Routine adjustments in physiological systems are made by the autonomic nervous system (ANS).

- The ANS regulates body temperature and coordinates cardiovascular, respiratory, digestive, excretory, and reproductive functions.
- It adjusts internal water, electrolyte, nutrient, and dissolved-gas concentrations in body fluids outside our conscious awareness.
A Comparison of the Somatic and Autonomic Nervous Systems

- The autonomic nervous system differs from the somatic nervous system in the arrangement of the neurons connecting the central nervous system to the effector organs.

- **Visceral motor neurons** in the CNS, known as *preganglionic neurons*, send their axons, called preganglionic fibers, to synapse on *ganglionic neurons*, whose cell bodies are located outside the CNS, in *autonomic ganglia*.
  - Axons from the ganglionic neurons are called postganglionic fibers because they carry impulses away from the ganglion.
  - Postganglionic fibers innervate peripheral tissues and organs, such as cardiac and smooth muscle, adipose tissue, and glands.
A Comparison of the Somatic and Autonomic Nervous Systems

- Subdivision of the ANS
  - Sympathetic division
    - Generally predominant under resting conditions
  - Parasympathetic division
    - Generally kicks in during times of exertion, stress, or emergency
- Both divisions affect their target organs through the release of neurotransmitters by postganglionic fibers
Figure 17.1a Components and Anatomic Subdivisions of the ANS (Functional Components)
A Comparison of the Somatic and Autonomic Nervous Systems

Figure 17.1b Components and Anatomic Subdivisions of the ANS (Anatomical Subdivisions)

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The Sympathetic Division

The sympathetic division consists of the following:

- **Preganglionic neurons** located between segments of the spinal cord
- Two types of ganglionic neurons in ganglia near the vertebral column
- *Sympathetic chain ganglia*, also called paravertebral, or lateral ganglia
- *Collateral ganglia*, also known as prevertebral ganglia
- Specialized neurons in the interior of the suprarenal gland
Figure 17.2 Organization of the Sympathetic Division of the ANS
The Sympathetic Division

(a) SYMPATHETIC CHAIN GANGLIA

Major effects produced by sympathetic postganglionic fibers in spinal nerves:
- Constriction of cutaneous blood vessels, reduction in circulation to the skin and to most other organs in the body wall
- Acceleration of blood flow to skeletal muscles and brain
- Stimulation of energy production and use by skeletal muscle tissue
- Release of stored lipids from subcutaneous adipose tissue
- Stimulation of secretion by sweat glands
- Stimulation of arrector pili
- Dilation of the pupils and focusing for distant objects

Major effects produced by postganglionic fibers entering the thoracic cavity in sympathetic nerves:
- Acceleration of heart rate and increasing the strength of cardiac contractions
- Dilation of respiratory passageways

Figure 17.3a Sympathetic Pathways and Their General Functions (Sympathetic Chain Ganglia)
The Sympathetic Division

(b) COLLATERAL GANGLIA

Major effects produced by preganglionic fibers innervating the collateral ganglia:
- Constriction of small arteries and reduction in the flow of blood to visceral organs
- Decrease in the activity of digestive glands and organs
- Stimulation of the release of glucose from glycogen reserves in the liver
- Stimulation of the release of lipids from adipose tissue
- Relaxation of the smooth muscle in the wall of the urinary bladder
- Reduction of the rate of urine formation at the kidneys
- Control of some aspects of sexual function, such as ejaculation in males

Figure 17.3b Sympathetic Pathways and Their General Functions (Collateral Ganglia)
Figure 17.3c Sympathetic Pathways and Their General Functions (The Suprarenal Medullae)

The Sympathetic Division

(c) THE SUPRARENAL MEDULLAE

Major effect produced by preganglionic fibers innervating the suprarenal medullae:
- Release of epinephrine and norepinephrine into the general circulation
Figure 17.4 Anatomical Distribution of Sympathetic Postganglionic Fibers
Figure 17.5 Suprarenal Medulla
Figure 17.6 Sympathetic Postganglionic Nerve Endings
In summary:

- The sympathetic division of the ANS includes two sympathetic chains, three collateral ganglia, and two suprarenal medullae.
- Preganglionic fibers are short because the ganglia are close to the spinal cord.
- The sympathetic division shows extensive divergence.
- All preganglionic neurons release ACh at their synapses with ganglionic neurons.
- The effector response depends on the function of the membrane receptor.
Innervation Patterns
The Parasympathetic Division

The parasympathetic division of the ANS includes the following:

- Preganglionic neurons located in the brain stem and in sacral segments of the spinal cord
- Ganglionic neurons in peripheral ganglia located very close to—or even within—the target zones
  - As a result, effects are more specific and localized than those of sympathetic division
Figure 17.7 Organization of the Parasympathetic Division of the ANS
Figure 17.8 Anatomical Distribution of the Parasympathetic Output
The Parasympathetic Division

- General functions of the parasympathetic division:
  - Constriction of the pupils to restrict the amount of light entering the eyes; assists in focusing on nearby objects
  - Secretion by digestive glands, including salivary glands, gastric glands, duodenal and other intestinal glands, the pancreas, and the liver
  - Secretion of hormones that promote nutrient absorption by peripheral cells
  - Increased smooth muscle activity along the digestive tract
  - Stimulation and coordination of defecation
The Parasympathetic Division

- General functions of the parasympathetic division (continued)
  - Contraction of the urinary bladder during urination
  - Constriction of the respiratory passageways
  - Reduction in heart rate and force of contraction
  - Sexual arousal and stimulation of sexual glands in both sexes
In summary:

- The parasympathetic division includes visceral motor nuclei in the brain stem associated with four cranial nerves (III, VII, IX, and X).
- The ganglionic neurons are situated in intramural ganglia or in ganglia closely associated with their target organs.
- The parasympathetic division innervates structures in the head and organs in the thoracic and abdominopelvic cavities.
- All parasympathetic neurons are cholinergic.
- The effects of parasympathetic stimulation are usually brief and restricted to specific organs and sites.
Innervation Patterns
Relationships between the Sympathetic and Parasympathetic Divisions

- The divisions of the autonomic nervous system are not isolated.
- Sympathetic and parasympathetic divisions work together:
  - Dual innervation
  - Peripheral autonomic plexuses
Relationships between the Sympathetic and Parasympathetic Divisions

Figure 17.9 The Peripheral Autonomic Plexuses

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Figure 17.10 A Comparison of the Sympathetic and Parasympathetic Divisions
### Relationships between the Sympathetic and Parasympathetic Divisions

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sympathetic Division</th>
<th>Parasympathetic Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of CNS Visceral Motor Neurons</td>
<td>Lateral gray horns of spinal segments T1-L2</td>
<td>Brain stem and spinal segments S2-S4</td>
</tr>
<tr>
<td>Location of PNS Ganglia</td>
<td>Paravertebral sympathetic chain; collateral ganglia (celiac, superior mesenteric, and inferior mesenteric) located anterior and lateral to the descending aorta</td>
<td>Intramural or terminal</td>
</tr>
<tr>
<td>Preganglionic Fibers:</td>
<td>Relatively short, myelinated Acetylcholine</td>
<td>Relatively long, myelinated Acetylcholine</td>
</tr>
<tr>
<td>Length</td>
<td></td>
<td>Relatively short, unmyelinated</td>
</tr>
<tr>
<td>Neurotransmitter released</td>
<td></td>
<td>Usually norepinephrine</td>
</tr>
<tr>
<td>Postganglionic Fibers:</td>
<td>Relatively long, unmyelinated</td>
<td>Always acetylcholine</td>
</tr>
<tr>
<td>Length</td>
<td>Usually norepinephrine</td>
<td>Neuroeffector junctions that release transmitter to special receptor surface</td>
</tr>
<tr>
<td>Neuroeffector Junction</td>
<td>Varicosities and enlarged terminal knobs that release transmitter near target cells</td>
<td></td>
</tr>
<tr>
<td>Degree of Divergence from CNS to Ganglion Cells</td>
<td>Approximately 1:32 Stimulate metabolism, increase alertness, prepare for emergency “fight or flight” response</td>
<td>Approximately 1:6 Promote relaxation, nutrient uptake, energy storage (“rest and repose”)</td>
</tr>
<tr>
<td>General Functions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 17.1 A Comparison of the Sympathetic and Parasympathetic Divisions of the ANS**
Integration and Control of Autonomic Functions

The ANS is organized into a series of interacting levels

- Visceral reflexes
  - Short reflexes
  - Long reflexes
- Enteric nervous system (ENS)
- Higher levels of autonomic control
  - Hypothalamus
Figure 17.11 Visceral Reflexes
## TABLE 17.2 Representative Visceral Reflexes

<table>
<thead>
<tr>
<th>Reflex</th>
<th>Stimulus</th>
<th>Response</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARASYMPATHETIC REFLEXES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastric and intestinal reflexes  (see Chapter 25)</td>
<td>Pressure and physical contact with food materials</td>
<td>Smooth muscle contractions that propel food materials and mix food with secretions</td>
<td>Mediated by the vagus nerve (N X)</td>
</tr>
<tr>
<td>Defecation (see Chapter 25)</td>
<td>Distention of rectum</td>
<td>Relaxation of internal anal sphincter</td>
<td>Requires voluntary relaxation of external anal sphincter</td>
</tr>
<tr>
<td>Urination (see Chapter 26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct light and Consensual light reflexes (see Chapter 18)</td>
<td>Distention of urinary bladder</td>
<td>Contraction of urinary bladder walls, relaxation of internal urethral sphincter</td>
<td>Requires voluntary relaxation of external urethral sphincter</td>
</tr>
<tr>
<td>Swallowing reflex (see Chapter 25)</td>
<td>Bright light shining in eye(s)</td>
<td>Constriction of pupils of both eyes</td>
<td></td>
</tr>
<tr>
<td>Vomiting reflex (see Chapter 25)</td>
<td>Movement of food and drink into superior pharynx</td>
<td>Smooth muscle and skeletal muscle contractions</td>
<td>Coordinated by swallowing center in medulla oblongata</td>
</tr>
<tr>
<td>Coughing reflex (see Chapter 24)</td>
<td>Irritation of digestive tract lining</td>
<td>Reversal of normal smooth muscle action to eject contents</td>
<td>Coordinated by vomiting center in medulla oblongata</td>
</tr>
<tr>
<td>Baroreceptor reflex (see Chapter 21)</td>
<td>Irritation of respiratory tract lining</td>
<td>Sudden explosive ejection of air</td>
<td>Coordinated by coughing center in medulla oblongata</td>
</tr>
<tr>
<td>Sexual arousal (see Chapter 27)</td>
<td>Sudden rise in blood pressure in carotid artery</td>
<td>Reduction in heart rate and force of contraction</td>
<td>Coordinated in cardiac center in medulla oblongata</td>
</tr>
<tr>
<td>Baroreceptor reflex (see Chapter 21)</td>
<td>Erotic stimuli (visual or tactile)</td>
<td>Increased glandular secretions, sensitivity</td>
<td></td>
</tr>
<tr>
<td>SYMPATHETIC REFLEXES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardioacceleratory reflex (see Chapter 21)</td>
<td>Sudden decline in blood pressure in carotid artery</td>
<td>Increase in heart rate and force of contraction</td>
<td>Coordinated in cardiac center in medulla oblongata</td>
</tr>
<tr>
<td>Vasomotor reflexes (see Chapter 22)</td>
<td>Changes in blood pressure in major arteries</td>
<td>Changes in diameter of peripheral blood vessels</td>
<td>Coordinated in vasomotor center in medulla oblongata</td>
</tr>
<tr>
<td>Pupillary reflex (see Chapter 18)</td>
<td>Low light level reaching visual receptors</td>
<td>Dilation of pupil</td>
<td></td>
</tr>
<tr>
<td>Emission and ejaculation (in males) (see Chapter 27)</td>
<td>Erotic stimuli (tactile)</td>
<td>Contraction of seminal glands and prostate, and skeletal muscle contractions that eject semen</td>
<td>Ejaculation involves the contractions of the bulbospongiosus muscles</td>
</tr>
</tbody>
</table>
Figure 17.12 Levels of Autonomic Control