Autonomic Nervous System (ANS)

The autonomic nervous system is concerned with regulating visceral activities and maintaining homeostasis. Motor fibers extend to smooth and cardiac muscles and glands. The efferent pathways consist of a two-neuron chain - the preganglionic neuron (myelinated axon), which is a visceral motor neuron, in the CNS to a ganglion, and the postganglionic neuron (unmyelinated axon) in a ganglion to peripheral effectors.

The ANS consists of two divisions, the parasympathetic and the sympathetic, which normally exert antagonistic effects on many of the same target organs.

1. **parasympathetic (craniosacral) division** (resting and digesting system) - active under normal, ordinary (non-stressful) conditions. It conserves body energy and maintains body activities at basal levels. The effects include pupillary constriction, glandular secretion, increased digestive tract mobility, and muscle actions leading to elimination of feces and urine.

   Neurons arise from the brain stem and from the sacral region of the cord.

   Cranial fibers arise in the brain stem nuclei of cranial nerves III (oculomotor), VII (facial), IX (glossopharyngeal), and X (vagus) and synapse in ganglia of the head, thorax, and abdomen.

   Sacral fibers form pelvic splanchnic nerves that innervate the pelvic viscera.

2. **sympathetic (thoracolumbar) division** - activates the body under conditions of stress and emergency and is called the fight-or-flight system.

   Sympathetic responses include dilated pupils, increased heart and respiratory rates, increased blood pressure, dilation of the bronchioles of the lungs, increased blood glucose levels, and sweating.

   During exercise or flight, sympathetic vasoconstriction shunts blood from the skin and digestive viscera to the heart, brain, and skeletal muscles.

Two neurotransmitters are involved in the pathway - acetylcholine (ACh) and norepinephrine (NE). On the basis of the neurotransmitter released, the fibers are classified as cholinergic (ACh) or adrenergic (NE).

a. ACh is released by all preganglionic fibers (parasympathetic and sympathetic) and all parasympathetic postganglionic fibers at synapses with their effectors.
b. NE is released by all sympathetic postganglionic fibers except those serving the sweat glands of the skin, some blood vessels within the skeletal muscles, and the external genitalia (those fibers secrete ACh).

Most visceral organs are innervated by both divisions (parasympathetic and sympathetic). They interact in various ways but usually exert a dynamic antagonism which allows visceral activity to be very precisely controlled. One division or the other usually exerts the predominant effects in given circumstances. Antagonistic interactions mainly involve the heart, respiratory system, and gastrointestinal organs. Sympathetic activity increases heart and respiratory system activity and depresses gastrointestinal activity (peristalsis). Parasympathetic activity reverses these effects.

Most blood vessels are innervated only by sympathetic fibers and exhibit vasomotor tone (in a continuous partial state of contraction).

Parasympathetic activity dominates the heart and smooth muscles of the gastrointestinal and urinary tracts (which normally exhibit parasympathetic tone) and glands. When faster blood delivery is needed, these fibers deliver impulses more rapidly, causing blood vessels to constrict and blood pressure to rise. When blood pressure is to be decreased, the vessels are allowed to dilate.

The parasympathetic division prevents unnecessary heart acceleration and also determines the normal activity levels of the digestive and urinary tracts. The sympathetic division can override these parasympathetic effects during times of stress.

Except for the adrenal and sweat glands of the skin, most glands are activated by parasympathetic fibers.

The two ANS divisions exert cooperative effects on the external genitalia. Parasympathetic stimulation causes vasodilation of blood vessels in the external genitalia and is responsible for erection of the male penis or female clitoris during sexual excitement. Sympathetic stimulation then causes ejaculation of semen by the male or reflex peristalsis of a female’s vagina.

Roles unique to the sympathetic division are blood pressure regulation, shunting of blood in the vascular system, thermoregulatory responses, stimulation of renin release by the kidneys, and metabolic effects. The adrenal medulla, the sweat glands and arrector pili muscles of the skin, the kidneys, and most blood vessels receive only sympathetic fibers.

In thermoregulatory responses to heat, when the systemic body temperature is elevated, sympathetic nerves effect widespread dilation of the skin vascularization, allowing the skin to become flushed with warm blood. It also activates the sweat glands to
help cool the body. When body temperature is falling, skin blood vessels are constricted, and blood is restricted to deeper, more vital organs.

Sympathetic impulses stimulate the kidneys to release renin, an enzyme that promotes an increase in blood pressure.

Through both direct neural stimulation and release of adrenal medullary hormones, the sympathetic division promotes a number of metabolic effects not reversed by parasympathetic activity.

1. enhances metabolic rate of body cells
2. increases blood glucose levels
3. mobilizes fats to be used as fuels
4. increases mental alertness by way of the reticular activating system (RAS) of the brain stem

Activation of the sympathetic division causes widespread, long-lasting mobilization of the fight-or-flight response. Parasympathetic effects are highly localized and short-lived.

Regulation of Autonomic Function

Autonomic function is controlled at several levels from centers in the hypothalamus, brain stem and spinal cord.

1. Reflex activity is mediated by the spinal cord and brain stem (medullary) centers.

   The reticular formation of the brain stem appear to exert the most direct influence over autonomic functions.
   Many autonomic responses can be elicited by stimulating motor centers in the medulla that reflexively regulate heart rate (cardiac centers), blood vessel diameter (vasomotor center), respiration (respiratory centers), and many types of gastrointestinal activity (peristalsis). Most sensory impulses involved in eliciting these autonomic reflexes are delivered to the brain stem by way of vagus nerve afferents.
   The pons also contains respiratory centers that interact with those of the medulla, and there are midbrain centers (oculomotor nuclei) concerned with the size of the eye pupils.

2. Hypothalamic integration centers interact with both higher and lower centers to orchestrate autonomic, somatic, and endocrine responses. Medial and anterior regions direct parasympathetic functions, whereas lateral and posterior areas direct sympathetic functions. These centers exert their effects by way of relays through the reticular formation, which in turn influences the preganglionic ANS motor neurons in the spinal cord and brain.
The hypothalamus contains centers that coordinate heart activity, blood pressure, body temperature, water balance and endocrine activity, and it contains centers that help mediate various emotional states (rage, pleasure) and biological drives (thirst, hunger, sex).

The emotional responses of the limbic lobe of the cerebrum to danger and stress signals the hypothalamus to activate the sympathetic system to fight-or-flight states.

3. **Cortical centers** influence autonomic functioning by way of connections with the limbic system; conscious controls of autonomic function are possible, as illustrated by meditation and biofeedback techniques.