The autonomic nervous system is the portion of the nervous system which automatically controls the inner workings of your body and the visceral organs. The ANS is contained within the CNS (e.g. brain and spinal cord) and the PNS (e.g. spinal nerves). It is a solely efferent system, however, afferent visceral fibers, associated with the spinal nerve, travel with the efferent fibers and provide information to the CNS concerning the state of the viscera.

The ANS is subdivided into two parts; (a) the **sympathetic nervous system**; and (b) the **parasympathetic system**. Sympathetic stimulation requires body energy and is useful in emergency situations while the parasympathetic system conserves body energy and is useful in body homeostasis. Although the parasympathetic and sympathetic nervous systems are antagonistic in some organs (e.g. the heart), they are not dissimilar. Similarities in the two systems include the fact that both the sympathetic and parasympathetic system are two neuron pathways with the preganglionic neuron in the CNS and the postganglionic neuron in the PNS. The sympathetic system is more extensive than the parasympathetic system, however, since it is responsible for the innervation of blood vessels, sweat glands, and the arrector pili muscles of the entire body.

Nervous system is the master system of human body. It controls the activity of all other systems in such a way that all the systems collectively make a human being. Without a controlling system, there is no concept of life because in such case there will be no coordination between different body functions and they will all act separately. Nervous system not only controls the voluntary functions of human body that are directed by human will, but it also controls those functions that are below the level of consciousness of human beings. Control of a function means that the intensity of that function can be increase or decreased according to the demands of human body.

Nervous system not only produces coordination between different systems, but also between different organs of a system. To form an organ system, role of the component organs must also be coordinated. So nervous system is not only important for formation of an organism by different organ systems, but also for formation of a system by different organs of human body.

ANS is the part of the PNS, which control the unconscious functions of body. ANS controls involuntary activities of the body, like sweating, salivation, peristalsis, etc.

These reflexes are automatic, involuntary responses. They may or may not involve the brain for example blinking does not involve the brain. The Reflex arc is the main functional unit of the nervous system that helps a person react to a stimulus

The **ANS reflex arcs** maintain homeostasis via a process of ***negative feedback*** in which a sensory cell from within the peripheral nervous system takes a measurement, for example body temperature. This temperature reading is then relayed to the CNS where it is compared to a reference value. The CNS then uses efferent fibres to generate a response from effector cells given the comparison to the reference and thus adjusting the internal environment.

The nervous system has two major parts: **the central nervous system (CNS) and the peripheral nervous system (PNS**). The central system is the primary command center for the body, and is comprised of the brain and spinal cord. The peripheral nervous system consists of a network of nerves that connects the rest of the body to the CNS.

The two systems work together to collect information from inside the body and from the environment outside it. The systems process the collected information and then dispatch instructions to the rest of the body, facilitating an appropriate response.

In most cases, the brain is the final destination point for information gathered by the rest of the nervous system. Once data arrives, the brain sorts and files it before sending out any necessary commands.

The brain is divided into many different sections, including the cerebrum and brain stem.

Although the brain is the control center, its job would not be possible without the spinal cord, which is the major conduit for information traveling between brain and body.

Peripheral system nerves branch from either the brain stem or the spinal cord. Each nerve is connected to a particular area of the torso or limbs and is responsible for communication to and from those regions.

The PNS can also be subdivided into smaller components: **the somatic and autonomic systems.** The somatic involves parts of the body a person can command at will, and the autonomic helps run involuntary functions such as pumping blood.

Information conveyed through the nervous system moves along networks of cells called **neurons**. These neurons can only send information one way. Those transmitting to the brain are sensory neurons; those that transmit from the brain are known as motor neurons.

The somatic nervous system is a part of the peripheral nervous system and is also known as the voluntary nervous system. It is involved in the control and regulation of voluntary movements via the skeletal muscles and contains efferent nerves, which are associated with muscle contraction. The somatic nervous system consists of spinal nerves, cranial nerves and association nerves.

The nervous system of the body is made up of many different organs, such as the brain, spinal cord and etc. This highly complex system is responsible for several different activities, such as communicating, coordinating, controlling and regulating.

The somatic nervous system is a part of the peripheral nervous system and is also known as the voluntary nervous system. It is involved in the control and regulation of voluntary movements via the skeletal muscles and contains efferent nerves, which are associated with muscle contraction. **The somatic nervous system consists of spinal nerves, cranial nerves and association nerves.**

Spinal nerves are responsible for the transmission of sensory information into the spinal cord. They are also involved in motor commands and are peripheral nerves.

Cranial nerves are responsible for conducting information, such as smell, vision and taste, to and from the brain stem.

Association nerves are responsible for associating and coordinating motor output with the sensory input received.

The autonomic nervous system is a part of the peripheral nervous system, and is also known as the visceral nervous system and involuntary nervous system. It forms one of the many control systems of the body and does not operate at the full level of consciousness. It is divided into the sympathetic nervous system and parasympathetic nervous system.

The **sympathetic nervous system** activates the fight or flight mechanism in a human when he detects danger or is threatened. In this state, a redirection of energy takes place; digestion is put on hold, pupils dilate, the heart rate and breathing rate escalate and there is increased production of saliva and sweat.

As the **parasympathetic nervous system** has an opposite effect on the organs, it means that it calms the body down; digestion is started again, pupils contract to their normal size and breathing returns to normal.

The somatic nervous system includes the sensory and motor nerves that innervate the limbs and body wall. Sensory nerve fibers in the peripheral nerves are the peripheral axonal process of neurons in the dorsal root ganglion. The motor axons are the processes of anterior horn cells of the spinal cord.

Before a **sensory signal** can be relayed to the nervous system it must be transduced into an electrical signal in a nerve fiber. This involves a process of opening ion channels in the membrane in response to mechanical deformation, temperature or, in the case of nociceptive fibers, signals released from damaged tissue. Many receptors become less sensitive with continued stimuli and this is termed adaptation. This adaptation may be rapid or slow.

Motor nerve fibers end in myoneural junctions. These consist of a single motor axon terminal on a skeletal muscle fiber. The myoneural junction includes a complex infolding of the muscle membrane, the ridges of which contain nicotinic acetylcholine receptors. There is also a matrix in the synaptic cleft containing acetylcholinesterase, involved in termination of action of the neurotransmitter.

One motor neuron has connections with many muscle fibers through collateral branches of the axon. This is called the "motor unit" and can vary from a handful of muscle fibers per motor neuron in muscles of very fine control (such as eye muscles) up to several thousands (as in the gluteal muscles).

The **ANS** consists of two main divisions, the sympathetic and the parasympathetic nervous systems. The sympathetics are primarily involved in responses that would be associated with fighting or fleeing, such as increasing heart rate and blood pressure as well as constricting blood vessels in the skin and dilating them in muscles. The parasympathetic nervous system is involved in energy conservation functions and increases gastrointestinal motility and secretion. It also increases bladder contractility. There are some areas in which blood vessels are under competing sympathetic and parasympathetic control, such as in the nose or erectile tissues. There some areas where there is a competitive balance between sympathetics and parasympathetics, such as the effects on heart rate or the pupil. For some functions

sympathetics and parasympathetics cooperate; an example being parasympathetic nerves, which are necessary for erection and sympathetics for ejaculation.

Both the sympathetic and parasympathetic portions of the ANS have a two neuron pathway from the central nervous system to the peripheral organ. *Therefore, there is a ganglion interposed in each of these pathways, with the exception of the sympathetic pathway to the adrenal medulla. The adrenal medulla basically functions as a sympathetic ganglion.* The two nerve fibers in the pathway are termed **preganglionic** and **postganglionic**. At the level of the autonomic ganglia the neurotransmitter is typically **acetylcholine**. Postganglionic parasympathetic neurons also release acetylcholine while norepinephrine is the postganglionic transmitter for most sympathetic nerve fibers. The exception is the use of acetylcholine in sympathetic transmission to the sweat glands and erector pili muscles as well as to some blood vessels in muscle.

The actions of the ANS are largely involuntary (in contrast to those of the sensory-somatic system). It also differs from the sensory-somatic system is using two groups of motor neurons to stimulate the effectors instead of one.

- The first, the **preganglionic neurons**, arise in the CNS and run to a ganglion in the body. Here they synapse with
- **Postganglionic neurons**, which run to the effector organ (cardiac muscle, smooth mucle or a gland).

The ANS is subdivided into the sympathetic and the parasympathetic divisions and the enteric nervous system. The sympathetic and the parasympathetic divisions differ structurally in **(1) the location of their preganglionic neuron cell bodies within the CNS** and **(2) the location of their autonomic ganglia.**

The enteric nervous systém is a complex network of neuron cell bodies and axons within the wall of the digestive tract. An important part of this network is sampathetic and parasympathetic neurons. For this reasons, the enteric nervous systém is considered to be a part of the ANS.

Cell bodies of sympathetic preganglionic neurons are in the lateral horns of the spinal cord gray matter between the first thoracic (T1) and second lumbar (L2) segments. Because of the location of the preganglionic cell bodies , the sympathetic division is sometimes called the

thoracolumbar division. The axons of the preganglionic neurons pass through the ventral roots of spinal nerves T1-L2, course through the spinal nerves for a short distance, leave these nerves and project to autonomic ganglia on either side of the vertebral column behind the parietal pleura. These ganglia are called **sympathetic chain ganglia**, because they are connected to one another and form a chain or **paravertebral ganglia**, because they are located along both sides of the vertebral collumn.

The axons of preganglionic neurons are small in diameter and myelinated. The short connection between a spinal nerve and a sympathetic chain ganglion through which the preganglionic axons pass is called white ramus communicans because of the whitish color of the myelinated axons

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Sympathetic axons exit the sympathetic chain ganglia by the following four routes:

1. **Spinal nerves.** Preganglionic axons synapse with postganglionic neurons in sympathetic chain ganglia at the same level that the preganglionic axons enter the sympathetic chain. Alternatively, preganglionic axons pass either superiorly or inferiorly through one or more ganglia and synapse with postganglionic neurons in a sympathetic chain ganglion at a different level. Axons of the postganglionic neurons pass through a **gray ramus communicans** and reenter a spinal nerve. Postganglionic axons are not myelinated, thereby giving the gray ramus communicans its grayish color. The postagnglionic axons then project through the spinal nerve to the organs they innervate.

2. **Sympathetic nerves**. Preganglionic axons enter the sympathetic chain and synapse in a sympathetic chain ganglion at the same or a different level with postganglionic neurons. The postganglionic axons leaving the sympathetic chain ganglion form **sympathetic nerves**.

3. **Splanchnic nerves.** Some preganglionic axons enter sympathetic chain ganglia and without synapsing, exit at the same or a different level to form **splanchnic nerves**. Those preganglionic axons extend to **collateral or prevertebral ganglia**, where they

synapse with postganglionic neurons. Axons of the postganglionic neurons leave the collateral ganglia through small nerves that extend to target organs.

4. **Innervation of the adrenal gland**. The splanchnic nerve innervation to the adrenal glands is different from other ANS nerves because it consists of only preganglionic neurons. Axons of the preganglionic neurons do not synapse in sympathetic chain ganglia or in collateral ganglia. Instead, the axons pass through those ganglia and synapse with cells in the adrenal medulla. The **adrenal medulla** is the inner portion of the adrenal gland and consists of specialized cells derived during embryonic development from neural crest cells, which are the same population of cells that give rise to the postganglionic cells of the ANS. Adrenal medullary cells are round in shape, have no axons or dendrites and are divided into two groups. About 80% of the cells secrete **epinephrine**, also called **adrenaline**, and about 20% secrete norepinephrine, also called **noradrenaline**. Stimulation of these cells by preganglionic axons causes the release of epinephrine and norepinephrine. These substances circulate in the blood and affect all tissues having receptors to which they can bind. The general response to epinephrine and norepinephrine released from the adrenal medulla is to prepare the individual for physical activity. Secretion of the adrenal medulla are considered hormones because they are released into the general circulation and travel some distance to the tissues in which they have their effect.

Parasympathetic preganglionic neurons are located both superior and inferior to the thoracic and lumbar regions of the spinal cord where sympathetic preganglionic neurons are found. The cell bodies of parasympathetic preganglionic neurons are either within cranial nerve nuclei in the brainstem or within the lateral parts of the gray matter in the sacral region of the spinal cord from S2-S4. For that reason, the parasympathetic division is sometimes called the **craniosacral division**.

Axons of the parasympathetic preganglionic neurons from the brain are in **cranial nerves** III, VII, IX and X; and from the spinal cord in **pelvic nerves**. The preganglionic axons course through these nerves to **terminal ganglia** where they synapse with postganglionic neurons. The axons of the postganglionic neurons extend relatively short distances from the terminal ganglia to the target organs. The terminal ganglia are either near or embendded within the walls of the organs innervated by the parasympathetic neurons. Many of the parasympathetic ganglia are small in size, but some, such as those in the wall of the digestive tract, are large.

Sympathetic nervous system:

1. All neurons forming this system originate from T1 to L2 segment of spinal cord. So it is called thoracolumbar outflow.
2. Pre-ganglionic fibers are short, relay either in lateral ganglia or collateral ganglia
3. Post-ganglionic fibers are long Nerve endings are adrenergic in nature except in sweat gland
4. Functionally, sympathetic nerves are vasomotor, sudomotor and pilomotor to skin. It is seen when subject is in fear, fight and flight position. It dilates skeletal muscle blood vessels
5. Effect is widely diffused and directed towards mobilization of resources and expenditure of energy during emergency and emotional crisis
6. It supplies visceral blood vessels, skin. Afferents from viscera and specific area of skin reach the same spinal segment to go to the cerebrum. Since pain is better appreciated from the skin, it appears to be coming from skin rather than the viscera. This is the basis of referred pain.

Parasympathetic nervous system:

1. All neurons forming this system originate from brain (Ill, VII, IX, X cranial nerves) and S2—S4 segment of spinal cord. So it is called craniosacral outflow.
2. Pre-ganglionic fibers are very long reaching up to terminal ganglia mostly on viscera. Postganglionic fibers are short
3. Nerve endings are cholinergic in nature
4. Functionally, it is seen when subject is fully relaxed. Parasympathetic system has no effect on skin
5. Effect is discrete, isolated, directed towards conservation and restoration of the resources of
6. It only supplies viscera

Sympathetic division

Sympathetic axons pass from the sympathetic chain ganglia to their target tissues through the spinal, sympathetic and splanchnic nerves. The sympathetic and splanchnic nerves can join **autonomic nerve plexuses**, which are complex, interconnected neural networks formed by neurons of the sympathetic and parasympathetic divisions. In addition, the axons of sensory neurons contribute to these plexuses.

The autonomic nerve plexuses typically are named according to organs they supply or to blood vessels along which they are found. For example, the cardiac plexus supplies the heart and the thoracic aortic plexus is found along the thoracic aorta. Plexuses following the route of blood vessels is a major means by which autonomic axons are distributed throughout the body.

The major means by which sympathetic axons reach organs include the following:

1. **Spinal nerves**. From all levels of the sympathetic chain, some postganglionic axons project through gray rami communicantes to spinal nerves. The axons extend to the same structures innervated by the spinal nerves and supply sweat glands in the skin, smooth muscle in skeletal and skin blood vessels, and the smooth muscle of the arrector pili.

2. **Head and neck nerve plexuses**. Most of the sympathetic nerve supply to the head and neck is derived from the superior cervical ganglion of the sympathetic chain. Postganglionic axons of the sympathetic nerves form plexuses that extend superiorly to the head and inferiorly to the neck. The plexuses give off branches to supply sweat glands in the skin, smooth muscle in the skeletal and skin blood vessels , and the smooth muscle of the arrector pili. Axons from the plexuses also join branches of the trigeminal nerves (cranial nerve V) to supply the skin of the face, the salivary glands, thi iris, and the ciliary muscles of the eye.

3. **Thoracic nerve plexuses**. The sympathetic supply for organs of the thorax is mainly derived from the cervical and upper five thoracic sympathetic chain ganglia. Postganglionic axons in sympathetic nerves contribute to the **cardiac**

plexus, supplying the heart, the **pulmonary plexus**, supplying the lungs, and other thoracic plexuses.

4. **Abdominopelvic nerve plexuses**. Sympathetic chain ganglia from T5 and below mainly supply the abdominopelvic organs. The preganglionic axons of splanchnic nerves synapse with postganglionic neurons in the collateral ganglia of abdominopelvic nerve plexuses. Postganglionic axons from the collateral ganglia innervate smooth muscle and glands in the abdominopelvic organs. There are several abdominopelvic nerve plexuses. The **celiac plexus** has two large celiac ganglia and other smaller ganglia. It supplies the diaphragm, stomach, spleen, liver, gallblader, adrenal glands, kidneys, testes, and ovaries. The **superior mesenteric plexus** includes the superior mesenteric ganglion and supplies the pankreas, small intestine, ascending colon, and the transverse colon. The **inferior mesenteric plexus** includes the inferior mesenteric ganglion and supplies the transverse colon to the rectum. The **hypogastric plexuses** supply the descending colon to the rectum, the urinary bladder, and reproductive organs in the pelvis.

Parasympathetic division

Parasympathetic outflow is through cranial and sacral nerves. Branches of these nerves either supply organs or join nerve plexuses to be distributed to organs. The major means by which parasympathetic axons reach organs include the following:

1. *Cranial nerves supplying the head and neck.* Three pairs of cranial nerves have parasympathetic preganglionic axons that extend to terminal ganglia in the head. Postganglionic neurons from the teminal ganglia supply nearby structures. The parasympathetic cranial nerves, their terminal ganglia and the structures innervated are:

    1. **The oculomonor (III) nerve**, through the ciliary ganglion, supplies the ciliary muscles and the iris of the eye.

    2. **The facial (VII) nerve**, through the **pterygopalatine ganglion**, supplies the lacrimal gland and mucosal glands of the nasal cavity and palate. The facial nerve, through the **submandibular ganglion**, also supplies the submandibular and sublingual salivary glands.

3. **The glossopharyngeal (IX) nerve**, through the otic ganglion supplies the parotid salivary glands.

2. *The vagus nerve and thoracic nerve plexuses.* Although cranial nerve X**, the vagus nerve**, has somatic motor and sensory functions in the head and neck, its parasympathetic distribution is to the thorax and abdomen. Preganglionic axons extend through the vagus nerves to the thorax, where they pass through branches of the vagus nerves to contribute to the cardiac plexus, which supplies the heart, and the pulmonary plexus, which supplies the lungs. The vagus nerves continue down the oesophagus, and give off branches to form the **oesophagel plexus**.

3. *Abdominal nerve plexuses*. After the oesophageal plexus passes through the diaphragm, some of the vagal preganglionic axons supply terminal ganglia in the wall of the stomach, while others contribute to the celiac and superior mesenteric plexuses. Through these plexuses, the preganglionic axons supply terminal ganglia in the walls of the gallbladder, biliary dcts, pankreas, small intestine, ascending colon and the transverse colon.

4. *Pelvic nerves and pelvic nerve plesuses.* Parasympathetic preganglionic axons whose cell bodies are in the S2-S4 region of the spinal cord pass to the ventral rami of spinal nerves and enter the pelvic nerves. The pelvic nerves supply the transverse colon to the rectum, and they also contribute to the hypogastric pluxus. The hypogastric plexus and its derivatives supply the lower colon, rectum,urinary bladder, and organs of the reproductive syntem in the pelvis.

- **Sensory neurons in autonomic nerve plexuses**

Although not strictly part of the ANS, the axons of sensory neurons run alongside ANS axons within ANS nerves and plexuses. Some of these sensory neurons are part of reflex arcs regulating organ activities. Sensory neurons also transmit pain and pressure sensations from organs to the CNS. The cell bodies of these sensoryneurons are found in the dorsal root ganglia and in the sensry ganglia certain cranial nerves, which are swellings on the nerves close to their attachement to the brain.

Cholinergic and adrenergic fibers

The two main neurotransmitters in the ANS are **acetylcholine** and **norepinephrine**. The fibers that release acetylcholine are called **cholinergic,** and fibers releasing norepinephrine are called **adrenergic**.

All the preganglionic fibers are cholinergic, both in sympathetic and parasympathetic portion of the ANS. Almost all postganglionic parasympathetic fibers are also cholinergic. In contrast, most postganglionic sympathetic fibers are adrenergic. An exception among sympathetic fibers comprise those fibers that innervate sweat glands and piloerector muscles – these are cholinergic.

Neurotransmitters.

Sympathetic and parasympathetic nerve endings secrete one of two neurotransmitters. If the neuron secretes acetylcholine, it is a **cholinergic neuron**, and if it secretes norepinephrine, it is an **adrenergic neuron**. All preganglionic neurons of the sympathetic and parasympathetic divisions and all postganglionic neurons of the parasympathetic division are cholinergic. Almost all postganglionic neurons of the sympathetic division are adrenergic, but a few postganglionic neurons tat innervate thermoregulatory sweat glands are cholinergic.

In recent yearrs, substances in addition to the regular neurotransmitters have been extracted from ANS neurons. These substances include nitric oxide; fatty acids, such as prostaglandins; peptides, such as gastrin, somatostatin, cholecystokinin, vasoactive intestinal peptide, enkephalins, and substance P; and monoamines such as dopamin, serotonin and histamin. The specific role that many of these compunds play in regulation of the ANS is unclear, but they appear to function as either neurotransmitters or neuromodulator substances.

Receptors.

Receptors for acetylcholine and norepinephrine are located in the plasma mebrane of certain cells. The combination of neurotransmitter and receptor functions as a signal to cells, causing them to respond. Depending on type of cell, the response can be excitatory or inhibitory.

- Cholinergic receptors. Receptors to which ACh binds are called **cholinergic receptors**. They have two major structurally different forms. **Nicotinic receptors** also bind to nicotine, an alkaloid substance found in tobacco; and **muscarinic receptors** also bind to muskarine, an alkaloid extracted from some poisonous mushrooms. Although nicotine and muscarine are not naturally in he human body, they

demonstrate differences in the two classes of cholinergic receptors. Nicotine binds to nicotinic receptors but not to muscarinic receptors, whereas muskarine binds to muscarinic receptors but not to nicotinic receptors. On the other hand, nicotinic and muscarinic receptors are very similar because ACh binds to and activates both types of receptors. The membranes of all postganglionic neurons in autonomic ganglia and the membranes of skeletal muscle cells have nicotinic receptors. The membranes of effector cells that respond to ACh released from postganglionic neurons have muscarinic receptors. ACh binding to nicotinic receptors has an excitatory effect because it results in the direct opening of Na+ channels and the production of action potentials. When ACh binds to muscarinic receptors, the cell´s response is mediated through G proteins. The response is either excitatory or inhibitory depending on the target tissue in which the receptors are found. For example, ACh binds to muscarinic receptors in cardiac muscle, thereby reducing heart rate; and ACh binds to muscarinic receptors in smooth muscle cells of the stomach, thus increasing its rate of contractions.

- Adrenergic receptors. NE or E can bind to **adrenergic receptors**. NE that is released from adrenergic postganglionic neurons of the sympathetic division diffuses across the synapse and binds to receptor molecules within the plasma membranes of effector organs. E and NE released from the adrenal glands and carried to effector organs by the blood can als bind to adrenergic receptors. The response of cells to NE or E binding to adrenergic receptors is mediated through G proteins.

    - Adrenergic receptors are subdivided into two major categories: **alpha receptors** and **beta receptors**, each of which subtypes. The main subtypes for alpha receptors are alpha1 and alpha2 adrenergic receptors and for beta receptors are beta 1 and beta2 adrenergic receptors. Activation of alpha1 and beta1 receptors generally produces a stimulatory response. For example, stimulation of alpha1 receptors in most smooth muscle and beta1 receptors in cardiac muscle results in contraction. The response to the activation of alpha2 and beta2 receptors varies so much with different target cells that no simple generalization about their effecs is appropriate. Activation of alpha2 receptors on platelets promotes blood clotting btut decreases insulin secretion by the pankreas; activation of beta2 receptors stimulates the live to release glucose but causes smooth muscle relaxation.

- The alpha1 and beta1 receptors are typically found in the membranes of target cells in the vicinity of sympathetic nerve terminals. Thus, the sympathetic division controls target cells with alpha1 and beta1 receptors through sympathetic nerves. For example, at rest, stimulation of alpha1 receptors at sympathetic nerve terminals in smooth muscle cells of blood vessels results in partial constriction of the vessels. The sympathetic division regulates blood flow by slightly increasing or decreasing stimulation of the blood vessels. Increased stimulation causes further constriction and reduces blood flow, whereas decreased stimulation results in dilatation and increases blood flow. Control of blood vessel diameter plays an important role in regulation of blood flow and blood pressure.

- The alpha2 and beta2 are typically found in parts of the membrane that are not near nerve terminals releasing NE. These receptors respond to E and N released from the adrenal glands into the blood. During exercise, E and NE bind to beta2 receptors causes blood vesselsdilatation in skeletal muscles.

Much of the regulation of structures by the ANS occurs through autonomic reflexes, but input from the cerebrum, hypothalamus and other areas of the brain allows conscious thoughts and activations, emotions and other CNS activities to influence autonomic functions. Without the regulatory activity of the ANS, an individual has limited ability to maintain homeostasis.

Autonomic reflexes, like other reflexes, involve sensory receptors; sensory, association and motor neurons; and effector cells. For example, **baroreceptors** in the walls of large arteries near the heart detect changes in blood pressure, and sensory neurons transmit information from the baroreceptors through the glosopharyngeal and vagus nerves to the medulla oblongata. Interneurons in the medulla oblongata integrate the information, and action potentials are produced in autonomic neurons that extend to the heart. If baroreceptor detect a change in blood pressure, autonomic reflexes change heart rate, which returs blood pressure to normal. A sudden increase in blood pressure initiates a parasympathetic reflex that inhibits cardiac muscle cells and reduces heart rate, thus bringing blood pressure down toward its normal value. Conversely, a sudden decrease in blood pressure initiates a sympathetic reflex, which stimulates the heart to increase its rate and force of contraction, thus increasing blood pressure. Other autonomic reflexes participate in the regulation of blood pressure.

The brainstem and the spinal cord contain important autonomic reflex centers responsible for maintaining homeostasis. The hypothalamus, however, is in overal control of the ANS. Almost any type of autonomic response can be evoked by stimulating some part of the hypothalamus, which, in turn, stimulates ANS centers in the brainstem or spinal cord. Although there is overlap, stimulation of the posterior hypothalamus produces sympathetic responses, whereas stimulation of the antrior hypothalamus produces parasympathetic response. In addition, the hypothalamus monitors and controls body temperature.

The hypothalamus has connections with the cerebrum and is an important part of the limbic system, which plays an important role in emotions. The hypothalamus integrates thoughts and emotions to produce ANS responses. Pleasant thoughts of a delicious banquet initiate increased secretion by salivary glands and by glands within the stomach and increased smooth muscle contractions within the digestive system. These responses are controlled by parasympathetic neurons. Emotions like anger increase blood pressure by increasing heart rate and constricting blood vessels through sympathetic stimulation.

Generalizations can be made about the function of the ANS of effector organs, but most of the generalizations have exceptions.

- **Stimulatory versus inhibitory effects**. Both divisions of the ANS produce stimulatory and inhibitory effects. For example, the parasympathetic division stimulates contraction of the urinary bladder and inhibits the heart, causing a decrease in heart rate. The sympathetic division causes vasoconstriction by stimulating smooth muscle contraction in blood vessel walls and produces dilation of lung air passageways by inhibiting smooth muscle contraction in the walls of the passageways. Thus, *it is no true* that one division of the ANS is always stimulatory and other is always inhibitory.

- **Dual innervation**. Most organs thar receive autonomic neurons are innervated by both the parasympathetic and the sympathetic divisions. The GIT, heart, urinary bladder and reproductive tract are examples. Dual innervation of organs by both divisions of the ANS is not universal, however. Sweat glands and blood vessels, for example, are innervated by sympatheric neurons almost exclusively. In addition, most structures receiving dual innervation are not regulated equallyby both divisions. For example,

parasympathetic innervation of the GIT is more extensive and exhibits a greater influence than does sympathetic innervation.

- **Opposite effects**. When a *single* structure is innervated by both autonomic divisions, the two divisions usually produce opposite efects on the structure. As a consequence, the ANS is capable of both increasing and decreasing the aktivity of the structure. In he GIT, for example, parasympathetic stimulation increases secretion from the glands, whereas sympathetic stimulation decreases secretion. In a few instances, however, the effect of the two divisions is not cleary opposite. For example, both divisions of the ANS increase salivary secretion: the parasympathetic division initiates the production of a large volume of thin, watery saliva and the sympathetic division causes the secretion of a small volume of viscous saliva.

- **Cooperative effects**. One automomic division can coordinate the activities of *different* structures. For example, parasympathetic division stimulates the pancreas to release digestive enzymes into the small intestine and stimulates contractions to mix the digestive enzymes with food within the small intestine. These responses enhance the digestion and absorption of the food. Booth divisions of the ANS can act together to coordinate the activity of *different* structures. In the male, the parasympathetic division initiates erection of the penis, and the sympathetic division stimulates the release of secretions from male reproductive glands and helps initiate ejaculation in the male reproductive tract.

- **General versus localized effects**. The sympathetic division has a more general effect than the parasympathetic division because activation of the sympathetic division often causes secretion of both E and NE from the adrenal medulla. These hormones circulate in the blood and stimulate effector organs throughout the body. Because circulating E and NE can persist for a few minutes before being broken down, they can also produce an effect for a longer time than the direct stimulation of effector organs by postganglionic sympathetic axons.

The sympathetic division diverges more than the parasympathetic division. Each sympathetic preganglionic neuron synapses with many postganglionic neurons, whereas each parasympathetic preganglionic neuron synapses with about two postganglionic neurons. Consequently, stimulation of sympathetic preganglionic neurons can result in greater stimulation of an effector organ.

Sympathetic stimulation often activates many different kinds of effector organs at the same time as a result of CNS stimulation or E and NE release from the adrenal medulla. It´s possible, however, for the CNS to selectively activate effector organs. For example, vasoconstriction of cutaneous blood vessels in a cold hand is not always associated with an increased heart rate or other responses controlled by the sympathetic division.