

Autonomic Nervous System, Arteries, Nerves and Clinical Terms

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Introduction, Autonomic Nervous System, and Sympathetic Nervous System

Introduction

The **autonomic nervous system (ANS)** is the involuntary part of the nervous system that regulates the functions of **smooth muscles, cardiac muscle, and glands**.

Unlike the somatic system (which governs voluntary skeletal muscle activity), the ANS functions **automatically and subconsciously**, maintaining the body's internal environment in a state of dynamic balance — **homeostasis**.

Autonomic Nervous System (ANS)

The ANS is divided into two complementary divisions:

1. **Sympathetic (thoracolumbar) division**
2. **Parasympathetic (craniosacral) division**

Both divisions work in opposition but often in coordinated balance — one stimulating, the other inhibiting — to maintain internal stability.

Functional Organization

Each visceral efferent pathway involves **two neurons**:

- **Preganglionic neuron:** Cell body lies in the **central nervous system (CNS)** — brainstem or spinal cord.

- **Postganglionic neuron:** Cell body lies in an **autonomic ganglion** outside the CNS; its axon ends in the target organ (gland, smooth or cardiac muscle).

General Functions of ANS

- **Heart:** Regulates rate and force of contraction.
 - **Lungs:** Controls bronchial diameter.
 - **Gastrointestinal tract:** Modulates motility and secretions.
 - **Pupil:** Controls constriction and dilation.
 - **Blood vessels:** Governs vasoconstriction and vasodilation.
 - **Glands:** Stimulates or inhibits secretion depending on the division activated.
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Sympathetic Nervous System

Also known as the **thoracolumbar outflow**, the sympathetic system prepares the body for “**fight, flight, or fright**” reactions.

Its main function is to **mobilize energy resources** and **increase alertness** in emergencies or stress.

Origin

- **Preganglionic neurons** arise from the **lateral horn (intermediolateral column)** of the **spinal cord** segments **T1 to L2**.
 - Axons leave the spinal cord through the **anterior roots**, join the **spinal nerve**, and pass into the **white rami communicantes** to reach the **sympathetic chain (paravertebral ganglia)**.
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Structure of the Sympathetic System

1. Sympathetic Chain (Paravertebral Ganglia):

- A paired vertical chain of ganglia on each side of the vertebral column, extending from the **base of skull to coccyx**.
- The two chains join in front of the coccyx to form the **ganglion impar**.
- Each chain has **3 cervical, 11 thoracic, 4 lumbar, 4 sacral, and 1 coccygeal** ganglion (variations may occur).

2. Connections to Spinal Nerves:

- **White rami communicantes:** Carry **preganglionic fibers** from spinal nerves **T1–L2** into the sympathetic chain.
- **Gray rami communicantes:** Carry **postganglionic fibers** from the sympathetic chain back to all spinal nerves for distribution to **blood vessels, sweat glands, and arrector pili muscles**.

3. Distribution of Sympathetic Fibers:

- **Somatic distribution:** To skin, blood vessels, and sweat glands of body wall and limbs.
- **Visceral distribution:** To thoracic, abdominal, and pelvic organs through **splanchnic nerves**.

Pathways of Sympathetic Fibers

A preganglionic fiber entering the sympathetic chain may:

1. **Synapse** in the ganglion at the same level, and the postganglionic fiber exits via a gray ramus to a spinal nerve.
2. **Ascend or descend** to synapse in a higher or lower ganglion within the chain.
3. **Pass through** the chain without synapsing, forming **splanchnic nerves**, which synapse in **prevertebral (collateral) ganglia** such as:
 - **Celiac ganglion**
 - **Superior mesenteric ganglion**
 - **Inferior mesenteric ganglion**

These postganglionic fibers then supply abdominal and pelvic viscera.

Major Sympathetic Pathways and Effects

TARGET ORGAN	SPINAL ORIGIN	EFFECT
Pupil (via superior cervical ganglion)	T1	Dilatation (mydriasis)
Heart	T1–T5	Increases rate and force
Lungs	T2–T5	Bronchodilation
Blood vessels (skin, skeletal muscle)	T1–L2	Vasoconstriction or vasodilation
Sweat glands	T1–L2	Secretion (only sympathetic fibers are cholinergic)

TARGET ORGAN	SPINAL ORIGIN	EFFECT
Abdominal viscera	T6–L2	Inhibits motility, contracts sphincters
Adrenal medulla	T8–L1	Secretes adrenaline and noradrenaline

Neurotransmitters

- **Preganglionic fibers:** Release **acetylcholine (ACh)**.
- **Postganglionic fibers:** Usually release **noradrenaline (norepinephrine)** (except to sweat glands and some blood vessels, where ACh is used).

Clinical Correlations

1. Horner's Syndrome:

- Results from interruption of sympathetic supply to the head and neck.
- Features: **Ptosis (drooping eyelid)**, **miosis (pupil constriction)**, **anhidrosis (no sweating)**, and **enophthalmos (sunken eyeball)**.
- Common causes: **Pancoast tumor**, **cervical rib**, or **neck trauma**.

2. Raynaud's Disease:

- Episodic constriction of digital arteries due to excessive sympathetic vasoconstriction ? pallor and pain in fingers.

3. Sympathectomy:

- Surgical interruption of sympathetic chain used to treat **hyperhidrosis** (excessive sweating) or **vasospastic disorders**.

Thoracic Part of Sympathetic Trunk, Nerve Supply of Heart, and Nerve Supply of Lungs

Thoracic Part of Sympathetic Trunk

The **thoracic sympathetic trunk** is the continuation of the cervical part above and the lumbar part below. It lies in the **posterior mediastinum**, forming part of the **autonomic control pathway** for thoracic and abdominal viscera.

Position and Extent

- Lies along the **heads of ribs** on each side of the vertebral column.
 - Extends from the **neck of the first rib** (continuing from the inferior cervical ganglion) to the **body of the last thoracic vertebra (T12)**.
 - It passes behind the **medial arcuate ligament** of the diaphragm to become continuous with the **lumbar sympathetic trunk**.
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Number of Ganglia

- Usually **11 thoracic ganglia** are present (sometimes 10 due to fusion of the first with the inferior cervical ganglion to form the **stellate ganglion**).
- Each ganglion is connected to the corresponding **intercostal nerve** by **gray rami communicantes**.
- The **upper thoracic ganglia (T1–T5)** mainly supply **thoracic viscera** (heart, lungs).

- The **lower ganglia (T6–T12)** give rise to **splanchnic nerves** for the abdomen.
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Branches

Each thoracic ganglion gives off:

1. **Gray rami communicantes** – To all thoracic spinal nerves for vasomotor, pilomotor, and sudomotor (sweat gland) fibers.
 2. **Visceral branches** – To thoracic organs (heart, lungs, oesophagus).
 3. **Splanchnic nerves** – Preganglionic fibers that pass through the chain to prevertebral ganglia.
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Thoracic Splanchnic Nerves

1. **Greater Splanchnic Nerve (T5–T9):**
 - Descends obliquely on the vertebral bodies.
 - Pierces the diaphragm's crus to end in the **celiac ganglion**.
 - Supplies liver, stomach, pancreas, and upper small intestine.
2. **Lesser Splanchnic Nerve (T10–T11):**
 - Ends in the **aorticorenal ganglion**.
 - Supplies kidneys and suprarenal glands.
3. **Least (Lowest) Splanchnic Nerve (T12):**

- Smallest and most variable.
 - Ends in the **renal plexus**.
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Clinical Relevance

- **Sympathetic overactivity** can cause hypertension or tachycardia.
 - **Thoracic sympathectomy** (T2–T4) is performed to reduce excessive sweating or treat vasospastic disorders like **Raynaud's disease**.
 - **Pancoast tumor** at the lung apex can involve the **stellate ganglion**, leading to **Horner's syndrome**.
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Nerve Supply of the Heart

The heart receives **autonomic innervation** from both **sympathetic** and **parasympathetic** systems, which form the **cardiac plexuses** — regulating heart rate, force, and conduction.

1. Sympathetic Supply

- **Preganglionic fibers:** Originate from the **lateral horn of T1–T5 spinal segments**.
- They synapse in the **cervical and upper thoracic sympathetic ganglia**.
- **Postganglionic fibers** form the **superior, middle, and inferior cardiac nerves**, which join the **cardiac plexus**.

Effects:

- Increases **heart rate (positive chronotropy)**.

- Increases **force of contraction (positive inotropy)**.
 - Dilates **coronary vessels** (via metabolic autoregulation).
 - Carries **pain fibers**, explaining **referred pain** to the left arm and chest in angina.
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2. Parasympathetic Supply

- From the **vagus nerve (cranial nerve X)**.
- **Preganglionic fibers** arise from the **dorsal motor nucleus of the vagus**.
- They form **cardiac branches** that join the **cardiac plexuses** and synapse in **intramural ganglia** within the heart wall.

Effects:

- Decreases **heart rate (negative chronotropy)**.
 - Reduces **force of contraction (negative inotropy)**.
 - Causes **vasoconstriction** of coronary arteries.
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3. Cardiac Plexuses

There are two interconnected cardiac plexuses:

- **Superficial Cardiac Plexus:**
 - Lies below the **aortic arch**, in front of the **right pulmonary artery**.

- Formed by the **superior cervical sympathetic cardiac branch** and the **lower cervical vagal branch**.
 - **Deep Cardiac Plexus:**
 - Lies in front of the **tracheal bifurcation**.
 - Receives fibers from **both vagi** and **sympathetic trunks**.
 - Sends branches to **coronary plexuses**, **atria**, and **ventricles**.
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Clinical Correlations

- **Referred cardiac pain:** Travels via sympathetic afferents (T1–T5 dermatomes) to the left chest and arm.
 - **Vagal stimulation:** Causes **bradycardia** or **heart block**.
 - **Sympathetic overactivity:** Causes **tachycardia** and **arrhythmias**.
 - **Stellate ganglion block:** Used therapeutically to reduce refractory angina by lowering sympathetic tone.
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Nerve Supply of the Lungs

The lungs are richly innervated by autonomic fibers that regulate **bronchial tone**, **vascular flow**, and **secretions**.

1. Pulmonary Plexuses

Two plexuses are formed by mixed sympathetic and parasympathetic fibers:

- **Anterior pulmonary plexus** — lies in front of the root of the lung.
- **Posterior pulmonary plexus** — lies behind the root of the lung.

Both plexuses distribute fibers along the bronchi and pulmonary vessels into the lung substance.

2. Sympathetic Supply

- **Origin:** From **T2–T5 thoracic ganglia**.
 - **Pathway:** Postganglionic fibers reach the pulmonary plexuses.
 - **Effects:**
 - **Bronchodilation** (relaxation of bronchial muscles).
 - **Vasoconstriction** of pulmonary vessels.
 - **Decreased mucus secretion** from bronchial glands.
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3. Parasympathetic Supply

- Derived from the **vagus nerve**.
 - **Effects:**
 - **Bronchoconstriction**.
 - **Vasodilation** of pulmonary vessels.
 - **Increased mucus secretion** from glands in the bronchial wall.
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4. Sensory (Afferent) Fibers

- From both vagus and sympathetic nerves.
 - Vagal afferents mediate **cough reflex** and **stretch sensation**.
 - Sympathetic afferents carry **pain fibers** from bronchi and lungs.
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Clinical Correlations

- **Asthma:** Results from overactivity of parasympathetic system ? bronchospasm and mucus hypersecretion.
- **Bronchodilators (?? agonists):** Mimic sympathetic stimulation.
- **Vagal stimulation:** Can induce cough and bronchoconstriction.
- **Sympathectomy:** May relieve certain cases of bronchial spasm.

Typical Intercostal Nerve

- **Definition:**
A **typical intercostal nerve** refers to the **3rd to 6th thoracic spinal nerves**, which run entirely within the intercostal spaces and supply the thoracic wall.
- **Origin:**
Each arises from the **anterior (ventral) ramus** of the corresponding thoracic spinal nerve after the dorsal ramus is given off.
- **Course:**

- Enters the posterior part of the intercostal space, passing **behind the posterior intercostal vessels**.
- Lies in the **neurovascular bundle** along the costal groove in the order: **Vein–Artery–Nerve (VAN)** from above downward.
- Initially lies between **posterior intercostal membrane and subcostalis**, then between **internal and innermost intercostal muscles**.
- Near the sternum, it passes **in front of internal thoracic vessels**, pierces the **intercostal muscles** and **anterior intercostal membrane**, and ends as the **anterior cutaneous branch**.

• **Branches:**

1. **Communicating branches** – Connect to sympathetic ganglia through white and gray rami communicantes.
2. **Collateral branch** – Runs along the upper border of the rib below, supplying intercostal muscles, pleura, and periosteum.
3. **Lateral cutaneous branch** – Arises near the midaxillary line; divides into anterior and posterior branches to supply thoracic wall skin.
4. **Muscular branches** – To intercostal, subcostalis, and transversus thoracis muscles.
5. **Anterior cutaneous branch** – Terminal branch near the sternum; divides into medial and lateral divisions to supply anterior thoracic skin.

Atypical Intercostal Nerves

- **Definition:**

Intercostal nerves that deviate from the typical pattern in distribution or course.

- **Examples:**

- **First intercostal nerve:**

- Joins the **brachial plexus** completely; gives no branches to the first intercostal space.
 - Skin of this space is supplied by **supraclavicular nerves (C3–C4)**.

- **Second intercostal nerve:**

- Gives a large **lateral cutaneous branch** — the **intercostobrachial nerve**, which supplies the **skin of axilla** and medial arm.

- **7th–11th intercostal nerves:**

- Extend beyond the thoracic wall to supply **abdominal wall muscles** and **overlying skin**; also provide branches to **parietal peritoneum**.

- **12th thoracic nerve (subcostal nerve):**

- Runs below the 12th rib, supplies **anterolateral abdominal wall** and **buttock skin**.

Arteries of the Thorax

The main arteries of the thorax include:

1. **Internal Thoracic Artery:**

- Origin: 1st part of the **subclavian artery**.
- Course: Descends behind the **costal cartilages** about 1 cm from the sternum.
- Termination: Divides in the **6th intercostal space** into **superior epigastric** and **musculophrenic arteries**.
- Distribution: **Anterior thoracic wall, mammary gland, diaphragm, and anterior abdominal wall**.

2. **Pericardiophrenic Artery:**

- Branch of internal thoracic artery; accompanies the **phrenic nerve**.
- Supplies the **pericardium** and **diaphragm**.

3. **Mediastinal Arteries:**

- Small branches from internal thoracic artery; supply **thymus** and **mediastinal fat**.

4. **Posterior Intercostal Arteries:**

- 1st and 2nd arise from **superior intercostal artery** (a branch of costocervical trunk).
- 3rd to 11th arise from **descending thoracic aorta**.
- Run in costal grooves with veins and nerves (VAN), supplying **intercostal muscles**, **skin**, and **spinal cord branches**.

5. **Subcostal Artery:**

- Lowest pair from the thoracic aorta below the 12th ribs; continue into abdominal wall.
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Clinical Terms

1. Site of Pericardial Tapping (Pericardiocentesis):

- Performed in the **left 4th or 5th intercostal space just next to the sternum**, where pleura deviates laterally, exposing pericardium.
- Alternate approach: **Left xiphicostal angle**, directing needle upward and backward toward pericardial cavity.
- **Precaution:** Avoid injuring the **internal thoracic artery**, which lies about 1 cm lateral to the sternum.

2. Foreign Bodies in Trachea:

- Commonly enter the **right main bronchus** due to its wider, shorter, and more vertical course.
- Typically settle in **posterior basal segments of the right lower lobe**.

3. Site of Bone Marrow Puncture:

- **Manubrium sterni** is preferred for sternal marrow aspiration due to accessibility and thickness.

The **intercostal nerves and thoracic arteries** together form the vital neurovascular network of the chest wall, ensuring effective **motor, sensory, and vascular supply** for respiration and protection — while the **clinical applications** highlight the precision required in thoracic procedures.