Control of Breathing

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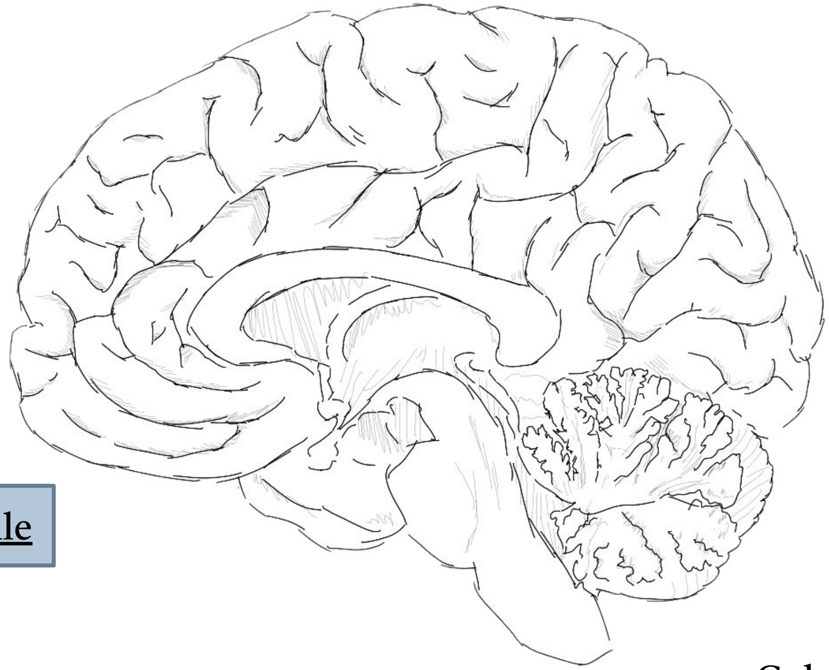

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-Main Text -Important -Notes
-Boy Slides -Girl Slides -Extra

Special Thanks to Hasan Alsughayir for the Sketch <3

Objectives

01 Understand the role of the medulla oblongata in determining the basic pattern of respiratory activity.

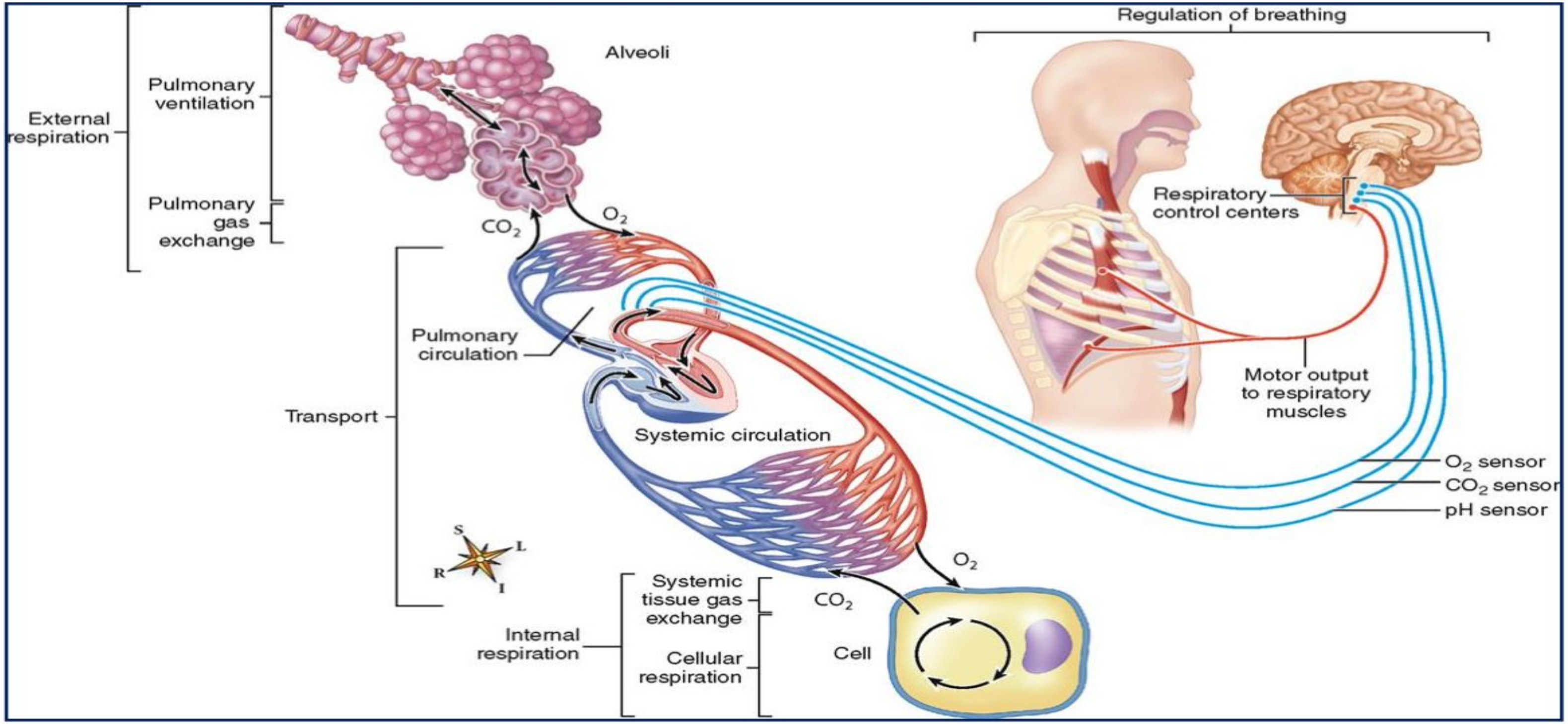
02 List some factors that can modify the basic breathing pattern like e.g. The Hering-Breuer reflexes, The proprioceptor reflexes, The protective reflexes, like the irritant reflex, and the J-receptors.

03 Understand the respiratory consequences of changing PO 2, PCO2, and PH.

04 Describe the locations and roles of the peripheral and central chemoreceptors.

05 Compare and contrast metabolic and respiratory acidosis and metabolic and respiratory alkalosis.

Overall Processes of External Respiration



Control of Rate & Depth of Respiration

-The goal of respiration is to maintain proper concentrations of O_2 , CO_2, and H^+ ions in the tissue (preventing hypo/hyperoxia and hypo/hypercapnia).
-The nervous system normally adjusts the alveolar ventilation rate almost exactly to body demands.
-The respiratory activity is highly responsive (sensitive) to changes in each of these substances:

Arterial PO_2

When PO_2 is is very low (Hypoxia), ventilation increases in rate and depth i.e the patient will <u>hyperventilate</u> .

الجسم حساس جدا لCO2 أكثر من O2

Arterial PCO_2

The most important regulator of ventilation is PCO_2. A small increase in PCO_2, greatly <u>increases ventilation.</u>

Arterial pH

As H^+ ions increase (Acidosis), alveolar <u>ventilation increases.</u>

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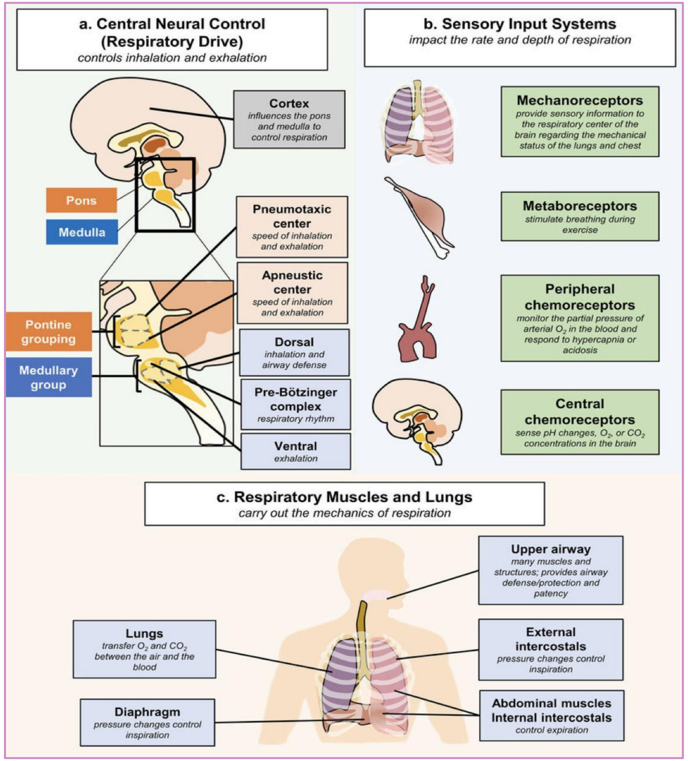
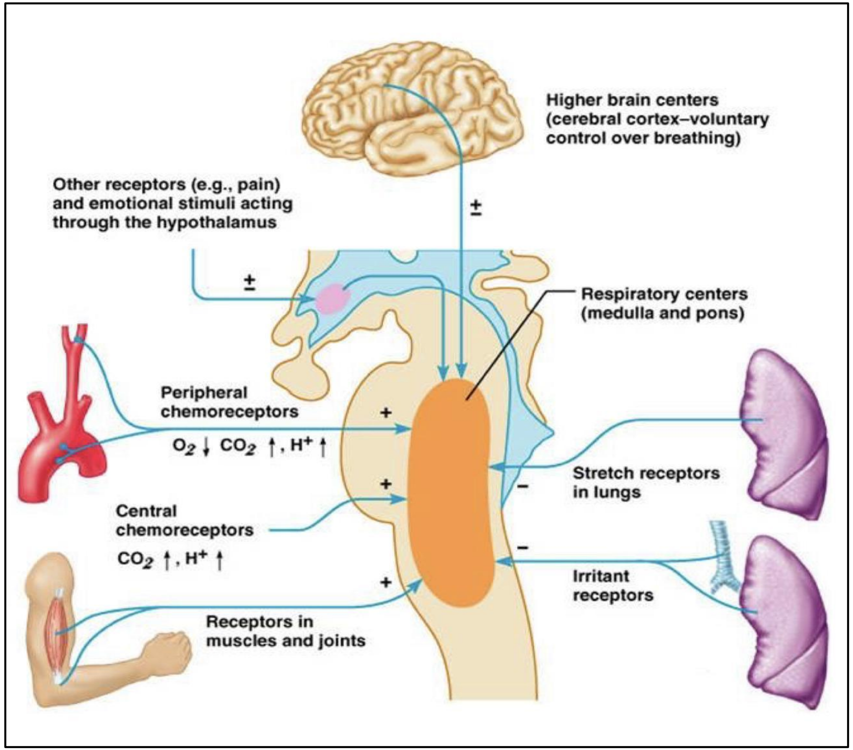
Control of Ventilation

Several mechanisms are involved which can be grouped into two main categories which are closely integrated:

- Nervous control mechanism
- Chemical control mechanism

The Control of Respiration





Respiratory Neuronal Center

- Composed of several groups of neurons
- Located in the entire length of the medulla and pons.
- Divided into: (4 groups/collections of neurons)

- Located In brain stem (pons & medulla)

02

The pneumotaxic center (Fast and Shallow)
Located dorsally in the superior portion of the pons, which mainly controls rate and depth of breathing, by turning off the inspiratory signals from the DRG. Inhibits apneustic center.

03

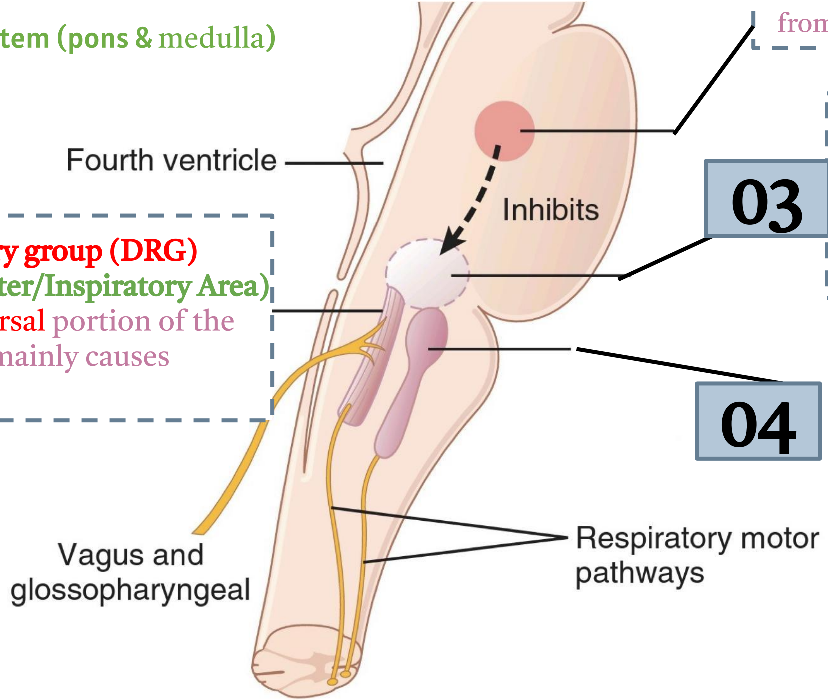
The apneustic center (Slow and Deep)
located in the inferior portion of the pons, it turns on stimulatory impulses to the DRG of neurons. it stimulates inspiratory area of medulla.

01

Dorsal respiratory group (DRG) (Rythmicity Center/Inspiratory Area)
located in the dorsal portion of the medulla, which mainly causes inspiration.

04

Ventral respiratory group (VRG) (Expiratory Area)
located in the ventrolateral part of the medulla, which mainly causes forced expiration.



Medullary respiratory center

Located within the Nucleus of the Tractus Solitarius (NTS), with additional neurons in the adjacent reticular substance of the medulla. which is the sensory termination of both the vagal (X) and the glossopharyngeal (IX) nerves (which transmit sensory signals into the respiratory center from Peripheral chemoreceptors, Baroreceptors, and several types of receptors in the lung) .

Inspiratory area (Dorsal Respiratory group)-DRG:

الدكتور مره ركز عليه وضرب
أمثله زي: اذا الواحد تمرن هل
يشتغل DRG ولا لا؟
ايه لانه يشتغل طول الوقت

- Determines basic **rhythm** of breathing **(rhythmicity center).**
- Causes contraction of diaphragm and external intercostals.
- The rhythmicity center receives impulses from:
  1-Higher brain centers
  2-Centers in the brain stem (medulla and pons)
  3-Special receptors (respiratory reflexes)
- The rhythmicity center sends excitatory impulses via the intercostal and phrenic nerves to the external intercostal muscles and diaphragm
- NTS is the sensory termination of vagal and glossopharyngeal nerve which transmit sensory signals to the respiratory center.
- The medullary respiratory center stimulates basic inspiration for about 2 seconds and then basic expiration for about 3 seconds (5sec/breath = 12 breaths/min).

Medullary respiratory center

Expiratory area (Ventral Respiratory Group)-VRG:

- Although it contains both inspiratory and expiratory neurons, It is totally inactive during normal quiet breathing.
- Activated by inspiratory area (DRG) during forceful breathing.
- Causes contraction of the internal intercostals and abdominal muscles during forced breathing (mainly expiratory).
- Located on ventral(front)area of Medulla

Pontine Respiratory Centers

Transition between inhalation & exhalation is controlled by:

Both are located in pons

Apneustic Area (Slow and Deep)

- ★ Stimulates inspiratory area of medulla to prolong inhalation. Therefore, If it is stimulated it prolongs the respiratory cycles and slows the respiration rate.
- ★ It receives **inhibitory impulses** from the **sensory vagal** fibers and inhibitory impulses from the **pneumotaxic** center.

Pneumotaxic Area (Fast and Shallow)

- ★ It transmits inhibitory impulses to the apneustic center and to the inspiratory area to switch off inspiration.
- ★ Inhibits the inspiratory area of medulla to stop inhalation.• Limitation of inspiration also shortens expiration and the entire period of each respiration.
- ★ Breathing is more rapid when pneumotaxic area is active.

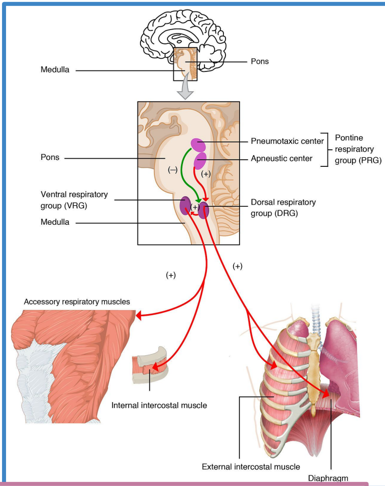
Hering-Breuer Inflation Reflex

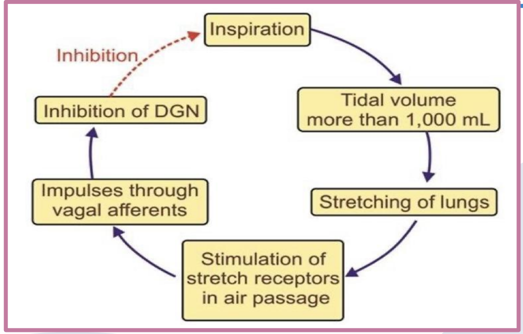
01 When the Lung becomes overstretched (tidal volume is about >= 1.5L/breath) → stretch receptors located in the wall of bronchi & bronchioles transmit signals through vagus nerve to DRG → effect similar to pneumotaxic center stimulation is produced.

02 Switches off inspiratory signals → stops further inspiration.

03 Increases the rate of respiration as does the pneumotaxic center.

04 Appears to be mainly a protective mechanism for preventing excess lung inflation.





Chemical Control of Ventilation/Respiration

Rhythmicity center is affected by chemical changes in blood via two types of chemoreceptors:

Peripheral chemoreceptors

- ★ Located mainly in the Carotid and Aortic bodies but may be found anywhere in the circulatory system.
- ★ Highly sensitive to changes in arterial PO_2 and to a lesser extent to PCO_2 and pH, Fall of PO_2, rise in PCO_2 and fall of pH, stimulate the chemoreceptors to increase ventilation.
- ★ When stimulated, send excitatory impulses to the (DRG) rhythmicity center (via glossopharyngeal IX and vagus X nerves).

Central chemoreceptors.

- ★ Most probably located on the ventrolateral surface of medulla oblongata (which is bathed with cerebrospinal fluid), has direct connections with the inspiratory area (DRG).
- ★ Evoked by arterial PCO_2 (CO_2 can freely cross blood brain barrier(BBB) into CSF, while BBB is relatively impermeable to H^+ and HCO_3^- ions).
- ★ Highly sensitive to the hydrogen ion concentration of the cerebrospinal fluid CSF.

The **aortic** body receives sensory innervation from the aortic nerve, which is a branch of the **vagus** nerve. the **glossopharyngeal** nerve innervates the **carotid** sinus.

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Respiratory control by <u>peripheral chemoreceptors</u> in carotid and aortic bodies

01 Normal PO2, PCO2 and pH, low grade in the first activities in the nerves.

02 ↓PCO2, ↑pH causes low tonic activity which cause decrease ventilation.

03 **In metabolic acidosis:**
↓pH causes increase in ventilation to wash out CO2 and to bring pH to normal

04 **In metabolic alkalosis:**
↑pH causes decrease ventilation. CO2 retained in the blood to compensate

Effect of changes of CO_2 and H^+ levels on chemoreceptor activity

01

Excess CO_2 or H^+ in the blood stimulate the:

1. the central chemoreceptors which act on the respiratory center, causing increased strength of both the inspiratory and the expiratory motor signals to the respiratory muscles (hyperventilation).
2. the peripheral chemoreceptors and in this way, indirectly Increases respiratory activity.

02

The effects of CO_2 or H^+ on the central chemoreceptors are (about seven times as powerful) than their effects on the peripheral chemoreceptors.

03

However, there is one difference between the peripheral and central effects of carbon dioxide: the stimulation of the peripheral chemoreceptors occurs five times as rapidly as the central stimulation,So the peripheral chemoreceptors might be especially important in increasing the rapidity of response to CO_2 at the onset of exercise.

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Direct effect of H+ ions on the central chemoreceptors

- The central chemoreceptors are especially excited by H+ ions.
- In fact, it is believed that H+ ions may be **<u>direct</u> the only important direct stimulus for these neurons**
- However, The blood- brain barrier (BBB) is nearly impermeable to H+ ions, but CO2 passes this barrier very easily.
- For this reason, changes in H+ ion concentration in the blood have considerably less effect in stimulating the central chemosensitive neurons than do changes in blood CO2 even though CO2 is believed to stimulate these neurons secondarily by changing the hydrogen ion concentration

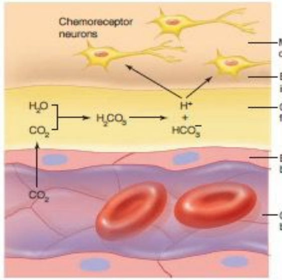

Figure 16.29 How blood CO_2 affects chemoreceptors in the medulla oblongata. An increase in blood CO_2 stimulates breathing indirectly by lowering the pH of blood and cerebrospinal fluid (CSF). This figure illustrates how a rise in blood CO_2 increases the H^+ concentration (lowers the pH) of CSF and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

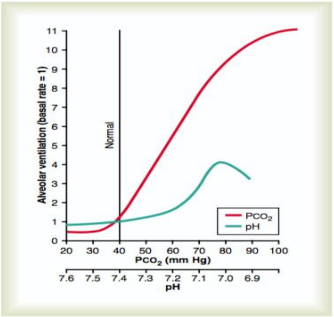

Figure 41–3

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

Effect of CO_2 on central chemoreceptors

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

01

Although carbon dioxide has little direct effect in stimulating the neurons in the chemosensitive area, it does have a potent 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.

02

When the blood PCO_2 increases, so does the PCO_2 of both the interstitial fluid of the medulla and the CSF

03

In these fluids, the CO_2 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 CO_2 concentration increases than when the blood H^+ ion increases. For this reason, respiratory center activity is increased very strongly by changes in blood CO_2.

Blood brain barrier(BBB) is nearly impermeable to H^+ ions, but CO_2 passes this barrier very easily. When the blood PCO_2 increases, so does the PCO_2 of both the interstitial fluid of the medulla and the CSF.

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

1 — 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.

2 — 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.

3 — The kidneys increase the blood HCO_3, which binds with H^+ ions in the blood and CSF to reduce their concentrations.

4 — Over a period of hours, the HCO_3 ions slowly diffuse through the BBB– 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.

When HCO_3 (Bicarbonate) binds with H^+, it becomes H_2CO_3 (Carbonic acid).

- Kidney balance the CO_2 level by:

1. Increasing bicarbonate level which works as buffer.
2. Execret H ions in urine.

Peripheral chemoreceptors system activity Role of oxygen in respiratory control

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- When the oxygen concentration in the arterial blood falls below normal, it acts almost entirely on peripheral chemoreceptors.
- 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.
- Because the effect of hypoxia on ventilation is modest for PO2 values greater than 60 to 80 mm Hg, the PCO2 and the hydrogen ion response are mainly responsible for regulating ventilation in healthy humans at sea level.

Sensitive to PO2 more than PCO2

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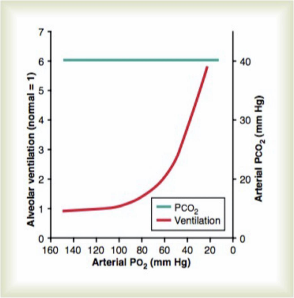


Figure 41–6

The lower curve demonstrates the effect of different levels of arterial P_{O_2} on alveolar ventilation, showing a sixfold increase in ventilation as the P_{O_2} decreases from the normal level of 100 mm Hg to 20 mm Hg. The upper line shows that the arterial P_{CO_2} was kept at a constant level during the measurements of this study; pH also was kept constant.

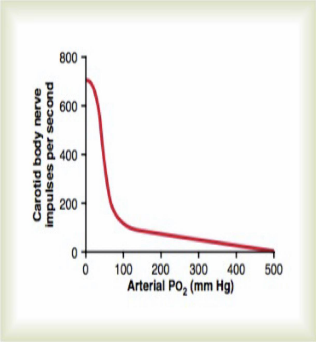


Figure 41–5

Effect of arterial P_{O_2} on impulse rate from the carotid body of a cat.

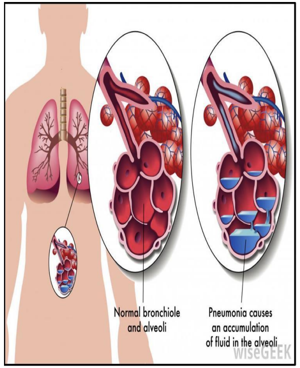
Other factors influencing respiration

Irritant Receptors in the Airways

★ The epithelium of the trachea, bronchi, and bronchioles is supplied with sensory nerve endings called **pulmonary irritant receptors**.

★ These receptors (that are stimulated by irritants that enters the respiratory airways) initiate causing coughing and sneezing.

★ They may also cause bronchoconstriction in persons with diseases such as bronchial asthma and emphysema.

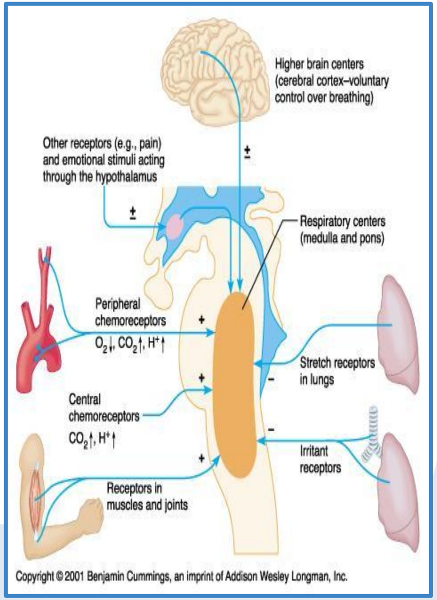


Lung J Receptors

★ Sensory nerve endings /Few receptors in the wall of the alveoli in juxta position (very close) to the pulmonary capillaries.

★ They are stimulated especially when the pulmonary capillary becomes engorged by blood or when pulmonary edema occurs in congestive heart failure (CHF).

★ Their stimulation/Excitation cause the patient a feeling of dyspnea and increase in breathing rate.



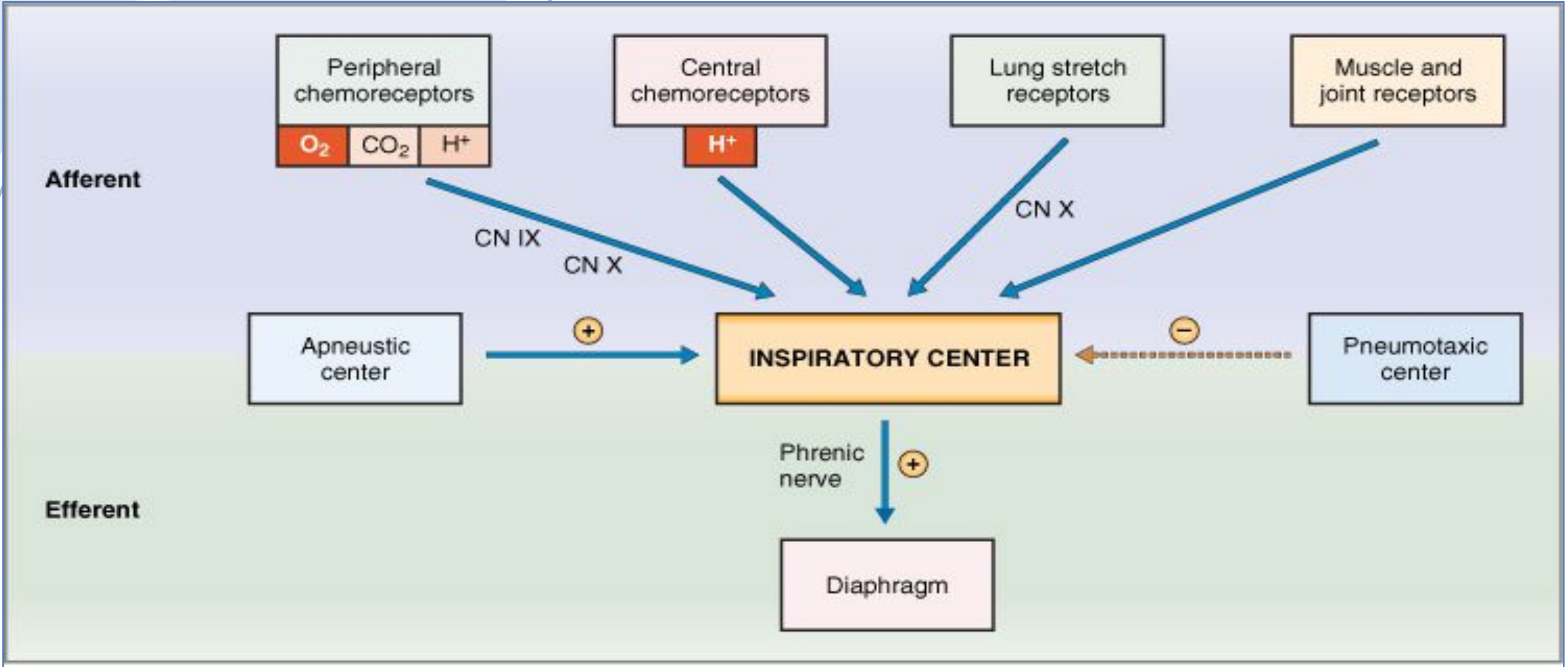
Respiratory Acidosis	Respiratory Alkalosis
★ Hypoventilation. ★ Accumulation of CO_2 in tissues. ★ PCO_2 increases. ★ PH decreases.	★ Hyperventilation. ★ Excessive loss CO_2. ★ PCO_2 decreases (Below 35mm Hg). ★ PH increases.

- If the primary change in the body is CO_2 -> Respiratory (Acidosis/Alkalosis).
- If the primary change in the body is PH and HCO_3^- -> Metabolic (Acidosis/ Alkalosis).

Respiratory acidosis or alkalosis is always compensated by Metabolic acidosis or alkalosis, for example: Respiratory Alkalosis is compensated by metabolic acidosis.

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

Metabolic Acidosis	Metabolic Alkalosis
★ Ingestion, infusion, or production of a fixed acid. ★ Decreased renal excretion of hydrogen ions. ★ Loss of bicarbonate or other bases from the extracellular compartment. ★ Metabolic disorders as diabetic ketoacidosis.	★ Excessive loss of fixed acids from the body. ★ Ingestion, infusion, or excessive renal ★ reabsorption of bases such as bicarbonate. ★ PH increases.



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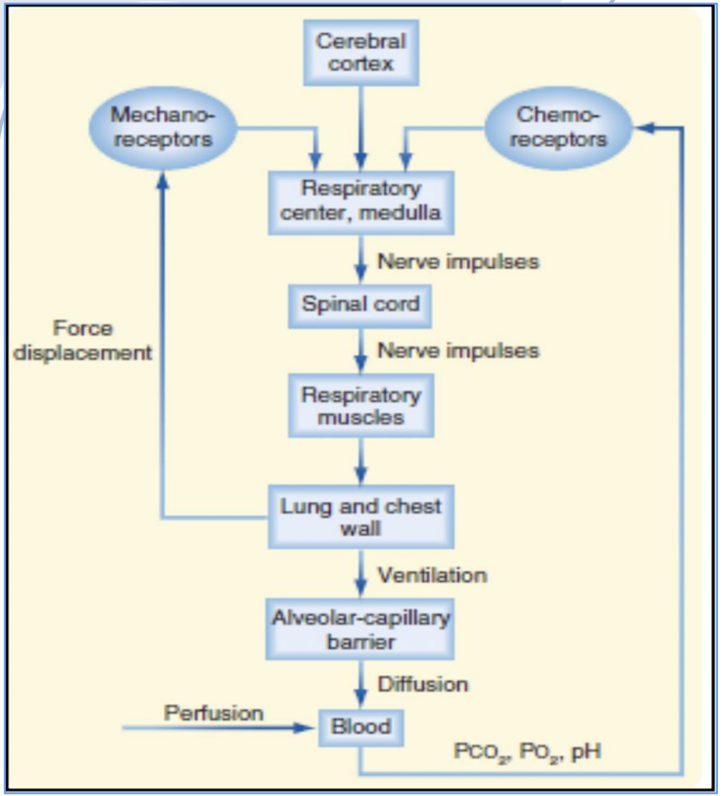
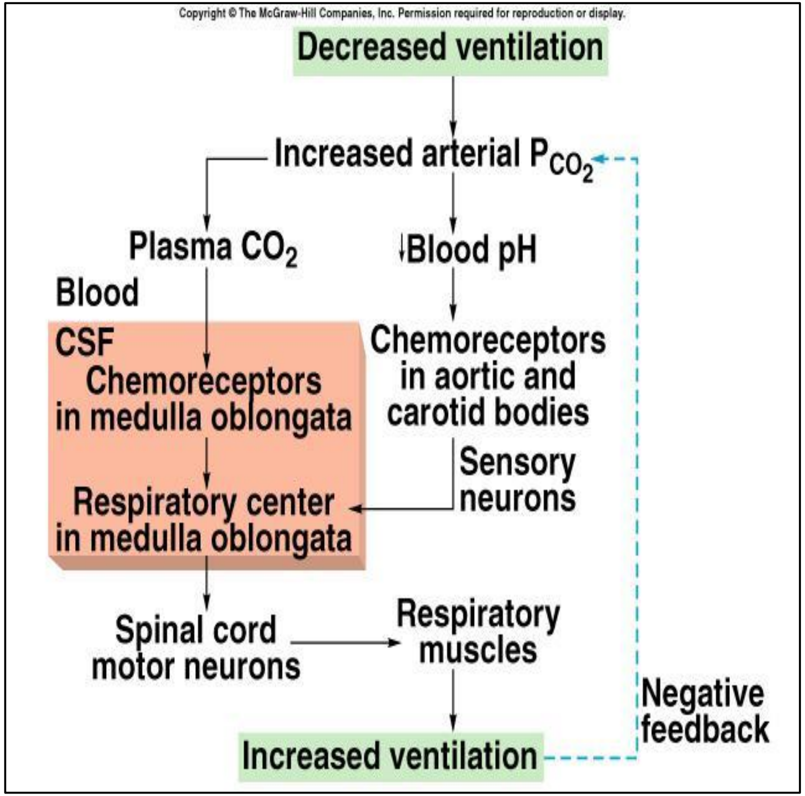
Summary of factors affecting respiration





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Overall process of respiration /Summary of chemoreceptors control of breathing

MCQs

Q1: when Co_2 increases; H+ Will ...., and pH will			
A- increase, decrease	B- decrease, increase	C- they will remain the same	D-no changes
Q2:Which of the following center will start during exercise?			
A- A. Pneumotaxic only	B- Apneustic only	C-Pneumotaxic & VRG	D- DRG only
Q3: The mechanism of Hering-Breuer reflex similar to which of the following			
A-Apneustic	B-VRG	C- DRG	D- Pneumotaxic

1-A 2-C 3-D

MCQs

Q4:What center inhibits inspiration and promotes rapid breathing?			
A- DRG	B- VRG	C- Pneumotaxic	D- Apneustic
Q5:Which of the following is considered as a mechanism of Hering-Breuer reflex?			
A- A. switch on inspiratory signals	B- decreases the rate of respiration	C-prevents the lung from hyperinflation	D- prevents the lung for hyperinflation
Q6:Which ONE of the following molecules is mainly formed during carbon dioxide transport?			
A-Bicarbonate ions	B-Carboxyhemoglobin	C- Oxyhemoglobin	D- Sodium Chloride

4-C 5-C 6- A

MCQs

Q7:Metabolic acidosis will stimulate the receptors were they located at:			
A-Carotid Bodies	B- Stretch receptors	C- Trachea	D-Medulla Oblongata
Q8: Which of the following conditions increases respiration?			
A-activation of apneustic center	B- activation of pneumotaxic center	C-increase in arterial PO2	D- increase in blood PH

7-A 8-B

SAQs

Q1: What factor indirectly stimulates the central chemoreceptors?

Q2: Compare between respiratory acidosis and alkalosis.

Q3: What respiratory center region promotes shallow fast breathing.

A1: Increase in C02 levels

A2: On slide 20

A3: Pneumotaxic center

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