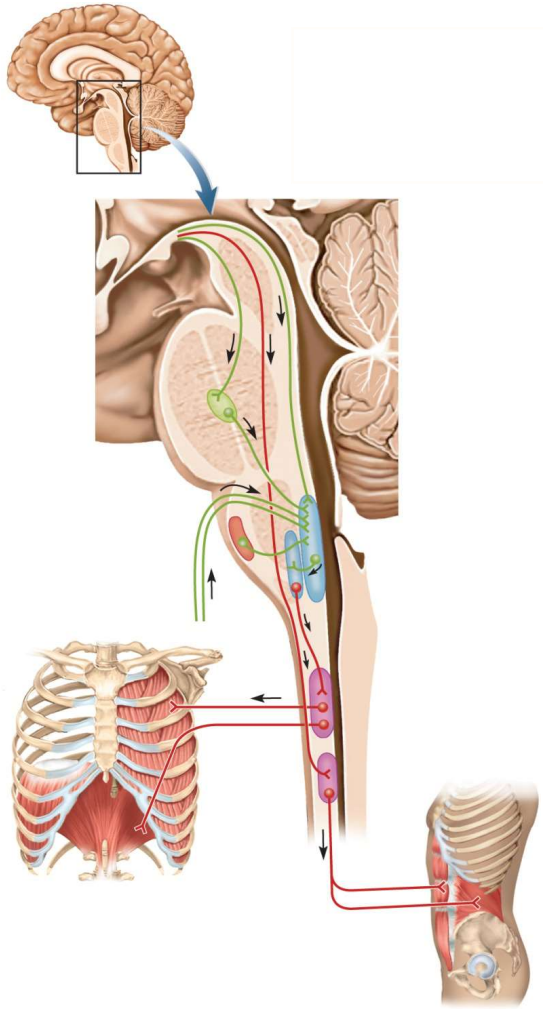
Chapter 23

Neural and Voluntary Control of Breathing



Neural Control of Breathing

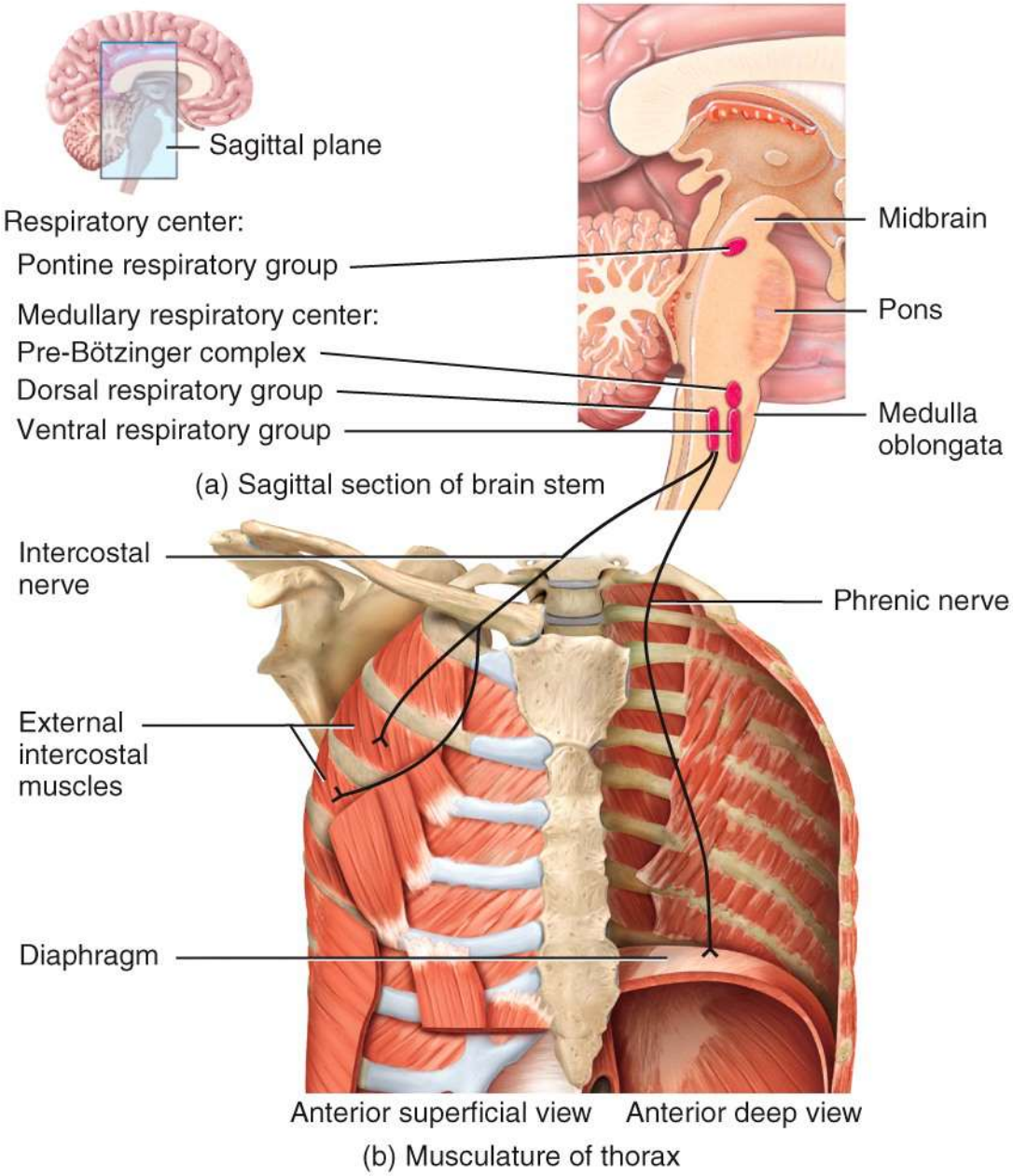
- This topic is still considered "unsettled science"

- *Exact mechanism for setting the rhythm of respiration remains unknown*

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

  - Dorsal respiratory group
  - Ventral respiratory group (with Botzinger complex)
  - Pontine respiratory group

- *Higher brain centers may also influence these nuclei in the brain stem to modify breathing //* cerebral cortex, limbic system, hypothalamus. // E.g. - When speaking or singing the cerebral cortex must adjust breathing rhythm


Sagittal plane
Respiratory center:
Pontine respiratory group
Medullary respiratory center:
Pre-Bötzinger complex
Dorsal respiratory group
Ventral respiratory group
Midbrain
Pons
Medulla oblongata
(a) Sagittal section of brain stem
Intercostal nerve
Phrenic nerve
External intercostal muscles
Diaphragm
Anterior superficial view
Anterior deep view
(b) Musculature of thorax

Neural Control of Breathing

- Medullary respiratory control center located in the medulla oblongata // two nuclei form the Medullary Respiratory Control Center

- Dorsal respiratory group – with two nuclei within DRG (inspiratory nuclei and expiratory nuclei)

  - send impulses to diaphragm via phrenic nerves (inspiratory muscles)

  - send impulses to external intercostal muscles via the intercostal nerves (inspiratory muscles)

- Ventral respiratory group – also location of the pre-Botzinger complex

  - generates the rhythm of breathing by sending action potentials to the DRG's inspiratory neurons

  - this last for 2 seconds – associated with inspiration /// followed by 3 seconds of inhibition of inspiratory muscles with elastic recoil

Neural Control of Breathing

Breathing depends on repetitive stimuli from brain stem 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)

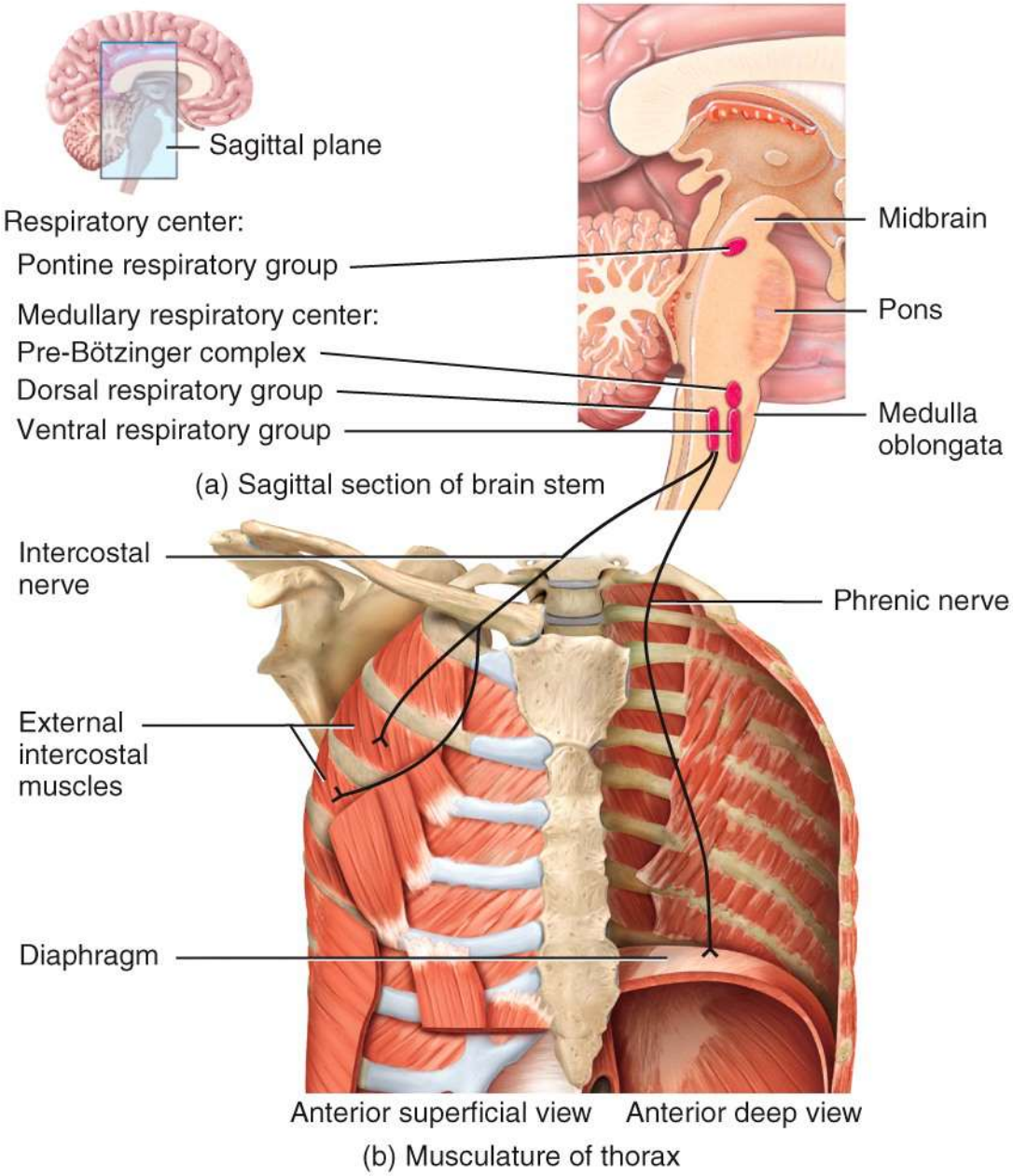
Expiratory neurons (DRG) /// fire to inhibit inspriatory neurons during eupnea (3 sec)

Respiratory cycle = 5 seconds or 12 breaths per minute

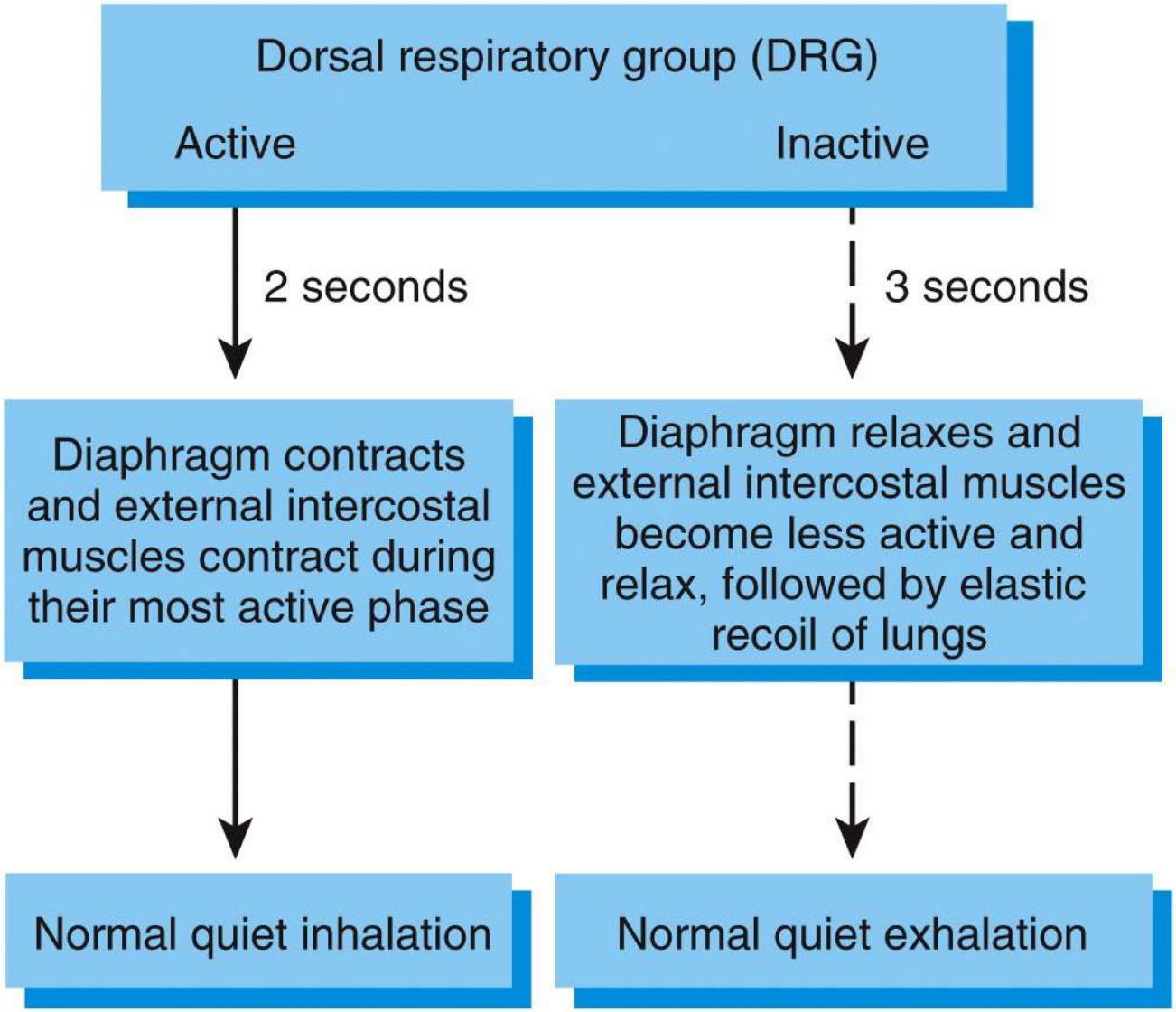
Voluntary control provided by motor cortex // e.g. - you can hold your breath or change breathing to sing or talk!

Neural Control of Breathing

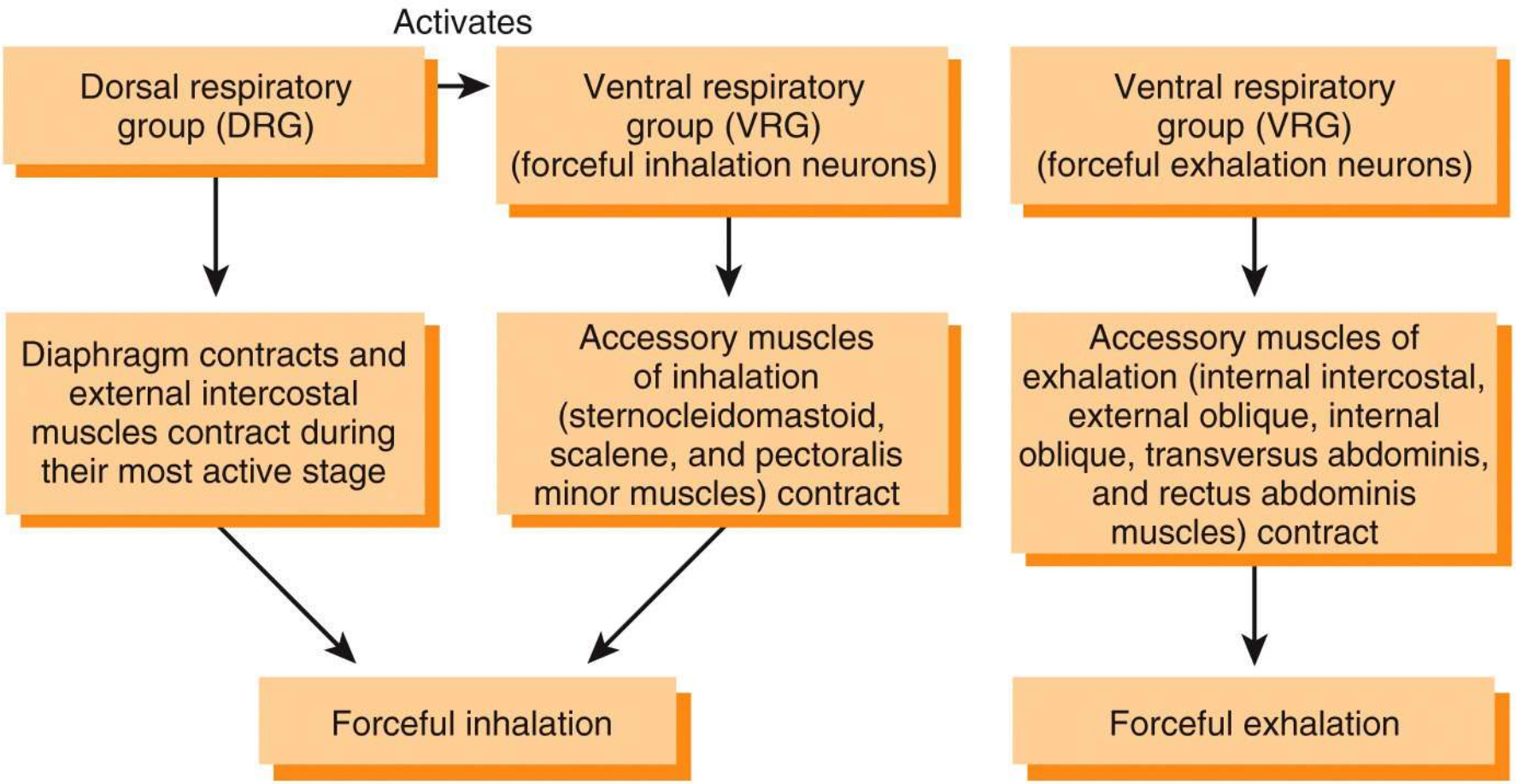
- Other factors -- used to regulate breathing to physiological state
  - central chemoreceptors
  - peripheral chemoreceptors
  - proprioceptors
  - lung stretch receptors (Hering-Breuer reflex)
  - irritant reflex
  - limbic system
  - temperature
  - pain
  - stretching the anal spincter
  - blood pressure (minor)


Sagittal plane
Respiratory center:
Pontine respiratory group
Medullary respiratory center:
Pre-Bötzinger complex
Dorsal respiratory group
Ventral respiratory group
Midbrain
Pons
Medulla oblongata
(a) Sagittal section of brain stem
Intercostal nerve
Phrenic nerve
External intercostal muscles
Diaphragm
Anterior superficial view
Anterior deep view
(b) Musculature of thorax

Quiet Breathing or Normal Quiet Breathing (Know This)



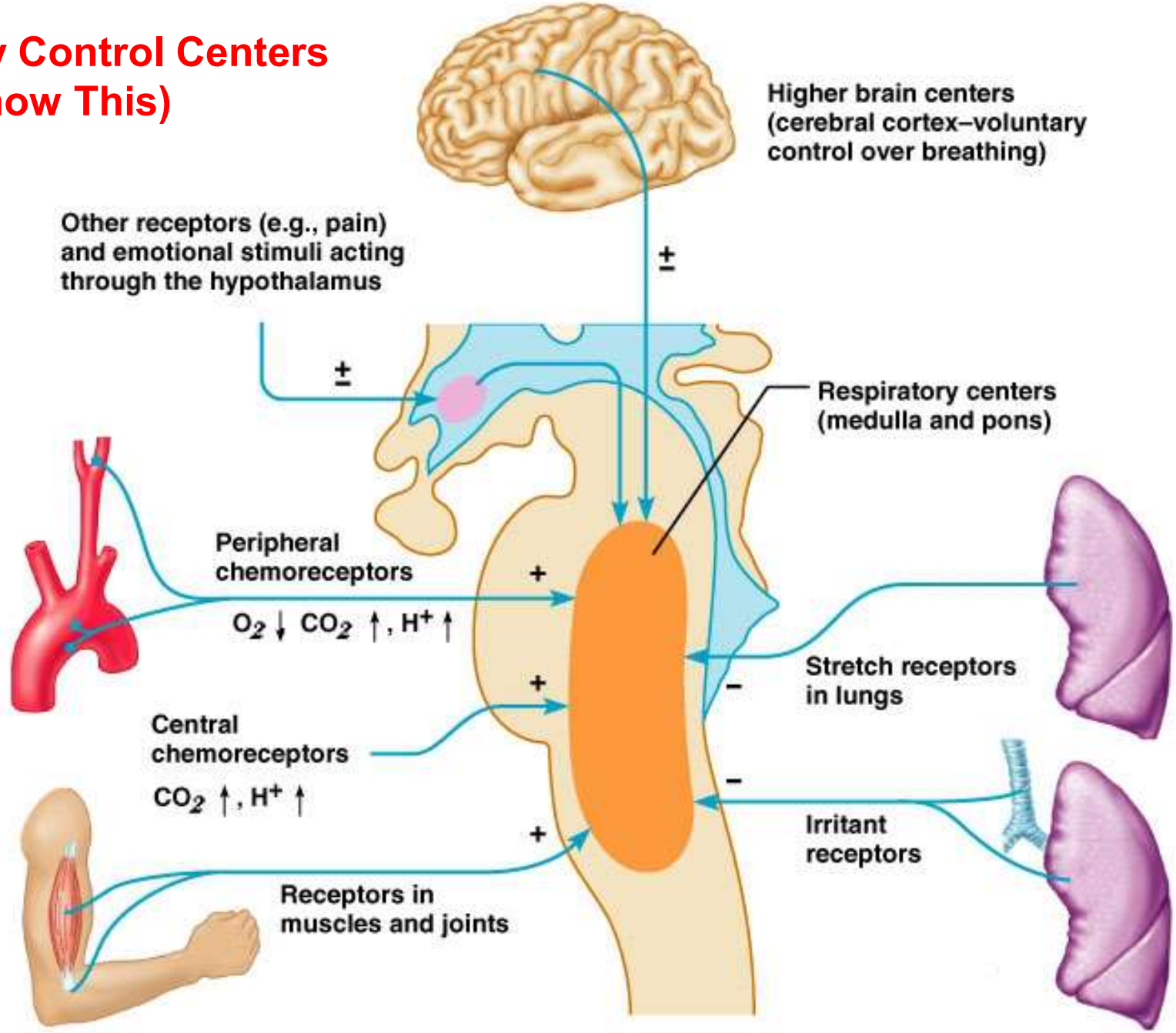
Forceful Breathing or Breathing During Exercise



Brainstem Respiratory Centers

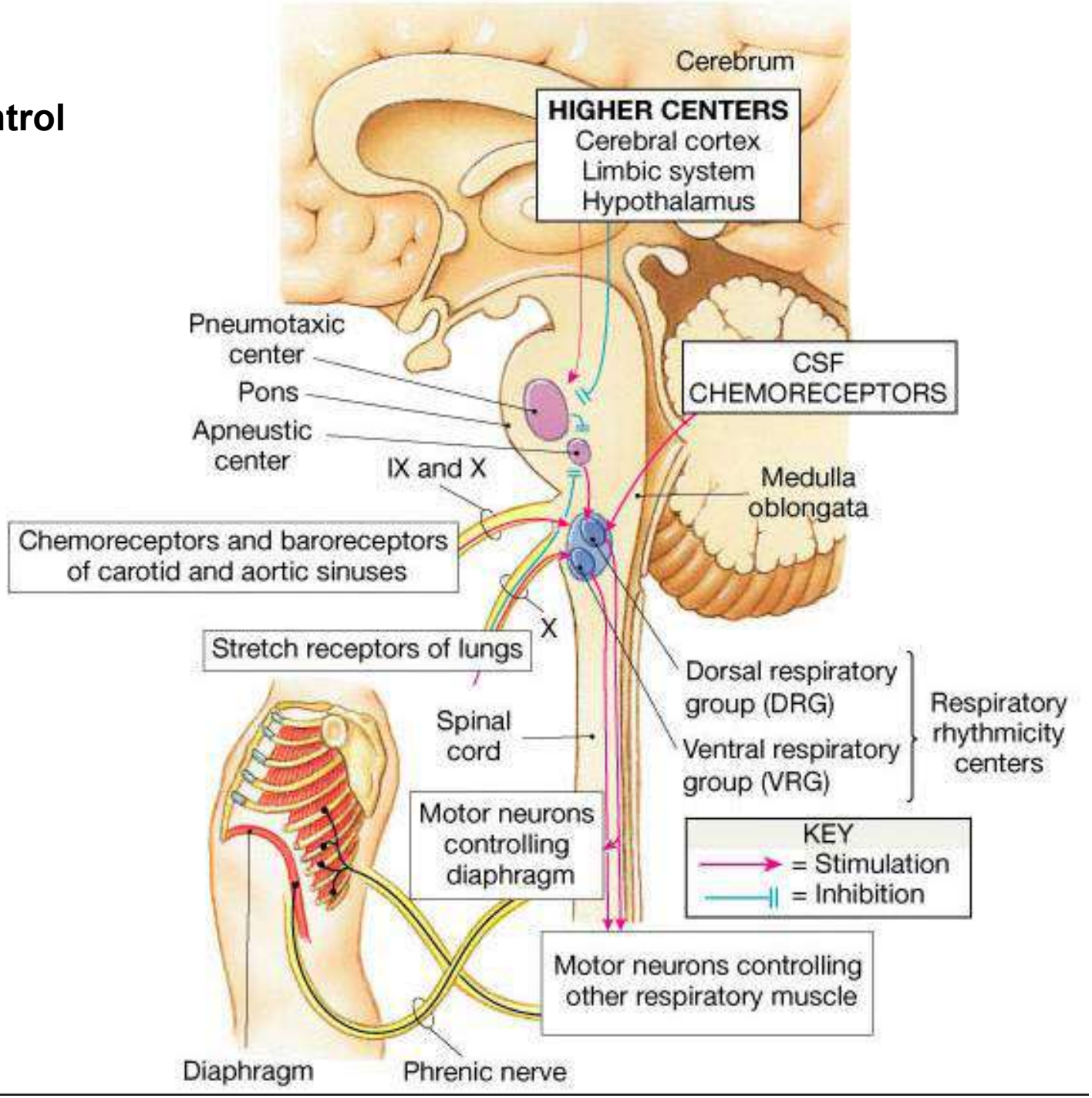
- Respiratory nuclei in pons
  - pons respiratory nuclei – signals to dorsal respiratory group
  - pontine respiratory group (PRG)
    - modifies rhythm by sending signals to both the VRG and DRG
    - adapts breathing to special circumstances such as sleep, exercise, vocalization, and emotional responses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

Respiratory Control Centers (Know This)

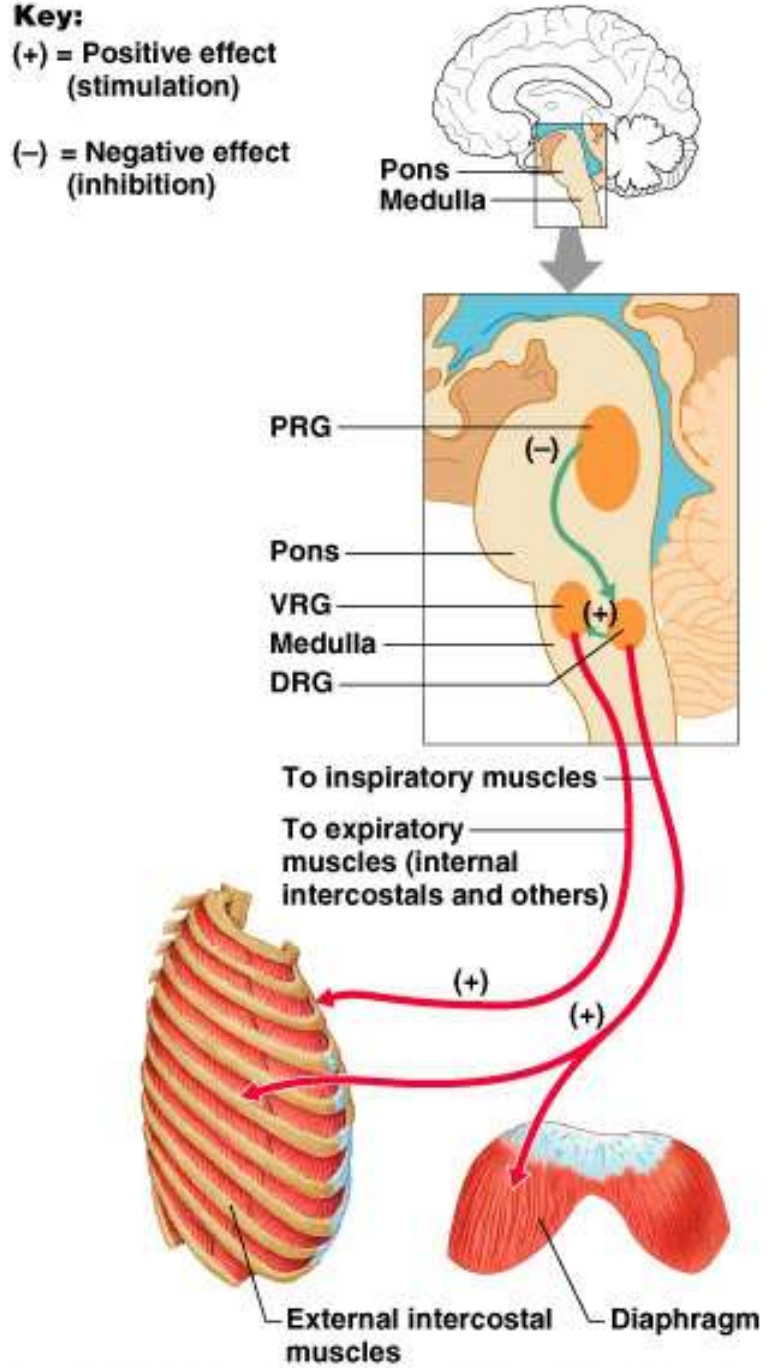


Copyright © 2004 Pearson Education, Inc., publishing as Benjamin Cummings.

Respiratory Control Centers



Respiratory Control Centers



Copyright © 2004 Pearson Education, Inc., publishing as Benjamin Cummings.

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
  - known as the inflation reflex or Hering-Breuer Reflex
    - triggered by excessive inflation
    - protective reflex
    - inhibits inspiratory neurons therefore able to stop inspiration

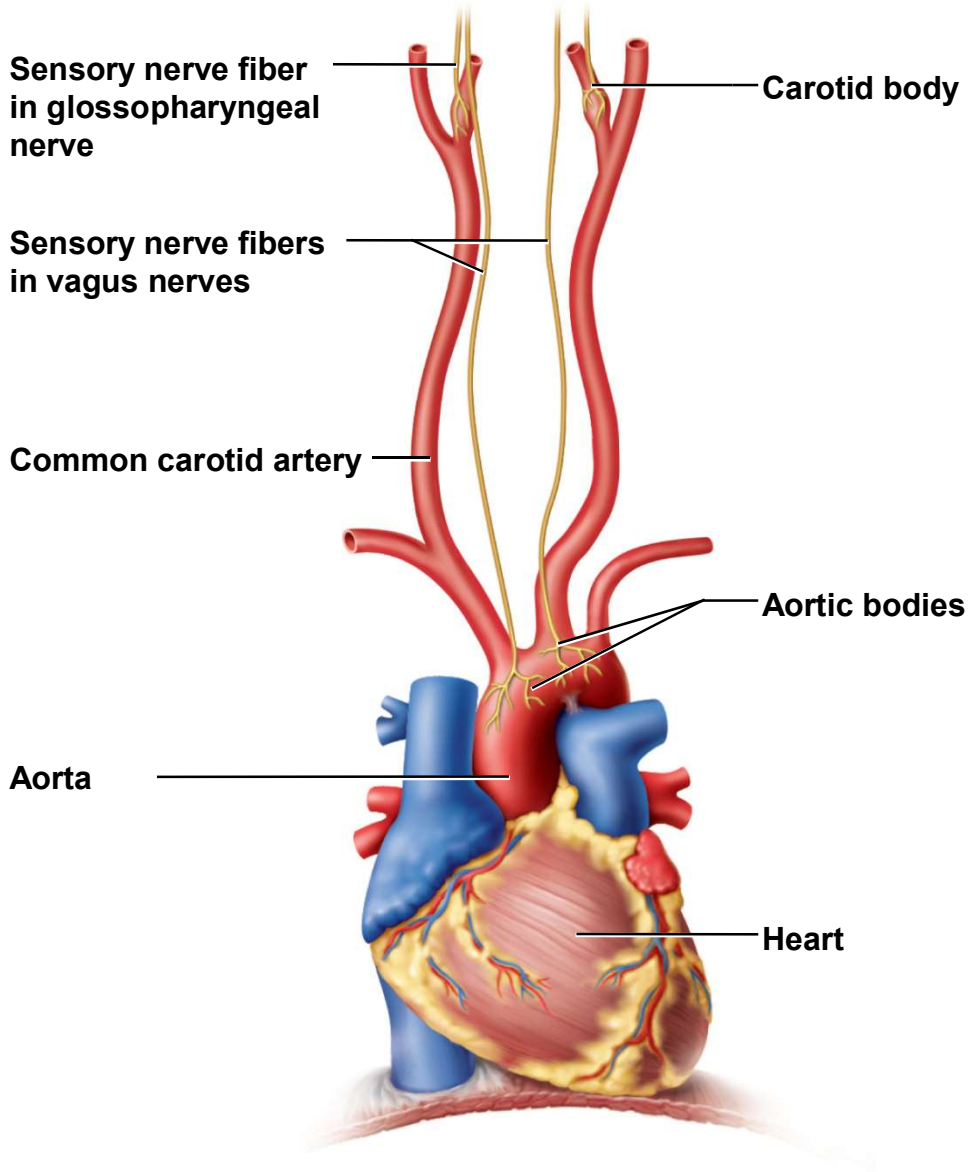
Central and Peripheral Input to Respiratory Centers

- **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) followed by strong coughing

Central and Peripheral Input to Respiratory Centers

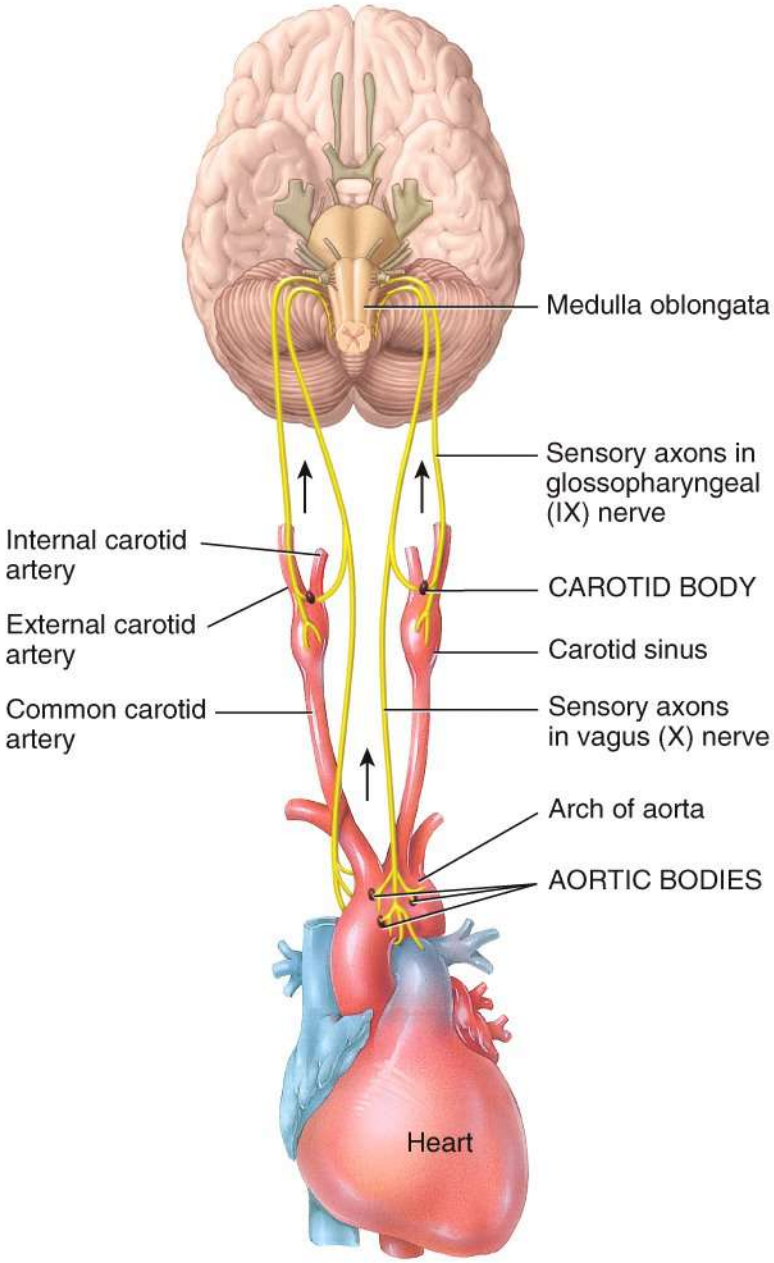
- Hyperventilation
  - anxiety triggered state in which breathing is so rapid that it expels CO_2 from the body faster than it is produced
  - CO_2 levels drop
  - pH rises causing the cerebral arteries to constrict reducing cerebral perfusion which may cause dizziness or fainting
  - can be brought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

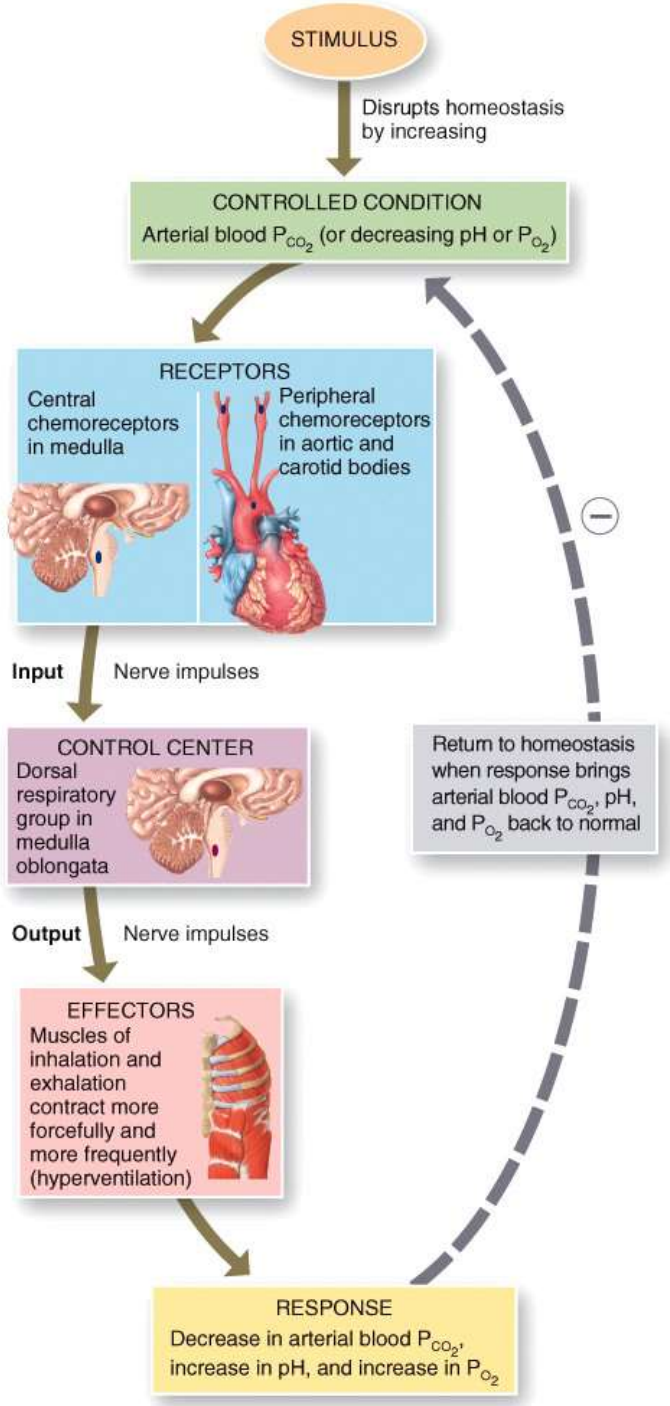
Peripheral Chemoreceptors



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
  - by passing brainstem
- limits to voluntary control
  - breaking point // when CO_2 levels rise to a point when automatic controls override one's will

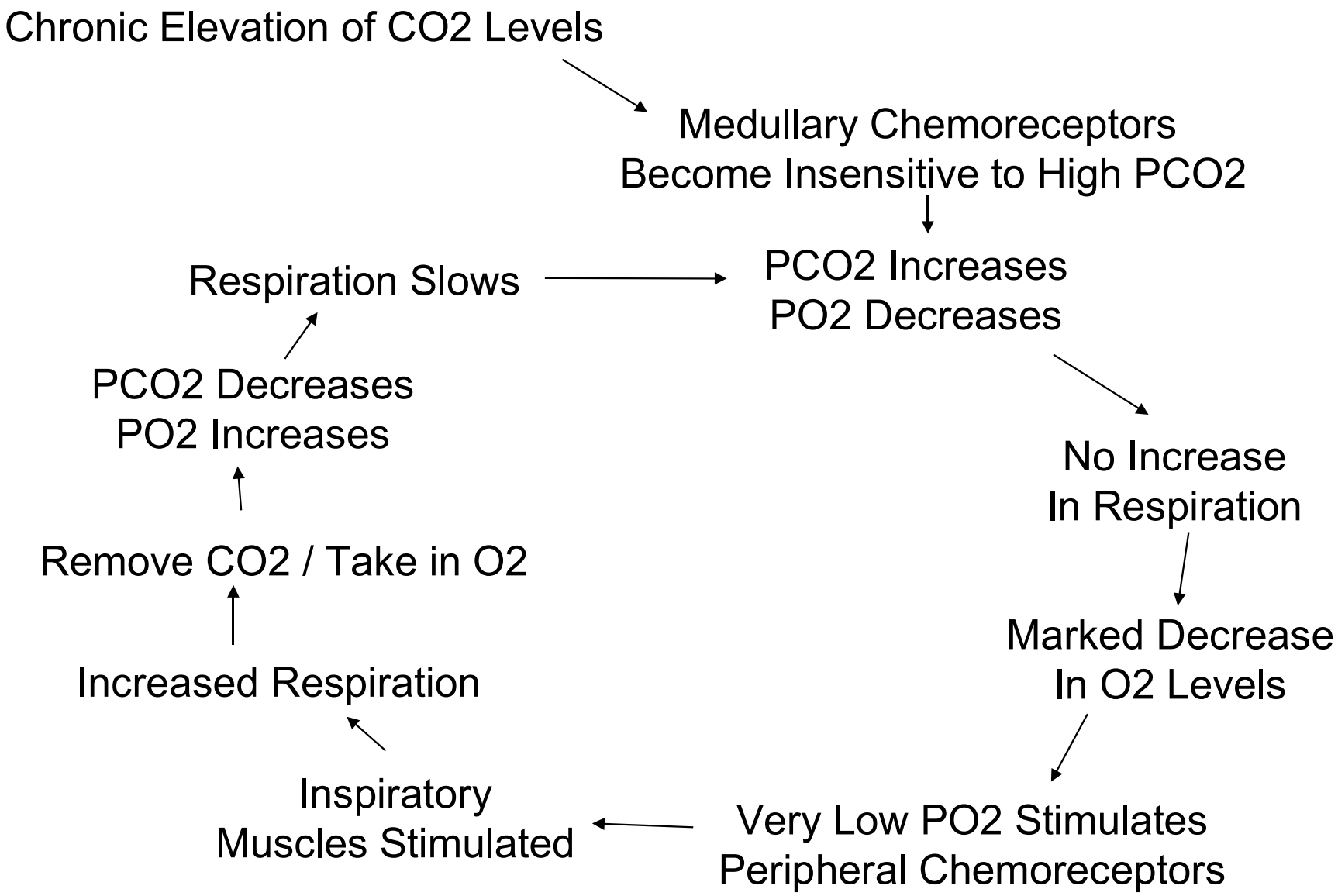

Medulla oblongata
Sensory axons in glossopharyngeal (IX) nerve
Internal carotid artery
CAROTID BODY
External carotid artery
Carotid sinus
Common carotid artery
Sensory axons in vagus (X) nerve
Arch of aorta
AORTIC BODIES
Heart


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

- Under normal conditions, PCO2 is the molecule used to stimulate inspiration.
- If high PCO2 becomes a chronic condition, then chemoreceptors in medulla become insensitive to PCO2
- Now chemoreceptors in medulla start to respond not to low PCO2 but to low PO2 /// hypoxia now is what stimulates inspiration.
- However, now high PO2 will also inhibit inspiration.
- *Therefore, if you give someone oxygen when they are in hypoxic drive, then they will stop breathing!!!!!*

Hypoxic Drive



©Imaginechina/Corbis