# Autonomic Nervous System, Arteries, Nerves and Clinical Terms

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## Introduction, Autonomic Nervous System, and Sympathetic Nervous System

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### 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**.

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### 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**.

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### 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.

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**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 |

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**Neurotransmitters**

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

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**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

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### 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.

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### 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.

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### 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**.

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### 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.

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**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.

### 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.

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**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**.

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**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. **Pericardiacophrenic 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.

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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.