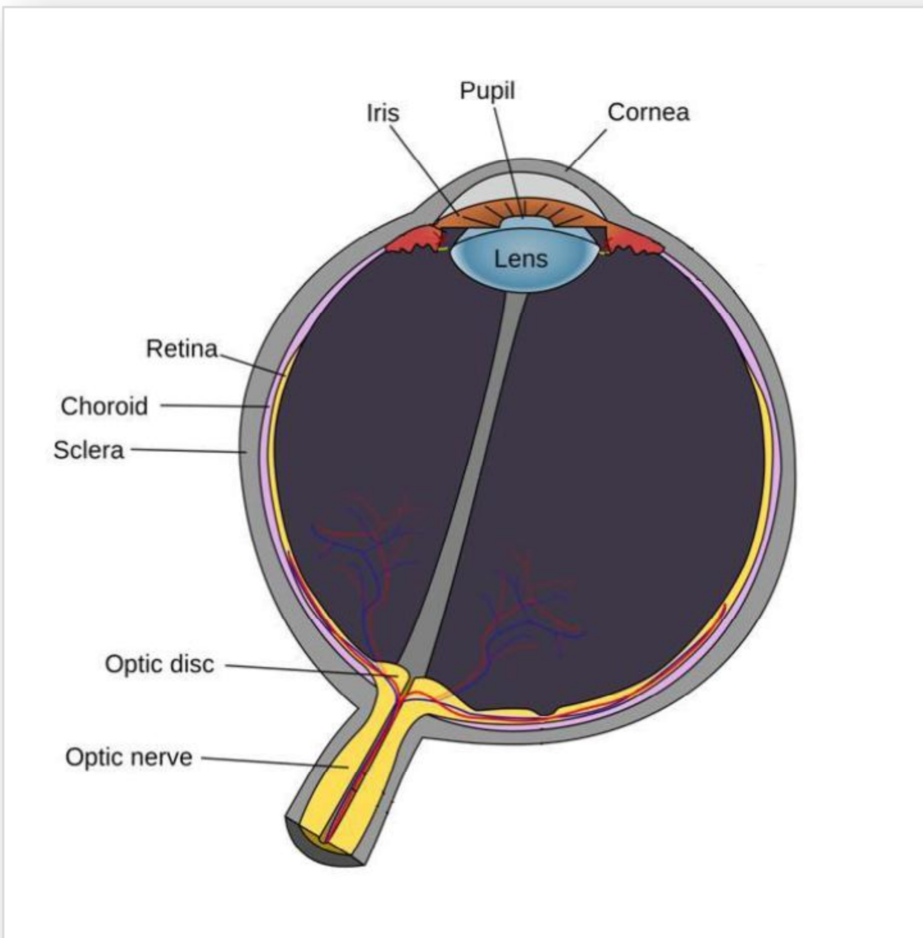
First of all, a sound wave is a vibration in the air that enters the auditory canal. A sound wave strikes the eardrum and causes it to vibrate. This vibration causes the three small bones in the middle ear to vibrate as well which, in turn, transfers this energy to the cochlea. The mechanoreceptors within the cochlea transmit nerve impulses to the brain which translates them into a sound you can understand.

Vision

Our eyes are complex anatomical structures. We could spend weeks just looking at this amazing organ! For the purpose of this book, however, let's look at a few of the basic structures and functions of the eyes...

Structure	Function
Sclera	White part of the eye; maintains the eye's shape
Cornea	Refracts (bends) and focuses light rays (much like the lens of a camera or telescope) into the pupil
Pupil	Black part of the eye which allows light to enter the eyeball
Iris	Changes the size of the pupil by thereby regulating the amount of incoming light; this is the colorful part of the eye
Lens	Refracts (bends) incoming light as well; focuses light onto the retina
Retina	Absorbs light; forms nerve impulses which are transmitted to brain
Optic nerve	Transmits nerve impulses to the brain

Simply put, the amount of light which enters the eye through the pupil is regulated by the iris. The pupil enlarges when the amount of available light is diminished so as to allow the maximum amount of light to enter the eye.



During periods of excessive light, the iris reduces the diameter of the pupil by blocking the majority of incoming light. As the light is passed through the pupil, it is bent by the cornea and then the lens which focuses the light onto the retina where photoreceptors begin a nerve impulse which is then sent via the optic nerve to the brain.

There are two different photoreceptors in the retina:

Rods

Rods are specialized for vision in dim light; they cannot detect color, but they are very good at detecting movement and visualizing shapes without much detail. Each eye may contain up to 125 million rods.

Cones

Cones provide us with color vision and work best within bright light. Each eye may contain up to seven million cones. Out of all the colors of the rainbow, cones can only detect three different colors of light: blue, green, and red.

If our eyes can only see three different colors, how do we visualize all the different colors of the rainbow?

Our brain determines the various colors of the rainbow by combining the amount of nerve impulses from all three types of cones. For example, our brain will be able to sense the color yellow by combining many nerve impulses from green cones and only a few from red cones.

(Yes... the mixing of red and green light will give you the color yellow! This is much different that when you mix the <u>pigments</u> red and green. This mixture gives you a brownish pigment.)

What about our sensation of temperature?

Much like our fishbowl analogy we have been mentioning throughout this textbook, our bodies have their own "thermometers" throughout our skin. The sensations we feel with increasing and decreasing temperatures are caused by two different nerve endings called:

Cold receptors and Warm receptors

Cold receptors are sensitive to temperatures that fall under 50°F (10°C). At this temperature, the cold receptors begin to stimulate **pain receptors** and provide us with the sensation of freezing. When temperatures reach above 113°F (45°C), **warm receptors** stimulate pain receptors which produce a burning sensation.

We've been spending a lot of time discussing how messages can be sent through electrochemical signals via nerves. Now it's time to look at another system which has the ability to send signals throughout our body. However, this new system uses an entirely different transportation system. See you next week!

Anatomy & Physiology - Connections

How the following body systems affect the nervous system		How the nervous system affects the following body systems	
Integumentary	Sensory receptor triggers nerve impulse; hair provides physical barrier/protection for skull	Controls arrector pili muscles (goosebumps) and secretions from sweat glands	**Integumentary**
Skeletal	Provision of calcium for nerve impulse/muscular contraction; protection of brain and spinal cord	Regulation of skeletal muscle contractions	**Skeletal**
Muscular	Specialized muscles provide facial expressions and vocal sounds	Regulation of skeletal muscle contractions	**Muscular**

Match the following vocabulary terms with their correct definition:

alkaline	**general senses**	**pinna**
auditory canal	**incus**	**pupil**
auditory occicles	**inner ear**	**retina**
chemoreceptors	**iris**	**rods**
cilia	**lens**	**sclera**
cochlea	**malleus**	**special senses**
cold receptors	**mechanoreceptors**	**stapes**
cones	**middle ear**	**taste buds**
cornea	**optic nerve**	**taste hairs**
eardrum	**pain receptors**	**thermoreceptors**
eustachian tube	**papillae**	**umami**
external ear	**photoreceptors**	**warm receptors**

1)	______________	a 1 inch (2.5 cm) tube within the pinna of the external ear
2)	______________	a flavor associated with a particular chemical called monosodium glutamate (MSG)
3)	______________	a small, air-filled space within the skull which contains the tympanic membrane and three small bones (auditory ossicles)
4)	______________	absorbs light; forms nerve impulses which are transmitted to brain
5)	______________	black part of the eye which allows light to enter the eyeball
6)	______________	branches of fingerlike projections from the cell body of dendrites; responsible for identifying specific chemicals

7) ______________ bundles of specialized cells located on the surface of the tongue, the roof of the mouth, and within the throat

8) ______________ changes the size of the pupil thereby regulating the amount of incoming light; colorful part of the eye

9) ______________ contains the cochlea; site where vibrations from middle ear are transferred into nerve impulses involving the sense of hearing

10) ______________ divides the external ear from the middle ear; vibrations from this membrane induce the mechanical act of hearing

11) ______________ funnel-shaped structure within the center of the visible, external ear

12) ______________ nerve endings within the skin that are are sensitive to temperatures that fall under 50°F (10°C)

13) ______________ nerve endings within the skin that are sensitive to temperatures above 113°F (45°C)

14) ______________ non-acidic compounds

15) ______________ one of three small bones in the ear known as the "anvil" within the middle ear that induces the sensation of hearing through its vibration

16) ______________ one of three small bones in the ear known as the "hammer" within the middle ear that induces the sensation of hearing through its vibration

17) ______________ one of three small bones in the ear known as the "stirrup" within the middle ear that induces the sensation of hearing through its vibration

18)	______________	photoreceptors in the retina; specialized for vision in bright light and can detect color
19)	______________	photoreceptors in the retina; specialized for vision in dim light and cannot detect color
20)	______________	refracts (bends) and focuses light rays (much like the lens of a camera or telescope) into the pupil
21)	______________	refracts (bends) incoming light as well; focuses light onto the retina
22)	______________	senses produced by very specific organs found only in certain areas of the body; includes the senses of smell, hearing, vision, taste, and balance
23)	______________	senses that can generally be found throughout our body as they are associated with the skin
24)	______________	sensory receptor which responds to changes in pressure or movement
25)	______________	sensory receptor which responds to changes in temperature
26)	______________	sensory receptor which responds to chemical compounds such as odor molecules
27)	______________	sensory receptor which responds to light
28)	______________	sensory receptor which responds to stimuli that result in the sensation of pain
29)	______________	specialized structures on the surface of taste buds which identify specific molecules
30)	______________	spiral-shaped fluid-filled chamber within the inner ear whose mechanoreceptors transmit nerve impulses to the CNS concerning our sense of hearing

31)	______________	the visible part of the ear
32)	______________	three small bones within the tympanic cavity known as the malleus (hammer), the incus (anvil), and stapes (stirrup); vibrations from these bones induce vibrations within the cochlea
33)	______________	transmits nerve impulses to the brain
34)	______________	tube which connects the middle ear to the throat and maintains air pressure between both sides of the eardrum
35)	______________	visible mushroom-shaped projections on your tongue which contain taste buds
36)	______________	white part of the eye; maintains the eye's shape

Choose the correct answer from the following questions:

1) **Sound waves entering the external auditory canal hit the eardrum, also known as the:**
   A) cochlea
   B) ossicles
   C) tympanic membrane
   D) stapes
   E) incus

2) **One of the three small bones within the middle ear known as the "anvil" is also called the:**
   A) incus
   B) stapes
   C) malleus
   D) bony labyrinth
   E) cochlea

3) **What structure of the eye focuses light on the retina:**
   A) optic nerve
   B) lens
   C) cornea
   D) sclera
   E) iris

4) **Which one of the following is part of the inner ear?**
   A) Eustachian tube
   B) auditory ossicles
   C) stapes
   D) cochlea
   E) malleus

5) **The colorful portion of the eye that has a rounded opening through which light passes is the:**
   A) cornea
   B) sclera
   C) iris
   D) lens
   E) retina

6) **True or False:** The pupil is the circular opening in the iris through which light passes.

7) **True or False:** In order to hear sound, vibrations pass from the eardrum to the ossicles, and on to the cochlea.

Application Question:

Phil has surgery to remove polyps (non-cancerous growths of tissue) from his sinuses. After he heals from the surgery, he notices that his sense of smell is not as strong as it was before the surgery. Can you suggest a possible reason for this?