

Control of Respiration

Breathing is controlled by two mechanisms:

- 1 An automatic mechanism (involuntary)
- 2 A voluntary mechanism (conscious control)

1) Automatic Mechanism

- The centers responsible for automatic control are located in the pons and medulla oblongata (parts of the brainstem).
- This mechanism allows subconscious (spontaneous) rhythmic respiration — meaning you breathe automatically without thinking about it.

2) Voluntary Mechanism

- The center for voluntary control lies in the **motor cerebral cortex**.
- It controls the **anterior horn cells** of the spinal cord that supply respiratory muscles, through the corticospinal tract.
- This allows voluntary control of breathing — for example:
 - Voluntary hyperventilation (breathing fast on purpose)
 - Apnea (holding your breath)
 - However, this control cannot last long, because the automatic centers take over when blood CO_2 increases.

Inspiratory Muscles and Nerve Supply

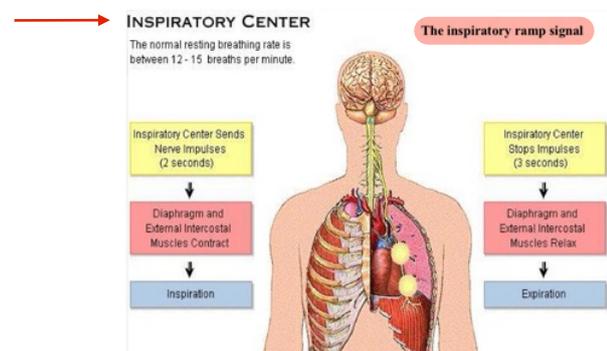
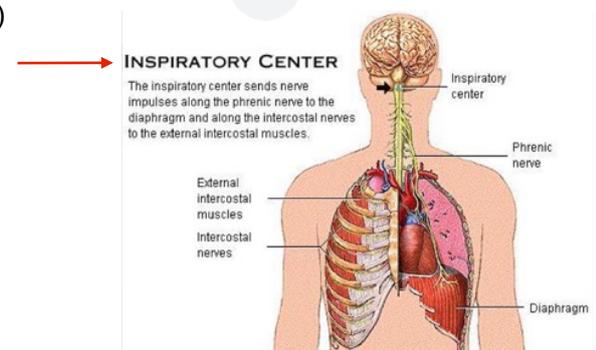
- The inspiratory muscles are:
 - Diaphragm
 - External intercostal muscles
 - Both are skeletal muscles, so they must be stimulated by nerves to contract.

Nerve supply:

- Phrenic nerves (2 nerves):**
 - Control the diaphragm
 - Originate from the 3rd, 4th, and 5th cervical spinal nerves (C3–C5)
 - Remember the rule: “C3, 4, 5 keep the diaphragm alive”
- Intercostal nerves (11 pairs):**
 - Originate from the 1st–11th thoracic spinal nerves (T1–T11)
 - Supply the intercostal muscles.

Inspiratory Center Function

- The inspiratory center sends nerve impulses:
 - Through the phrenic nerve → diaphragm
 - Through the intercostal nerves → external intercostal muscles
 - This stimulation causes inspiration (air entry into the lungs).



Respiratory Areas in the Brainstem

These centers are responsible for generating the basic automatic rhythm of respiration. They are located bilaterally in the brainstem and include two main parts:

1. Medullary Respiratory Centers
 - Located in the medulla oblongata
 - Include two neuron groups:
 - Dorsal Respiratory Group (DRG) → Inspiratory center
 - Ventral Respiratory Group (VRG) → Expiratory center
2. Pontine Respiratory Centers
 - Located in the pons
 - Responsible for switching between inspiration and expiration
 - Include:
 - Pneumotaxic center
 - Apneustic center

A. Medullary Respiratory Centers

◆ Functions

- Regulate the rate and pattern of breathing.
- Can accelerate or slow down the respiratory rhythm.

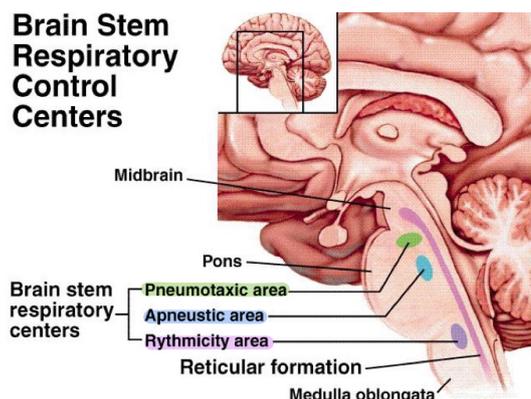
1. Dorsal Respiratory Group (DRG) — Inspiratory Center

- Located in the dorsal medulla.
- Responsible for **basic rhythmic breathing**.
- Contains inspiratory neurons.
- Sends impulses through:
- Phrenic nerve → diaphragm
- Intercostal nerves → external intercostal muscles
- These signals cause the inspiratory muscles to contract, expanding the lungs and drawing air in.

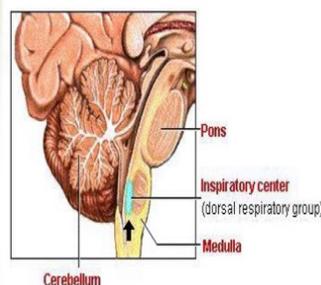
2. Ventral Respiratory Group (VRG) — Expiratory Center

- Located in the ventrolateral medulla.
- Contains mainly expiratory neurons, but also a few inspiratory ones.
- Normally inactive during quiet breathing, since **expiration is passive**.
- Becomes active during forced expiration, such as during exercise or coughing.
- Sends impulses through:
- Intercostal nerves → internal intercostal muscles
- Spinal nerves → anterior abdominal wall muscles
- These cause active (forced) expiration by compressing the thoracic cavity.

Brain Stem Respiratory Control Centers



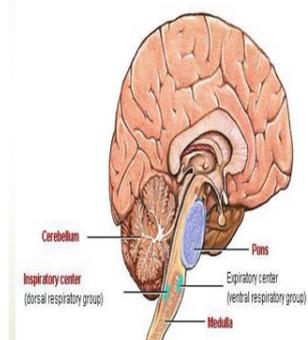
INSPIRATORY CENTER



The basic rhythm of breathing is controlled by respiratory centers located in the medulla and pons of the **brainstem**.
The inspiratory center (dorsal respiratory group) sets this rhythm by automatically initiating inspiration.

OTHER RESPIRATORY CONTROL CENTERS

The **expiratory center** in the medulla appears to function during forced expiration, stimulating the internal intercostal and abdominal muscles.
Other respiratory centers in the pons modify inspiration and allow for smooth transitions between inspiration and expiration. Their precise roles are not fully understood.



B. Pons Respiratory Centers

The pons modifies the activity of the medullary centers to make breathing smooth and coordinated.

1. Apneustic Center

- Located in the lower pons.
- Stimulates the inspiratory center (DRG) in the medulla.
- **Function:**
- Causes **longer, deeper, and slower breaths**
- Prevents the “switch-off” of inspiration (prolongs inspiration)
- Its activity is modulated (turned on and off) **by the pneumotaxic center.**
- **It is also inhibited intermittently by afferent vagal discharge from the lungs:**
- This inhibition is part of the Hering–Breuer inflation reflex, which prevents over-inflation of the lungs.
- The reflex arises from slowly adapting stretch receptors in the smooth muscles of the bronchi and bronchioles.
- Once these receptors are stimulated → **inspiration stops** → **expiration begins.**

2. Pneumotaxic Center

- Located in the upper pons.
- Its main role is **to limit inspiration** (inhibitory effect).
- Causes **shorter, shallower, and quicker breaths.**
- **Function:**
- Modulates the activity of the apneustic center, turning inspiration “off” at the proper time.
- This helps create the normal rhythm of breathing.
- **When inspiration stops**, the pneumotaxic inhibition ceases, and the next inspiratory impulse begins — maintaining rhythmic breathing.

Genesis of Normal Rhythmic Respiration

1. The apneustic center stimulates the inspiratory center (DRG) → inspiration switches on.
2. The inspiratory center sends **gradual increasing signals** to the inspiratory muscles → this is called the inspiratory ramp signal (a gradual rise in activity leading to smooth inspiration).
3. This inspiratory signal is then switched off by:
 - (a) **Vagal inhibition** → due to activation of stretch receptors in bronchi and bronchioles (Hering–Breuer reflex).
 - (b) **Pneumotaxic center** → also inhibits the inspiratory center but acts more slowly than the vagus.
4. Once inspiration stops → expiration follows passively (due to lung recoil).
 - **The expiratory center (VRG) is activated only during forced expiration.**

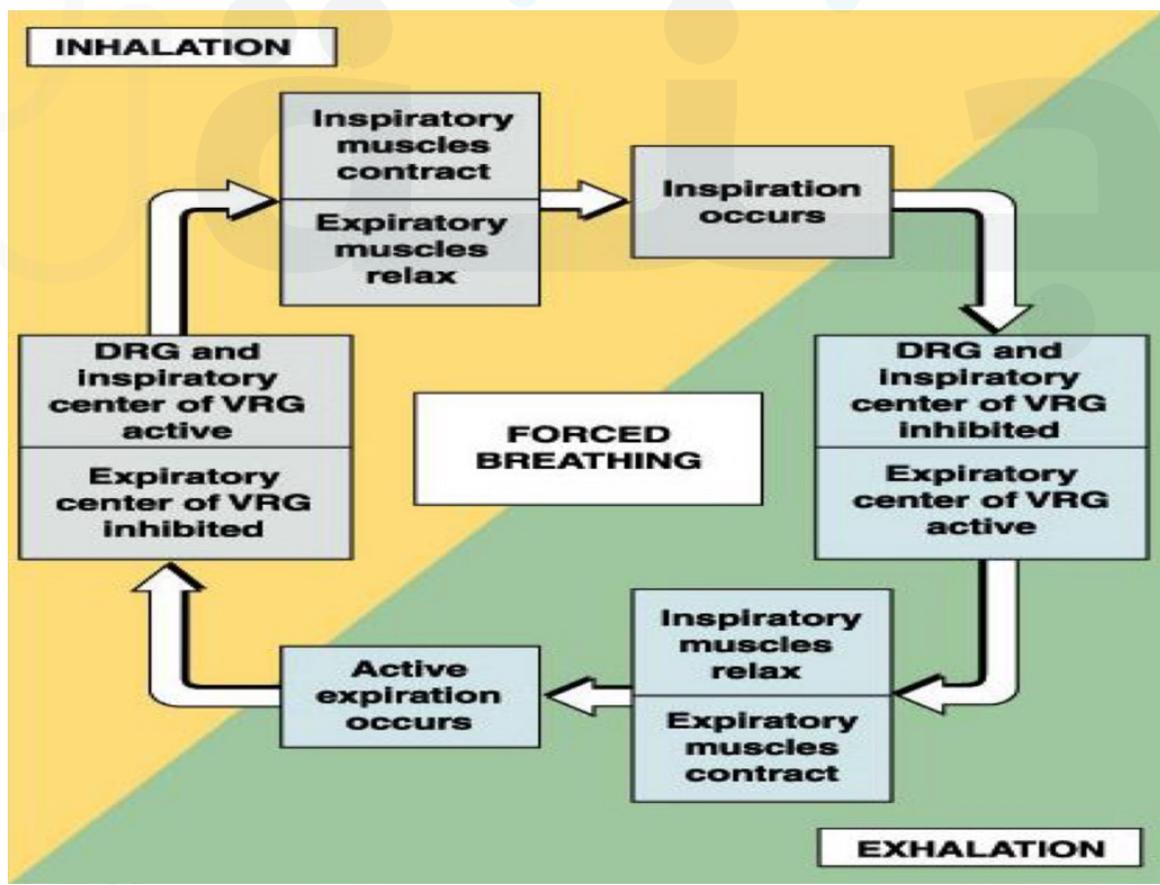
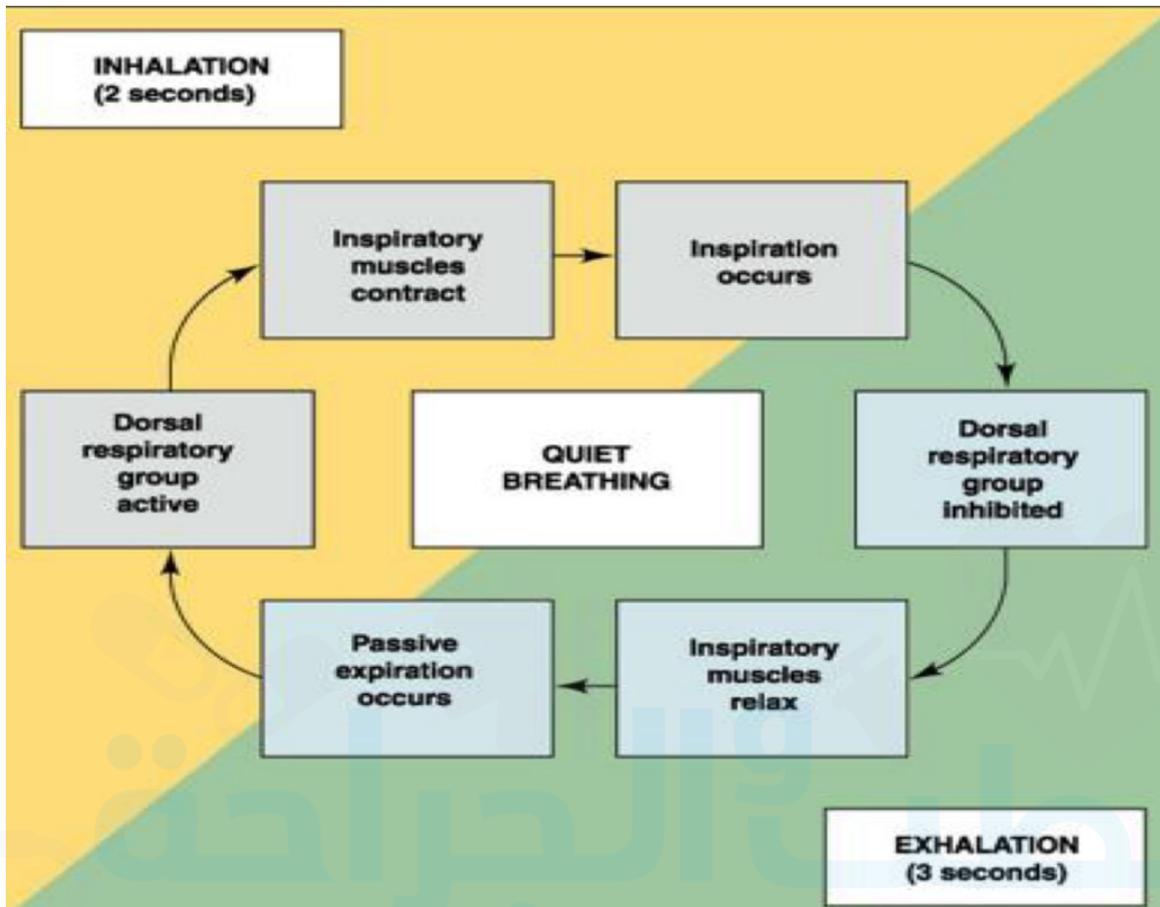
Pre-Bötzinger Complex (Respiratory Pacemaker)

- Located bilaterally in the medulla oblongata.
- Contains pacemaker neurons that generate rhythmic discharges to the phrenic nerve.
- Responsible for initiating the basic rhythmic pattern of breathing – similar to the pacemaker in the heart.

Summary:

- Medulla → generates the basic rhythm (DRG + VRG)
- Pons → modifies rhythm (apneustic + pneumotaxic centers)
- Cerebral cortex → allows voluntary control
- Vagus nerve → provides feedback to prevent lung overinflation
- Pre-Bötzinger complex → sets the rhythm (the true “pacemaker” of breathing)





Vagal (Inflation) Reflex – Hering–Breuer Reflex

The Hering–Breuer reflex is a protective mechanism that **prevents the lungs from overinflating during inspiration**. It operates through the **vagus nerve** (cranial nerve X) and helps regulate the rhythm of breathing.

Mechanism (Step by Step)

1. Lung Inflation (Stretch)

- When the lungs expand during inspiration, the smooth muscles in the bronchi and bronchioles are stretched.
- This stretch activates slowly adapting stretch receptors located in the airway walls.

2. Vagus Nerve Activation

- These stretch receptors send afferent (sensory) impulses through the vagus nerve (cranial nerve X) to the respiratory centers in the brainstem (medulla and pons).

3. Inhibitory Response

- The brainstem receives these signals and sends inhibitory impulses to the inspiratory center (DRG).
- This causes the inspiratory process to stop, ending further lung inflation.

4. Expiration Begins

- Once inspiration stops, expiration occurs passively.
- As the lungs deflate, the stretch receptors are no longer stimulated, and their inhibitory signals cease.

5. Next Inspiration

- With inhibition removed, the inspiratory center is reactivated, starting the next breathing cycle.

Physiological Role

- Limits the depth of inspiration → prevents overexpansion and possible lung damage.
- Maintains a normal rhythm of breathing.
- Most active during:
 - **Deep breathing**
 - **Sleep**
 - **Anesthesia**

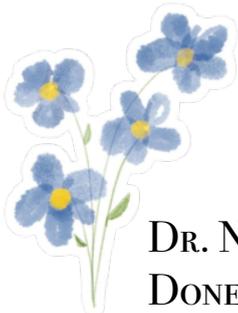
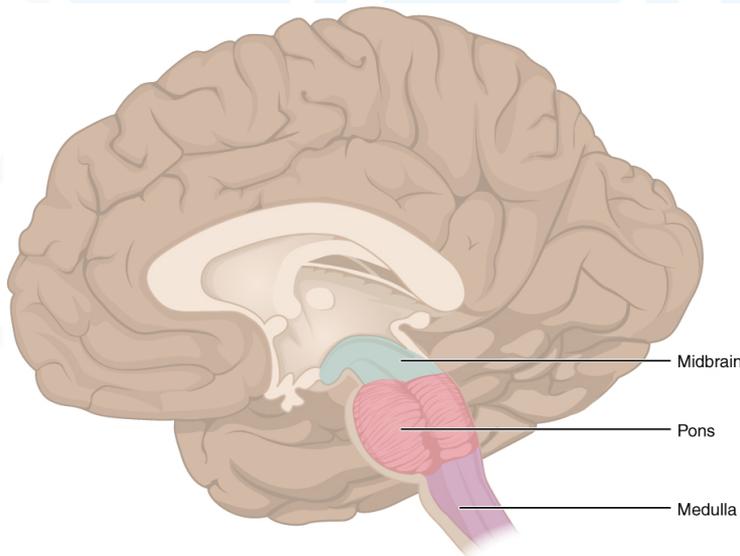
Summary Table

Description	Feature
Vagal (Hering–Breuer Inflation) Reflex	Name
Slowly adapting stretch receptors in bronchi and bronchioles	Receptors
Vagus nerve (Cranial Nerve X)	Afferent Pathway
Medullary and pontine respiratory centers	Center
Inhibits inspiration, starts expiration	Effect
Prevents lung overinflation and regulates breathing rhythm	Function
Deep breathing, sleep, and anesthesia	Most active during



Experimental evidence of respiratory center

Complete section of brain stem above pons	normal <u>A</u> utomatic respiration without voluntary control
Section at lower medulla or upper cervical	<u>d</u> eath (as in Hanging)
Section of lower cervical	<u>d</u> iaphragmatic respiration
Bilateral vagotomy	<u>d</u> eep & slow respiration
Bilateral vagotomy + Damage of pneumotoxic center	<u>A</u> pneusis (inspiratory spasm interrupted by short expiration by fatigue of muscles).



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لَا حَوْلَ وَلَا قُوَّةَ إِلَّا بِاللَّهِ
"من كنوز الجنة"