

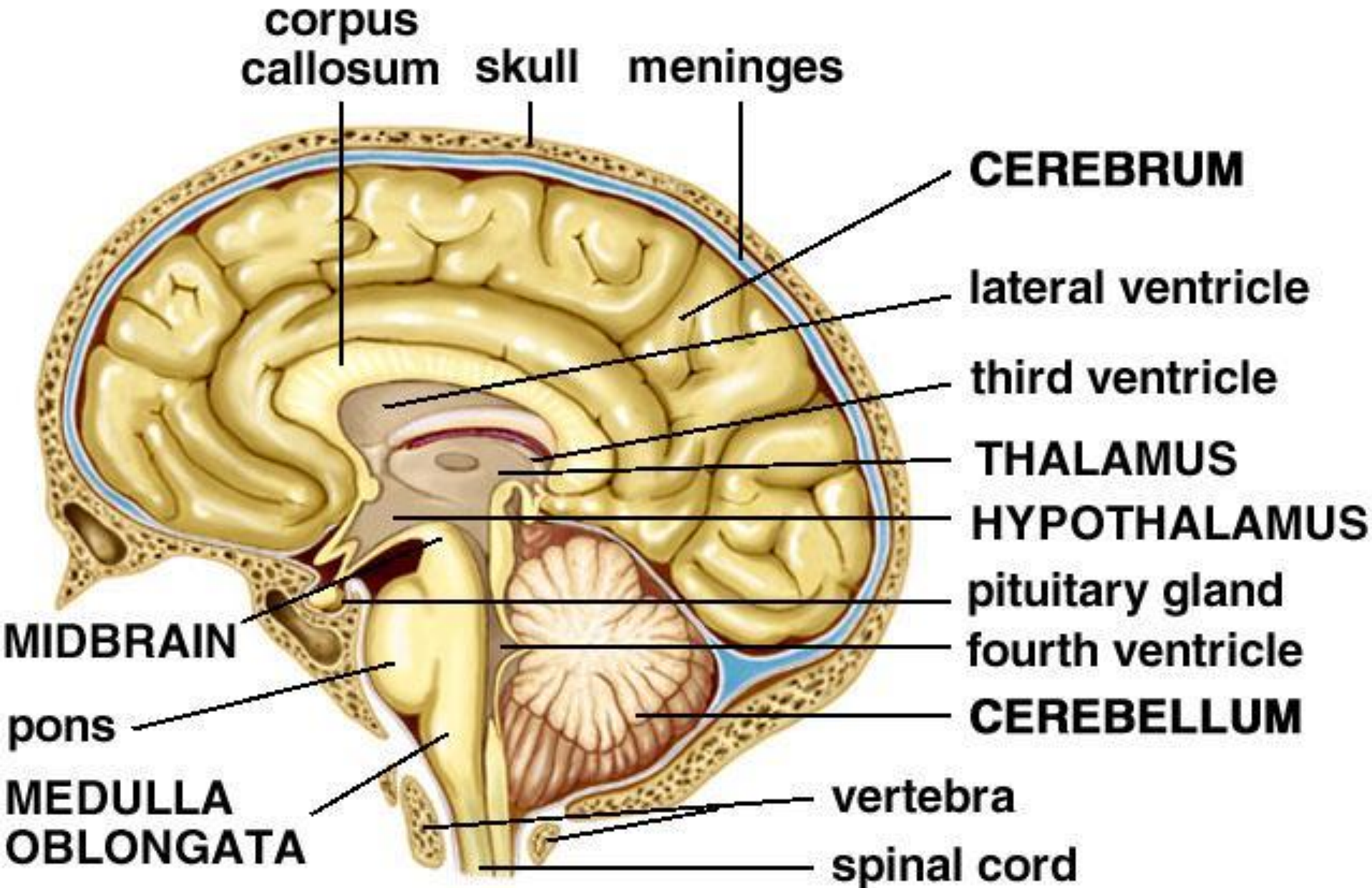
Section 4

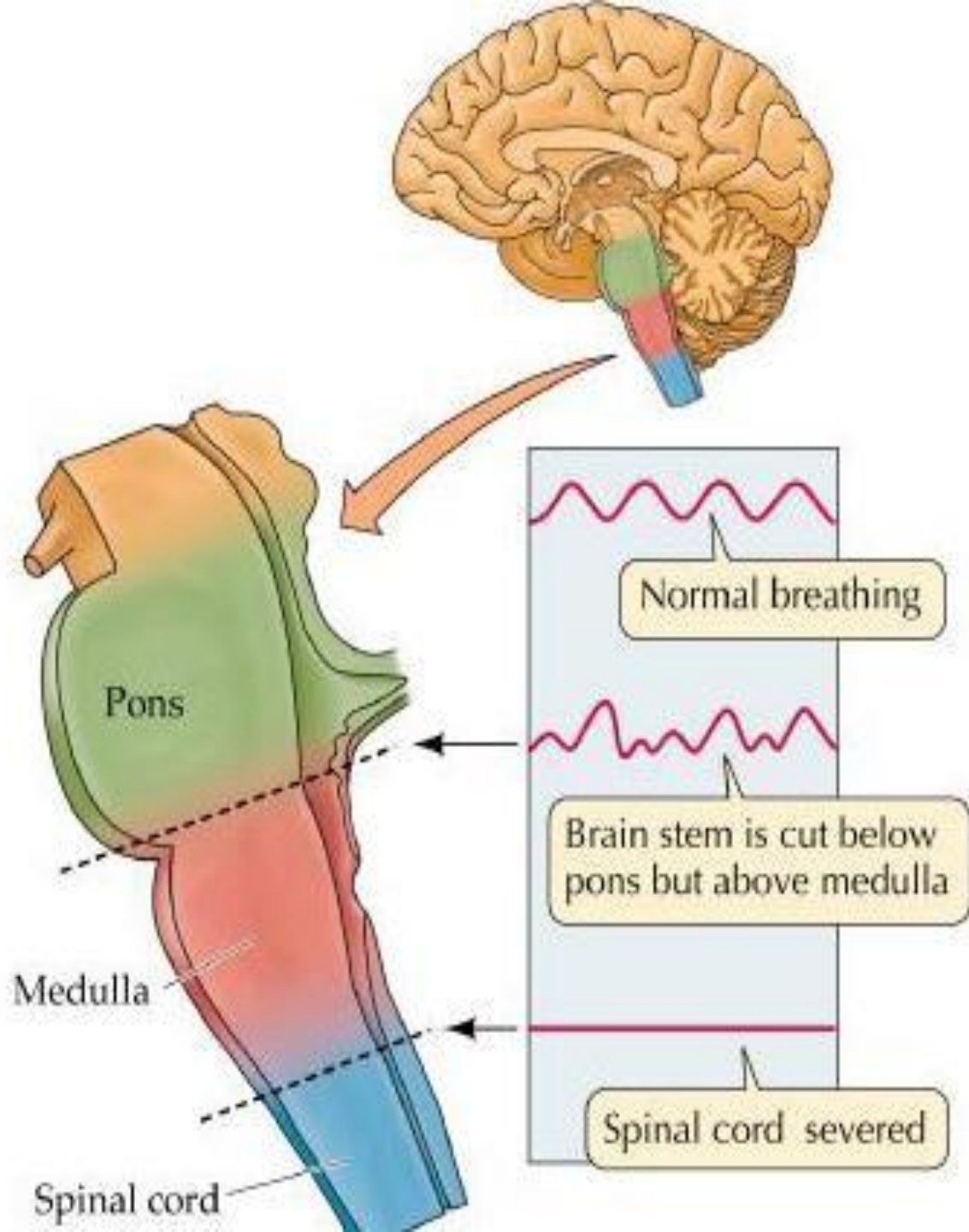
Regulation of the Respiration

I. Respiratory Center and Formation of the Respiratory Rhythm

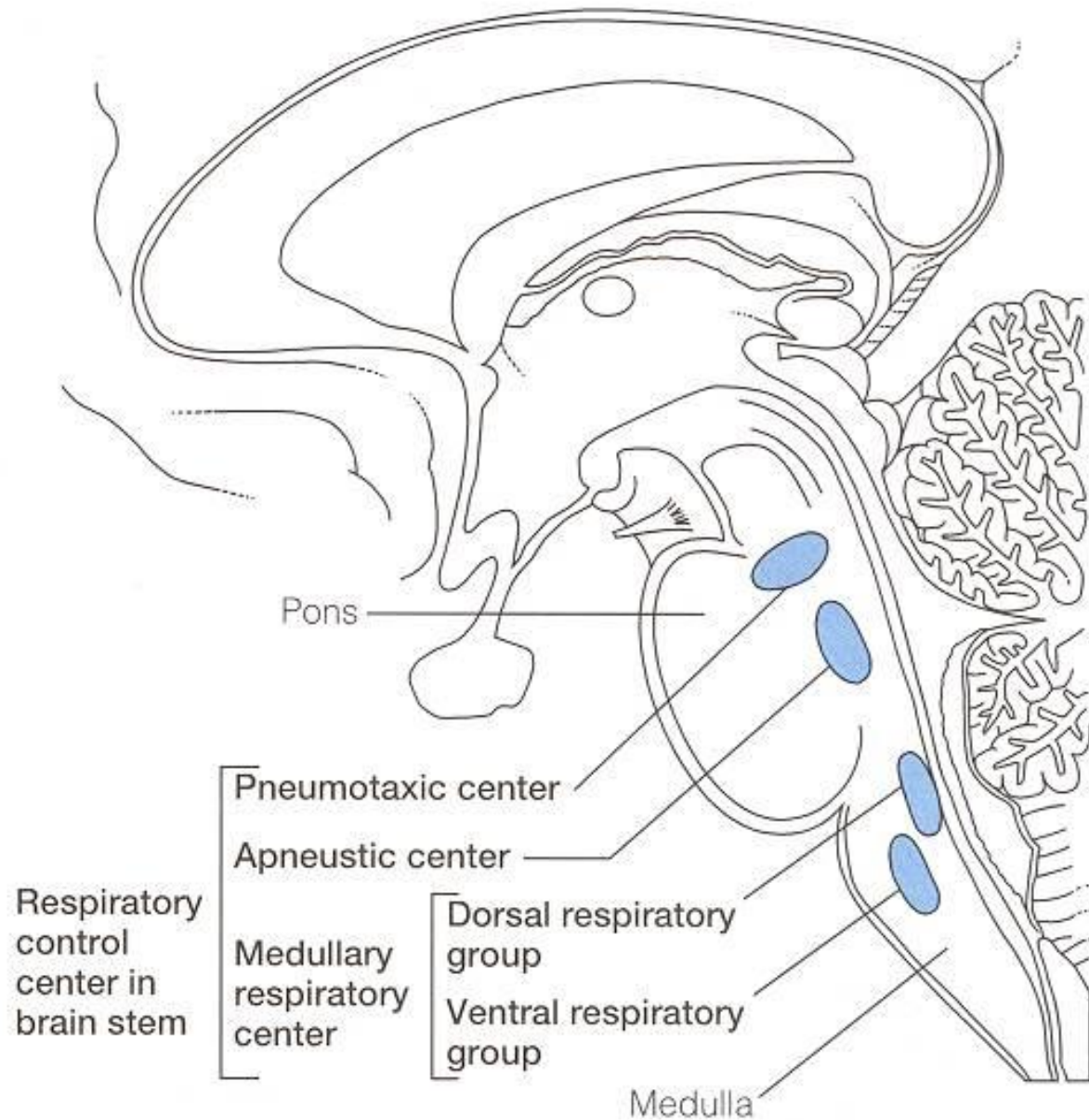
1 Respiratory Center

The Human Brain





Respiratory Centers



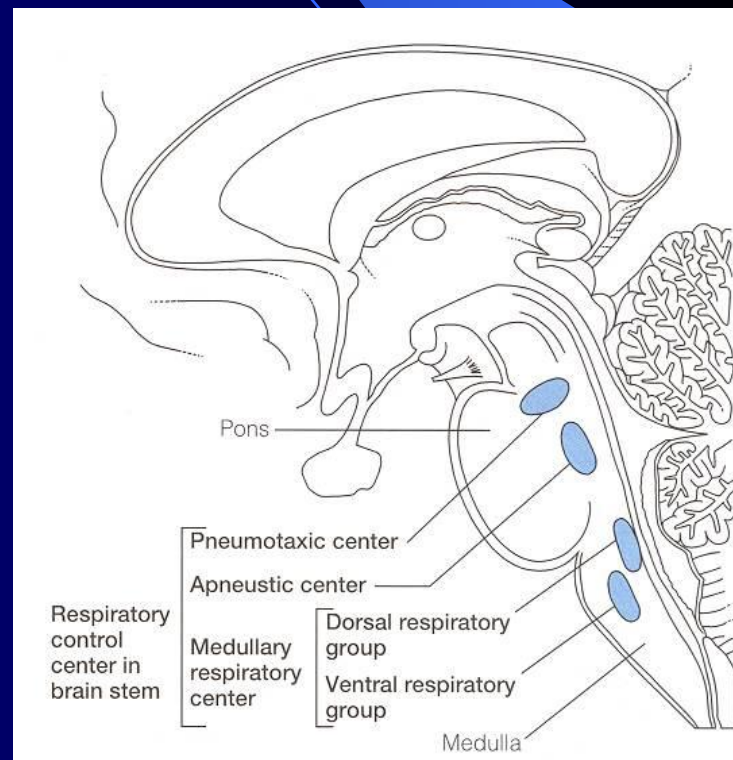
Two respiratory nuclei in medulla oblongata

Inspiratory center (dorsal respiratory group, DRG)

- more frequently they fire, more deeply you inhale
- longer duration they fire, breath is prolonged, slow rate

Expiratory center (ventral respiratory group, VRG)

- involved in *forced* expiration



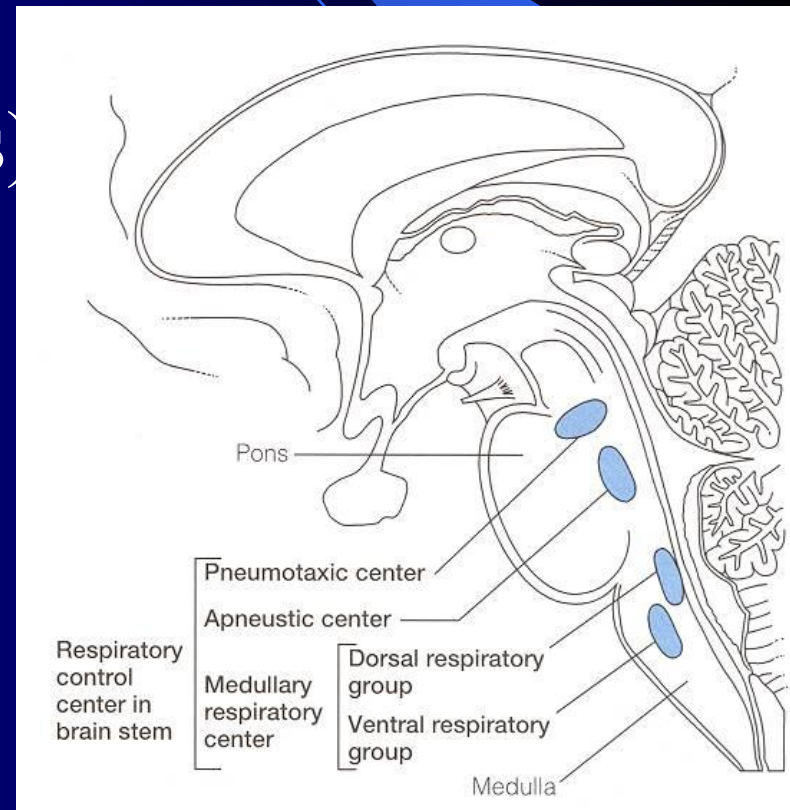
Respiratory Centers in Pons

Pneumotaxic center (upper pons)

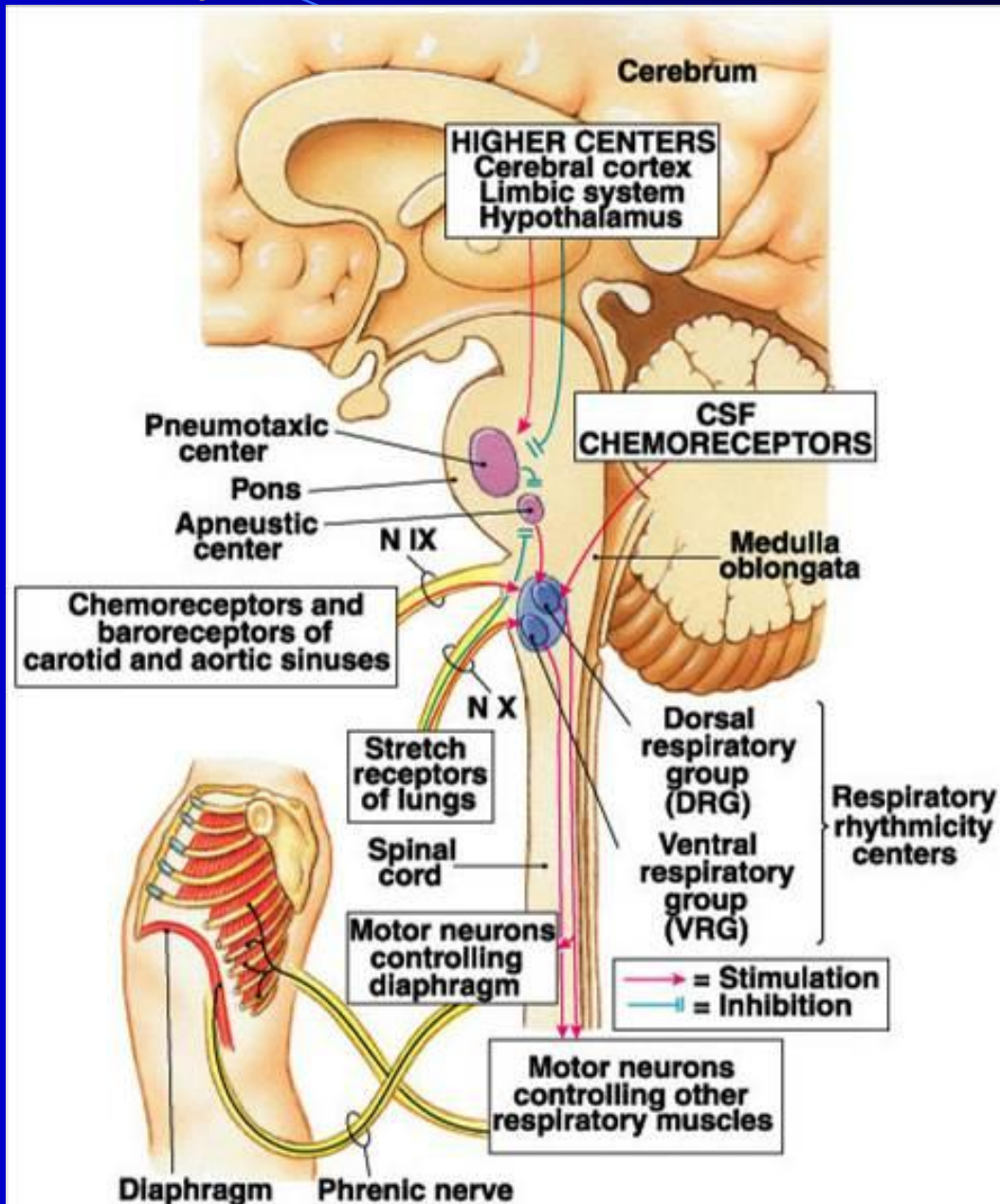
- Sends continual inhibitory impulses to inspiratory center of the medulla oblongata,
- As impulse frequency rises, breathe faster and shallower

Apneustic center (lower pons)

- Stimulation causes apneusis
- Integrates inspiratory cutoff information



Respiratory Structures in Brainstem



2. Rhythmic Ventilation (Inspiratory Off Switch)

- **Starting inspiration**

- Medullary respiratory center neurons are continuously active (**spontaneous**)
- Center receives stimulation from receptors and brain concerned with voluntary respiratory movements and emotion
- Combined input from all sources causes action potentials to stimulate respiratory muscles

• **Increasing inspiration**

- More and more neurons are activated

• **Stopping inspiration**

- Neurons receive input from pontine group and stretch receptors in lungs.
- Inhibitory neurons activated and relaxation of respiratory muscles results in expiration.
- Inspiratory off switch.

3. Higher Respiratory Centers

Modulate the activity of the more primitive controlling centers in the medulla and pons.

Allow the rate and depth of respiration to be controlled voluntarily.

During speaking, laughing, crying, eating, defecating, coughing, and sneezing.

Adaptations to changes in environmental temperature
--Panting

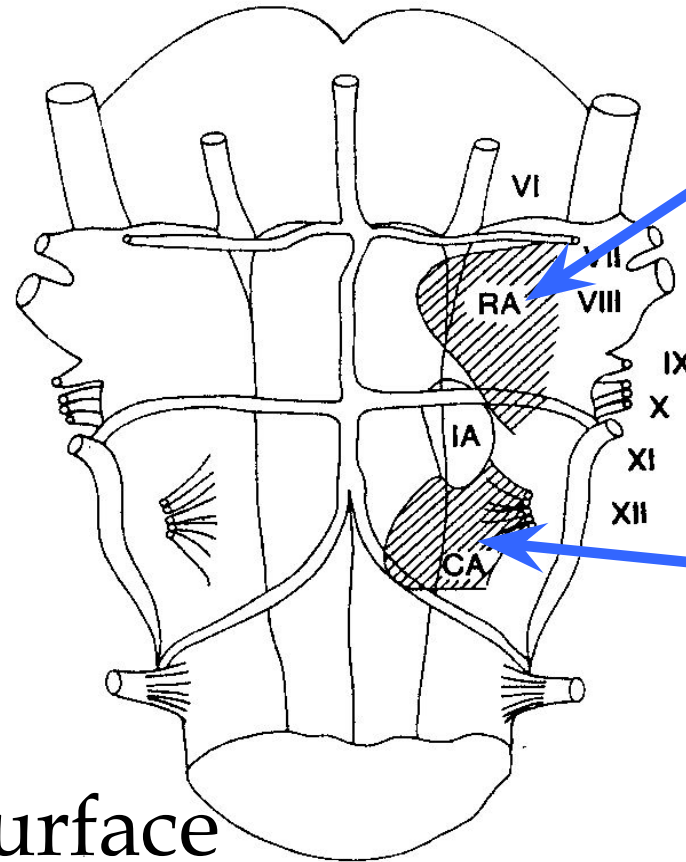
II Pulmonary Reflex

1. Chemoreceptor Reflex

Two Sets of Chemoreceptors Exist

- Central Chemoreceptors
 - Responsive to increased arterial PCO_2
 - Act by way of CSF $[\text{H}^+] \uparrow$.
- Peripheral Chemoreceptors
 - Responsive to decreased arterial PO_2
 - Responsive to increased arterial PCO_2
 - Responsive to increased H^+ ion concentration.

Central Chemoreceptor Location

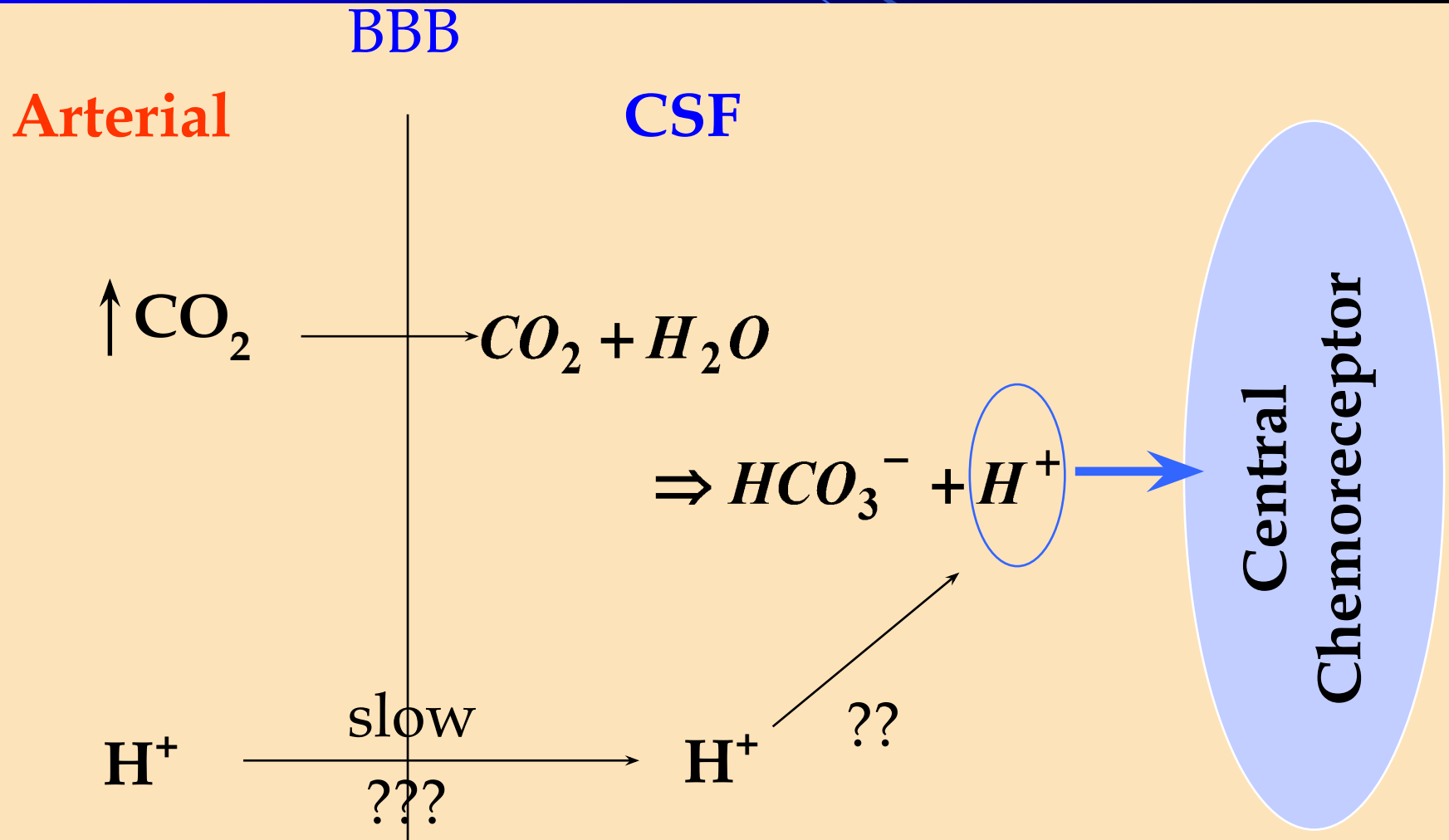


Rostral
Medulla

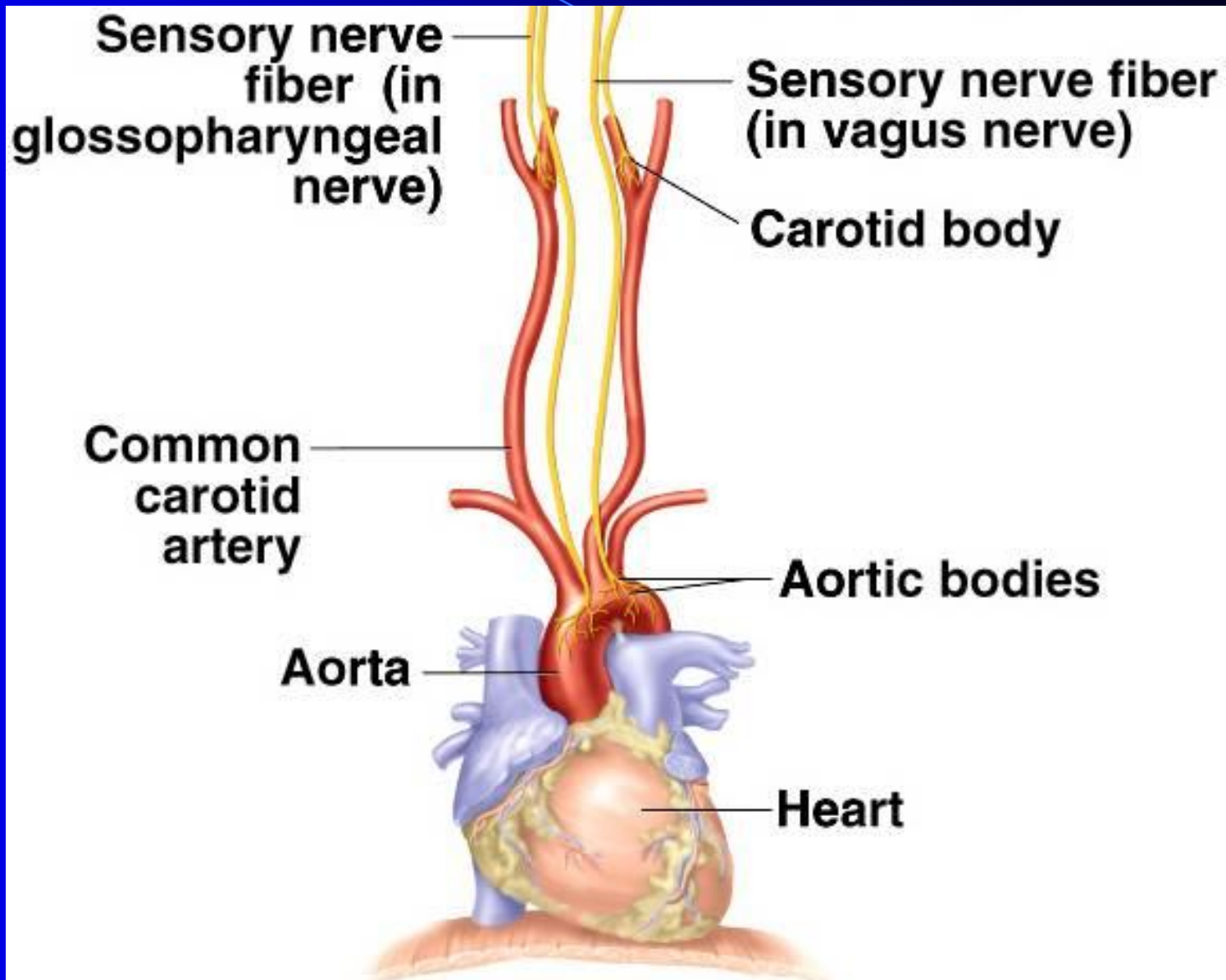
Caudal
Medulla

Ventral Surface

Central Chemoreceptor Stimulation

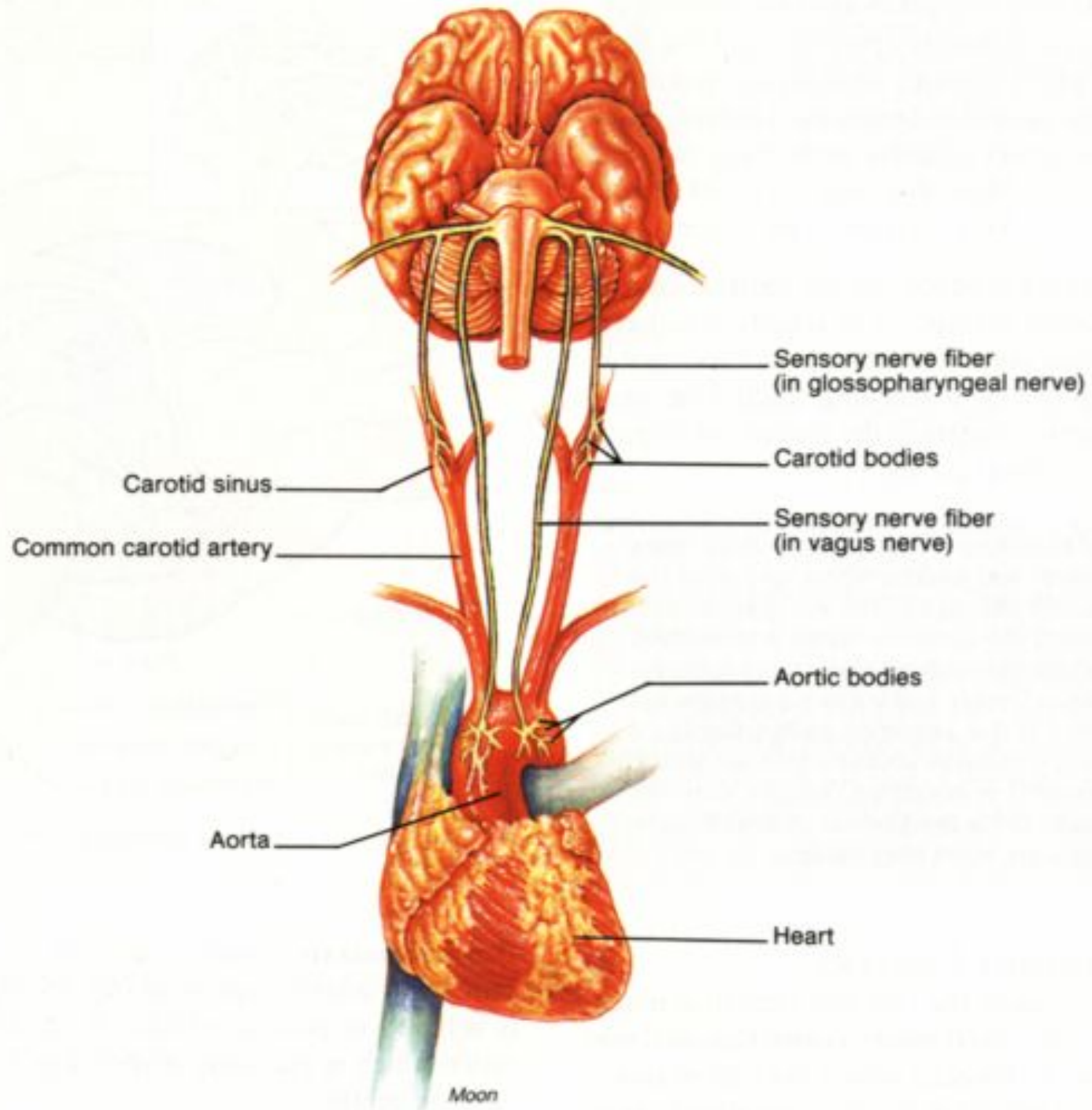


Peripheral Chemoreceptor Pathways



Peripheral Chemoreceptors

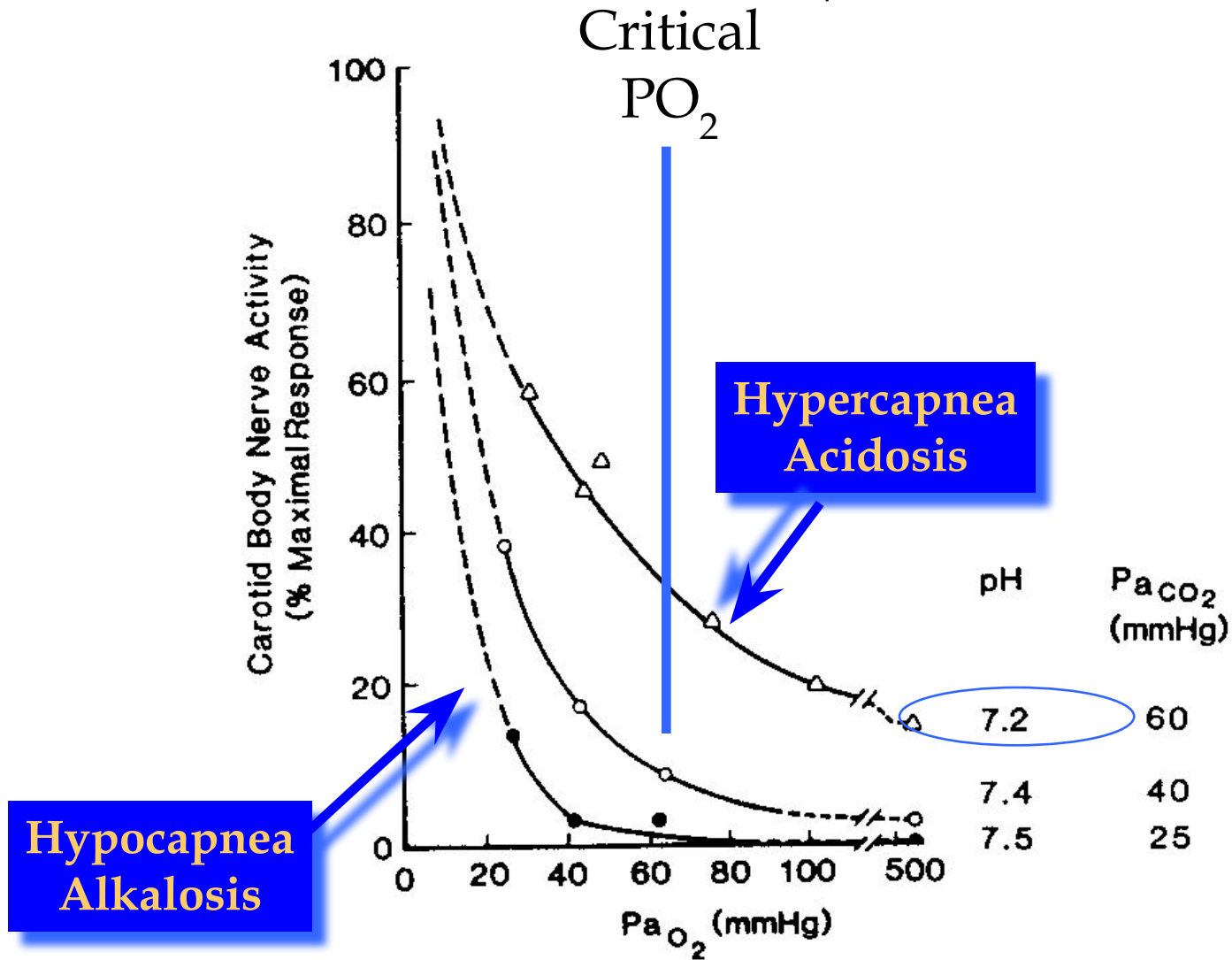
- Carotid bodies
 - Sensitive to: P_aO_2 , P_aCO_2 , and pH
 - Afferents in glossopharyngeal nerve.
- Aortic bodies
 - Sensitive to: P_aO_2 , P_aCO_2 , but not pH
 - Afferents in vagus



Carotid Body Function

- High flow per unit weight:
(2 L/min/100 g)
- High carotid body $\dot{V}O_2$ consumption:
(8 ml O_2 /min/100g)
- Tiny a-v O_2 difference: \longrightarrow
Receptor cells see arterial PO_2 .
- Responsiveness begins at P_aO_2 (**not the oxygen content**) below about 60 mmHg.

Carotid Body Response



Carbon Dioxide, Oxygen and pH Influence

Ventilation (through peripheral receptor)

- Peripheral chemoreceptors sensitive to P_{O_2} , P_{CO_2} and pH
- Receptors are activated by increase in P_{CO_2} or decrease in P_{O_2} and pH
- Send APs through sensory neurons to the brain
- Sensory info is integrated within the medulla
- Respiratory centers respond by sending efferent signals through somatic motor neurons to the skeletal muscles
- Ventilation is increased (decreased)

Effects of Hydrogen Ions (through central chemoreceptors)

- pH of CSF (most powerful respiratory stimulus)
 - Respiratory acidosis (pH < 7.35) caused by failure of pulmonary ventilation
 - hypercapnia (P_{CO_2}) > 43 mmHg
 - CO_2 easily crosses blood-brain barrier, in CSF the CO_2 reacts with water and releases H^+ , central chemoreceptors strongly stimulate inspiratory center
 - corrected by hyperventilation, pushes reaction to the left by “blowing off” CO_2
- $$\text{CO}_2 \text{ (expired)} + \text{H}_2\text{O} \leftarrow \text{H}_2\text{CO}_3 \leftarrow \text{HCO}_3^- + \text{H}^+$$

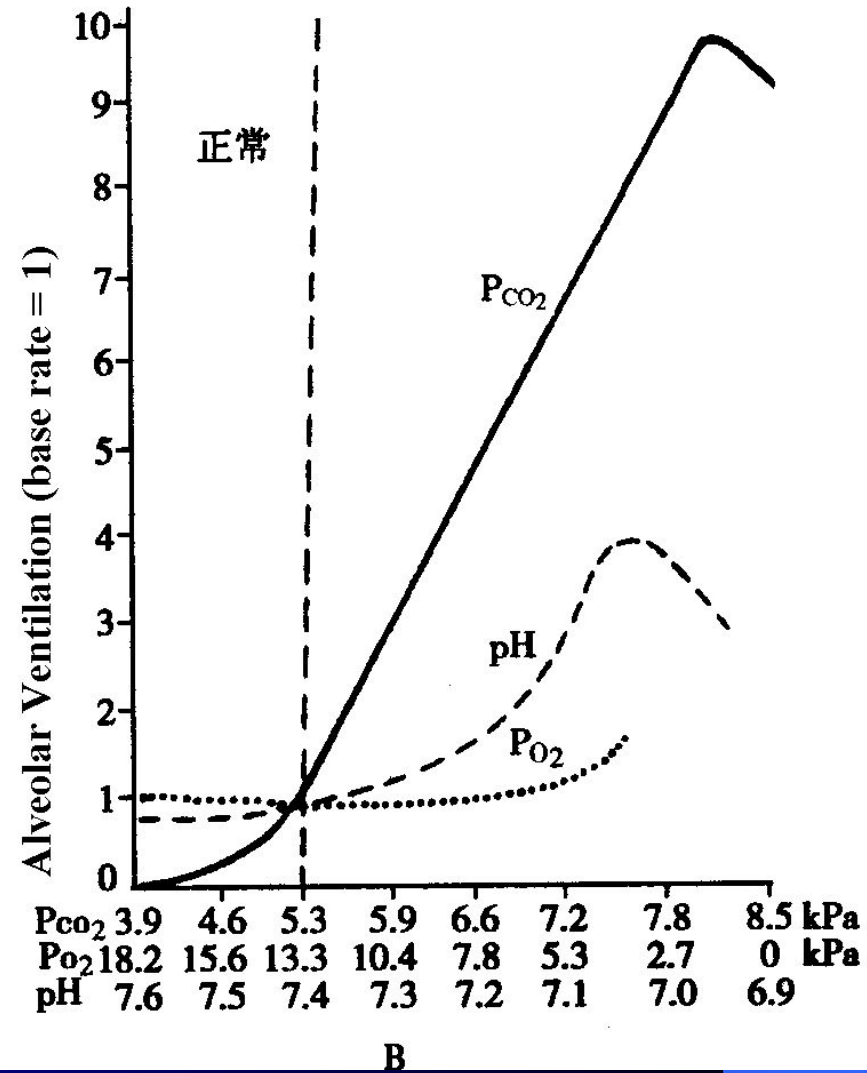
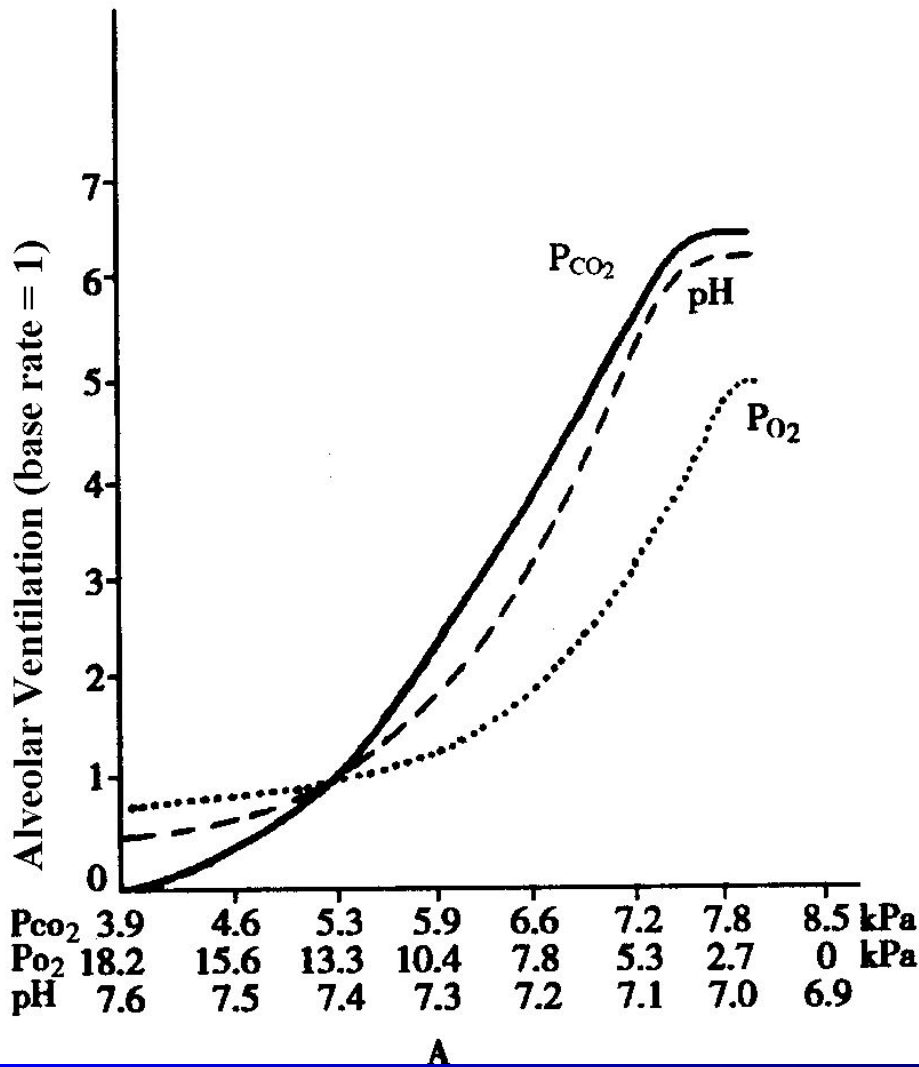
Carbon Dioxide

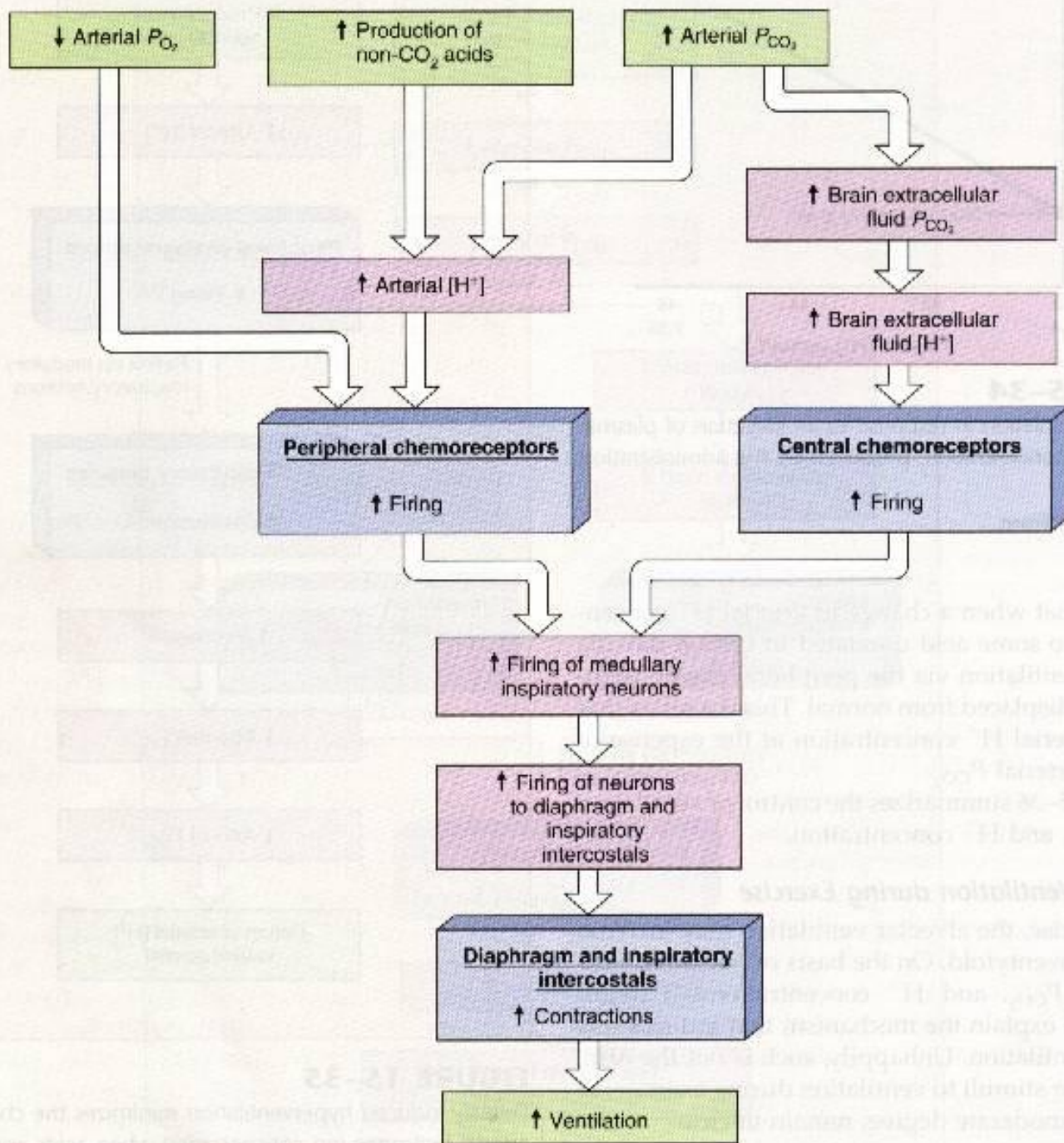
- Indirect effects
 - through pH as seen previously
- Direct effects
 - \uparrow CO_2 may directly stimulate peripheral chemoreceptors and trigger \uparrow ventilation more quickly than central chemoreceptors
- If the PCO_2 is too high, the respiratory center will be inhibited.

Oxygen

- Direct inhibitory effect of hypoxemia on the respiratory center
- Chronic hypoxemia, $PO_2 < 60$ mmHg, can significantly stimulate ventilation
 - emphysema, pneumonia
 - high altitudes after several days

Overall Response to P_{CO_2} , P_{O_2} and pH

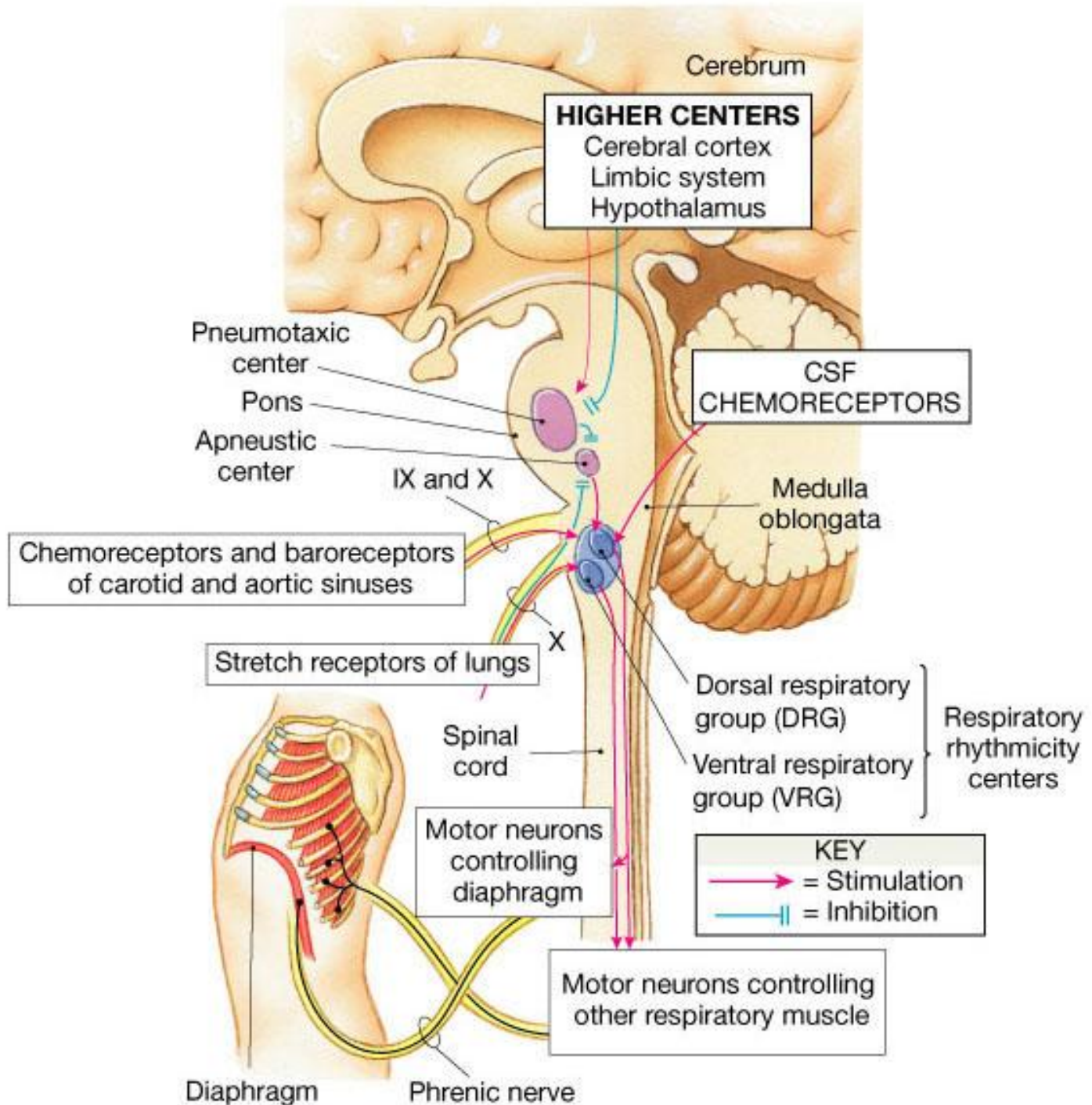




2. Neuroreceptor reflex

Hering-Breuer Reflex or Pulmonary Stretch Reflex

- Including pulmonary inflation reflex and pulmonary deflation reflex
- Receptor: Slowly adapting stretch receptors (SARs) in bronchial airways.
- Afferent: vagus nerve
- Pulmonary inflation reflex:
 - Terminate inspiration.
 - By speeding inspiratory termination they increase **respiratory frequency**.
 - **Sustained stimulation of SARs:** causes activation of expiratory neurons

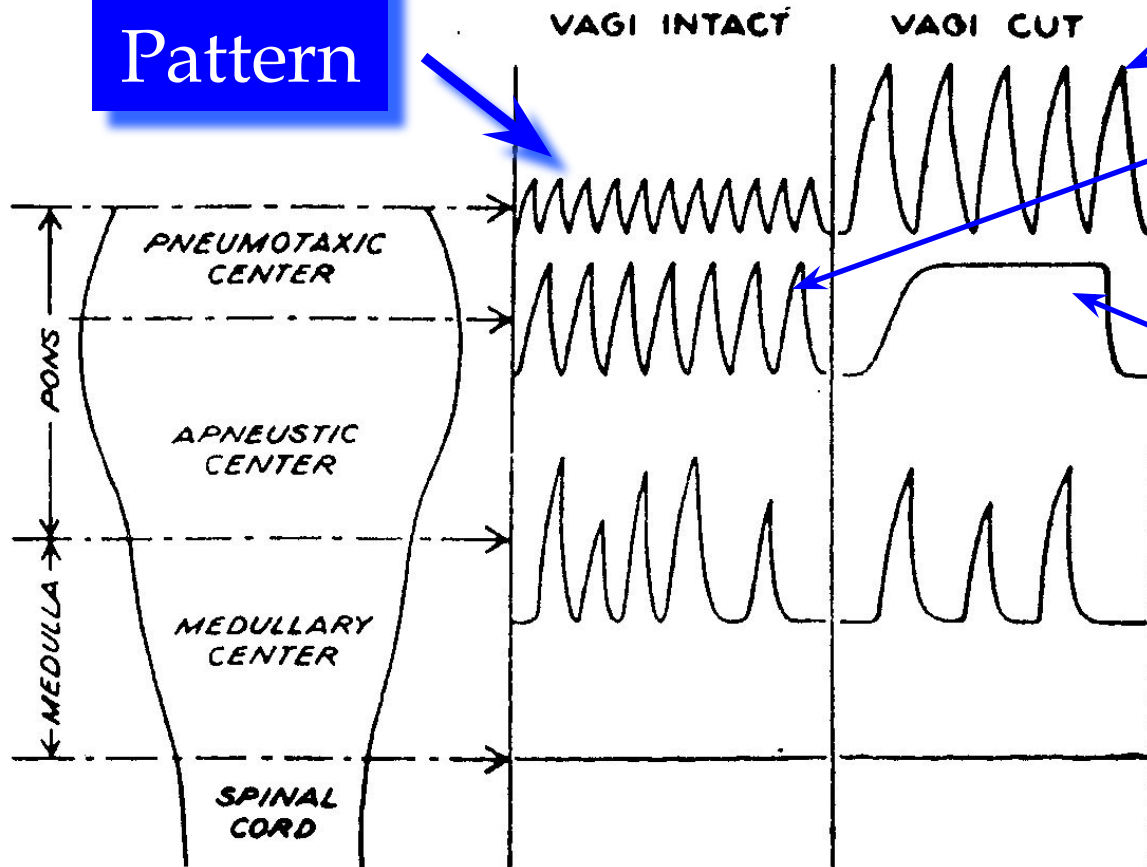


Significance of Hering-Breuer

- Normal adults. Receptors are not activated at end normal tidal volumes.
 - Become Important during **exercise** when tidal volume is increased.
 - Become Important in **Chronic obstructive lung diseases** when lungs are more distended.
- Infants. Probably help terminate normal inspiration.

Brainstem Transection

Normal
Pattern



Increased
Inspiratory
Depth

Apneustic
Breathing

Gasping
Patterns

Respiratory
Arrest

Factors Influencing Respiration

