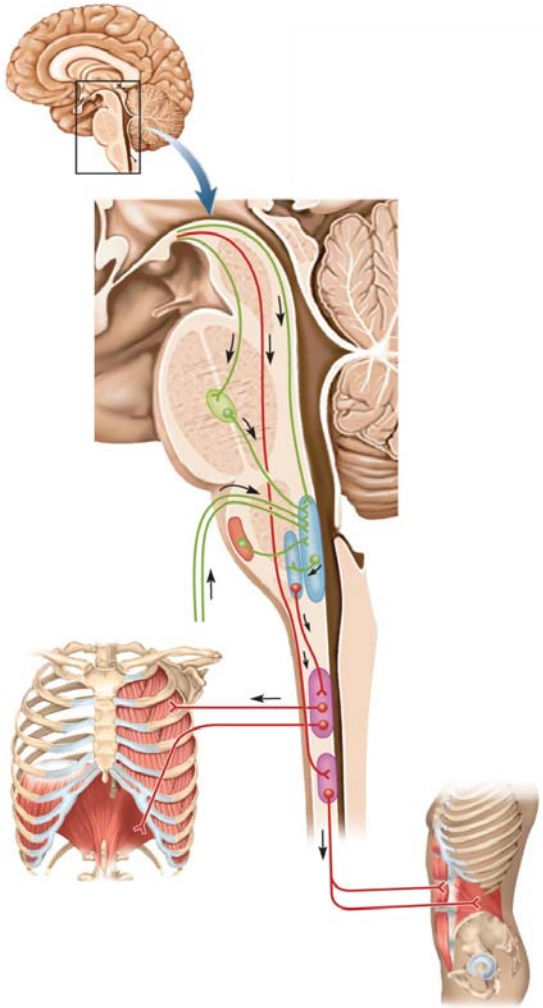
Chapter 23

Neural and Voluntary Control of Breathing



Neural Control of Breathing

- This topic is still "unsettled" science // *exact mechanism for setting the rhythm of respiration remains unknown*

- Currently, we understand there are three neural circuits (nuclei) within the brain stem which influence breathing

  – Dorsal respiratory group
  – Ventral respiratory group
  – Pontine respiratory group

- Higher brain centers may also influence these nuclei in the brain stem to modify breathing // cerebral cortex, limbic system, hypothalamus.

Neural Control of Breathing

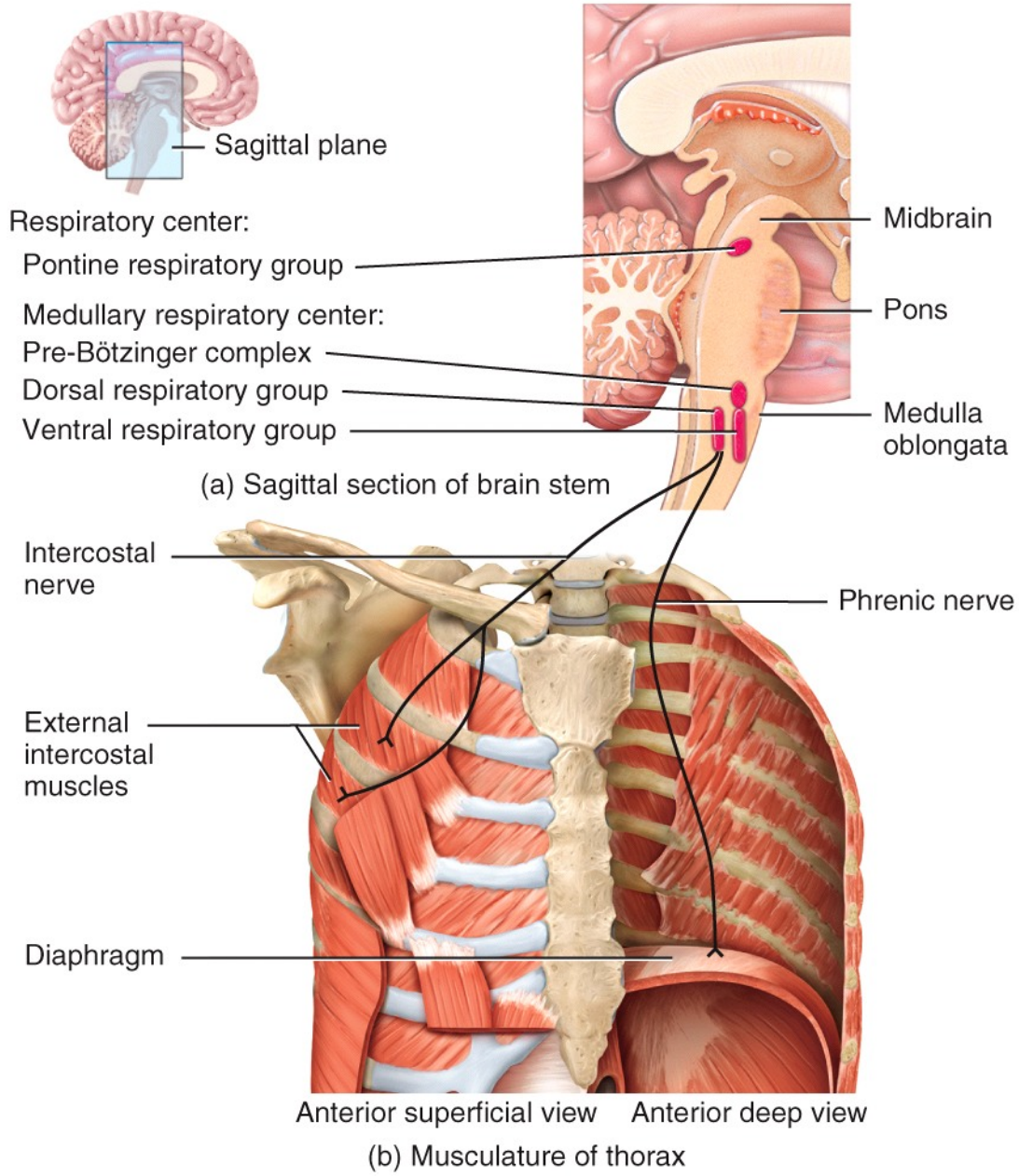
- Medullary respiratory center located in the medulla oblongata // two nuclei form the MRC
  - Dorsal respiratory group – quiet during normal breathing / location for two nuclei that send impulses to diaphragm via phrenic nerves and external intercostal muscles via the intercostal nerves
  - Ventral respiratory group – location of the *pre-Botzinger complex* // generates the rhythm of breathing by sending action potentials to the DRG's inspiratory neurons (2 seconds)

Neural Control of Breathing

- Pontine respiratory group
  - Located in the pons
  - Send signals to the DRG / modify breathing
  - Changes rate and force of both inspiration and expiration
  - Modify breathing for exercising, speaking, or sleeping, etc.

Neural Control of Breathing

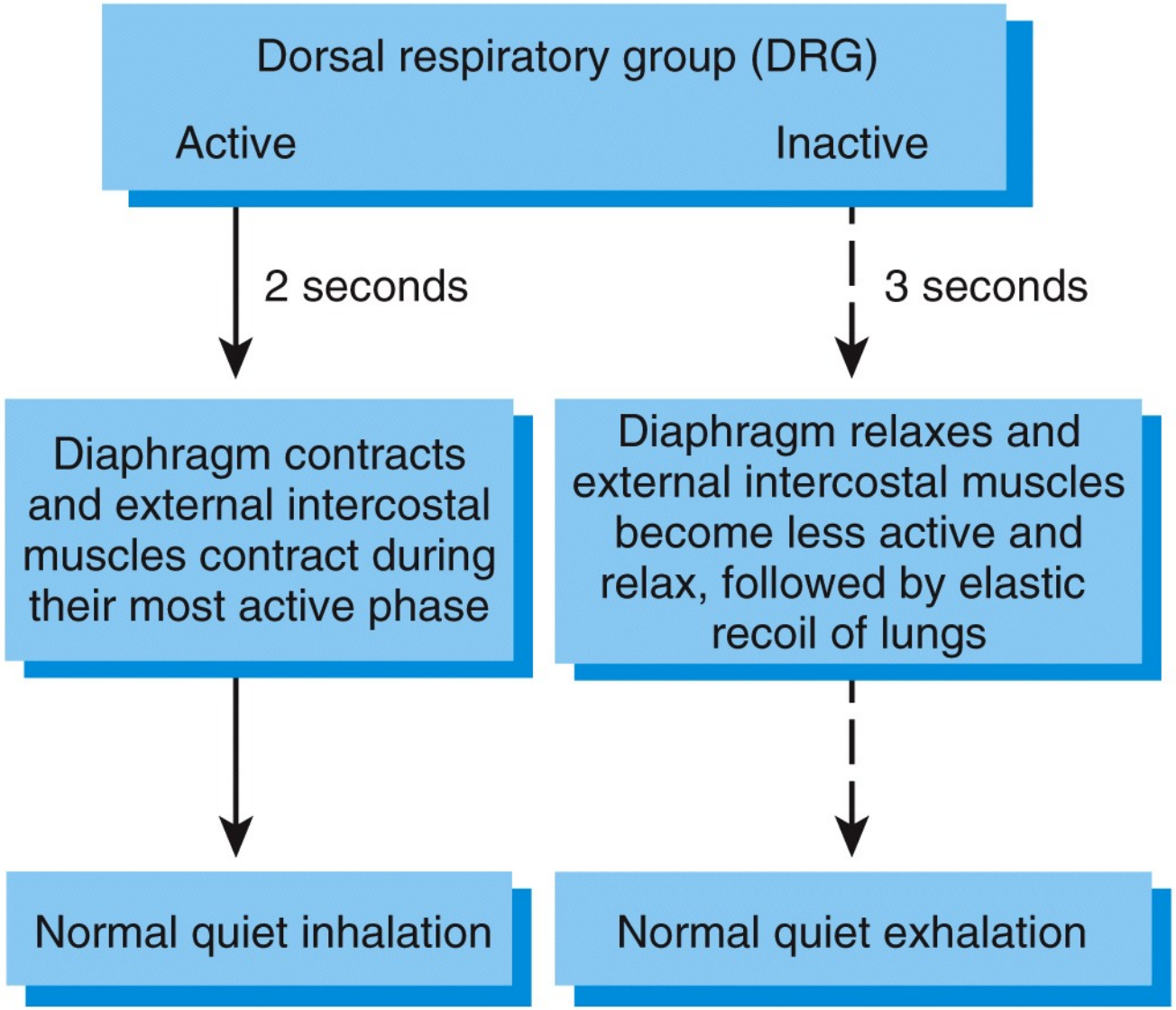
- Breathing depends on repetitive stimuli from brain to skeletal muscles of thorax (diaphragm and external intercostals)
  - neurons in medulla oblongata and pons control unconscious breathing
  - inspiratory neurons (DRG) /// fire during inspiration (2 sec)
  - expiratory neurons (DRG) /// fire to inhibit inspriatory neurons during eupnea (3 sec)
  - Respiratory cycle = 12 breaths per minute
  - voluntary control provided by motor cortex // you can hold your breath!
  - Other factors // in order to maintain hoeostasis // central chemoreceptors, peripheral chemoreceptors, proprioceptor lung stretch receptors (Hering-Breuer reflex), irritant reflex, limbic system, temperature, pain, stretching the anal spincter, blood pressure (minor)



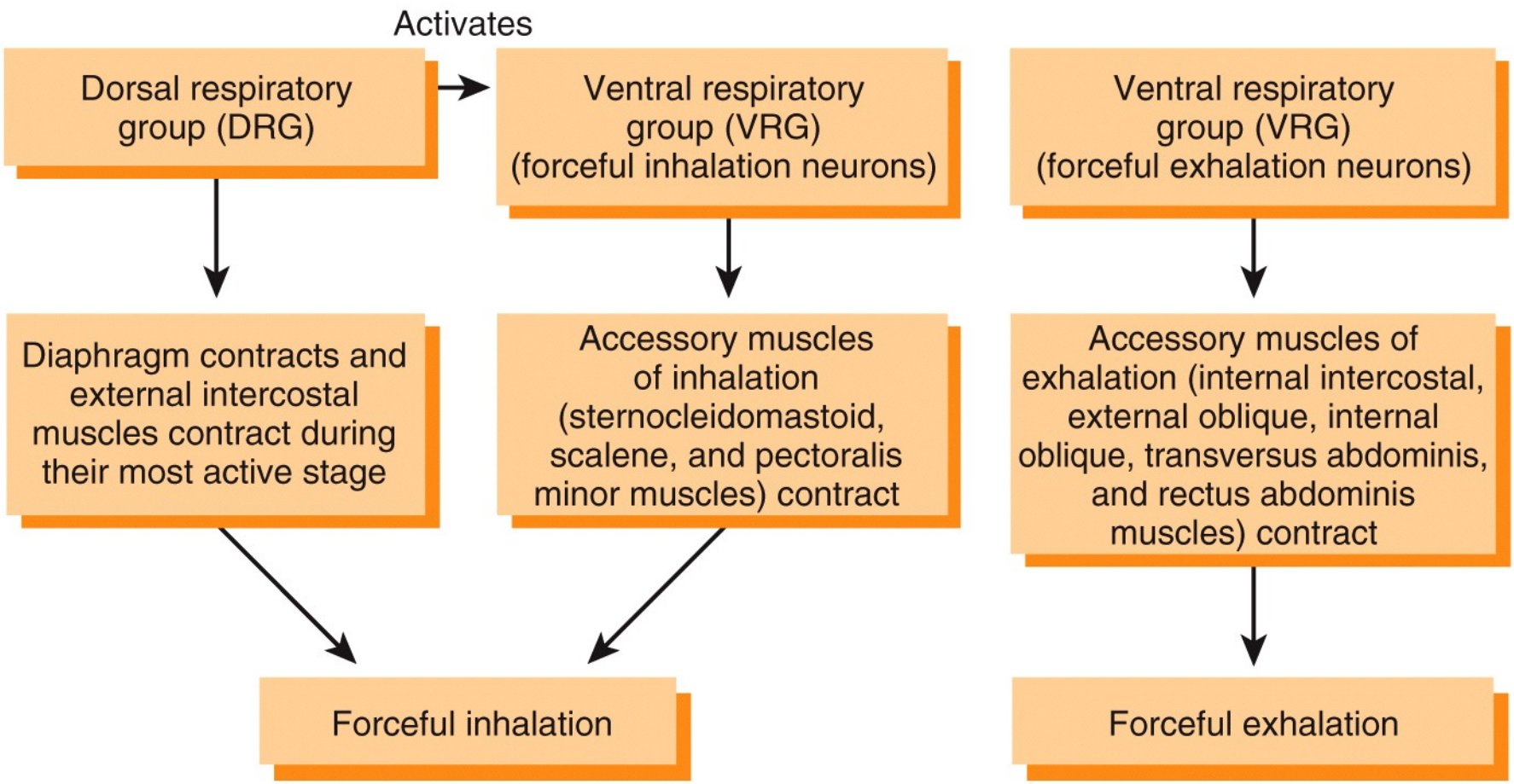
(a) Sagittal section of brain stem

(b) Musculature of thorax

Quiet Breathing / Normal Quiet Breathing (Know This)



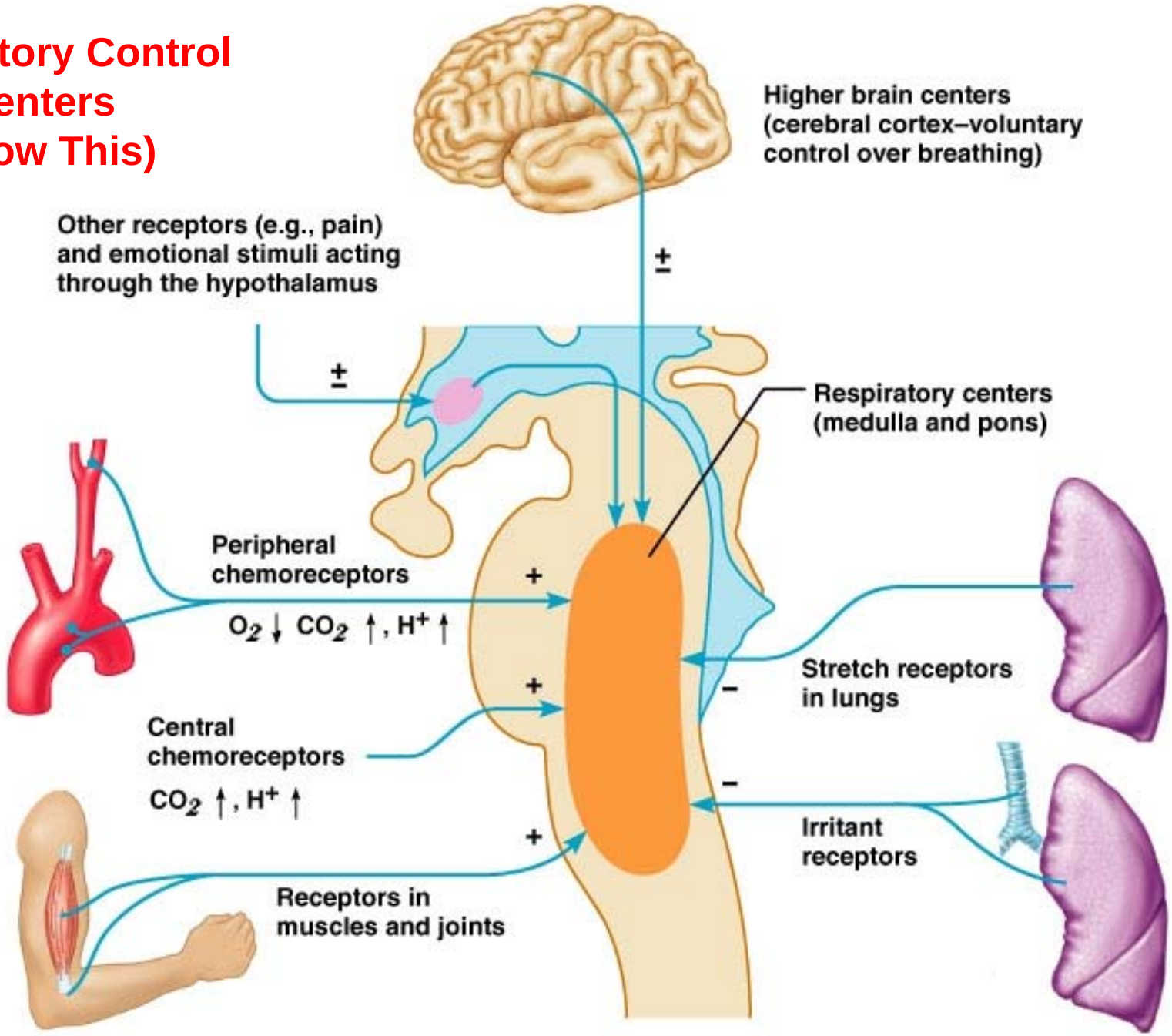
Forceful Breathing / Breathing During Exercise



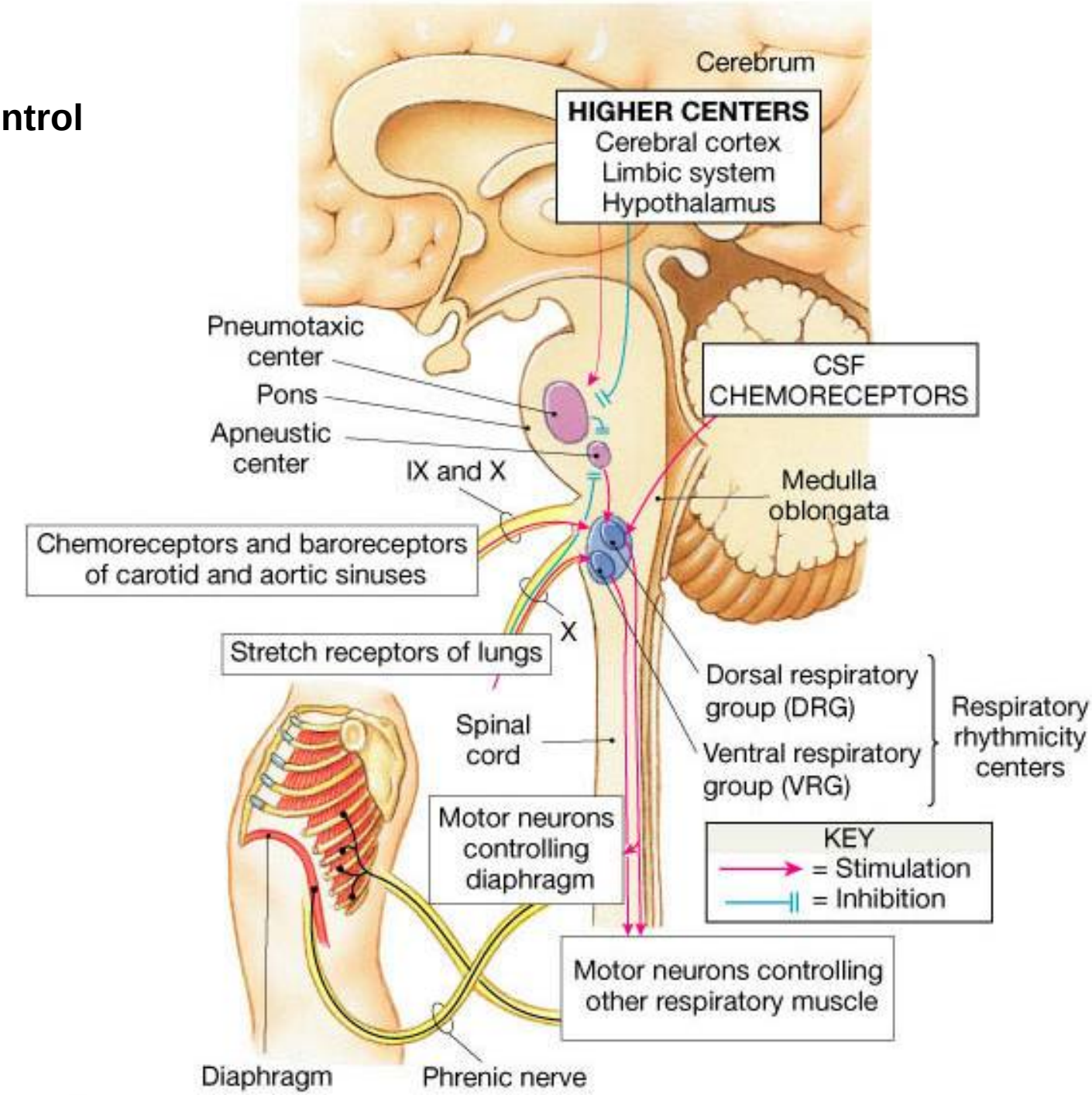
Brainstem Respiratory Centers

- Respiratory nuclei in pons
  - pons respiratory nuclei – signals to dorsal respiratory group
  - pontine respiratory group (PRG)
    - modifies rhythm by sending signals to both the VRG and DRG
    - adapts breathing to special circumstances such as sleep, exercise, vocalization, and emotional responses
    - Also receives Input from limbic system and cerebrum

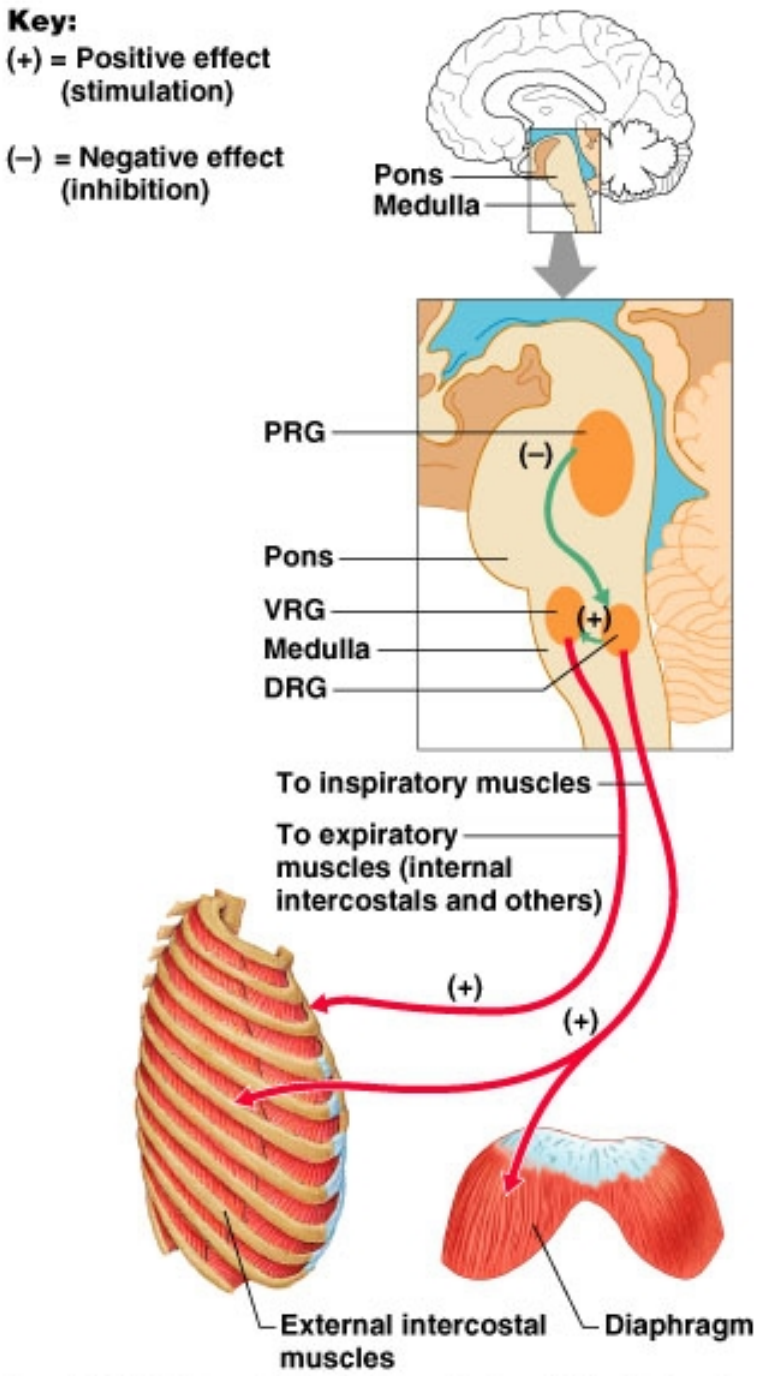
Respiratory Control Centers (Know This)



Respiratory Control Centers



Respiratory Control Centers



Central and Peripheral Input to Respiratory Centers

- central chemoreceptors
  - brainstem neurons that respond to changes in pH of cerebrospinal fluid
  - pH of cerebrospinal fluid reflects the CO_2 level in the blood
  - by regulating respiration to maintain stable pH /// respiratory center also ensures stable CO_2 level in the blood
- peripheral chemoreceptors
  - located in the carotid and aortic bodies of the large arteries above the heart
  - respond to the O_2 and CO_2 content and the pH of blood

Central and Peripheral Input to Respiratory Centers (Know This)

- **Stretch receptors**
  - found in the smooth muscles of bronchi and bronchioles, and in the visceral pleura
  - respond to inflation of the lungs
  - **inflation (Hering-Breuer) reflex**
    - triggered by excessive inflation
    - protective reflex
    - inhibits inspiratory neurons to stop inspiration

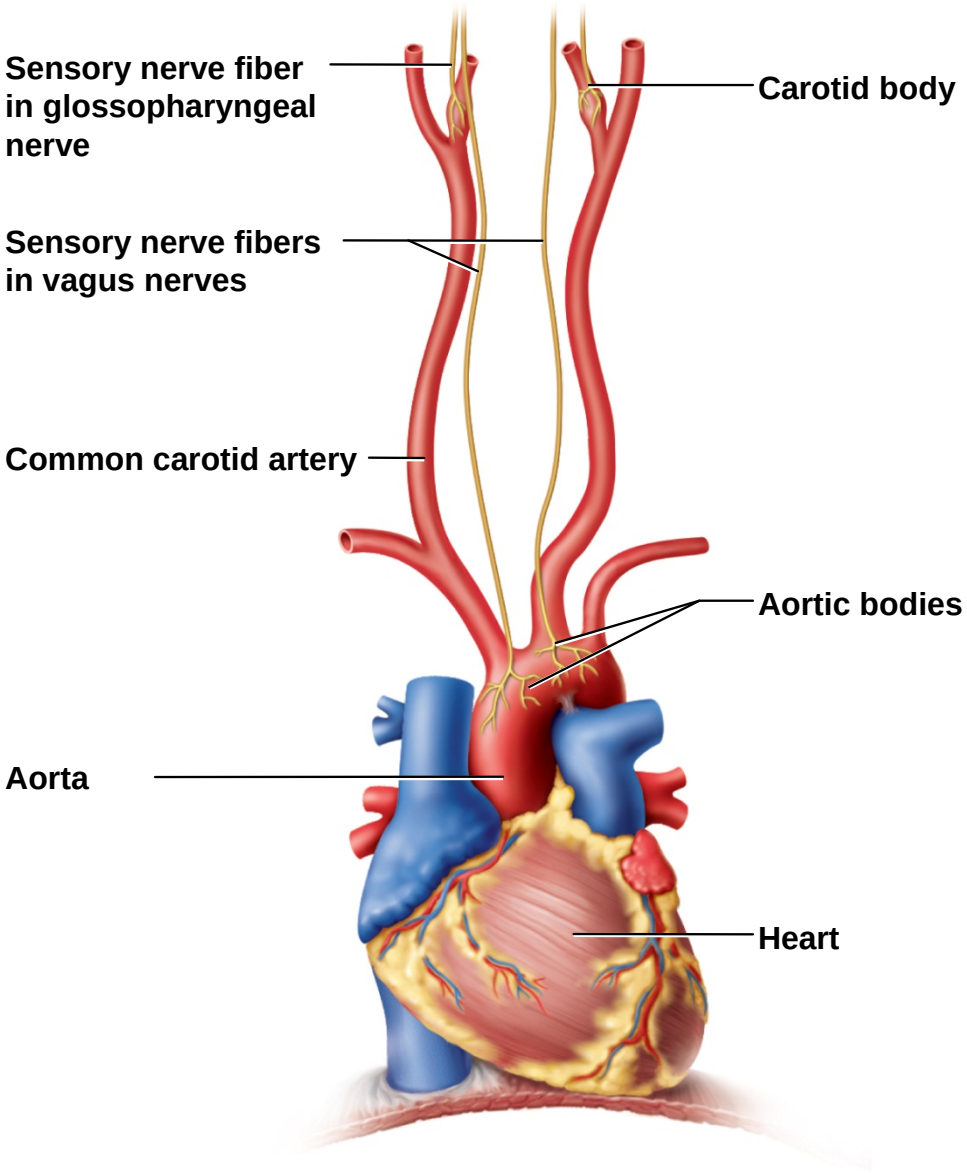
Central and Peripheral Input to Respiratory Centers (cont.)

- **Irritant receptors**
  - nerve endings amid the epithelial cells of the airway
  - respond to smoke, dust, pollen, chemical fumes, cold air, and excess mucus
  - trigger protective reflexes /// bronchoconstriction, shallower breathing, breath-holding (apnea), or coughing

Central and Peripheral Input to Respiratory Centers (cont.)

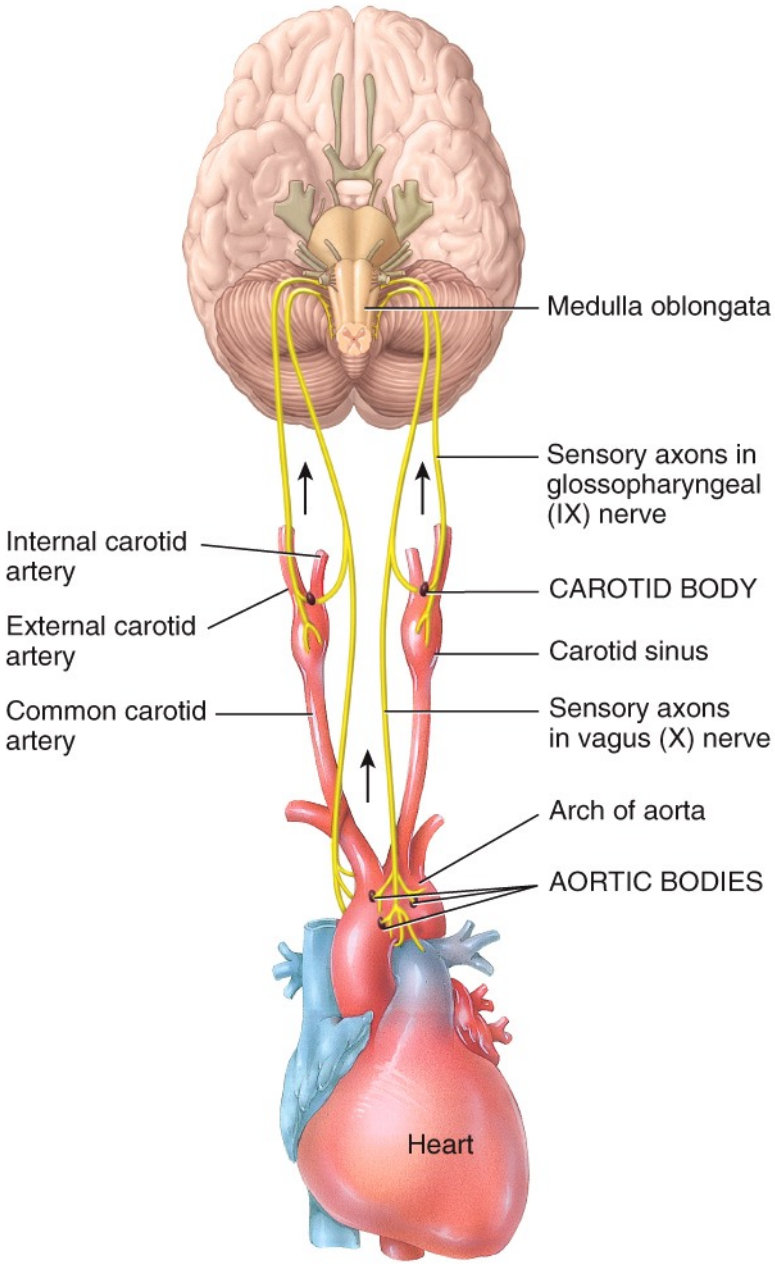
- Hyperventilation
  - anxiety triggered state in which breathing is so rapid that it expels CO_2 from the body faster than it is produced
  - CO_2 levels drop
  - pH rises causing the cerebral arteries to constrict reducing cerebral perfusion which may cause dizziness or fainting
  - can be brought under control by having the person re-breathe the expired CO_2 from a paper bag

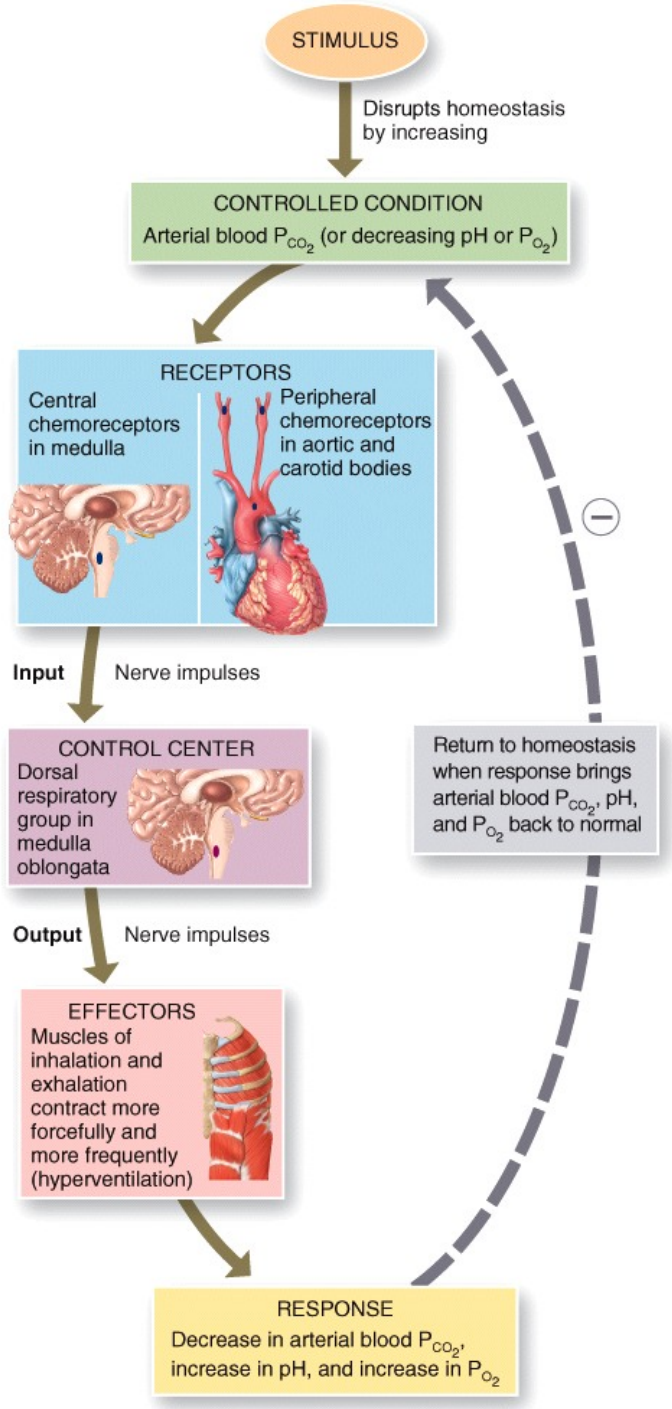
Peripheral Chemoreceptors



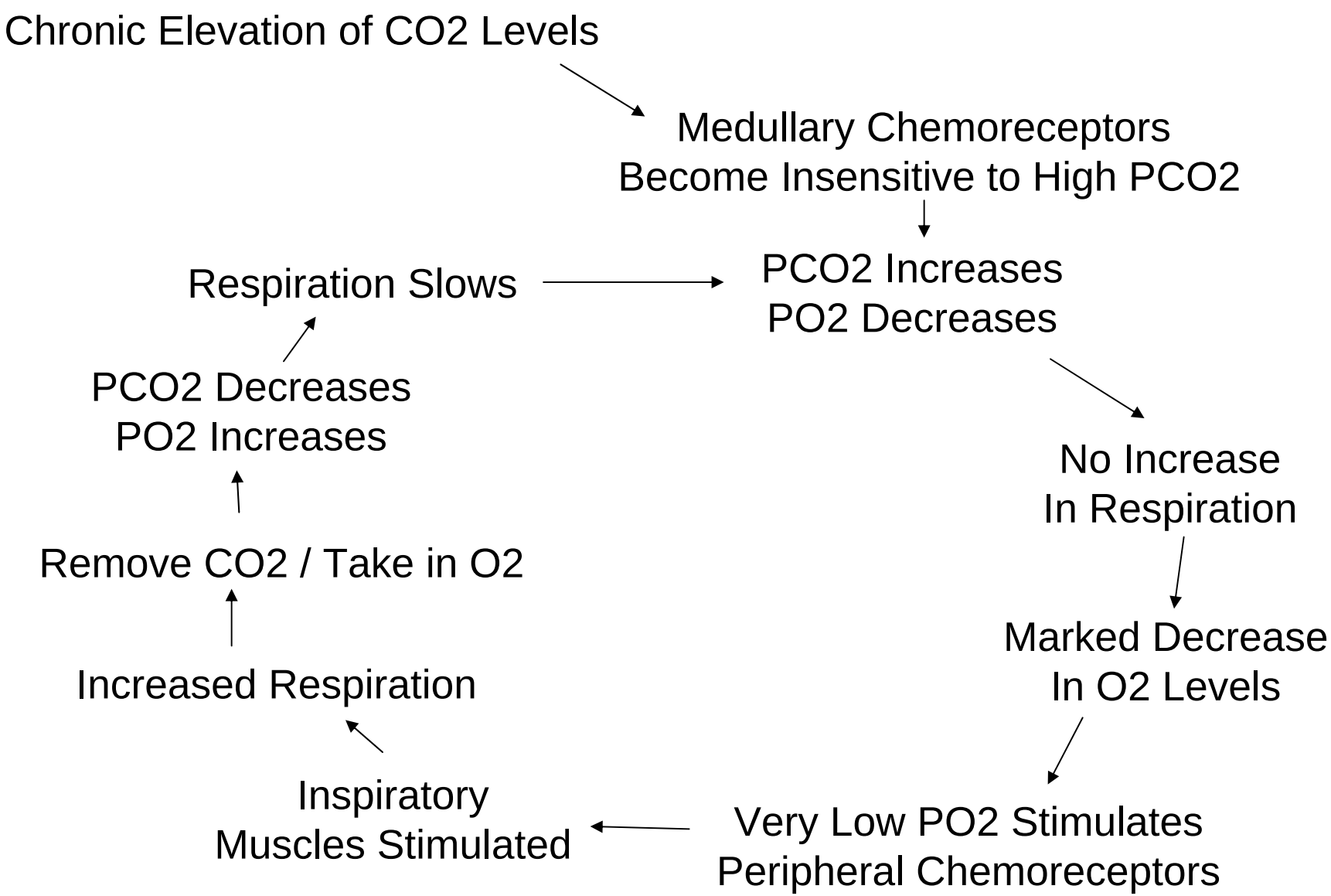
Voluntary Control of Breathing

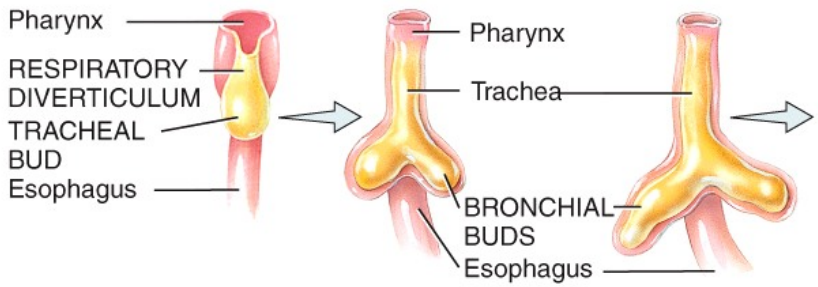
- originates in the motor cortex of frontal lobe of cerebrum
  - sends impulses down corticospinal tracts to respiratory neurons in spinal cord
  - bypassing brainstem
- limits to voluntary control
  - breaking point // when CO_2 levels rise to a point when automatic controls override one's will


Medulla oblongata
Sensory axons in glossopharyngeal (IX) nerve
Internal carotid artery
CAROTID BODY
External carotid artery
Carotid sinus
Common carotid artery
Sensory axons in vagus (X) nerve
Arch of aorta
AORTIC BODIES
Heart

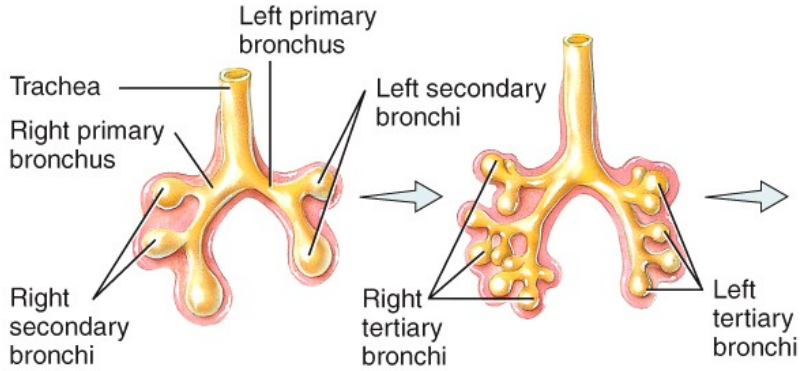

STIMULUS
Disrupts homeostasis by increasing
CONTROLLED CONDITION
Arterial blood P_{CO_2} (or decreasing pH or P_{O_2})
RECEPTORS
Central chemoreceptors in medulla
Peripheral chemoreceptors in aortic and carotid bodies
Input
Nerve impulses
CONTROL CENTER
Dorsal respiratory group in medulla oblongata
Output
Nerve impulses
EFFECTORS
Muscles of inhalation and exhalation contract more forcefully and more frequently (hyperventilation)
RESPONSE
Decrease in arterial blood P_{CO_2}, increase in pH, and increase in P_{O_2}
Return to homeostasis when response brings arterial blood P_{CO_2}, pH, and P_{O_2} back to normal
−

Hypoxic Drive



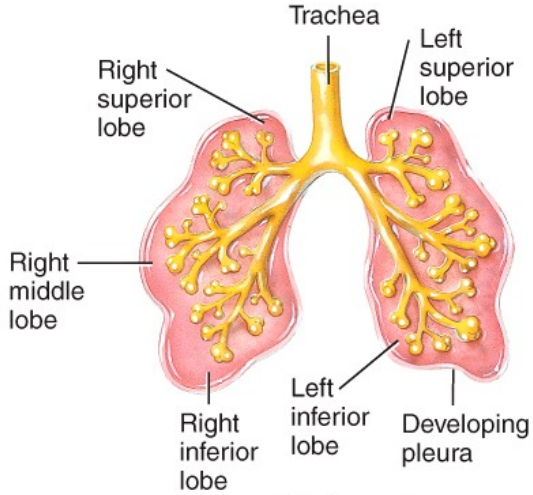


Fourth week

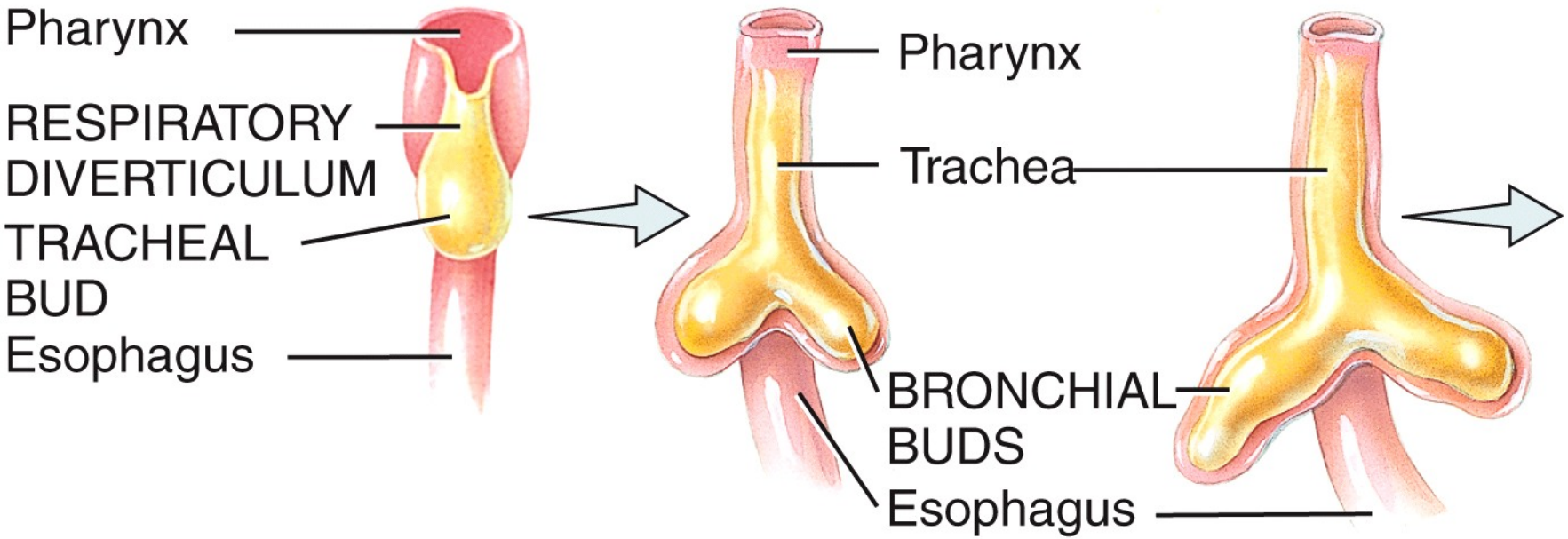


Fifth week

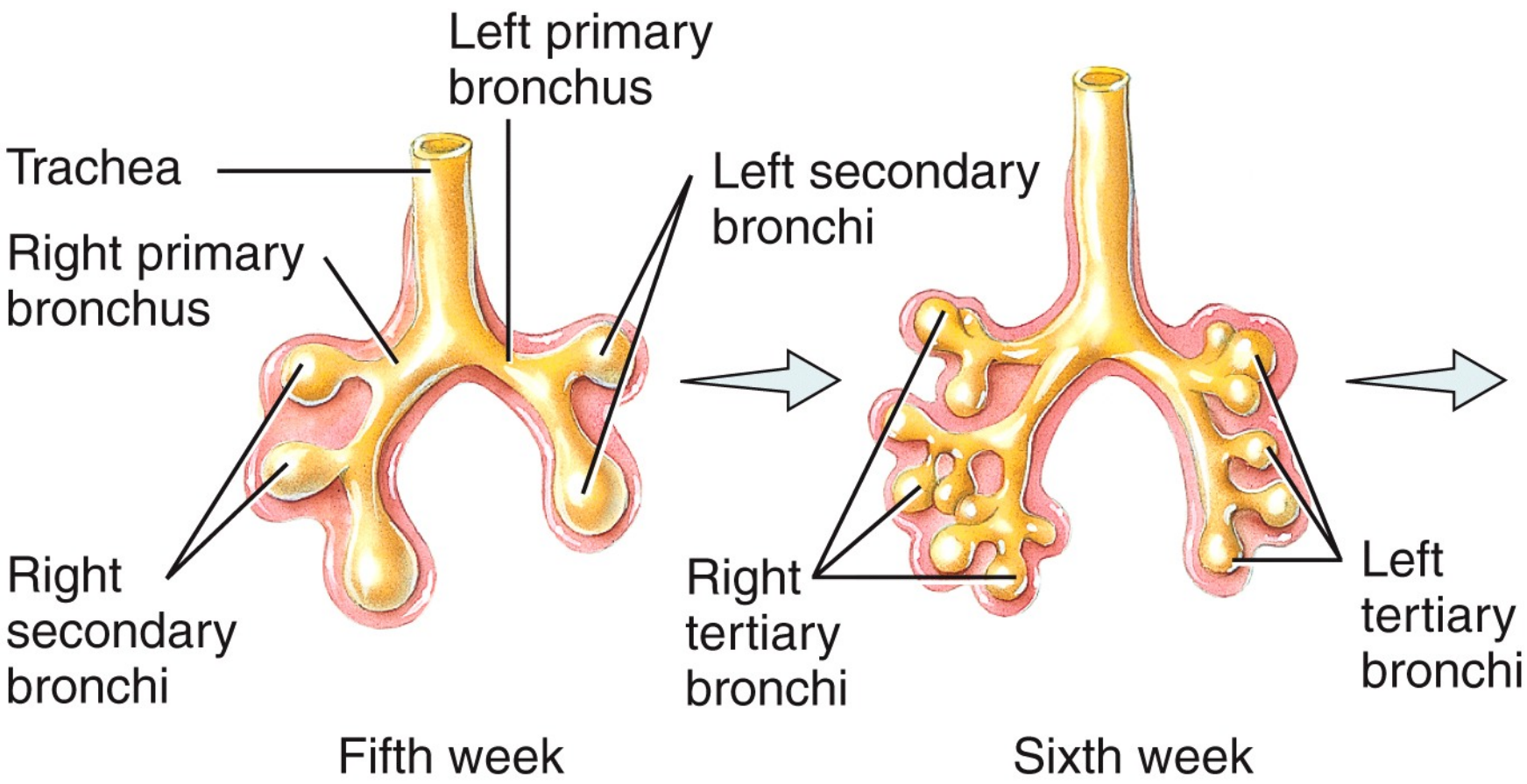
Sixth week

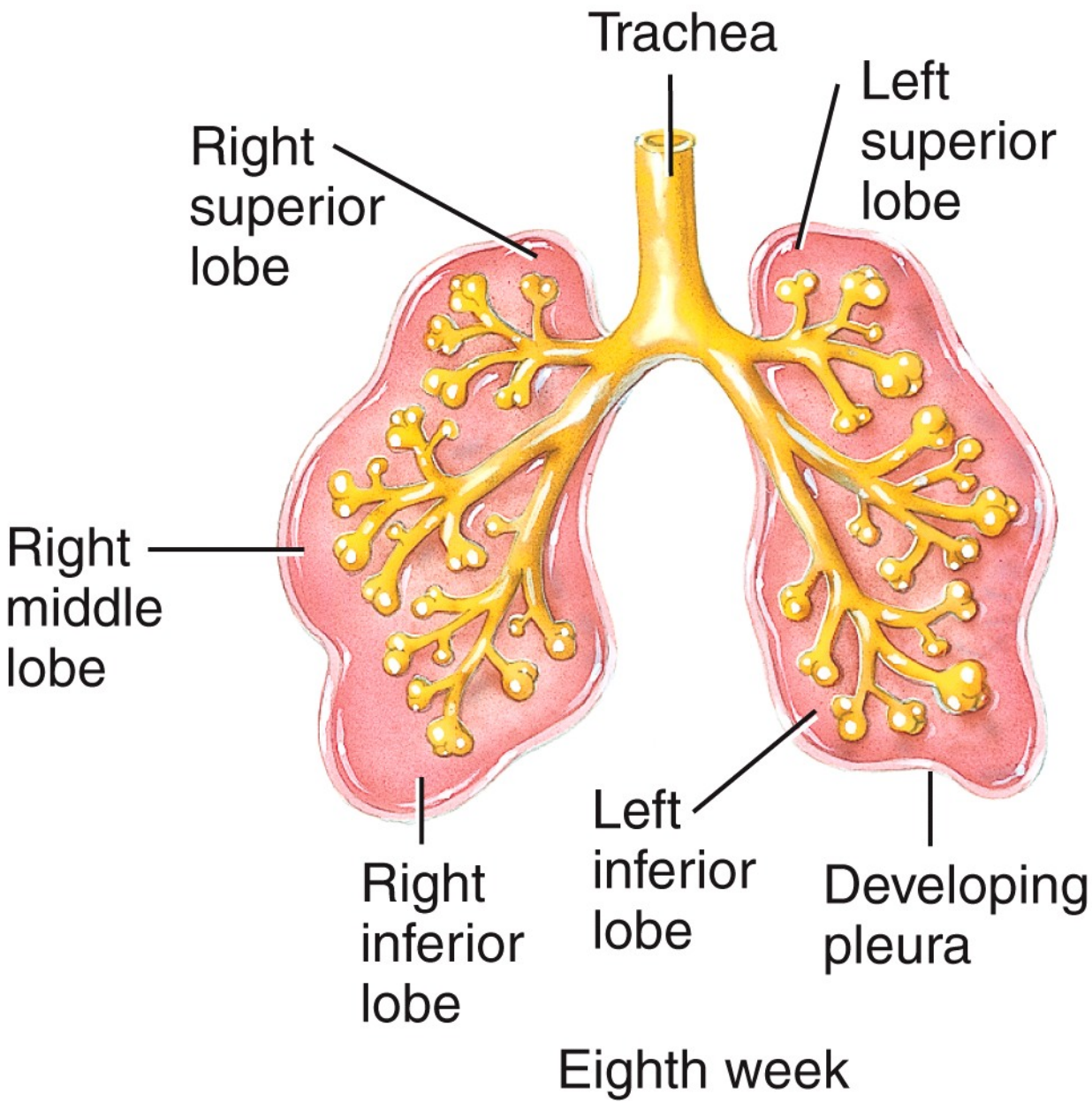


Eighth week


Pharynx
RESPIRATORY DIVERTICULUM
TRACHEAL BUD
Esophagus
Pharynx
Trachea
BRONCHIAL BUDS
Esophagus

Fourth week


Left primary bronchus
Trachea
Left secondary bronchi
Right primary bronchus
Right secondary bronchi
Right tertiary bronchi
Left tertiary bronchi
Fifth week
Sixth week


Trachea
Left superior lobe
Right superior lobe
Right middle lobe
Left inferior lobe
Right inferior lobe
Developing pleura
Eighth week