# Regulation of respiration

- Breathing is controlled by the central neuronal network to meet the metabolic demands of the body
  - Neural regulation
  - Chemical regulation

# Respiratory center

- Definition:
  - A collection of functionally similar neurons that help to regulate the respiratory movement

# Respiratory center

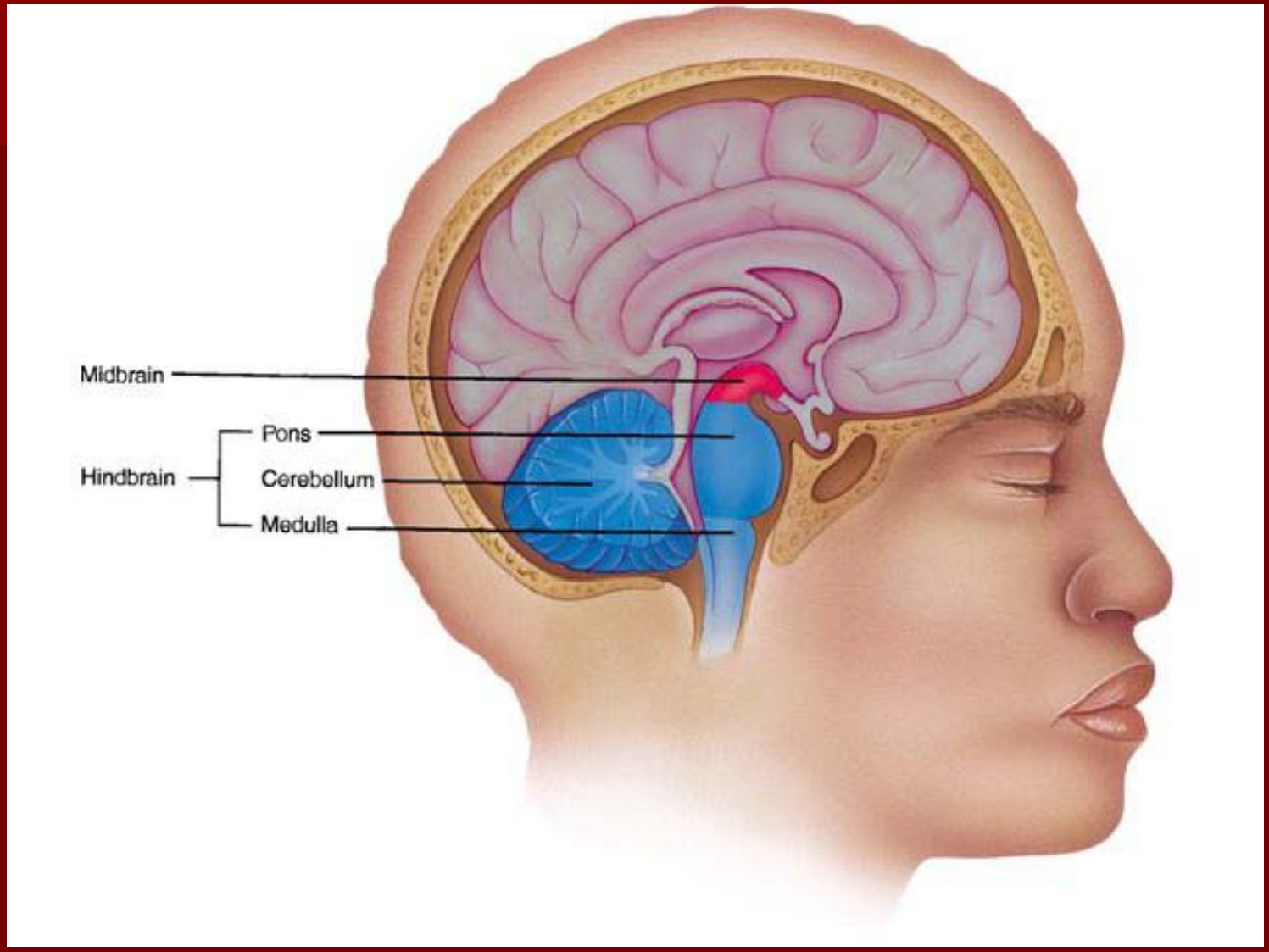
- Medulla
- Pons

} Basic respiratory center: produce and control the respiratory rhythm

- Higher respiratory center: cerebral cortex, hypothalamus & limbic system
- Spinal cord: motor neurons

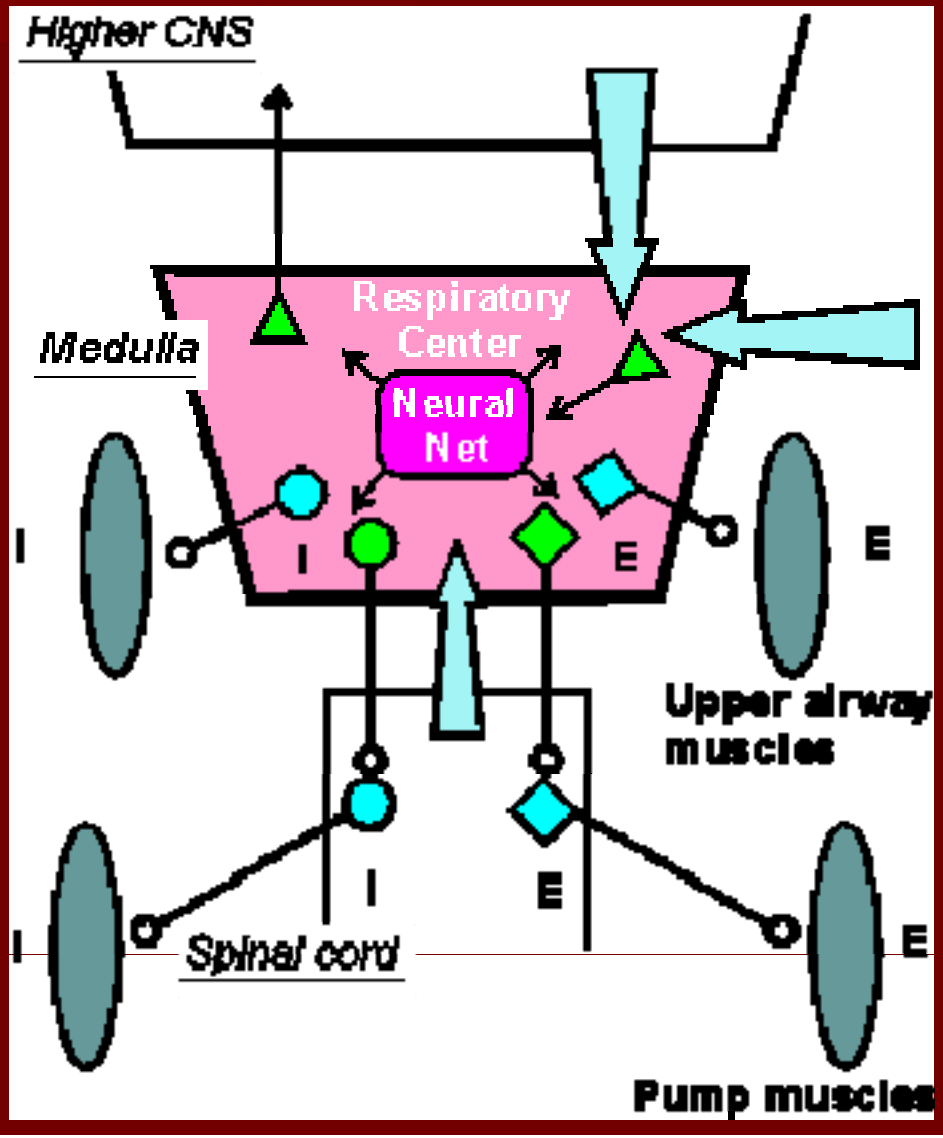
# Neural regulation of respiration

- Voluntary breathing center
  - Cerebral cortex
- Automatic (involuntary) breathing center
  - Medulla
  - Pons

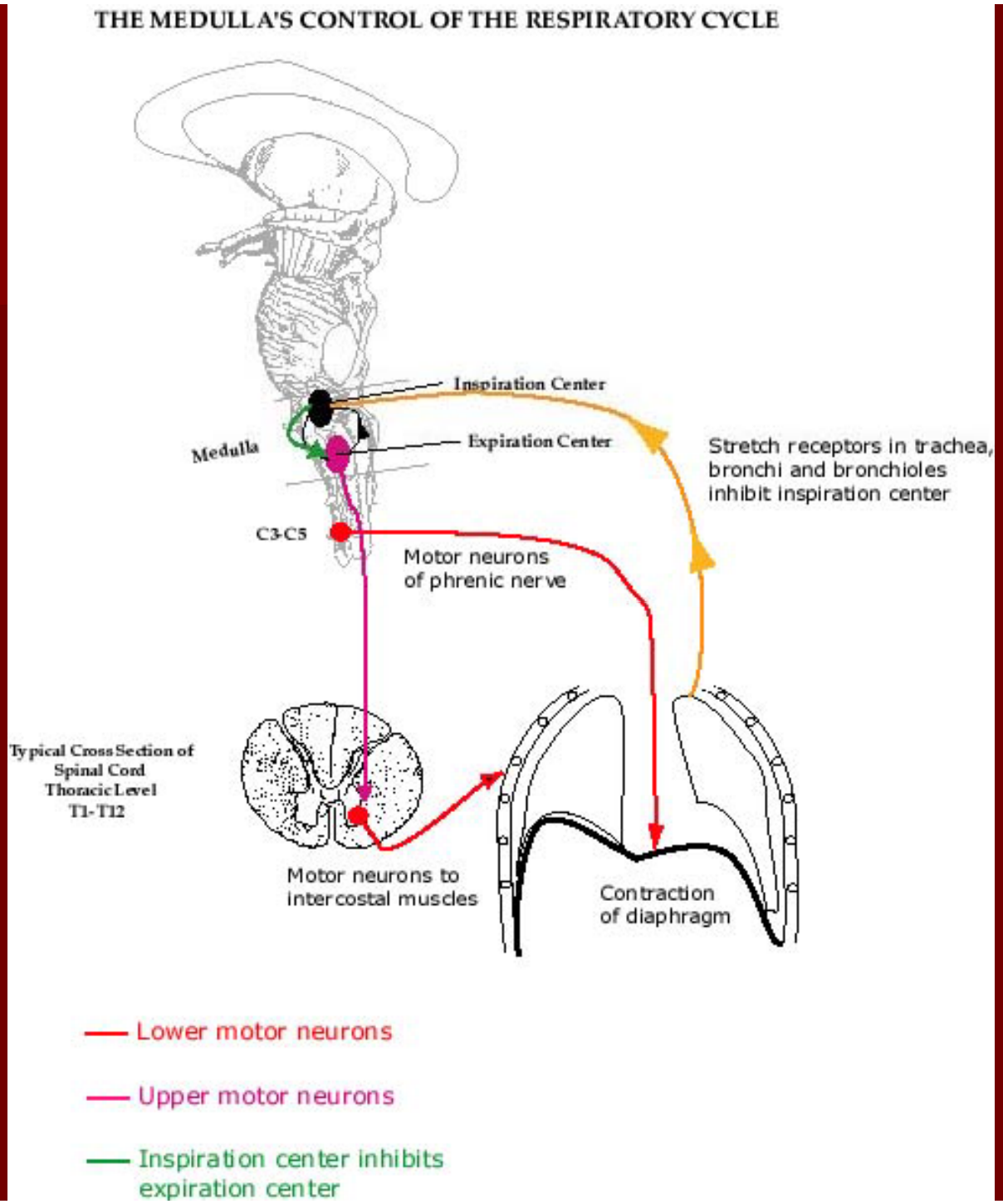

Midbrain
Hindbrain
Pons
Cerebellum
Medulla

# Neural generation of rhythmical breathing

The discharge of medullary inspiratory neurons provides rhythmic input to the motor neurons innervating the inspiratory muscles. Then the action potential cease, the inspiratory muscles relax, and expiration occurs as the elastic lungs recoil.

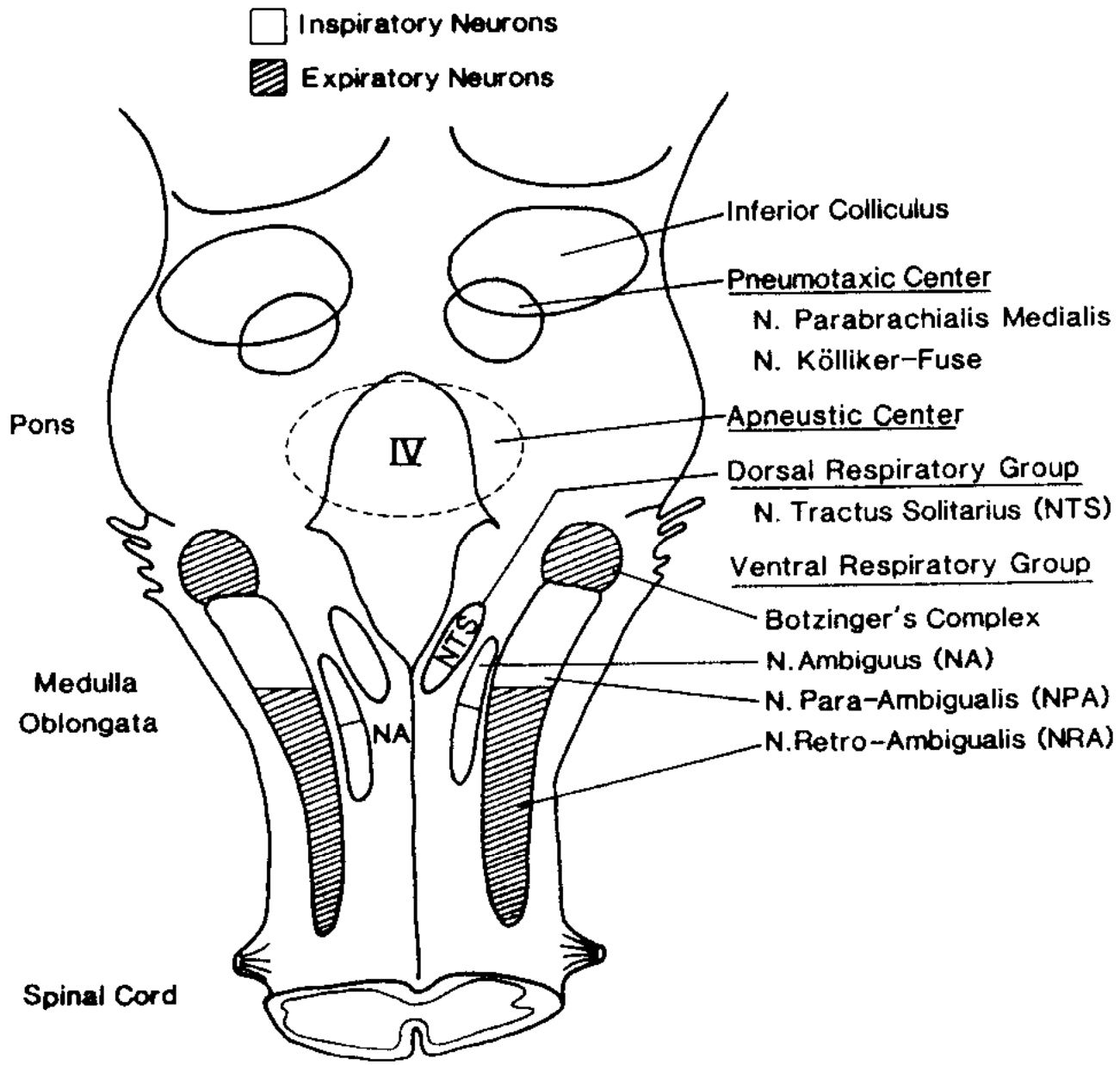


- Inspiratory neurons
- Expiratory neurons



# Respiratory center

- Dorsal respiratory group (medulla) – mainly causes inspiration
- Ventral respiratory group (medulla) – causes either expiration or inspiration
- Pneumotaxic center (upper pons) – inhibits apneustic center & inhibits inspiration,helps control the rate and pattern of breathing
- Apneustic center (lower pons) – to promote inspiration


Inspiratory Neurons
Expiratory Neurons
Inferior Colliculus
Pneumotaxic Center
N. Parabrachialis Medialis
N. Kölliker-Fuse
Pons
Apneustic Center
IV
Dorsal Respiratory Group
N. Tractus Solitarius (NTS)
Ventral Respiratory Group
Botzinger's Complex
NTS
N. Ambiguus (NA)
N. Para-Ambigualis (NPA)
Medulla
Oblongata
NA
N. Retro-Ambigualis (NRA)
Spinal Cord

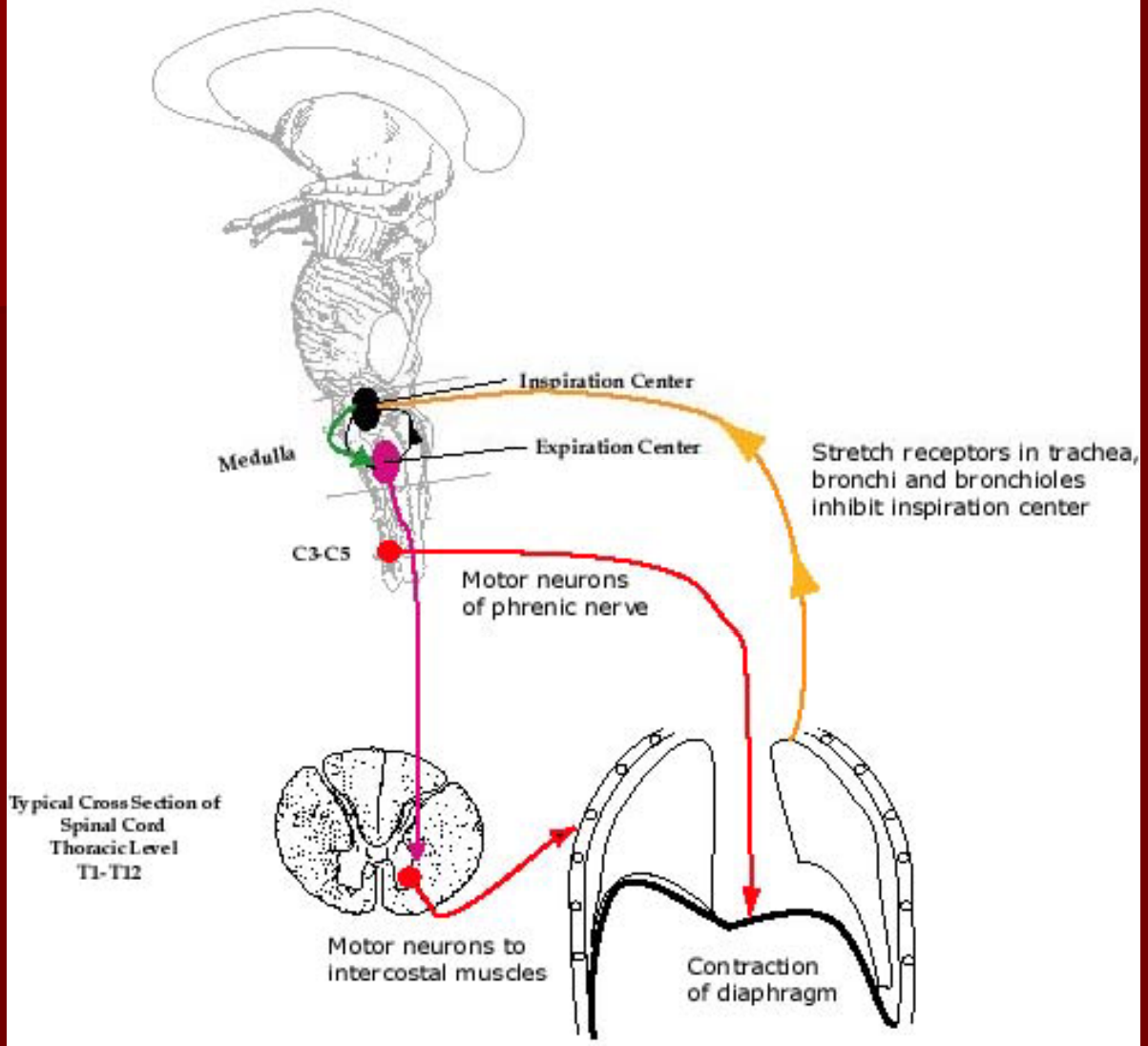
# Hering-Breuer inflation reflex (Pulmonary stretch reflex)

- The reflex is originated in the lungs and mediated by the fibers of the vagus nerve:
  - Pulmonary  inflation reflex:
    - inflation of the lungs, eliciting expiration.
  - Pulmonary  inflation reflex:
    - deflation, stimulating inspiration.

# Pulmonary inflation reflex

- Inflation of the lungs → +pulmonary stretch receptor →+vagus nerve → -medually inspiratory neurons → +eliciting expiration

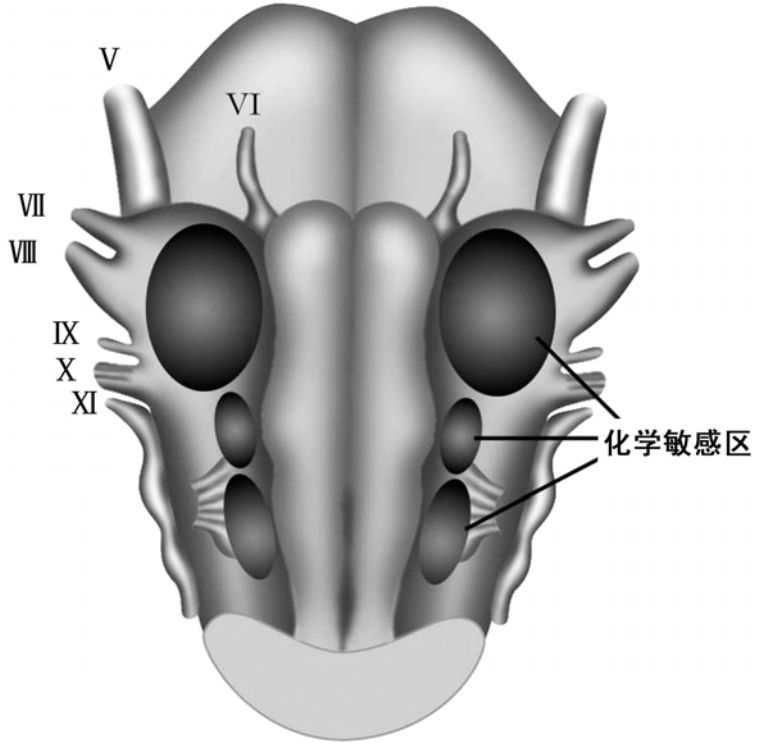
# THE MEDULLA'S CONTROL OF THE RESPIRATORY CYCLE

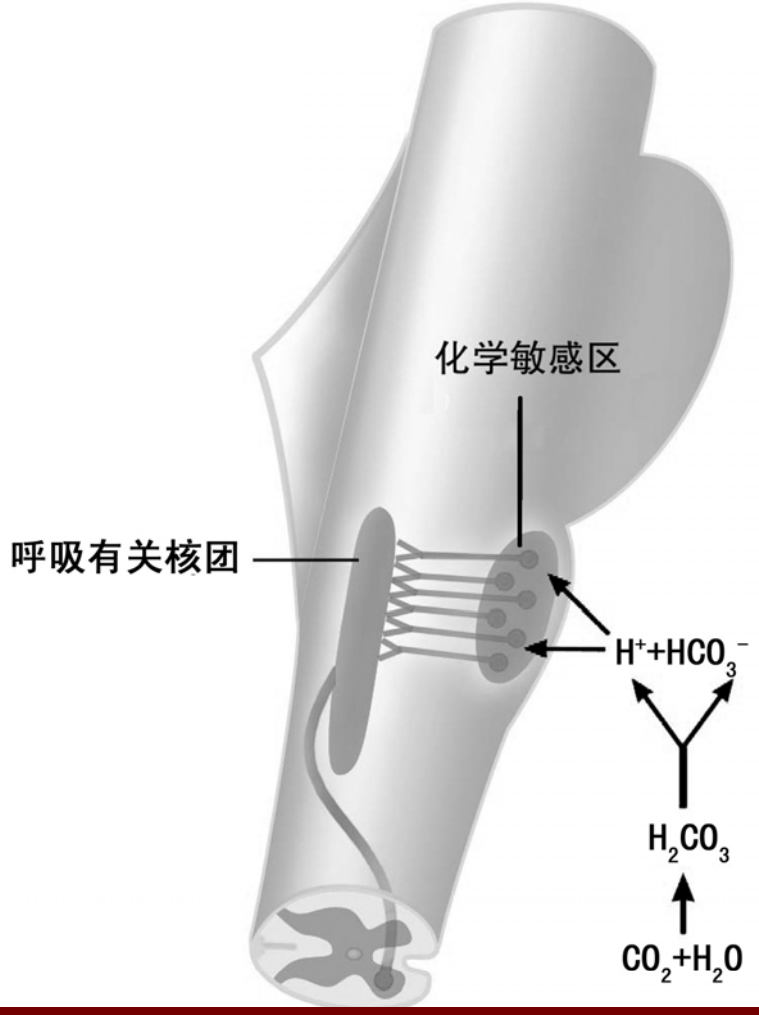


# Chemical control of respiration

- Chemoreceptors
  - Central chemoreceptors: medulla
    - Stimulated by $[H^+]\uparrow$ in the CSF
  - Peripheral chemoreceptors
    - Carotid body
      - Stimulated by arterial $PO_2\downarrow$ or $[H^+]\uparrow$
    - Aortic body

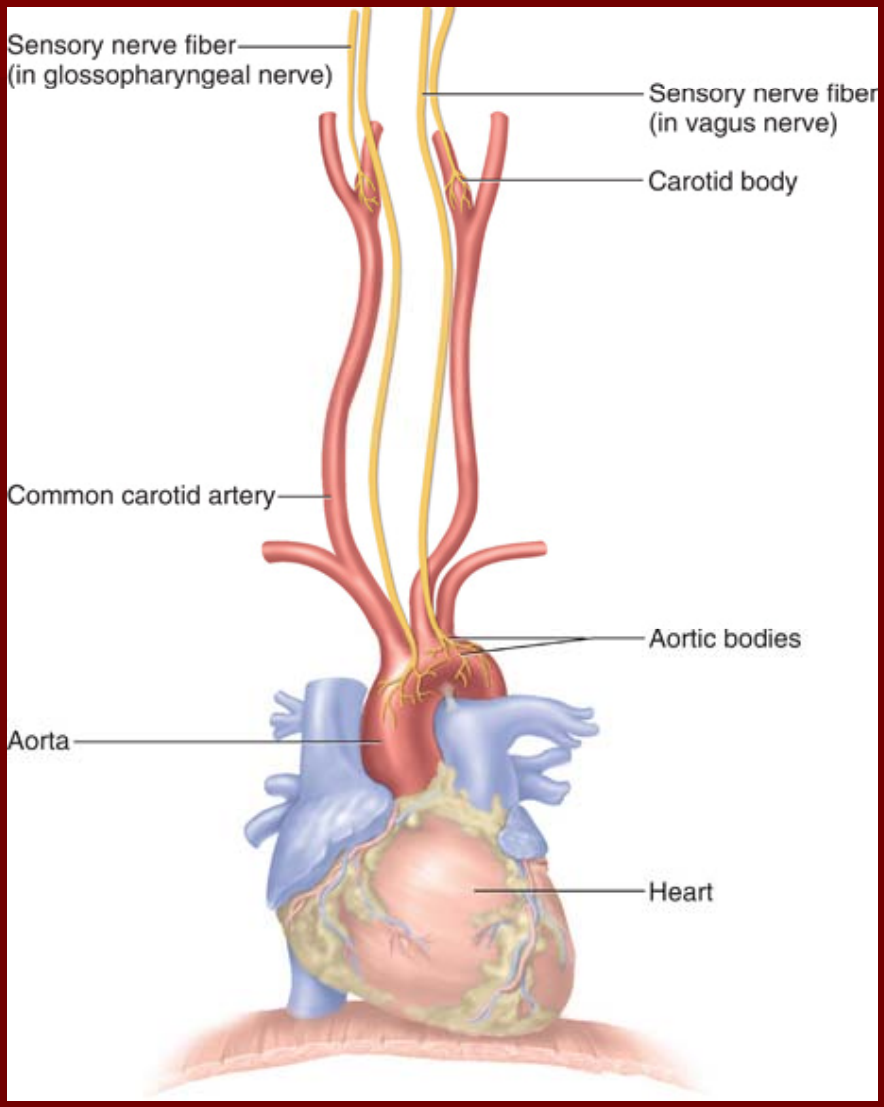
# Central chemoreceptors

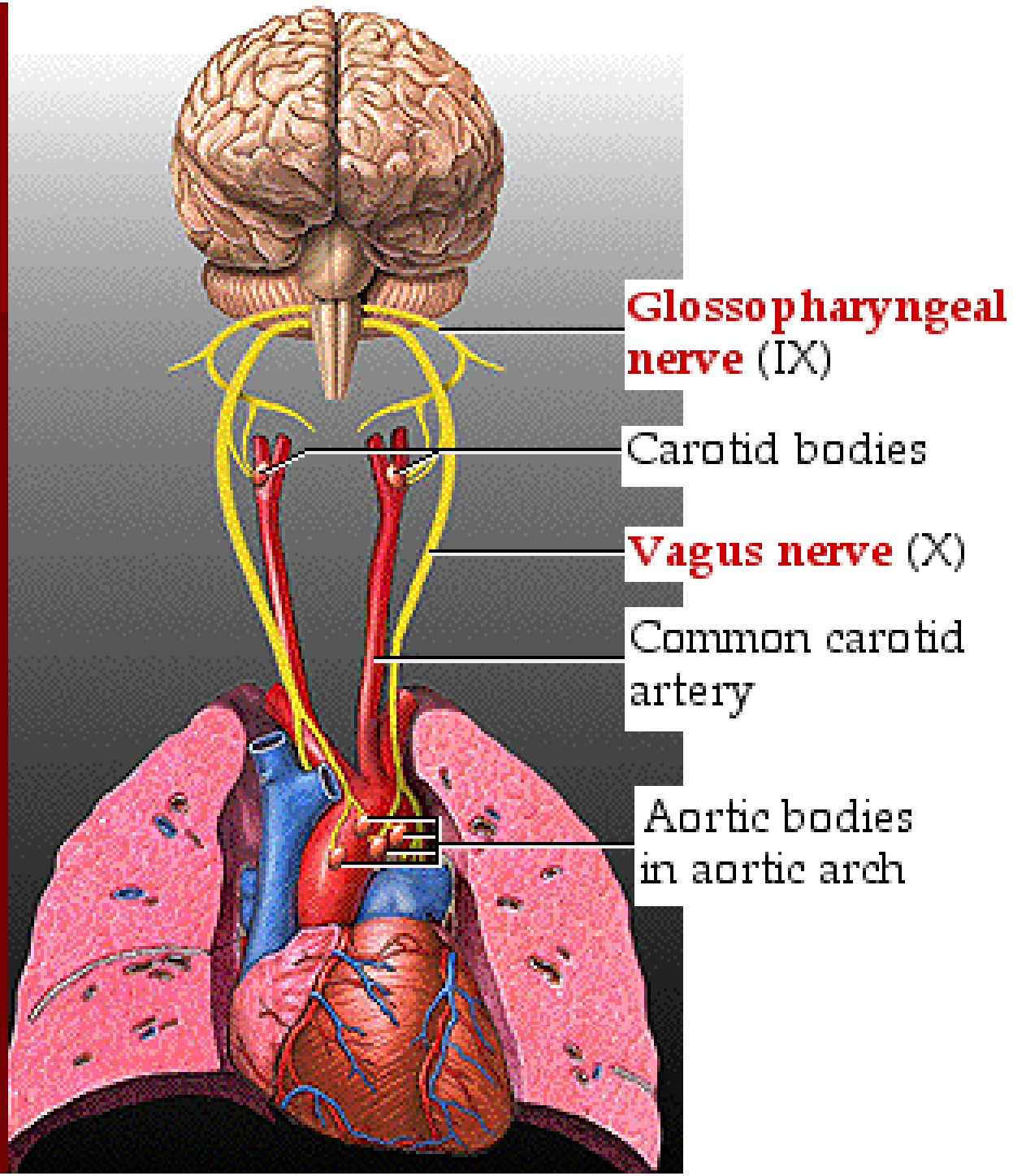


# Peripheral chemoreceptors

Chemosensory neurons that respond to changes in blood pH and gas content are located in the aorta and in the carotid sinuses; these sensory afferent neurons alter CNS regulation of the rate of ventilation.




Glossopharyngeal nerve (IX)
Carotid bodies
Vagus nerve (X)
Common carotid artery
Aortic bodies in aortic arch

## TABLE 13–10 *Major Stimuli for the Central and Peripheral Chemoreceptors*

**Peripheral chemoreceptors**—that is, carotid bodies and aortic bodies—respond to changes in the *arterial blood.* They are stimulated by:

1. Decreased $P_{O_2}$ (hypoxia)
2. Increased hydrogen ion concentration (metabolic acidosis)
3. Increased $P_{CO_2}$ (respiratory acidosis)

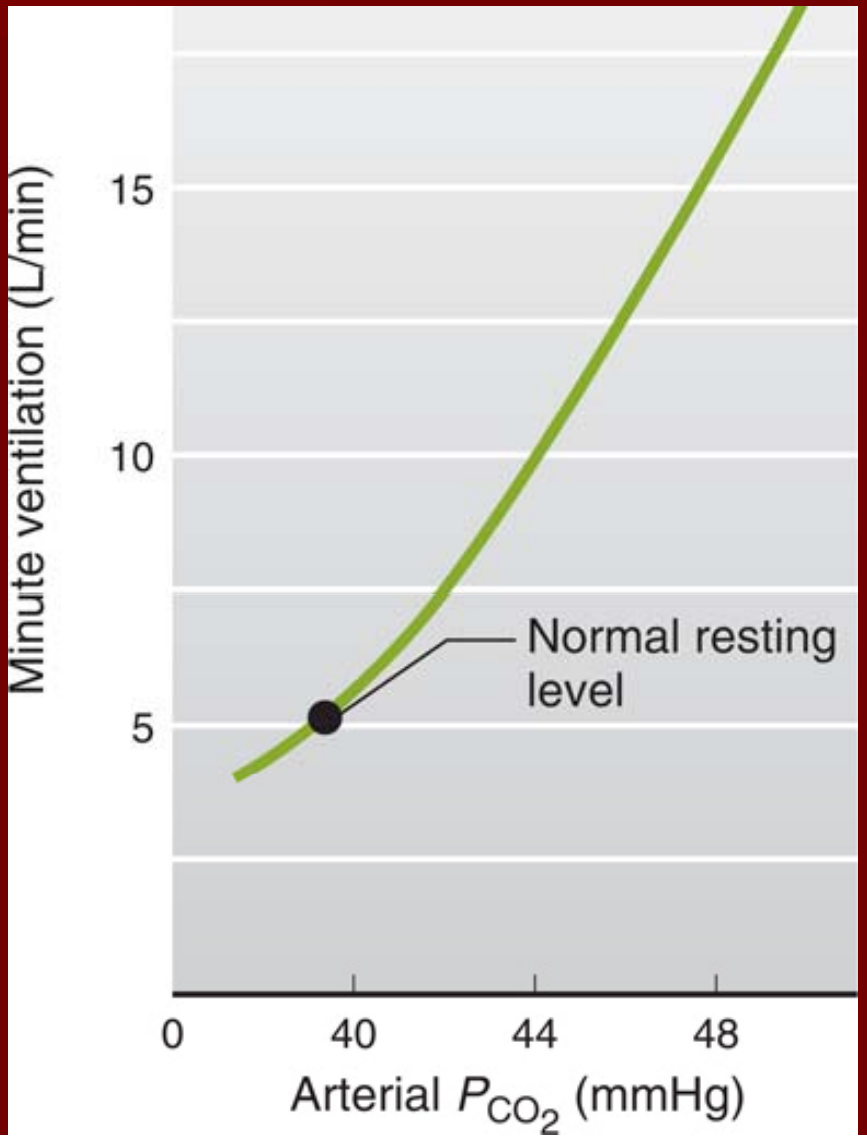
---

**Central chemoreceptors**—that is, located in the medulla oblongata—respond to changes in the *brain extracellular fluid.* They are stimulated by increased $P_{CO_2}$ via associated changes in hydrogen ion concentration. (See Equation 13–11.)

# Effect of carbon dioxide on pulmonary ventilation

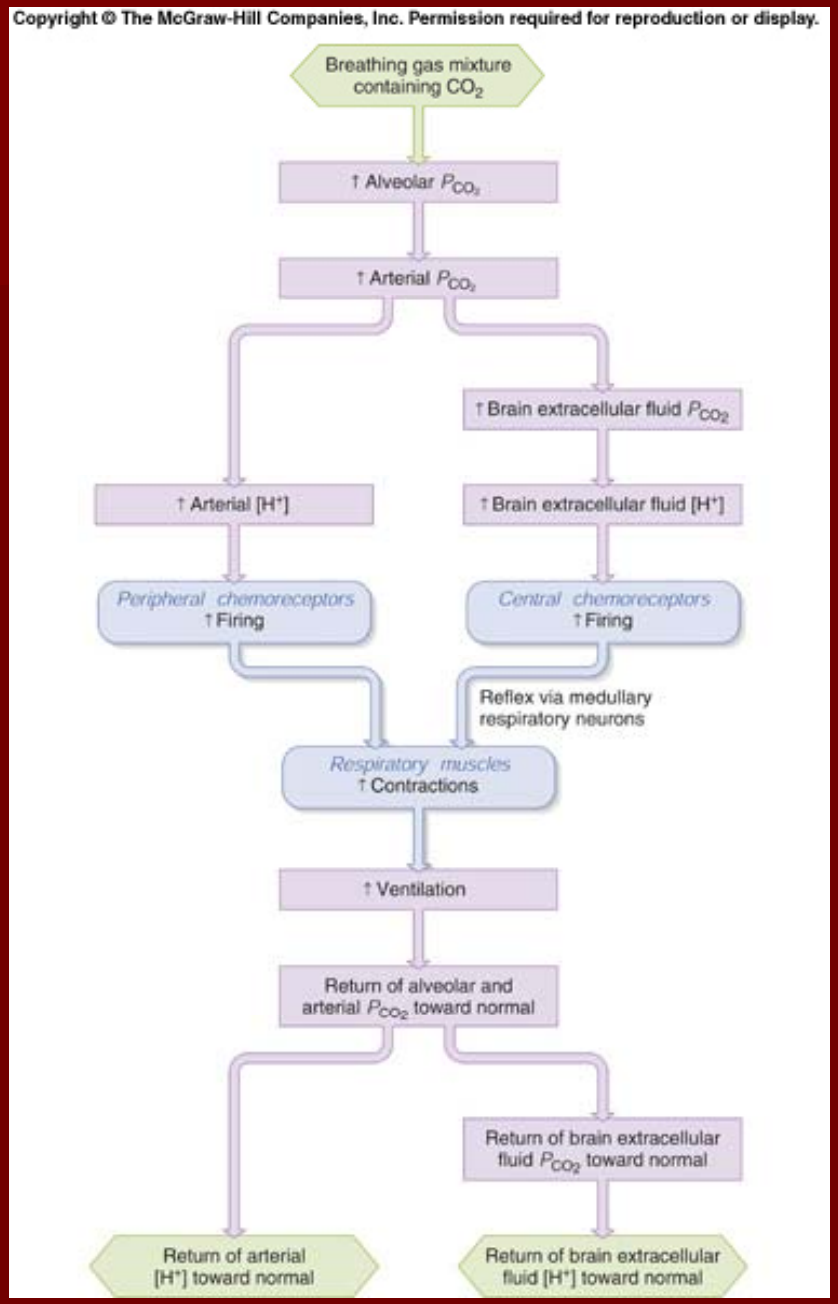
Small changes in the carbon dioxide content of the blood quickly trigger changes in ventilation rate.

$CO_2 \uparrow \rightarrow \uparrow$ respiratory activity



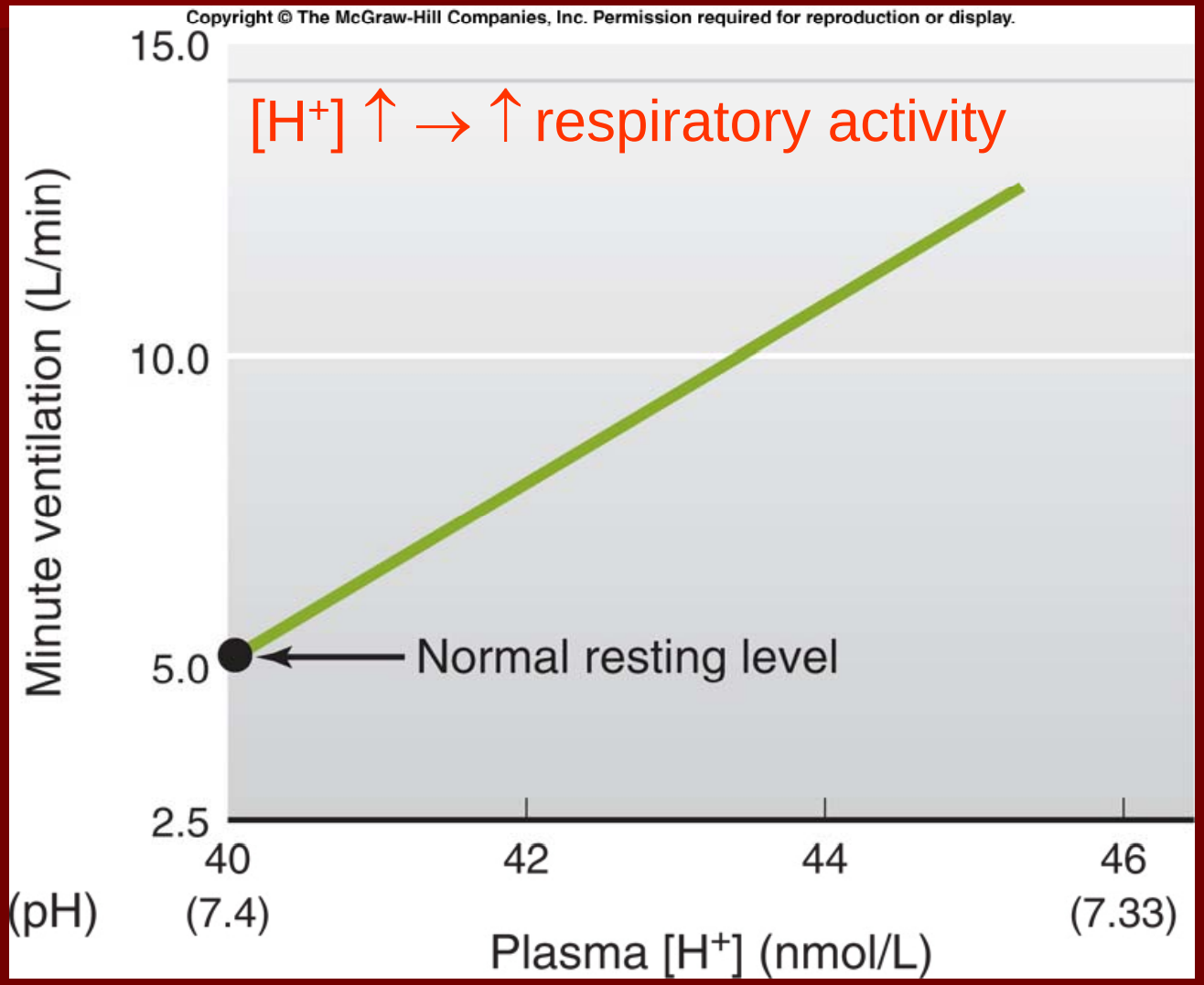
Central and peripheral chemosensory neurons that respond to increased carbon dioxide levels in the blood are also stimulated by the acidity from carbonic acid, so they “inform” the ventilation control center in the medulla to increase the rate of ventilation.

$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO^{3-}$

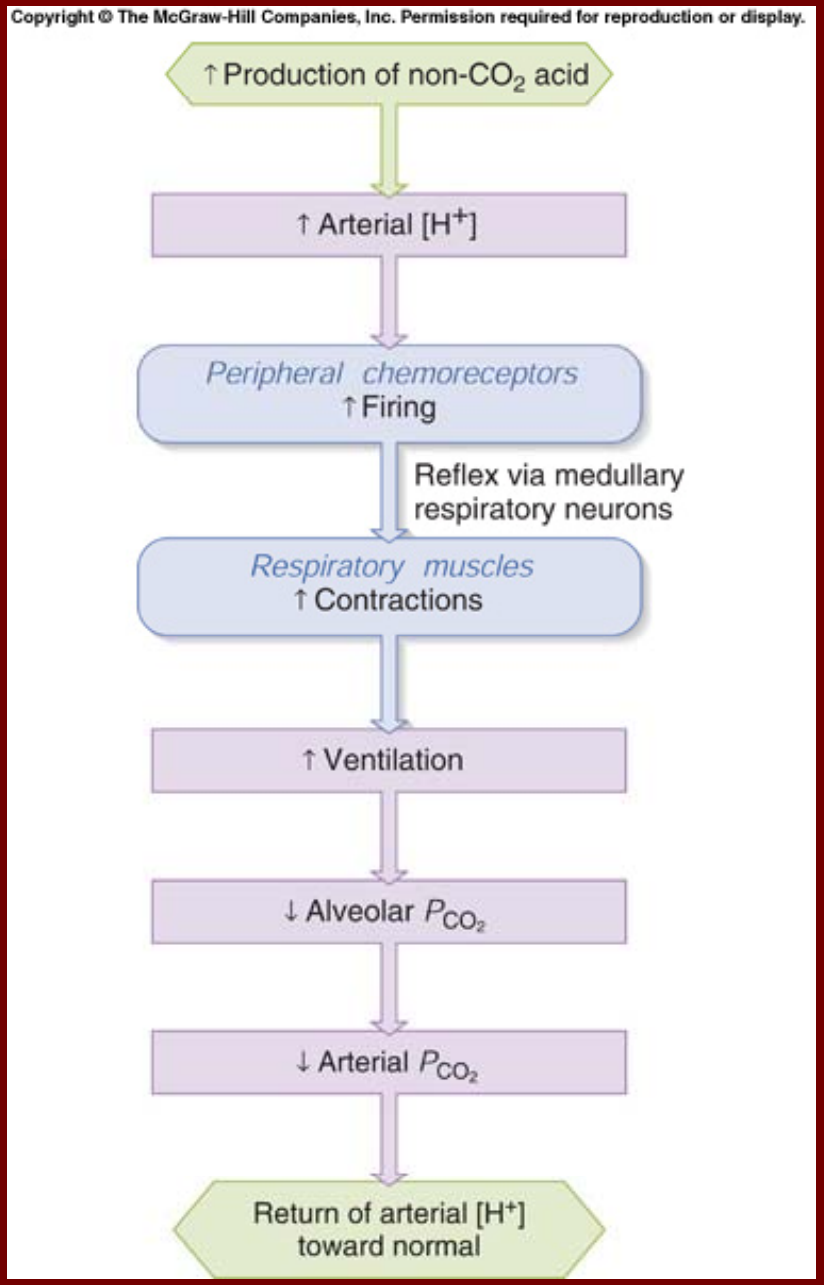


# Effect of hydrogen ion on pulmonary ventilation

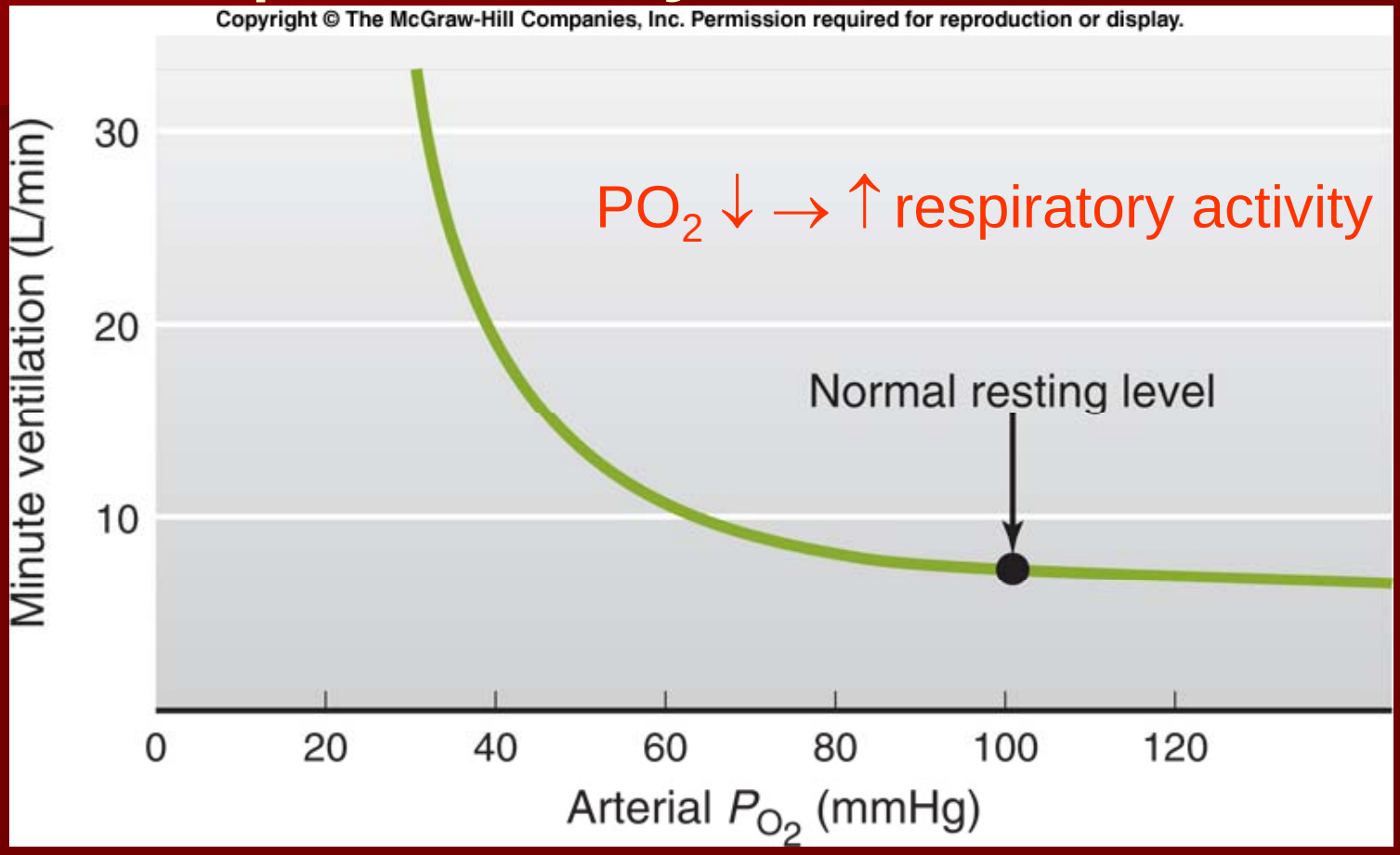
Regardless of the source, increases in the acidity of the blood cause hyperventilation.



Regardless of the source, increases in the acidity of the blood cause hyperventilation, even if carbon dioxide levels are driven to abnormally low levels.

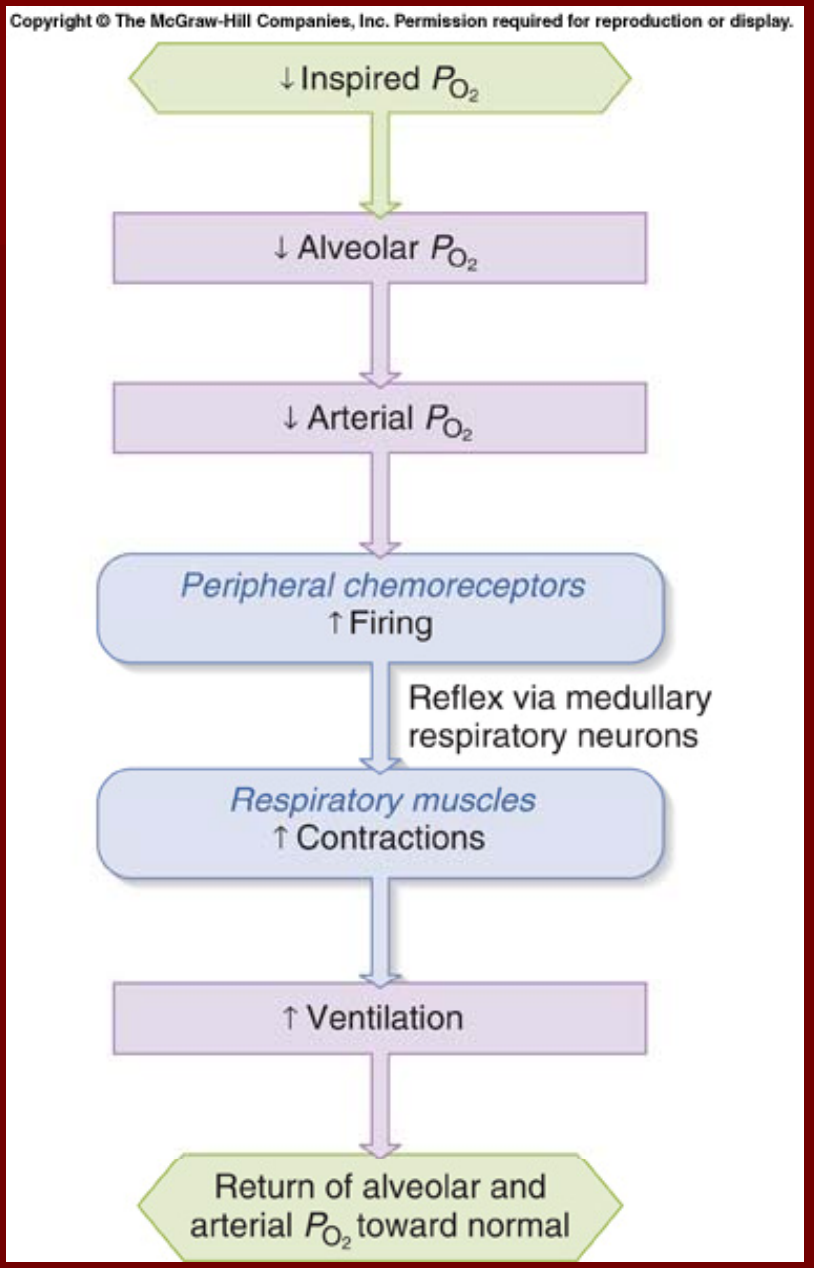


# Effect of low arterial $PO_2$ on pulmonary ventilation



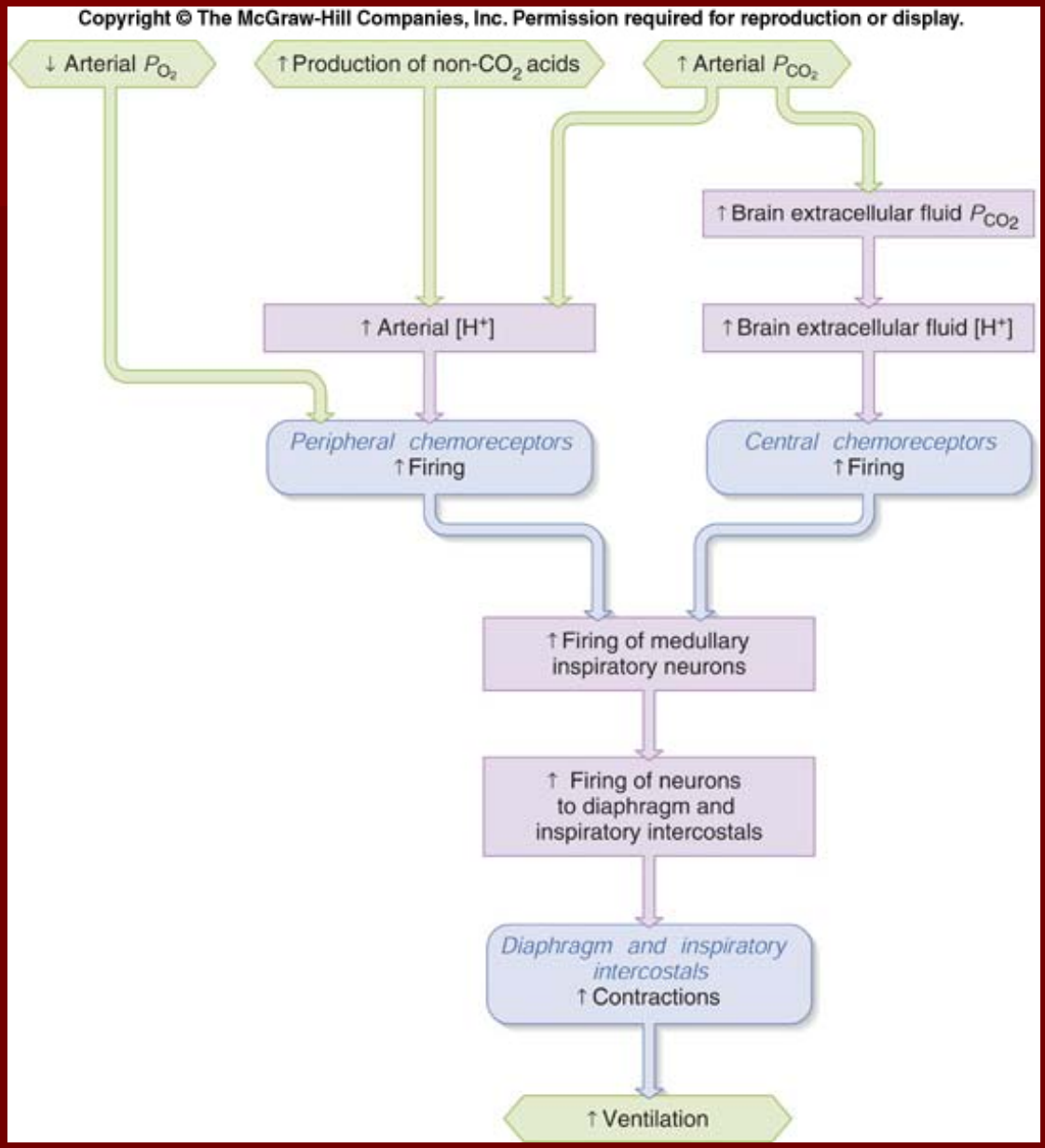

A severe reduction in the arterial concentration of oxygen in the blood can stimulate hyperventilation.

Chemosensory neurons that respond to decreased oxygen levels in the blood “inform” the ventilation control center in the medulla to increase the rate of ventilation.



## In summary:

The levels of oxygen, carbon dioxide, and hydrogen ions in blood and CSF provide information that alters the rate of ventilation.



# Regulation of respiration