CONTROL OF BREATHING

Objectives

1. Identify key brain structures responsible for automatic control of the resting quiet breathing rhythm.
2. List key sources of sensory input to the automatic rhythm generator.
3. Identify the location of the central & peripheral chemoreceptors. Describe their impact on ventilation in response to changes in arterial P_{CO_2}, P_{O_2} and pH.
4. Describe how metabolic acidosis (accompanying intense exercise or in diabetes) affects ventilation, P_{O_2} and P_{CO_2} in the blood.
5. Specify the effect of hyperventilation and hypoventilation on arterial blood gases (P_{CO_2} and P_{O_2}).
6. Describe congenital hypoventilation syndrome, its treatment and how it informs us about automatic versus the conscious/voluntary control of breathing.

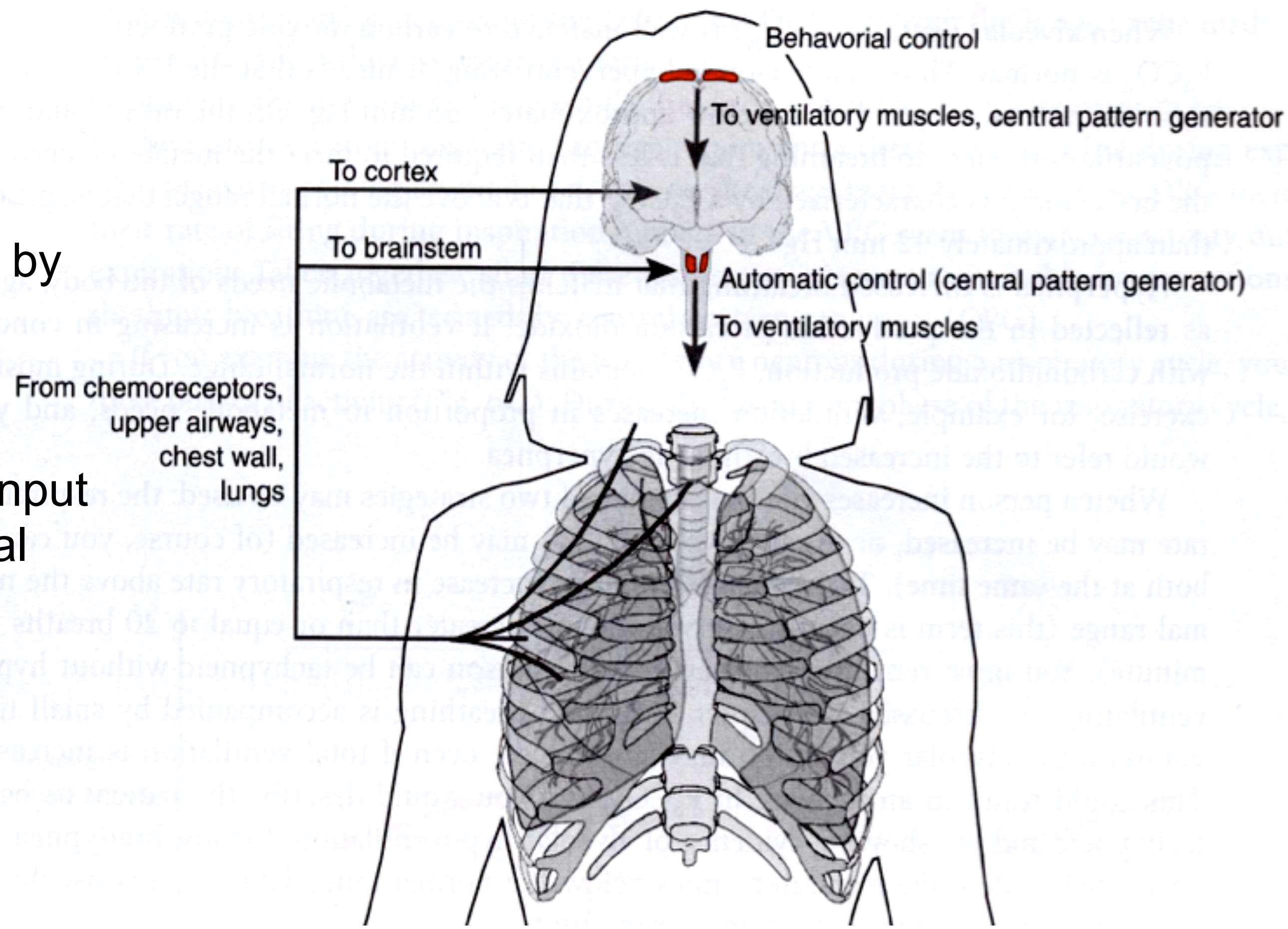
RHYTHM OF BREATHING IS ESTABLISHED IN THE CNS

AUTOMATIC *VERSUS* VOLUNTARY CONTROL

Breathing is:

initiated in the medulla by aggregates of neurons

modified by higher structures in CNS and input from central & peripheral chemoreceptors and mechanoceptors in the lungs & chest wall



Compare the control of the rhythmic activity of the heart & generation of cardiac output to rhythmic activity of the chest wall & breathing

AUTOMATIC BREATHING IS INITIATED IN THE MEDULLA

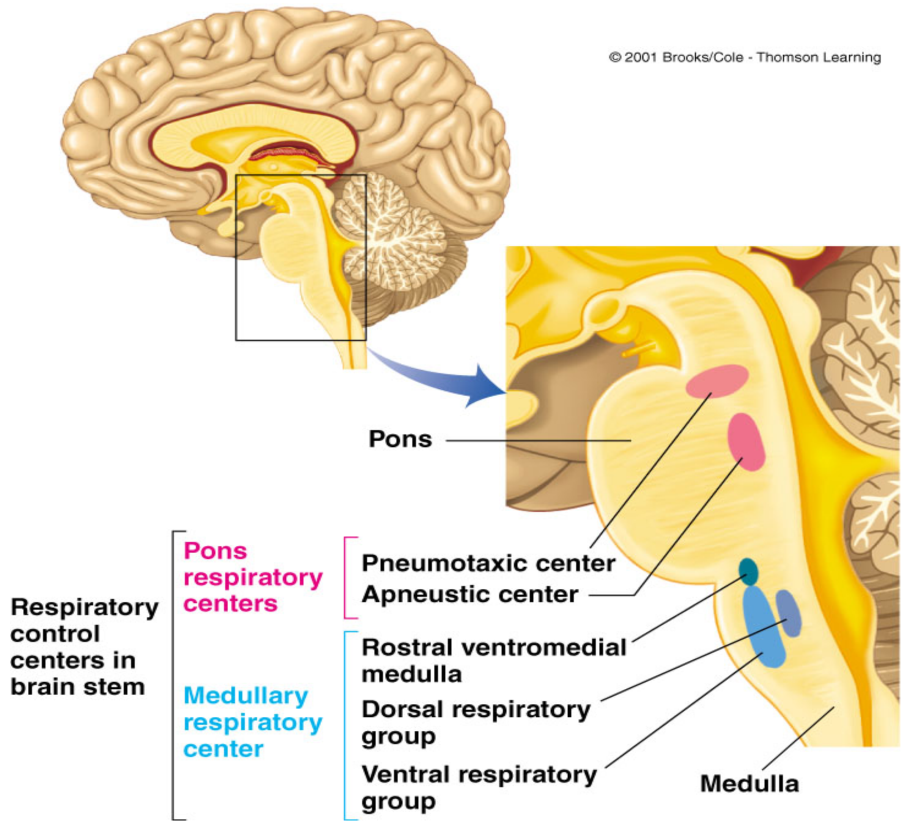
DRG

• mainly inspiratory neurons (active during inspiration) driving the inspiratory muscles

• receives input from peripheral chemoreceptors & mechanoreceptors

VRG

• mainly expiratory neurons, silent during quiet breathing & active during active expiration driving the expiratory muscles



RHYTHM REFINING ROLE OF AREAS IN THE PONS

Thomas Lumsden 1920 ablation experiments in anesthetized cats

Pneumotaxic Centre: stop inspiration, allows for expiration (inspiratory offswitch) when destroyed leads to apneusis (prolonged deep, sustained inspiration)

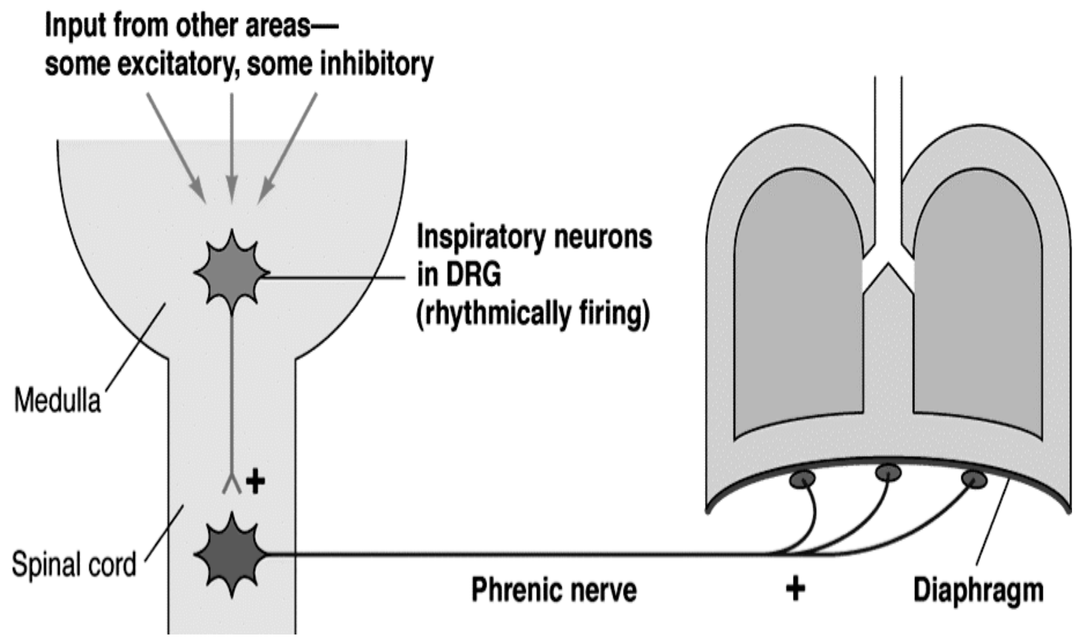
Apneustic Centre leads to apneusis

BULBOSPINAL INSPIRATORY NEURONS INITIATE INSPIRATION VIA SPINAL NERVES TO THE INSPIRATORY MUSCLES

THE PHRENIC NERVES SUPPLY MOTOR INPUT TO THE DIAPHRAGM

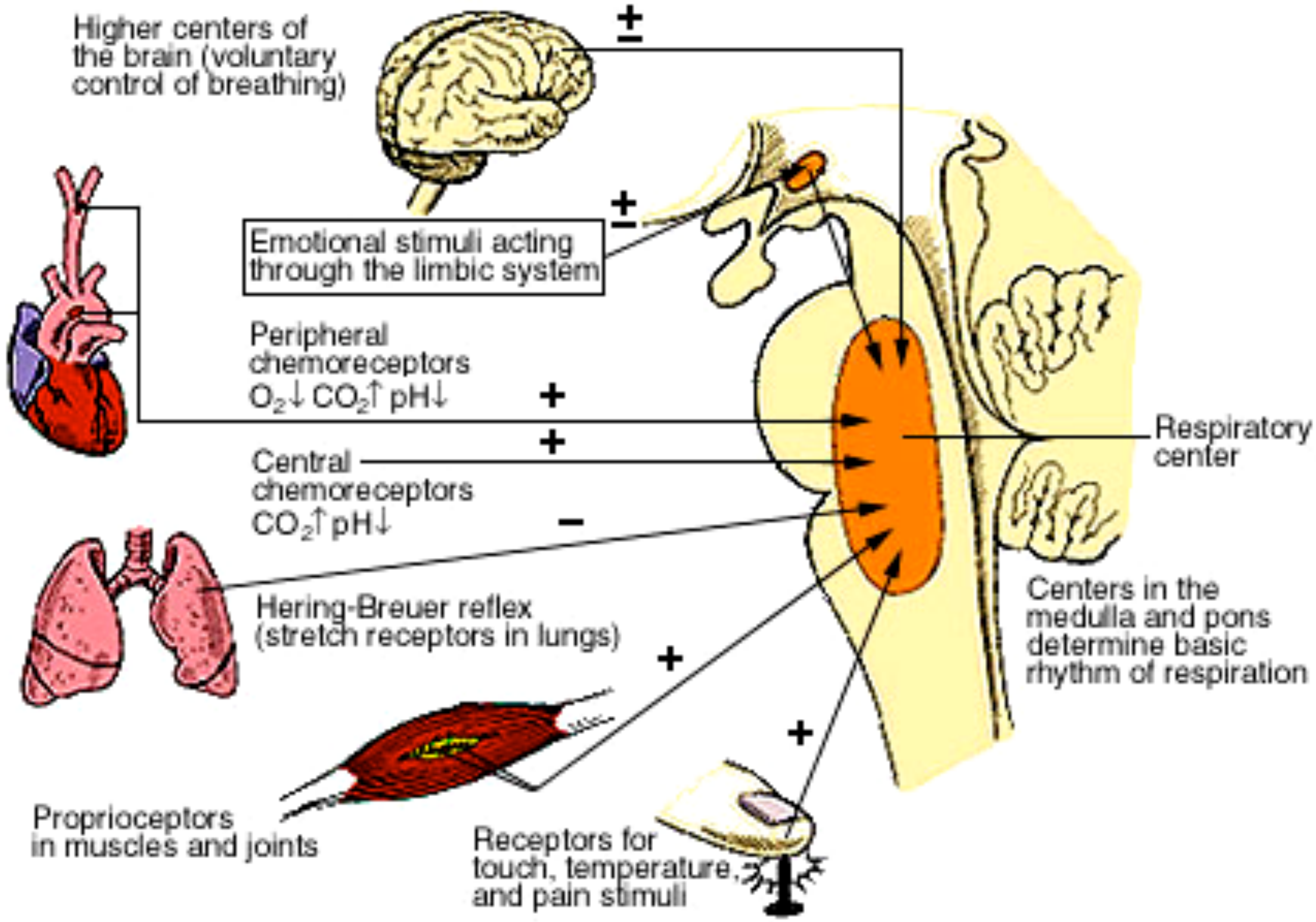
- The phrenic nerve is formed by rootlets exiting the cervical spine C3,C4,C5. Two bilateral phrenic nerves supply the hemi-diaphragms. ”C3,4,5 keep the diaphragm alive”.

- Intercostal nerves exiting thoracic & lumbar spine provide input to the intercostal & abdominal muscles.



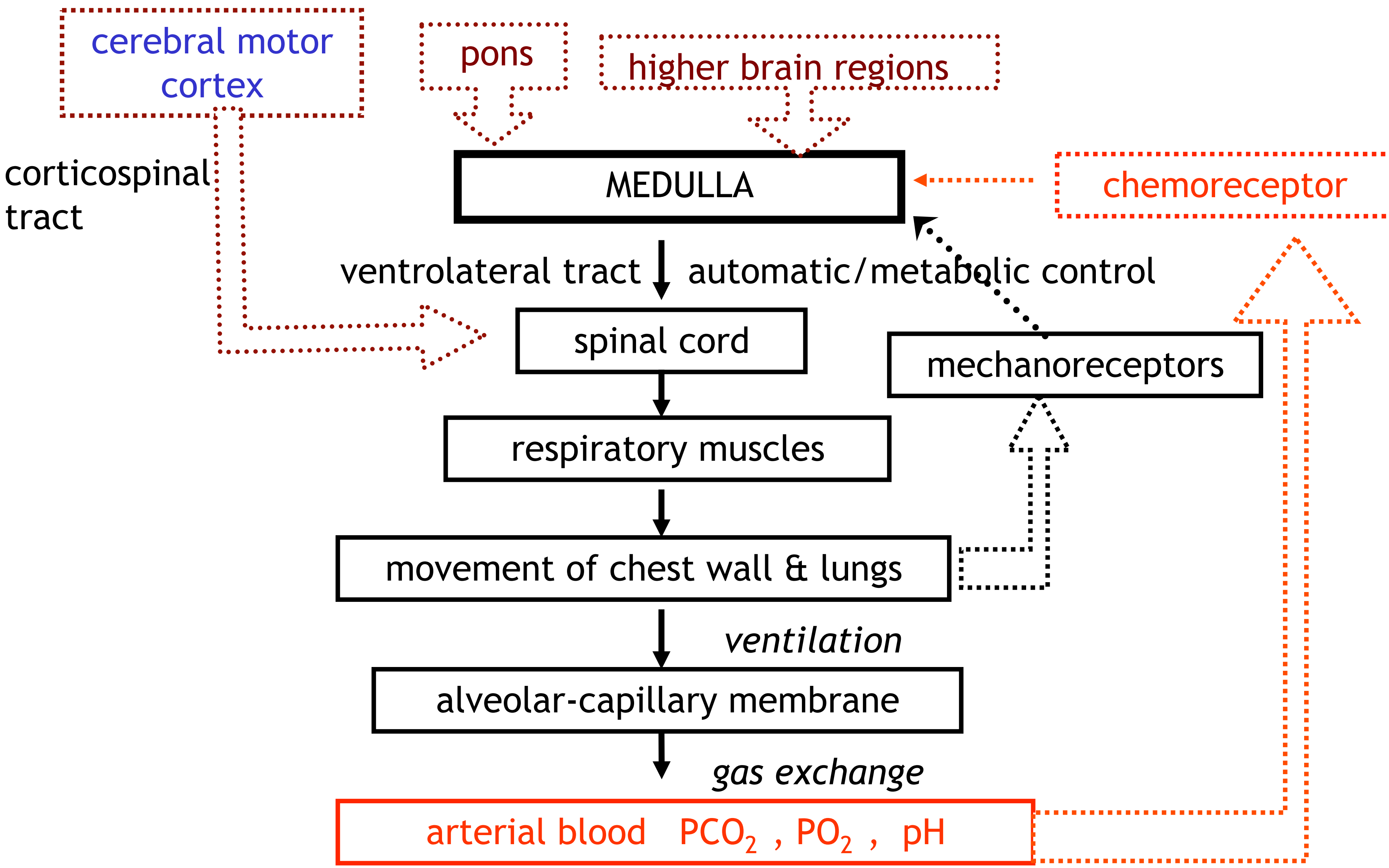
- Cranial nerves supply the motor output to the upper airway dilator muscles.

MANY INPUTS TO THE MEDULLA CONTRIBUTE TO THE RHYTHM OF BREATHING



FEEDBACK & FEED FORWARD INPUT

TO THE MEDULLARY RESPIRATORY CENTRE



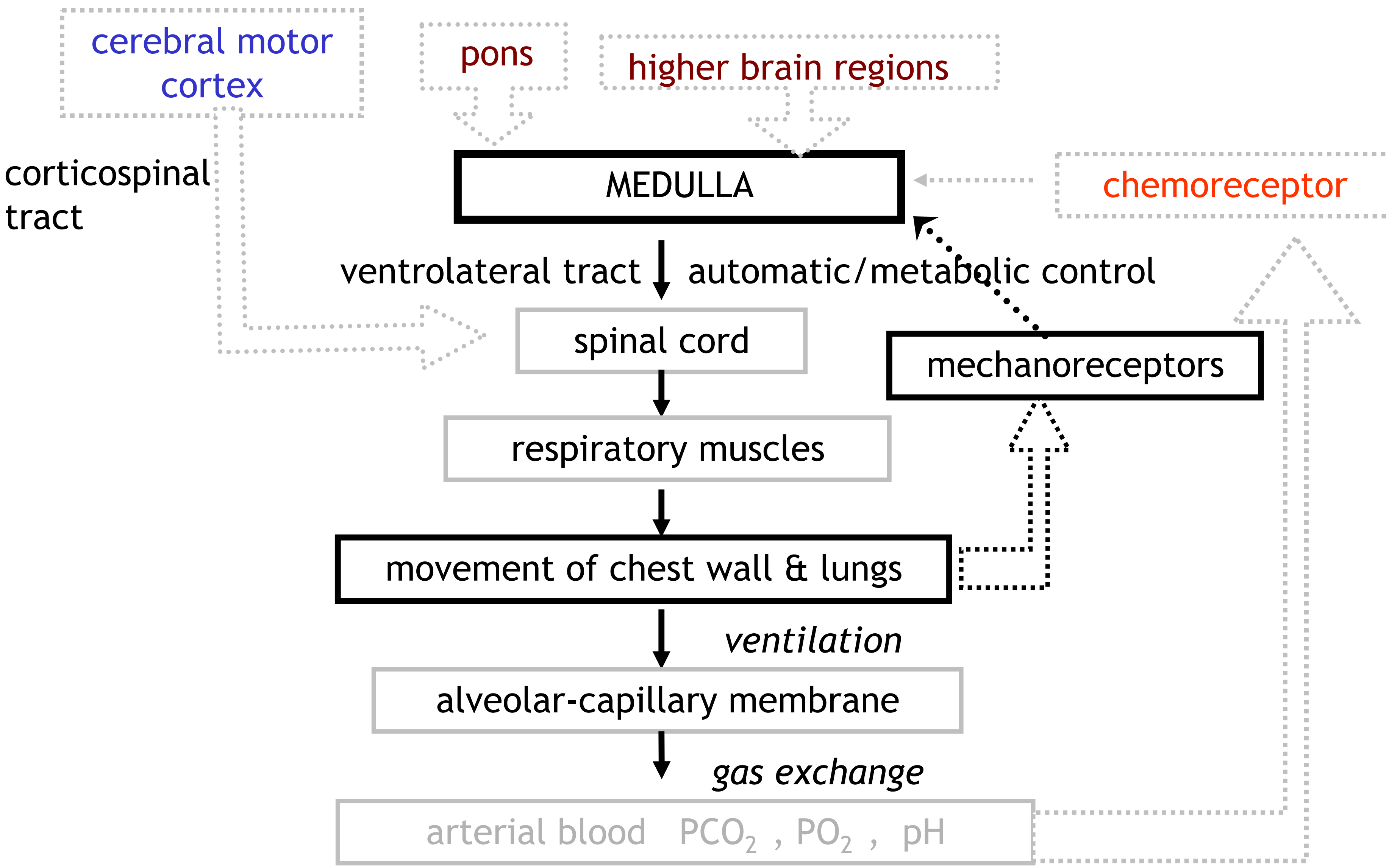
THE HERING BREUER REFLEX

AN EARLY HISTORIC (1868) EXAMPLE OF THE MANY MECHANORECEPTOR INPUTS REGULATING THE RHYTHM OF BREATHING

- a reflex triggered to prevent over inflation of the lungs
- stretch receptors in the smooth muscle of the airways respond to stretching of the lung during inflation, allowing expiration to occur- reflex is mediated by the vagus, X^{th} cranial nerve
- early physiologists believed the reflex played a major role in establishing the rate and depth (rhythm) of breathing in humans- - true for most mammals, not the case for adult humans at rest
- the reflex may determine breathing rate and depth in newborns and in the adult human when tidal volume > 1 L, as during exercise

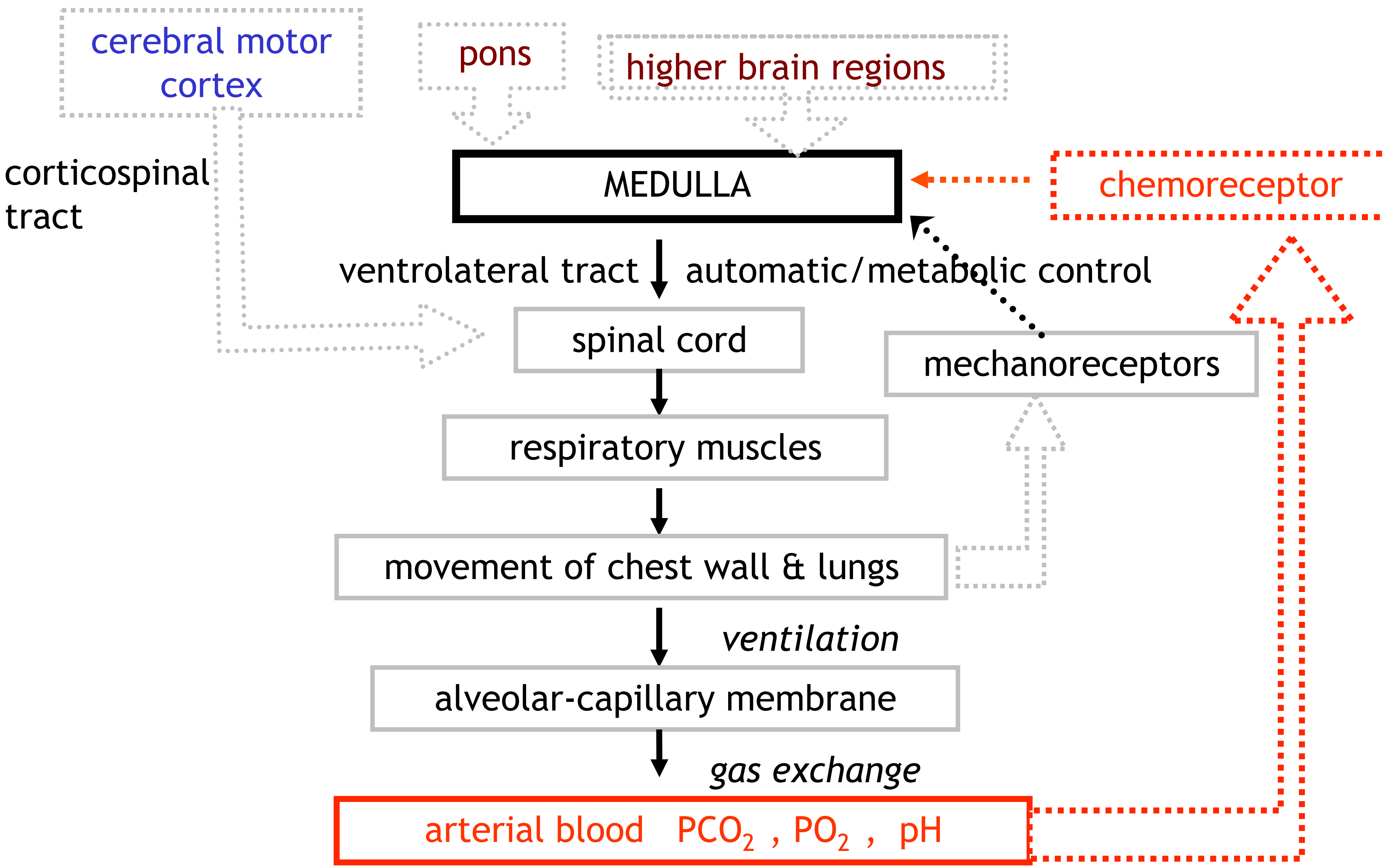
MECHANORECEPTOR FEED BACK

TO THE MEDULLARY RESPIRATORY CENTRE



CHEMORECEPTOR FEED BACK

TO THE MEDULLARY RESPIRATORY CENTRE



TWO TYPES OF CHEMORECEPTORS PROVIDE FEEDBACK TO THE RESPIRATORY NEURONS IN THE MEDULLA

CENTRAL CHEMORECEPTORS

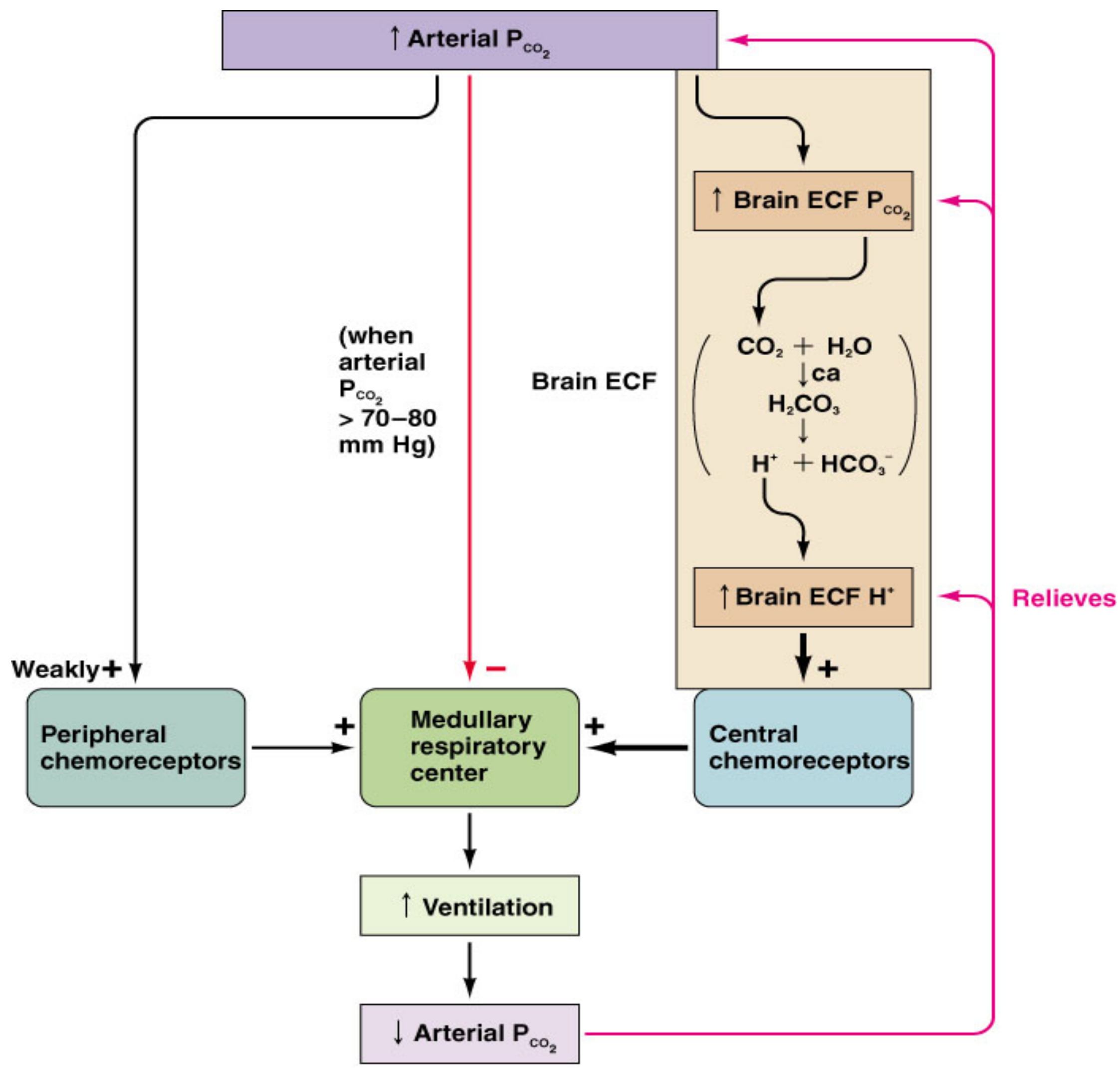
•few mm below the ventral surface of the medulla

•stimulated by small changes (few mmHg) in arterial PCO2
via the associated changes in $[H^+]$ in the brain ECF

•arterial PCO2 primary regulator of breathing normal range=35-45 mmHg

•What would happen to arterial PCO2 if you:

1. held your breath?
2. Hyperventilated?



TWO TYPES OF CHEMORECEPTORS PROVIDE FEEDBACK TO THE RESPIRATORY NEURONS IN THE MEDULLA

PERIPHERAL CHEMORECEPTORS

- Carotid & Aortic Bodies
- minuscule structures "tasting" blood
- have a high blood supply
- sense mainly arterial PO_2 as well as arterial PCO_2 & pH
- separate entities from baroreceptors (stretch receptors)
- CB sensory information carried via glossopharyngial nerve
- AB sensory information carried via vagus nerve

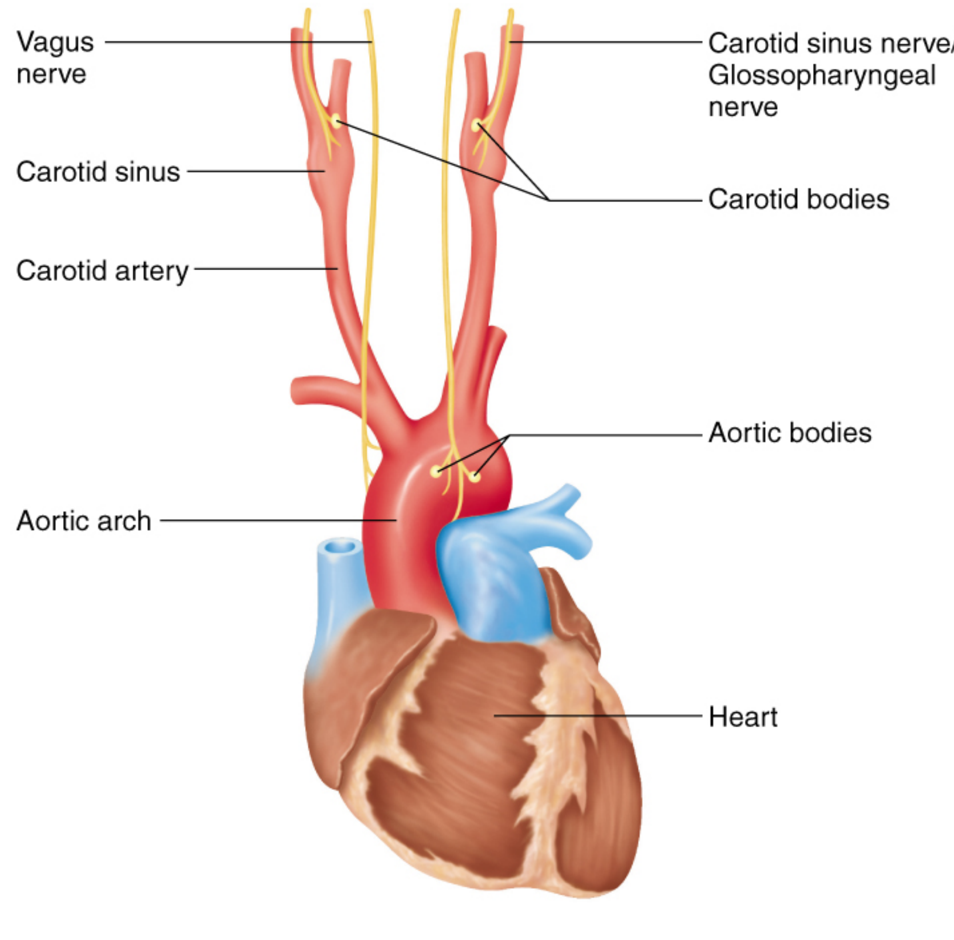


Figure 11-41, p. 497

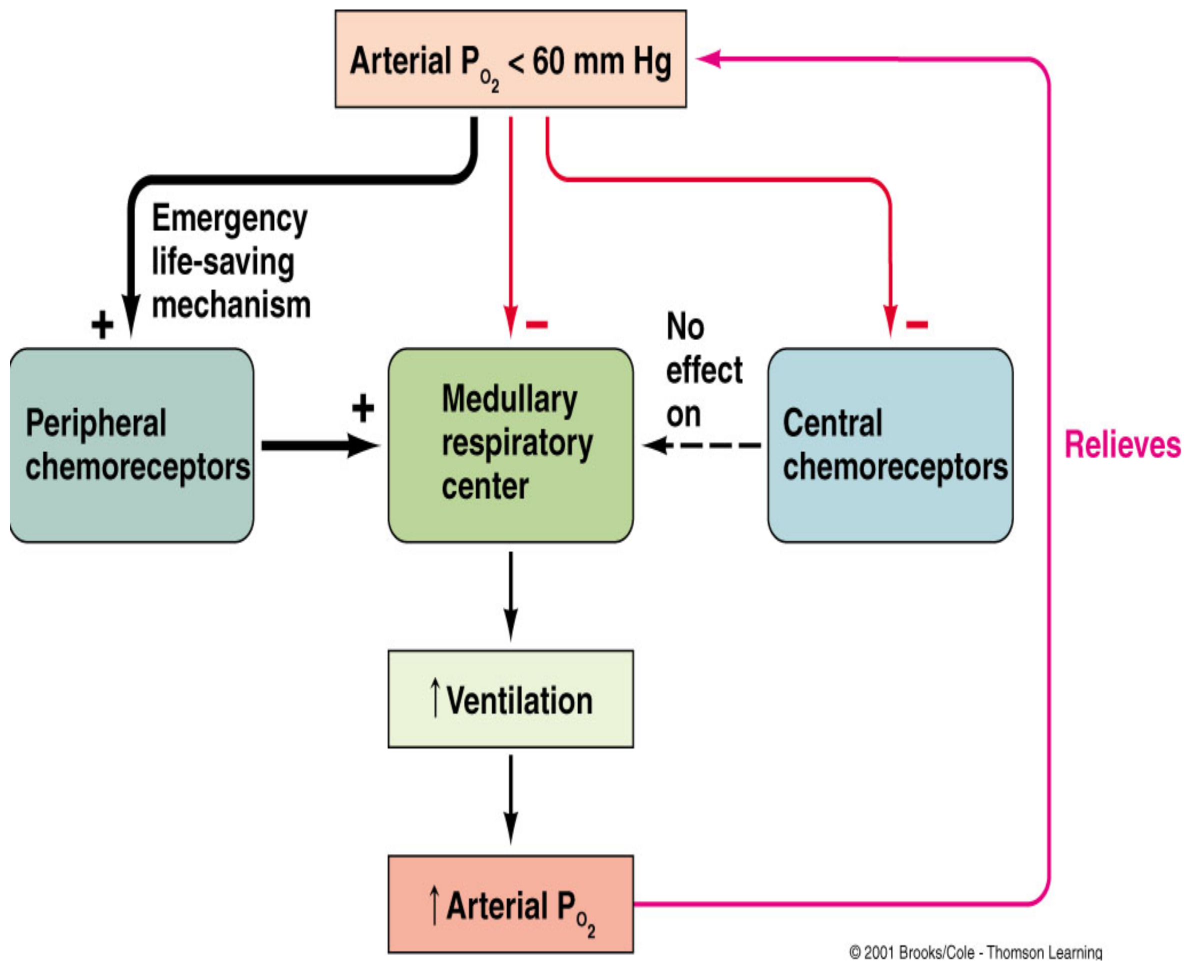
PERIPHERAL CHEMORECEPTORS

KEY OXYGEN SENSORS

PERIPHERAL CHEMORECEPTORS

• mainly sense a ↓ in arterial PO_2 levels < 60 mmHg with exposure to high altitude or in disease states

• the ventilatory response to ↓ PO_2 is hyperventilation which in turn results in a ↓ PCO_2 below normal resting levels (hypocapnia) and an ↑ PO_2 above normal resting levels (hyperoxia)



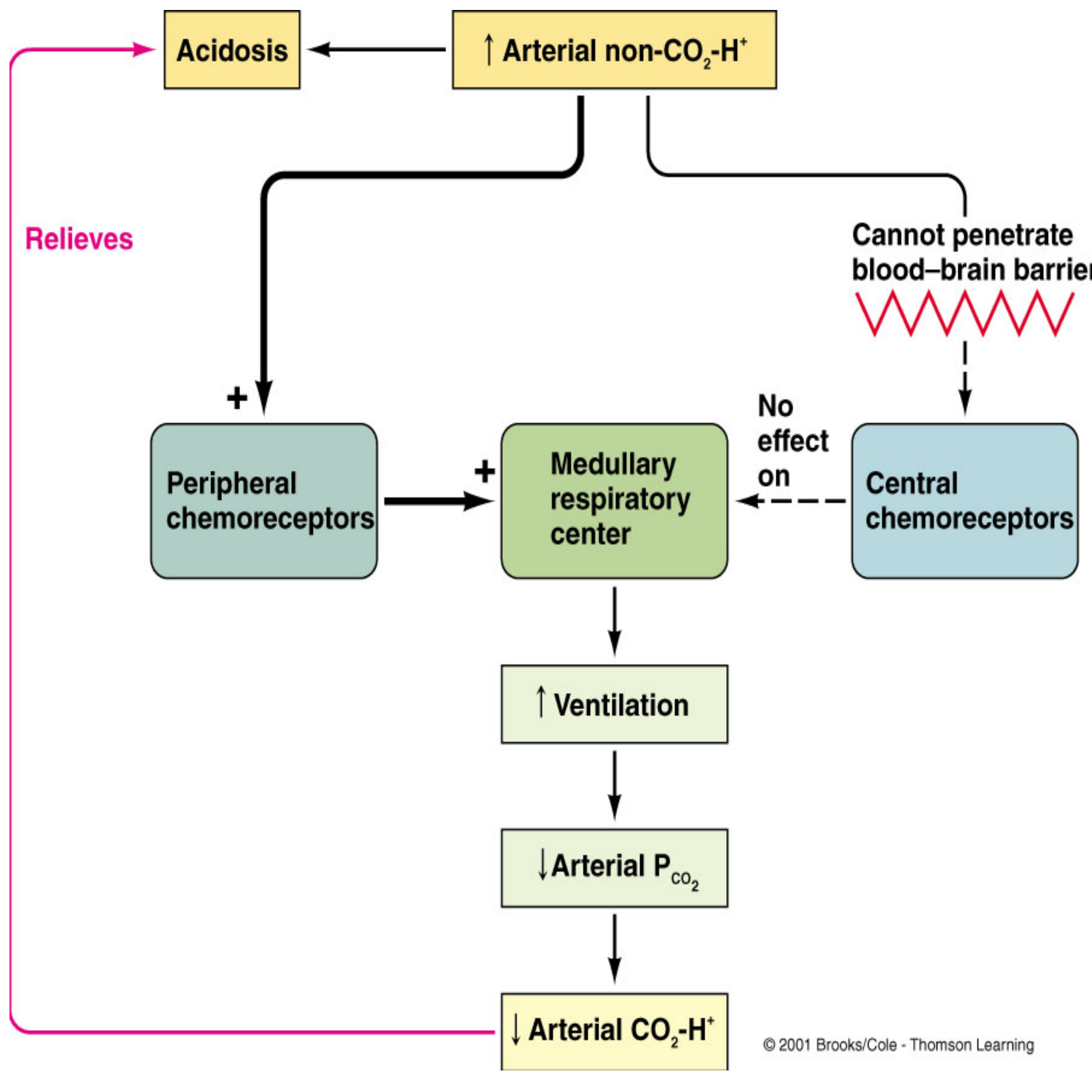
SENSING ARTERIAL PLASMA pH

THE ROLE OF PERIPHERAL CHEMORECEPTORS

Metabolic acids stimulate peripheral chemoreceptors increasing ventilation. Examples:

- lactic acid produced in skeletal muscle during intense exercise
- diabetic ketoacidosis *(Kussmaul breathing)*
- the ventilatory response to acidosis is hyperventilation and the ensuing hypocapnia & hyperoxia

Metabolic alkalosis has the opposite effect.



CONGENITAL CENTRAL HYPOVENTILATION SYNDROME
“ONDINE’S CURSE”— FORGETTING TO BREATH
a rare disorder in children (1200 cases known world wide)

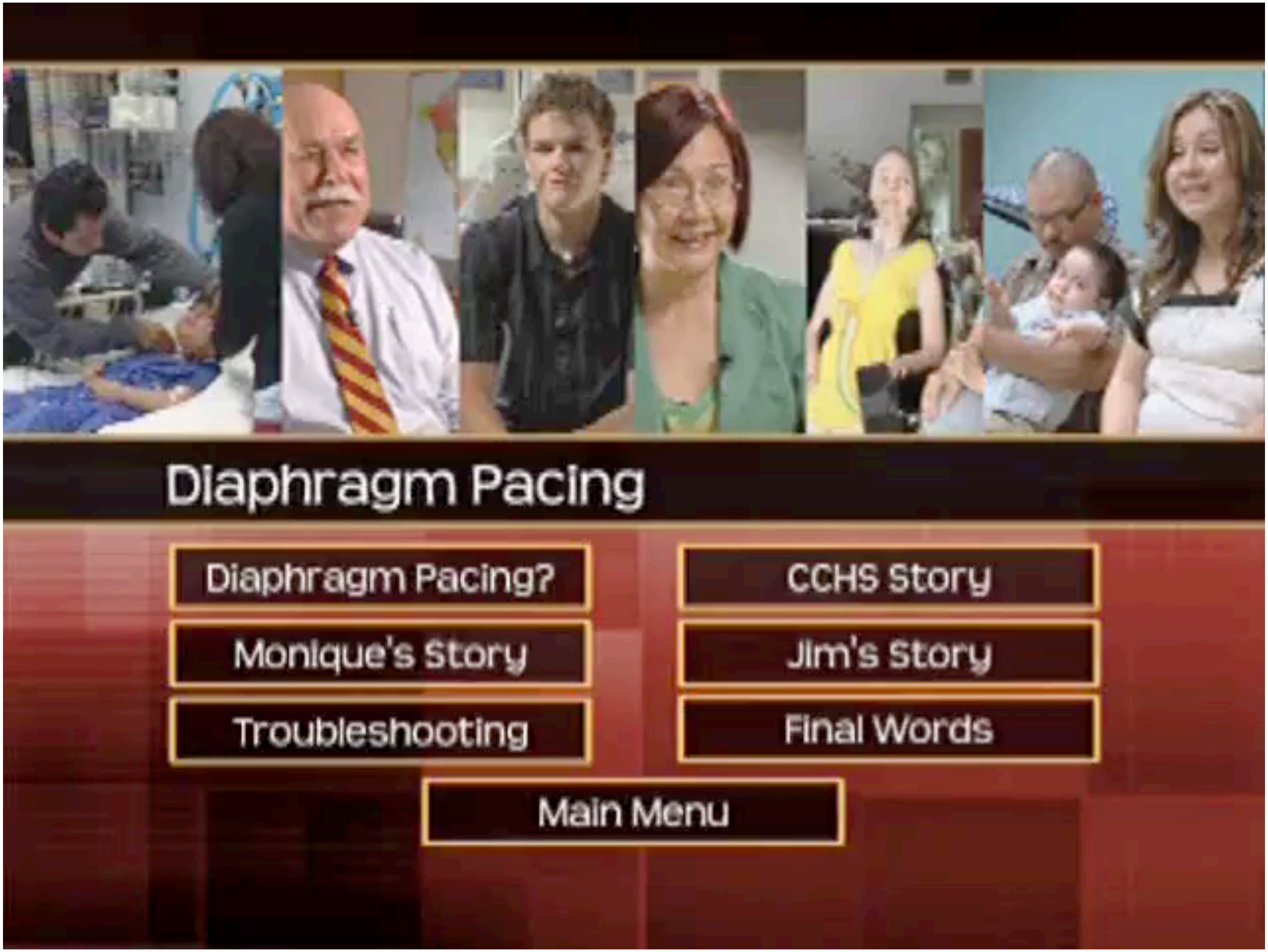
Breathing is adequate when awake (conscious/voluntary breathing is working)

Breathing is inadequate or absent during sleep (automatic breathing is not working)

Treatment: mechanical ventilation / Diaphragm Pacing

Some patients with CCHS have low or absent ventilatory response to elevated CO_2, low O_2 and metabolic acidosis.

note: Diaphragm/Phrenic Nerve Pacing is often used in cases of congenital central hypoventilation syndrome, diaphragm paralysis and spinal chord injury.


Diaphragm Pacing
Diaphragm Pacing?
CCHS Story
Monique's Story
Jim's Story
Troubleshooting
Final Words
Main Menu