

Autonomic Nervous System (ANS)

- The ANS consists of motor neurons that:
 - Innervate smooth and cardiac muscle and glands
 - Make adjustments to ensure optimal support for body activities
 - Operate via subconscious control
 - Have viscera as most of their effectors

ANS Versus Somatic Nervous System (SNS)

- The ANS differs from the SNS in the following three areas
 - Effectors
 - Efferent pathways
 - Target organ responses

Effectors

- The effectors of the SNS are skeletal muscles
- The effectors of the ANS are cardiac muscle, smooth muscle, and glands

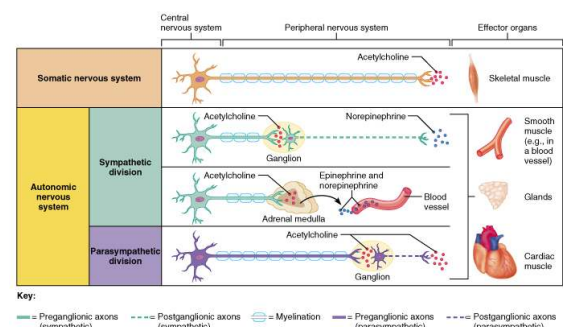
Efferent Pathways

- Heavily myelinated axons of the somatic motor neurons extend from the CNS to the effector
- Axons of the ANS are a two-neuron chain
 - The preganglionic (first) neuron with a lightly myelinated axon
 - The ganglionic (second) neuron that extends to an effector organ

Neurotransmitter Effects

- All somatic motor neurons release ACh, which has an excitatory effect
- In the ANS:
 - Preganglionic fibers release ACh
 - Postganglionic fibers release norepinephrine or ACh and the effect is either stimulatory or inhibitory
 - ANS effect on the target organ is dependent upon the neurotransmitter released and the receptor type of the effector

Neurotransmitter Effects



Divisions of the ANS

- The two divisions of the ANS are the sympathetic and parasympathetic
- The sympathetic mobilizes the body during extreme situations
- The parasympathetic performs maintenance activities and conserves body energy
- The two divisions counterbalance each other's activity

Autonomic Nervous System

Dr. Salah A. Martin

7

Role of the Parasympathetic Division

- Concerned with keeping body energy use low
- Involves the **D** activities – digestion, defecation, and diuresis
- Its activity is illustrated in a person who relaxes after a meal
 - Blood pressure, heart rate, and respiratory rates are low
 - Gastrointestinal tract activity is high
 - The skin is warm and the pupils are constricted

Autonomic Nervous System

Dr. Salah A. Martin

8

Role of the Sympathetic Division

- The sympathetic division is the “fight-or-flight” system
- Involves **E** activities – exercise, excitement, emergency, and embarrassment
- Promotes adjustments during exercise – blood flow to organs is reduced, flow to muscles is increased
- Its activity is illustrated by a person who is threatened
 - Heart rate increases, and breathing is rapid and deep
 - The skin is cold and sweaty, and the pupils dilate

Autonomic Nervous System

Dr. Salah A. Martin

9

Anatomy of ANS

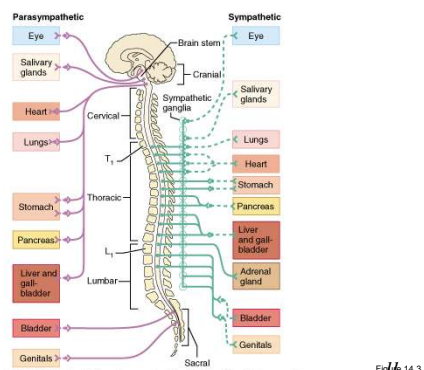
Division	Origin of Fibers	Length of Fibers	Location of Ganglia
Sympathetic	Thoracolumbar region of the spinal cord	Short preganglionic and long postganglionic	Close to the spinal cord
Parasympathetic	Brain and sacral spinal cord	Long preganglionic and short postganglionic	In the visceral effector organs

Autonomic Nervous System

Dr. Salah A. Martin

10

Anatomy of ANS



Autonomic Nervous System

Figure 14.3

Parasympathetic Division Outflow

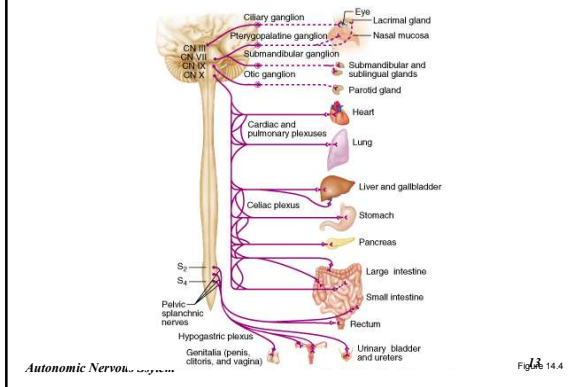
Cranial Outflow	Cranial Nerve	Ganglion	Effector Organ(s)
	Oculomotor (III)	Ciliary	Eye
	Facial (VII)	Pterygopalatine Submandibular	Salivary, nasal, and lacrimal glands
	Glossopharyngeal (IX)	Otic	Parotid salivary glands
	Vagus (X)	Located within the walls of target organs	Heart, lungs, and most visceral organs
Sacral Outflow	S ₂ -S ₄	Located within the walls of the target organs	Large intestine, urinary bladder, ureters, and reproductive organs

Autonomic Nervous System

Dr. Salah A. Martin

12

Parasympathetic Division Outflow



Sympathetic Outflow

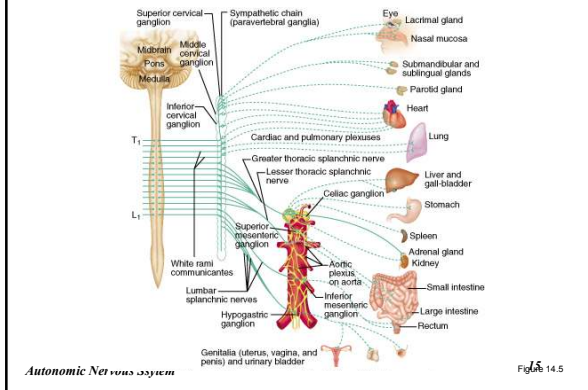
- From nerves T₁ through L₂
- Sympathetic neurons produce the lateral horns of the spinal cord
- Preganglionic fibers pass through the white rami communicantes and synapse in the paravertebral ganglia
- Fibers from T₅-L₂ form splanchnic nerves and synapse in collateral ganglia
- Postganglionic fibers innervate the numerous organs of the body

Autonomic Nervous System

Dr. Salah A. Martin

14

Sympathetic Outflow



Sympathetic Trunks and Pathways

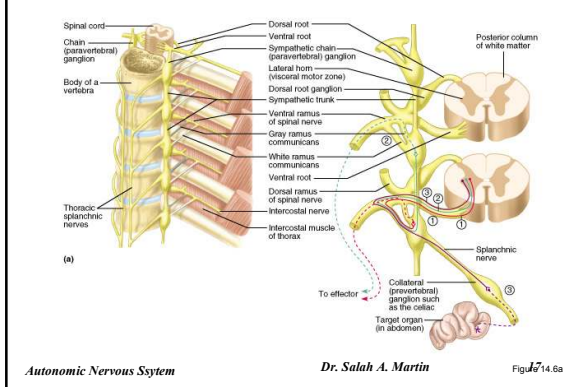
- Preganglionic fibers pass through white rami communicantes and enter paravertebral ganglia
- The paravertebral ganglia form part of the sympathetic chain
- Typically there are 23 ganglia – 3 cervical, 11 thoracic, 4 lumbar, 4 sacral, and 1 coccygeal

Autonomic Nervous System

Dr. Salah A. Martin

16

Sympathetic Trunks and Pathways

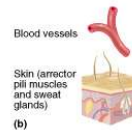


Autonomic Nervous System

Dr. Salah A. Martin

Sympathetic Trunks and Pathways

- A preganglionic fiber follows one of three pathways upon entering the paravertebral ganglia:
 - Synapse with the ganglionic neuron within the same ganglion
 - Ascend or descend the sympathetic chain to synapse in another chain ganglion
 - Pass through the chain ganglion and emerge without synapsing



Autonomic Nervous System

Dr. Salah A. Martin

Figure 14.6b

Pathways with Synapses in a Chain Ganglion

- Postganglionic axons enter the ventral rami via the gray rami communicantes
- These fibers innervate sweat glands and arrector pili muscles
- Rami communicantes are associated only with the sympathetic division

Autonomic Nervous System

Dr. Salah A. Martin

19

Pathways to the Head

- Preganglionic fibers emerge from T₁–T₄ and synapse in the superior cervical ganglion
- These fibers:
 - Serve the skin and blood vessels of the head
 - Stimulate dilator muscles of the iris
 - Inhibit nasal and salivary glands

Autonomic Nervous System

Dr. Salah A. Martin

20

Pathways to the Thorax

- Preganglionic fibers emerge from T₁–T₆ and synapse in the cervical chain ganglia
- Postganglionic fibers emerge from the middle and inferior cervical ganglia and enter nerves C₄–C₈
- These fibers innervate the heart via the cardiac plexus, as well as innervating the thyroid and the skin
- Other T₁–T₆ preganglionic fibers synapse in the nearest chain ganglia
- Postganglionic fibers directly serve the heart, aorta, lungs, and esophagus

Autonomic Nervous System

Dr. Salah A. Martin

21

Pathways with Synapses in a Collateral Ganglion

- These fibers (T₅–L₂) leave the sympathetic chain without synapsing
- They form thoracic, lumbar, and sacral splanchnic nerves
- Their ganglia include the celiac, the superior and inferior mesenterics, and the hypogastric

Autonomic Nervous System

Dr. Salah A. Martin

22

Pathways to the Abdomen

- Sympathetic nerves innervating the abdomen have preganglionic fibers from T₅–L₂
 - They travel through the thoracic splanchnic nerves and synapse at the celiac and superior mesenteric ganglia
- Postganglionic fibers serve the stomach, intestines, liver, spleen, and kidneys

Autonomic Nervous System

Dr. Salah A. Martin

23

Pathways to the Pelvis

- Preganglionic fibers originate from T₁₀–L₂
- Most travel via the lumbar and sacral splanchnic nerves to the inferior mesenteric and hypogastric ganglia
- Postganglionic fibers serve the distal half of the large intestine, the urinary bladder, and the reproductive organs

Autonomic Nervous System

Dr. Salah A. Martin

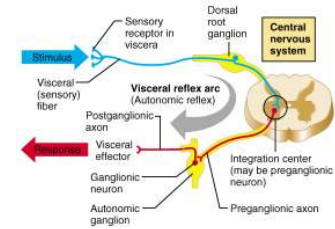
24

Pathways with Synapses in the Adrenal Medulla

- Fibers of the thoracic splanchnic nerve pass directly to the adrenal medulla
- Upon stimulation, medullary cells secrete norepinephrine and epinephrine into the blood

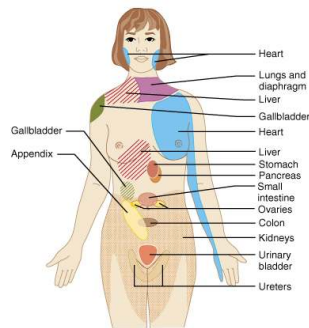
Visceral Reflexes

- Visceral reflexes have the same elements as somatic reflexes
- They are always polysynaptic pathways
- Afferent fibers are found in spinal and autonomic nerves



Referred Pain

- Pain arising from the viscera but is perceived as somatic in origin
- This may be due to the fact that visceral pain afferents travel along the same pathways as somatic pain fibers



Neurotransmitters and Receptors

- Acetylcholine (ACh) and norepinephrine (NE) are the two major neurotransmitters of the ANS
- ACh is released by all preganglionic axons and all parasympathetic postganglionic axons
- Cholinergic fibers – ACh-releasing fibers
- Adrenergic fibers – sympathetic postganglionic axons that release NE
- Neurotransmitter effects can be excitatory or inhibitory depending upon the receptor type

Cholinergic Receptors

- The two types of receptors that bind ACh are nicotinic and muscarinic
- These are named after drugs that bind them and mimic ACh effects

Nicotinic Receptors

- Nicotinic receptors are found on:
 - Motor end plates (somatic targets)
 - All ganglionic neurons of both sympathetic and parasympathetic divisions
 - The hormone-producing cells of the adrenal medulla
- The effect of ACh binding to nicotinic receptors is always stimulatory

Muscarinic Receptors

- Muscarinic receptors occur on all effector cells stimulated by postganglionic cholinergic fibers
- The effect of ACh binding:
 - Can be either inhibitory or excitatory
 - Depends on the receptor type of the target organ

Autonomic Nervous System

Dr. Salah A. Martin

31

Adrenergic Receptors

- The two types of adrenergic receptors are alpha and beta
- Each type has two or three subclasses (α_1 , α_2 , β_1 , β_2 , β_3)
- Effects of NE binding to:
 - α receptors is generally stimulatory
 - β receptors is generally inhibitory
- A notable exception – NE binding to β receptors of the heart is stimulatory

Autonomic Nervous System

Dr. Salah A. Martin

32

Effects of Drugs

- Atropine – blocks parasympathetic effects
- Neostigmine – inhibits acetylcholinesterase and is used to treat myasthenia gravis
- Tricyclic antidepressants – prolong the activity of NE on postsynaptic membranes
- Over-the-counter drugs for colds, allergies, and nasal congestion – stimulate α -adrenergic receptors
- Beta-blockers – attach mainly to β_1 receptors and reduce heart rate and prevent arrhythmias

Autonomic Nervous System

Dr. Salah A. Martin

33

Interactions of the Autonomic Divisions

- Most visceral organs are innervated by both sympathetic and parasympathetic fibers
- This results in dynamic antagonisms that precisely control visceral activity
- Sympathetic fibers increase heart and respiratory rates, and inhibit digestion and elimination
- Parasympathetic fibers decrease heart and respiratory rates, and allow for digestion and the discarding of wastes

Autonomic Nervous System

Dr. Salah A. Martin

34

Sympathetic Tone

- The sympathetic division controls blood pressure and keeps the blood vessels in a continual state of partial constriction
- This sympathetic tone (vasomotor tone):
 - Constricts blood vessels and causes blood pressure to rise as needed
 - Prompts vessels to dilate if blood pressure is to be decreased
- Alpha-blocker drugs interfere with vasomotor fibers and are used to treat hypertension

Autonomic Nervous System

Dr. Salah A. Martin

35

Parasympathetic Tone

- Parasympathetic tone:
 - Slows the heart
 - Dictates normal activity levels of the digestive and urinary systems
- The sympathetic division can override these effects during times of stress
- Drugs that block parasympathetic responses increase heart rate and block fecal and urinary retention

Autonomic Nervous System

Dr. Salah A. Martin

36

Cooperative Effects

- ANS cooperation is best seen in control of the external genitalia
- Parasympathetic fibers cause vasodilation and are responsible for erection of the penis and clitoris
- Sympathetic fibers cause ejaculation of semen in males and reflex peristalsis in females

Autonomic Nervous System

Dr. Salah A. Martin

37

Unique Roles of the Sympathetic Division

- Regulates many functions not subject to parasympathetic influence
- These include the activity of the adrenal medulla, sweat glands, arrector pili muscles, kidneys, and most blood vessels
- The sympathetic division controls:
 - Thermoregulatory responses to heat
 - Release of renin from the kidneys
 - Metabolic effects

Autonomic Nervous System

Dr. Salah A. Martin

38

Thermoregulatory Responses to Heat

- Applying heat to the skin causes reflex dilation of blood vessels
- Systemic body temperature elevation results in widespread dilation of blood vessels
- This dilation brings warm blood to the surface and activates sweat glands to cool the body
- When temperature falls, blood vessels constrict and blood is retained in deeper vital organs

Autonomic Nervous System

Dr. Salah A. Martin

39

Release of Renin

- Sympathetic impulses activate the kidneys to release renin
- Renin is an enzyme that promotes increased blood pressure

Autonomic Nervous System

Dr. Salah A. Martin

40

Metabolic Effects

- The sympathetic division promotes metabolic effects that are not reversed by the parasympathetic division
 - Increases the metabolic rate of body cells
 - Raises blood glucose levels
 - Mobilizes fat as a food source
 - Stimulates the reticular activating system (RAS) of the brain, increasing mental alertness

Autonomic Nervous System

Dr. Salah A. Martin

41

Localized Versus Diffuse Effects

- The parasympathetic division exerts short-lived, highly localized control
- The sympathetic division exerts long-lasting, diffuse effects

Autonomic Nervous System

Dr. Salah A. Martin

42

Effects of Sympathetic Activation

- Sympathetic activation is long-lasting because NE:
 - Is inactivated more slowly than ACh
 - Is an indirectly acting neurotransmitter, using a second-messenger system
 - NE and epinephrine are released into the blood and remain there until destroyed by the liver

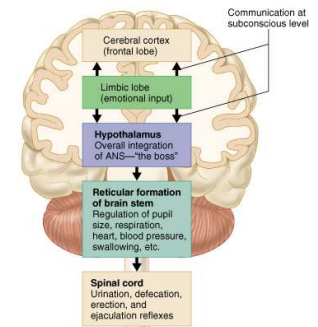
Autonomic Nervous System

Dr. Salah A. Martin

43

Levels of ANS Control

- The hypothalamus is the main integration center of ANS activity
- Subconscious cerebral input via limbic lobe connections influences hypothalamic function



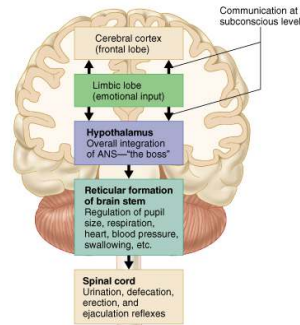
Dr. Salah A. Martin

Figure 14.9

Autonomic Nervous System

Levels of ANS Control

- Other controls come from the cerebral cortex, the reticular formation, and the spinal cord



Autonomic Nervous System

Dr. Salah A. Martin

Figure 14.9

Hypothalamic Control

- Centers of the hypothalamus control:
 - Heart activity and blood pressure
 - Body temperature, water balance, and endocrine activity
 - Emotional states (rage, pleasure) and biological drives (hunger, thirst, sex)
 - Reactions to fear and the “fight-or-flight” response

Autonomic Nervous System

Dr. Salah A. Martin

46