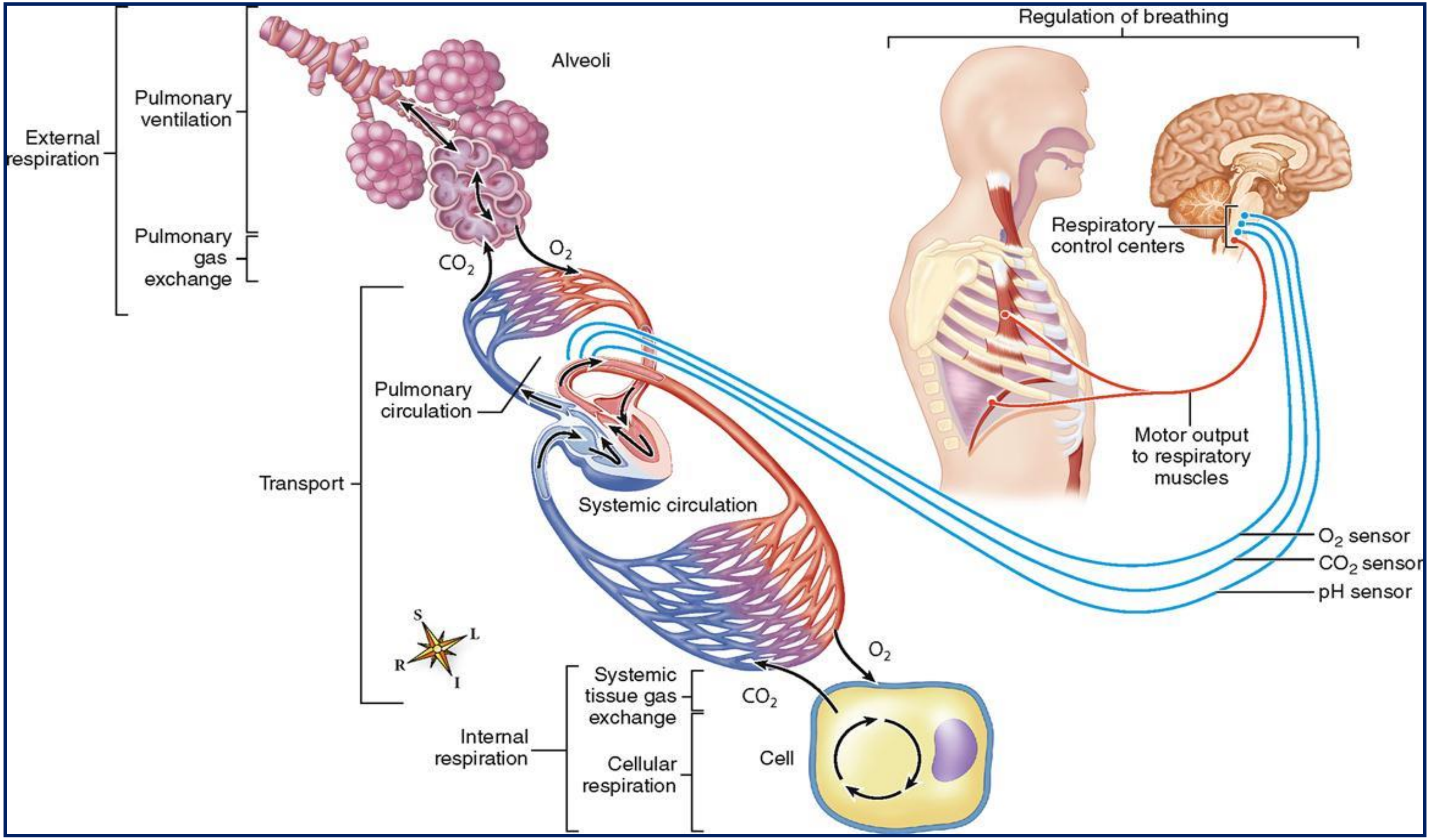
Control of Breathing

The overall processes of External Respiration



Objectives

- By the end of this lecture you should be able to: -
- Understand the role of the medulla oblongata in determining the basic pattern of respiratory activity.
- List some factors that can modify the basic breathing pattern like e.g.
- a- The Hering-Breuer reflexes, b- The proprioreceptor reflexes, c- The protective reflexes, like the irritant, and the J-receptors.
- Understand the respiratory consequences of changing PO_2, PCO_2, and PH.
- Describe the locations and roles of the peripheral and central chemoreceptors.
- Compare and contrast metabolic and respiratory acidosis and metabolic and respiratory alkalosis.

Controls of rate and depth of respiration

- Arterial PO2
  - When PO2 is VERY low (Hypoxia), ventilation increases.
- Arterial PCO2
  - The most important regulator of ventilation is PCO2, small increases in PCO2, greatly increases ventilation.
- Arterial pH
  - As hydrogen ions increase (acidosis), alveolar ventilation increases.

Respiratory Centers

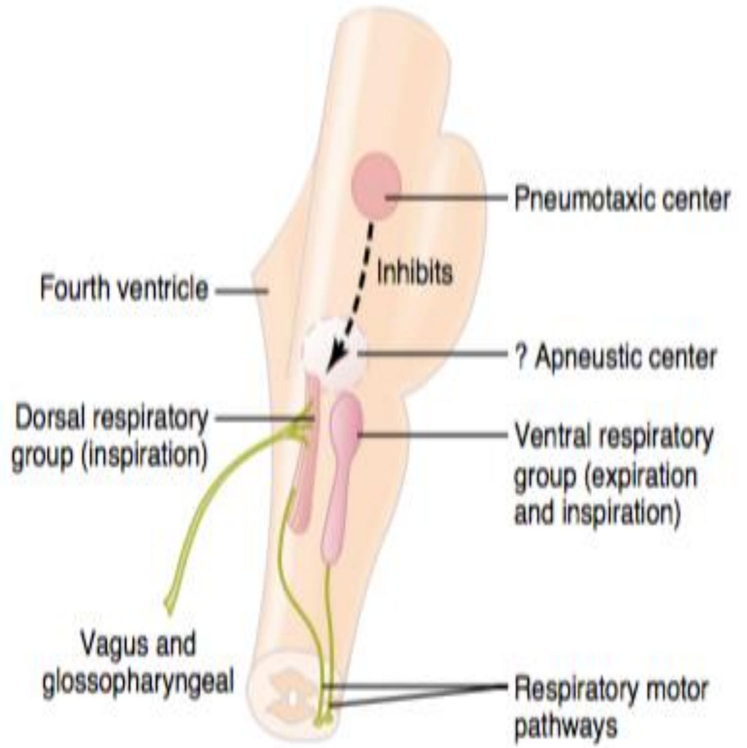
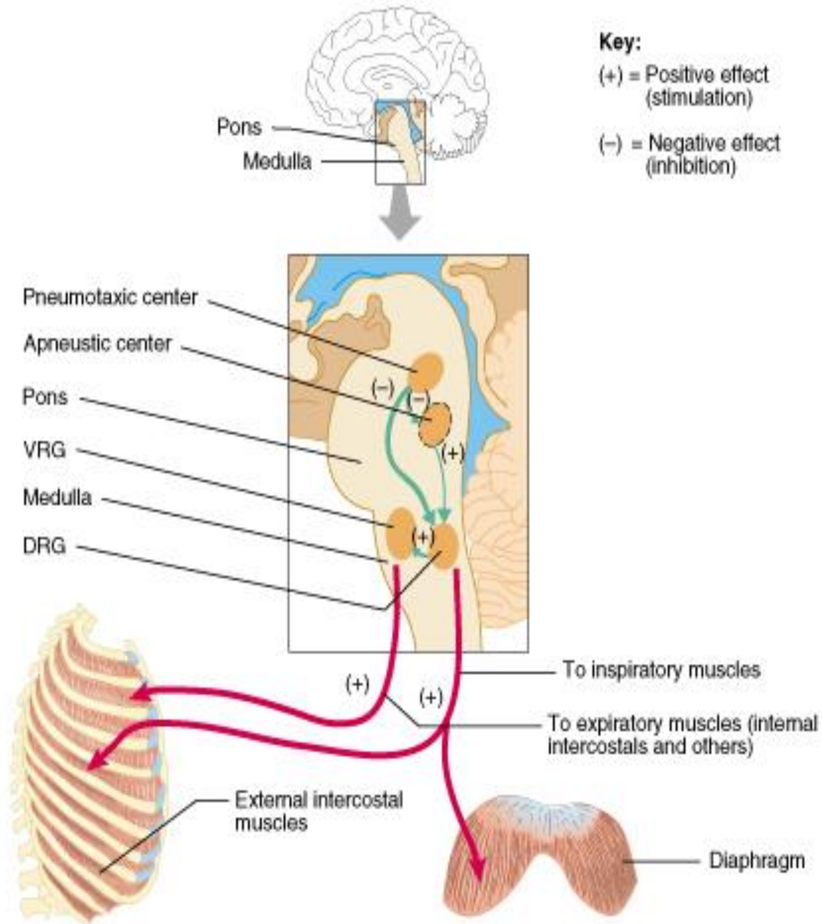


Figure 41–1

Organization of the respiratory center.



Medullary Respiratory centers

- Inspiratory area (Dorsal Respiratory Group) DRG

  -Determines basic rhythm of breathing.

  -Causes contraction of diaphragm and external intercostals.

- Expiratory area (Ventral Respiratory Group) VRG

-Although it contains both inspiratory and expiratory neurons. It is inactive during normal quiet breathing.

  -Activated by inspiratory area during forceful breathing.

  -Causes contraction of the internal intercostals and abdominal muscles.

- The medullary respiratory center stimulates basic inspiration for about 2 seconds and then basic expiration for about 3 seconds (5sec/ breath = 12breaths/min).

Pontine (Bridge) Respiratory centers

- Transition between inhalation and exhalation is controlled by:

Pneumotaxic area

Inhibits inspiratory area of medulla to stop inhalation.

Therefore, breathing is more rapid when pneumotaxic area is active.

Apneustic area

Stimulates inspiratory area of medulla to prolong inhalation. Therefore slow respiration and prolonged respiratory cycles will result if it is stimulated.

Hering-Breuer inflation reflex

- When the lung becomes overstretched (tidal volume is about 1.5 L), stretch receptors located in the wall of bronchi and bronchioles transmit signals through vagus nerve to DRG producing effect similar to pneumotaxic center stimulation.
- Switches off inspiratory signals and thus stops further inspiration .
- This reflex also increases the rate of respiration as does the pneumotaxic center.
- This reflex appears to be mainly a protective mechanism for preventing excess lung inflation

Chemical Control of Respiration

Peripheral and central chemoreceptors

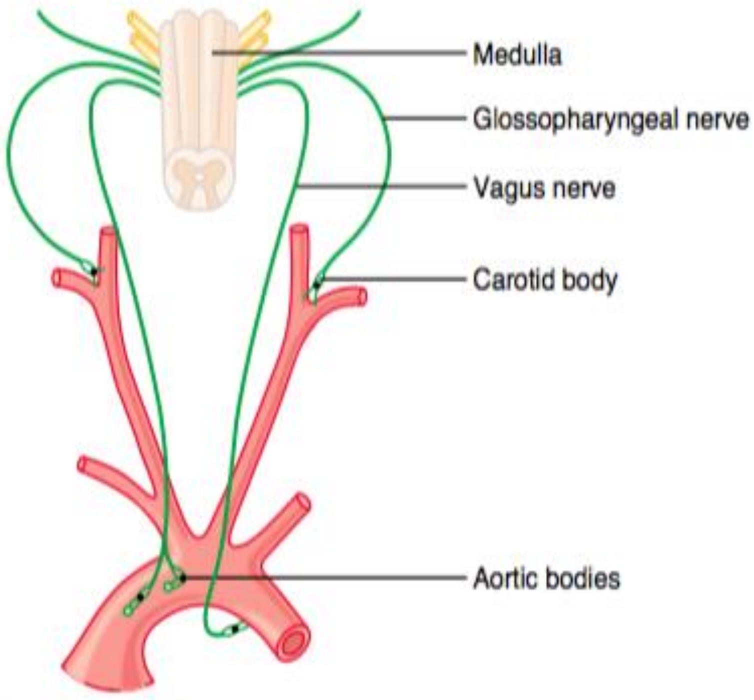


Figure 41–4

Respiratory control by peripheral chemoreceptors in the carotid and aortic bodies.

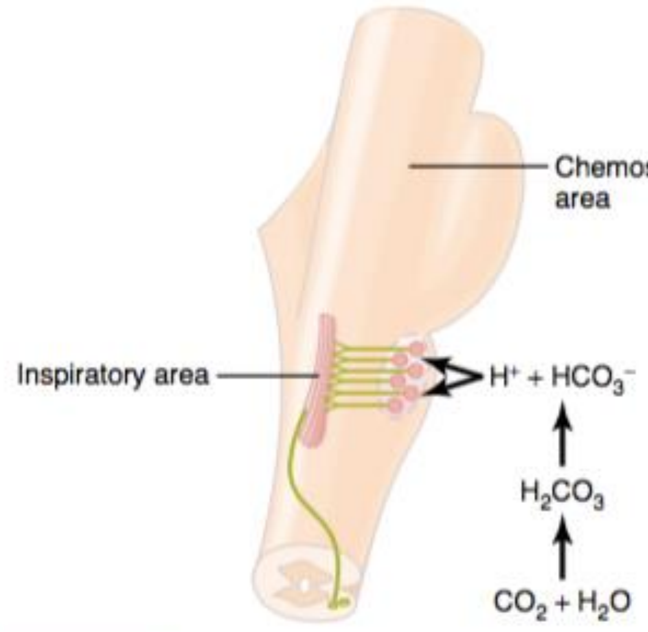
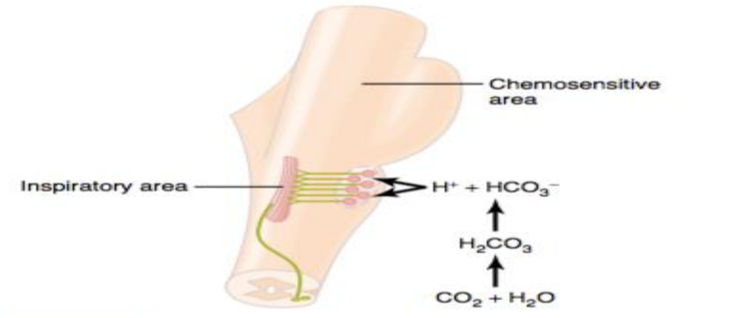


Figure 41–2

Stimulation of the *brain stem inspiratory* area by signals from the *chemosensitive area* located bilaterally in the medulla, lying only a fraction of a millimeter beneath the ventral medullary surface. Note also that hydrogen ions stimulate the chemosensitive area, but carbon dioxide in the fluid gives rise to most of the hydrogen ions.

Effect of blood CO2 level on central chemoreceptors

Although carbon dioxide has little direct effect in stimulating the neurons in the chemosensitive area, it does have a potent (effective) indirect effect. It does this by reacting with the water of the tissues to form carbonic acid, which dissociates into hydrogen and bicarbonate ions; the hydrogen ions then have a potent direct stimulatory effect on respiration.



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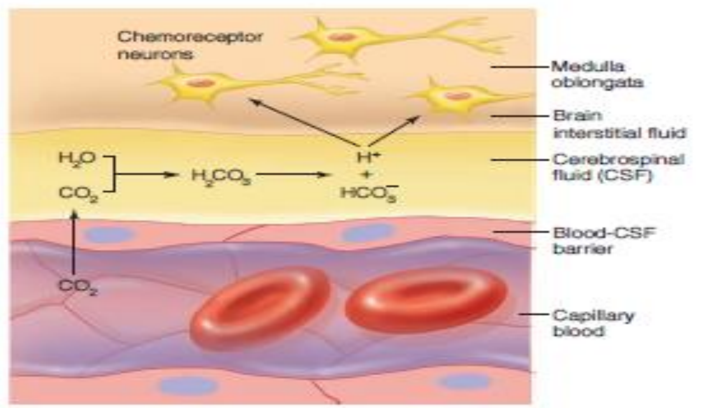


Figure 16.29 How blood CO_2 affects chemoreceptors in the medulla oblongata. An increase in blood CO_2 stimulates breathing indirectly by lowering the pH of blood and cerebrospinal fluid (CSF). This figure illustrates how a rise in blood CO_2 increases the H^+ concentration (lowers the pH) of CSF and thereby stimulates chemoreceptor neurons in the medulla oblongata.

Why does blood carbon dioxide have a more **potent effect** in stimulating the chemosensitive neurons than do blood hydrogen ions?

The blood- brain barrier (BBB) is nearly impermeable to H+ ions, but CO2passes this barrier very easily. When the blood PCO2 increases, so does the PCO2 of both the interstitial fluid of the medulla and the CSF. In these fluids, the CO2 reacts with the water to form new H+ ions. Thus, more H+ ions are released into the respiratory chemosensitive sensory area of the medulla when the blood CO2 concentration increases than when the blood H+ ion increases. For this reason, respiratory center activity is increased very strongly by changes in blood CO2, a fact that we subsequently discuss quantitatively.

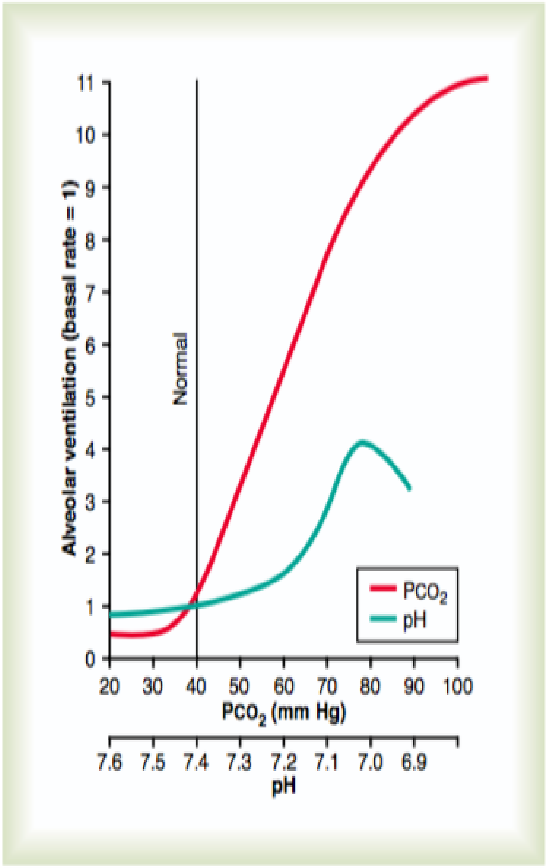


Figure 41–3

Effects of increased arterial blood P_{CO_2} and decreased arterial pH (increased hydrogen ion concentration) on the rate of alveolar ventilation.

A change in blood CO_2 concentration has a potent *acute* effect on controlling respiratory drive but only a weak *chronic* effect after a few days' adaptation.

- Excitation of the respiratory center by CO_2 is great after the blood CO_2 first increases, but it gradually declines over the next 1 to 2 days.
- Part of this decline results from renal readjustment of the H^+ ion concentration in the circulating blood back toward normal after the CO_2 first increases.
- The kidneys increasing the blood HCO_3, which binds with H^+ ions in the blood and CSF to reduce their concentrations.
- Over a period of hours, the HCO_3 (Bicarbonate) ions slowly diffuse through the BBB (blood- brain barrier) – CSF barriers and combine directly with the H^+ ions adjacent to the respiratory neurons as well, thus reducing the H^+ ions back to near normal.

Peripheral Chemoreceptor System Activity—Role of Oxygen in Respiratory Control

- Most of the chemoreceptors are in the *carotid bodies.* However, a few are also in the *aortic bodies.*
- When the oxygen concentration in the arterial blood falls below normal, the chemoreceptors become strongly stimulated.
- The impulse rate is particularly sensitive to changes in arterial PO2 in the range of 60 down to 30 mm Hg.
- Under these conditions, low arterial PO2 obviously drives the ventilatory process quite strongly.

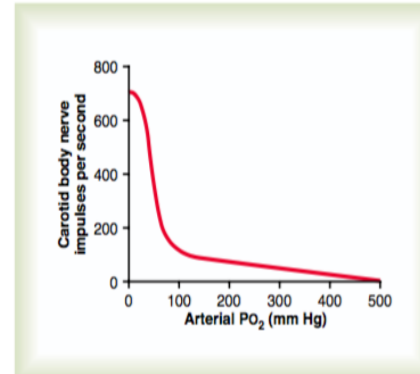


Figure 41–5

Effect of arterial PO_2 on impulse rate from the carotid body of a cat.

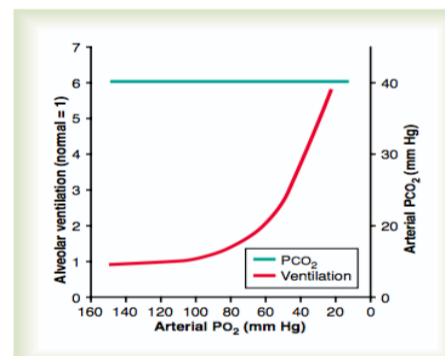
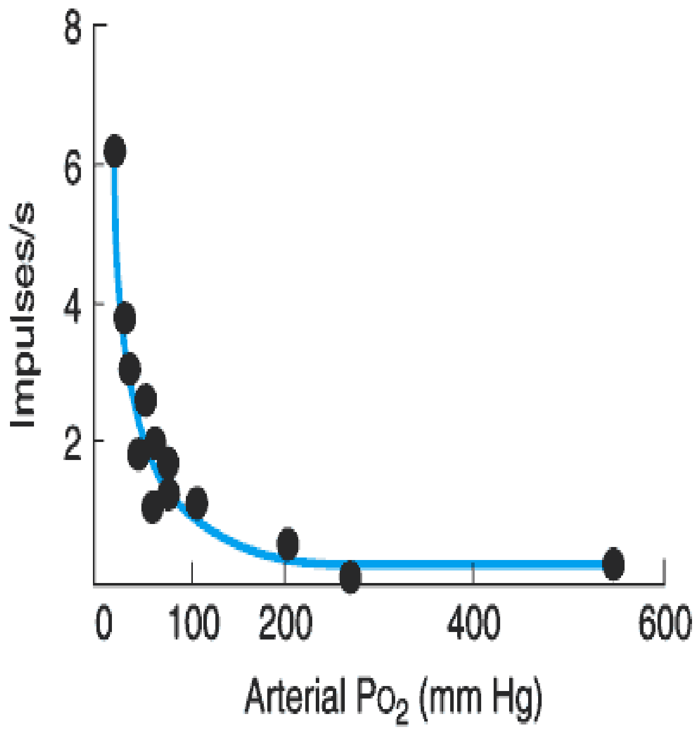


Figure 41–6

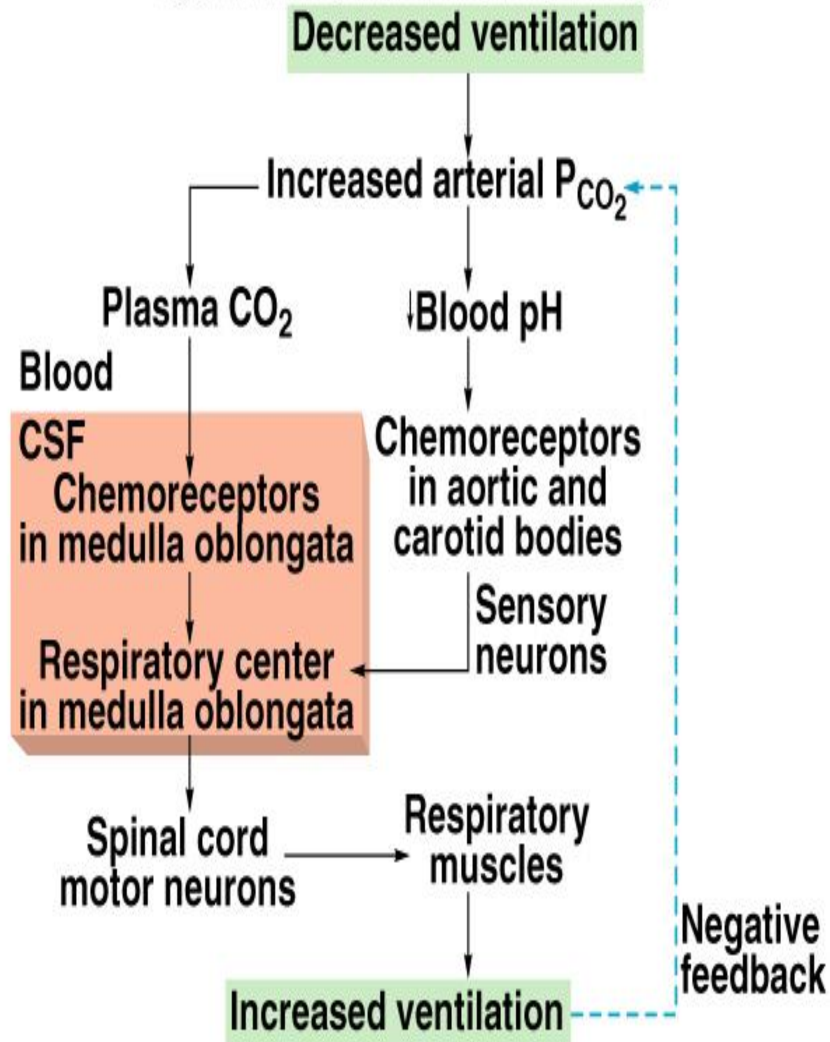
The lower curve demonstrates the effect of different levels of arterial PO_2 on alveolar ventilation, showing a sixfold increase in ventilation as the PO_2 decreases from the normal level of 100 mm Hg to 20 mm Hg. The upper line shows that the arterial PCO_2 was kept at a constant level during the measurements of this study; pH also was kept constant.

Summary of Chemoreceptor Control of Breathing

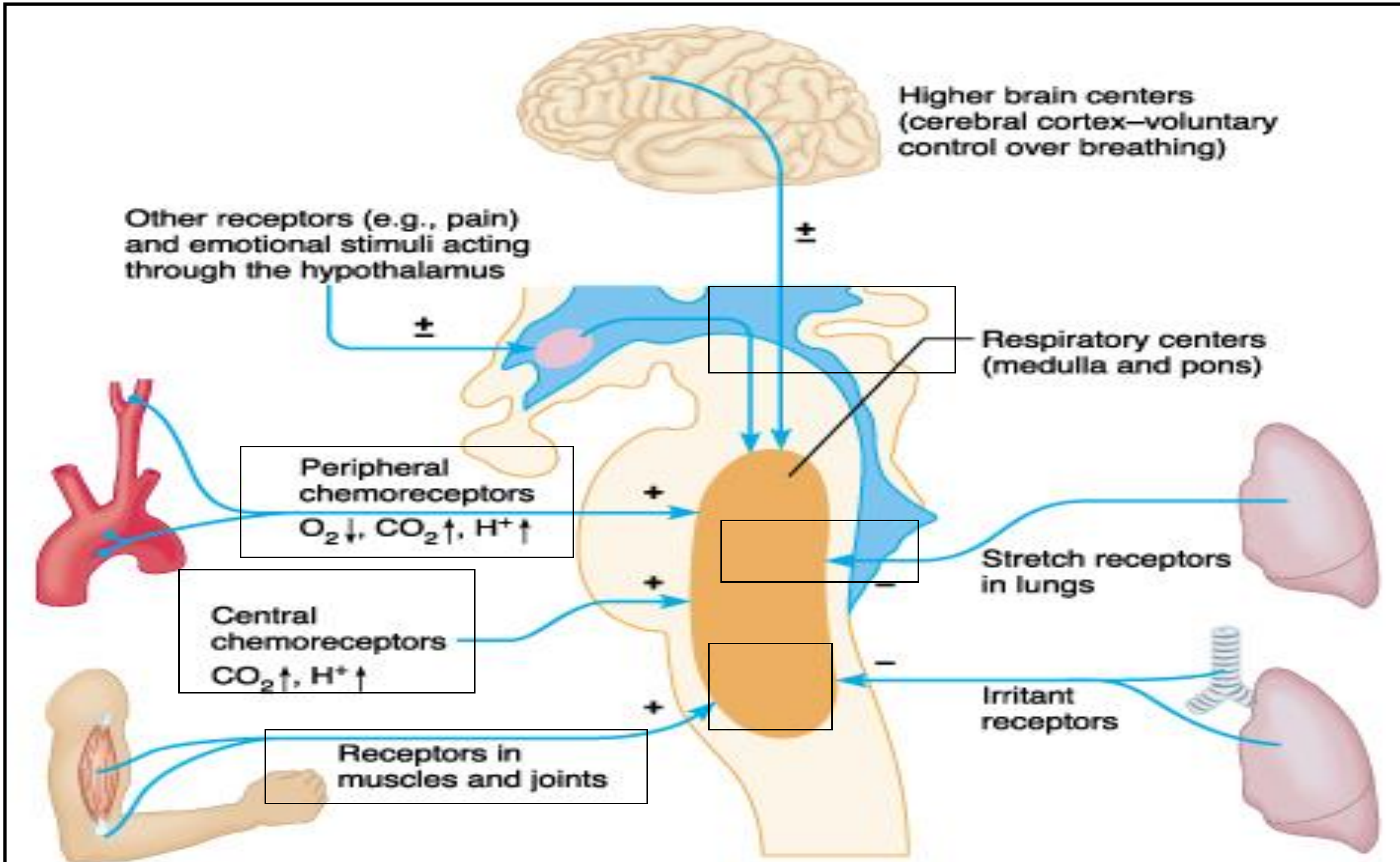
Figure 36–6.



Change in the rate of discharge of a single afferent fiber from the carotid body when arterial PO_2 is reduced. (Courtesy of S Sampson.)



Other Factors Influencing Respiration

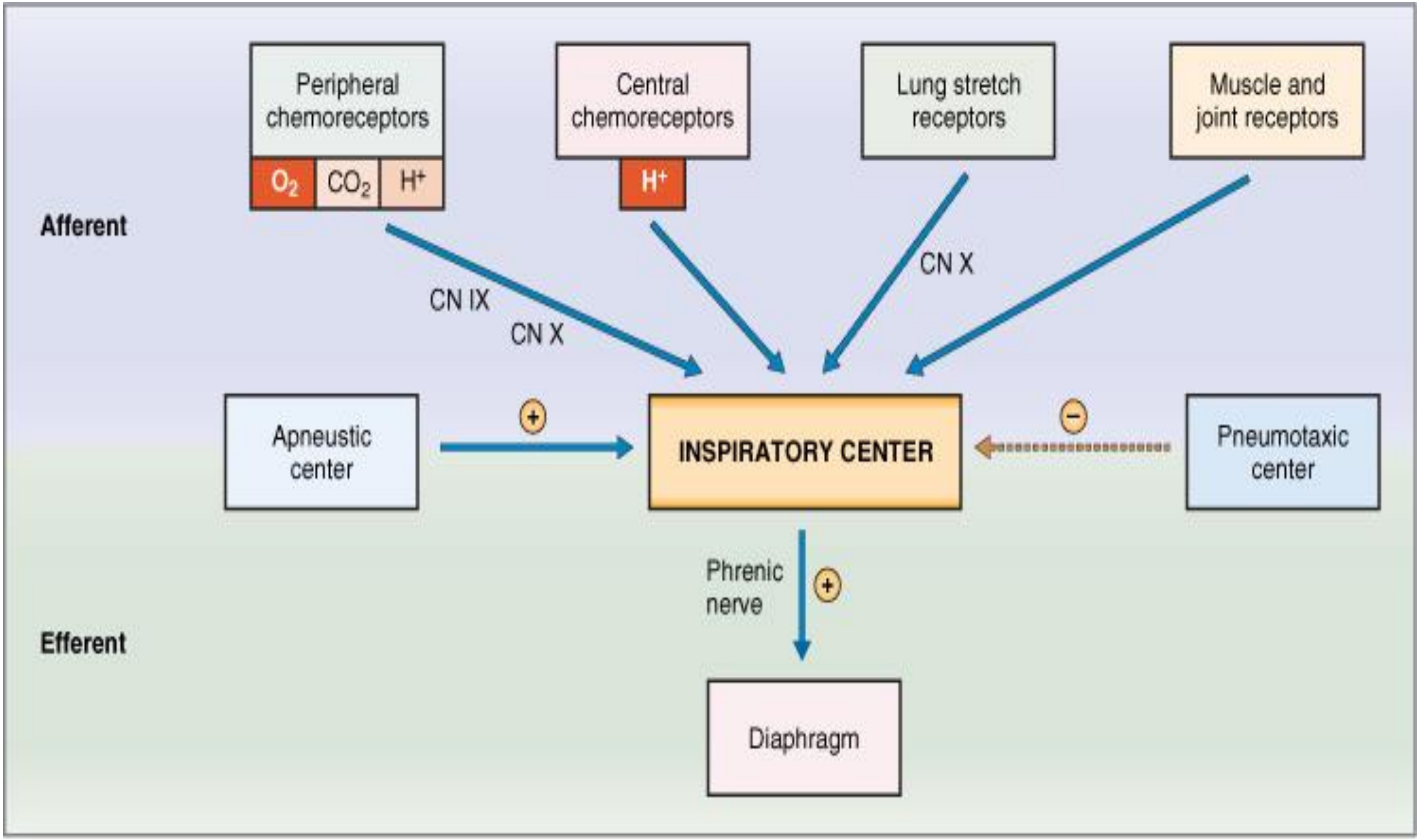


Cont. factor affecting respiratory centers

- **Effect of Irritant receptors in the airways:** the epithelium of trachea, bronchi, and bronchioles is supplied by irritant receptors that are stimulated by irritants that enter the respiratory airways causing coughing, sneezing and bronchoconstriction in bronchial asthma and emphysema.
- **Function of lung J receptors.**

Few receptors in the wall of the alveoli in juxta position to the pulmonary capillaries. They are stimulated especially when pulmonary capillaries become engorged by blood or when pulmonary edema occur e.g in CHF, their excitation cause the person a feeling of dyspnea.

Cont..factors affecting respiration



Respiratory Acidosis

- Hypoventilation.
- Accumulation of CO_2 in the tissues.
  - P_{CO2} increases
  - pH decreases.

Respiratory Alkalosis

- Hyperventilation.
- Excessive loss of CO_2.
  - P_{CO2} decreases (↓35 mmHg).
  - pH increases.

Metabolic Acidosis	Metabolic Alkalosis
• Ingestion (In), infusion, or production of a fixed acid. • decreased renal excretion of hydrogen ions. • loss of bicarbonate or other bases from the extracellular compartment	• Excessive loss of fixed acids from the body • Ingestion, infusion, or excessive renal reabsorption of bases such as bicarbonate • pH increases.

The respiratory system can compensate for metabolic acidosis or alkalosis by altering alveolar ventilation