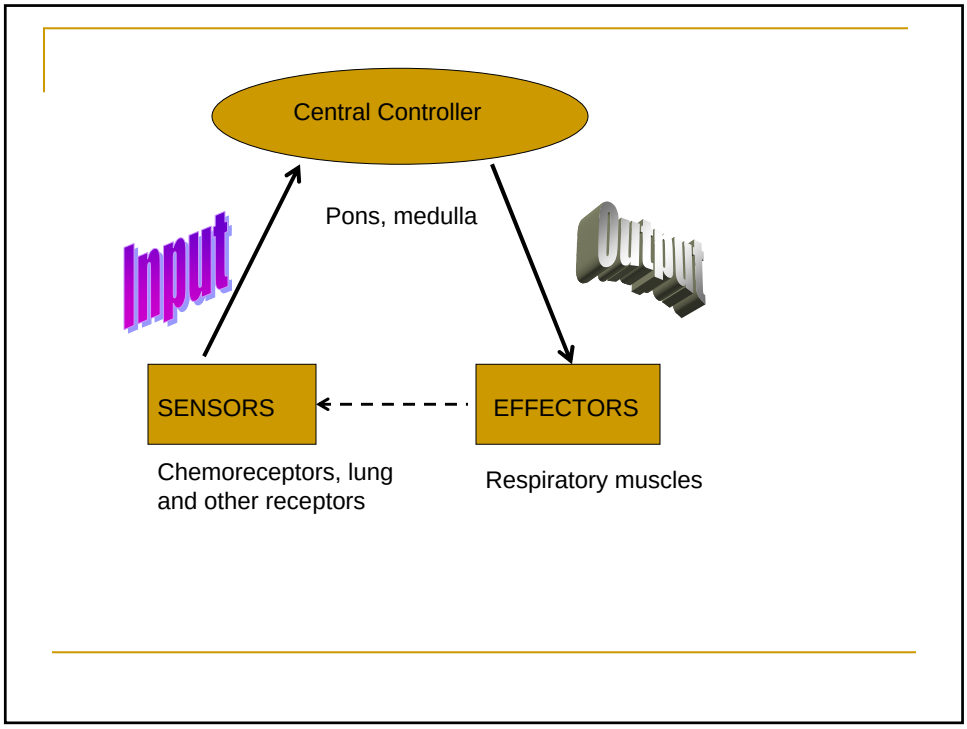
PHYSIOLOGY OF RESPIRATION

- Regulation of Respiration
- Physiology of Exercise

Rodolfo T. Rafael, M.D.

Three Basic Elements of the Respiratory Control System

- Sensors
  - gather information
- Central controller or respiratory center
  - Coordinates the information and send impulses
- Effectors
  - ventilation



Control System

- Neural Mechanism Regulate Respiration
  - Voluntary control
    - Cerebral cortex
  - Automatic control
    - Pons and medulla

Control System

- Central Controller
- Effectors
- Sensors

Control System

- Central Controller “Respiratory Center”
  - Medullary respiratory center
  - Apneustic Center
  - Pneumotaxic Center

Control System

- Central Controller “Respiratory Center”
  - Medullary respiratory center
    - Dorsal- inspiratory center
      - Intrinsic periodic firing
      - Impulse (vagal and glossopharyngeal nerves)
    - Ventral- expiratory center

Control System

- Central Controller
  - Apneustic Center
    - lower pons
    - prolonged inspiratory gasps (apneuses) interrupted by transient expiratory efforts
    - role in normal respiration is not yet known
    - severe brain injury

Control System

- Central Controller
  - Pneumotaxic Center
    - upper pons
    - inhibits inspiration and thus regulate inspiratory volume and secondarily, respiratory rate
    - fine tuning

Control System

- Role of the Cortex
  - can override the function of the brainstem within limits

Control System

- Effectors
  - diaphragm
  - intercostal muscles
  - abdominal muscles
  - accessory muscles

Respiratory Muscle

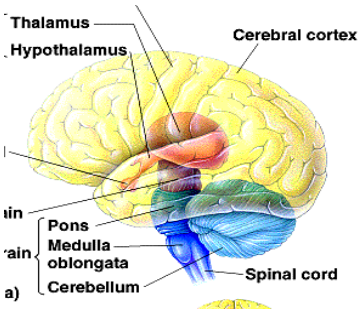
- Inspiration muscle
  - Diaphragm
  - External intercostal muscle
  - Scalene
  - Sternocleidomastoid
- Expiration muscle
  - Internal Intercostal Muscle
  - External Oblique
  - Internal Oblique
  - Rectus Abdominis
  - Transversus abdominis

Control System

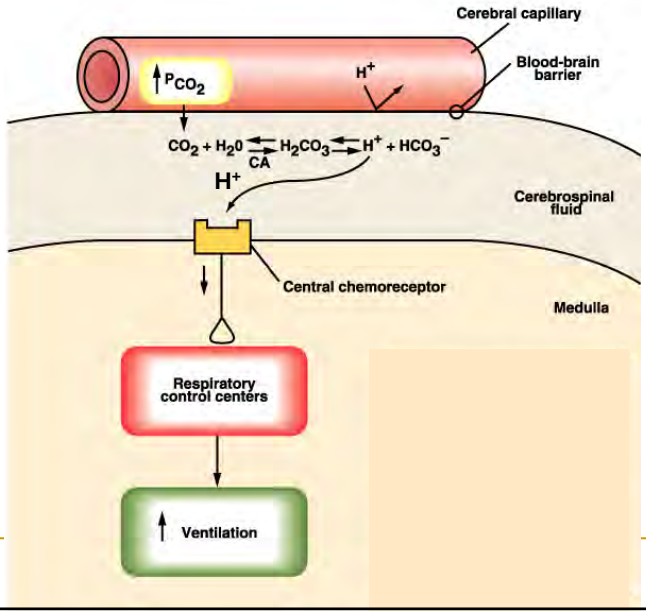
- Sensors
  - Central Chemoreceptors
  - Peripheral Chemoreceptors
  - Lung and other Receptors
    - LUNG
      - Pulmonary stretch receptors
      - Irritant receptors
      - J receptors
    - Other
      - Nose and upper airway receptors
      - Joint and muscle receptors
      - Gamma system
      - Arterial baroreceptors
      - Pain and temperature

Control System

- Sensors
  - Central Chemoreceptors
    - ventral surface of the medulla in the vicinity of the exit of the 9th and 10th nerves
    - surrounded by brain extracellular fluid
      - increase of hydrogen ion
      - decrease hydrogen ion



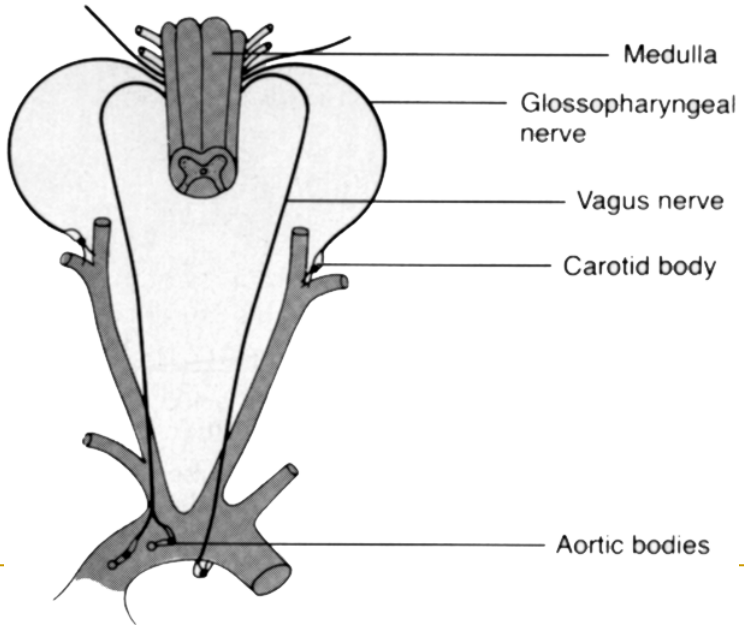
Central (medullary) Chemoreceptors the H^+ (CO_2) sensors



Control System

- Sensors
  - Peripheral Chemoreceptors
    - carotid bodies at the bifurcation of the common carotid arteries and in the aortic bodies above and below the aortic arch
    - decrease pO_2 and pH, increase pCO_2
    - pO_2 range 60-30mmHg
    - responsible for increase in ventilation
    - response to arterial pCO2 much less than central
    - increase chemoreceptor activity in respond to decrease pH (metabolic or respiratory)

The Oxygen Sensors



Control System

- Sensors
  - LUNG

    Pulmonary Stretch Receptors

    Irritant Receptors

    J Receptors

Control System

- Sensors
  - LUNG
    - Pulmonary stretch receptors
      - lie within airway smooth muscle
      - stimulated by distention of the lung
      - slowing of respiratory frequency “Hering-Breuer inflation reflex”
      - inactive in adult

Control System

- Sensors
  - LUNG
    - Irritant receptors
      - lie between epithelial cell
      - noxious gases, cigarette smoke, inhaled dust and cold air→ vagus→ bronchoconstriction and hyperpnea

Control System

- Sensors
  - LUNG
    - J receptors
      - alveolar walls close to the capillaries “juxta-capillary” or J
      - vagus
      - do not show a firing pattern
      - engorgement of the pulmonary capillary and increases in interstitial fluid volume of the alveolar wall

Control System

- Other Receptors
  - Nose and upper airway receptors
    - nose, nasopharynx, larynx, and trachea
      - mechanical, chemical
      - sneezing, coughing, bronchoconstriction
      - laryngeal spasm

Control System

- Other Receptors
  - Nose and upper airway receptors
  - Joint and muscle receptors
    - proprioceptors stimulate respiratory system
  - Gamma system
    - intercostal muscle, diaphragm contain muscle spindles, sense elongation of muscle→ reflexly control strength of contraction
  - Arterial baroreceptors
    - increase ABP→ hypoventilation
  - Pain and temperature
    - apnea → hyperventilation
    - hypothalamic thermoreceptors

Regulation of Respiratory Center Activity

- Functions of the Respiratory Center
- Stimuli Affecting the Respiratory Center

Regulation of Respiratory Center Activity

- Functions of the Respiratory Center
  - Coordinates the activity of respiratory muscle
  - Regulates the frequency and strength of contraction of the respiratory muscles

Nervous Control of Respiration

- Neurogenic stimuli of cortical origin
- Neurogenic stimuli of visceral origin
- Neurogenic stimuli of somatic origin

Neurogenic Stimuli of Cortical Origin

- limited degree of voluntary control of breathing
- depth and rate varied
- breatholding cannot be done indefinitely→ increase CO2→ respiration

Neurogenic Stimuli of Visceral Origin

- Protective Reflexes
- Pulmonary Stretch Reflex (Hering-Breuer reflex)
- Thoracic chemoreflexes (Bezold-Jarisch reflex)
- Circulatory factors

Neurogenic Stimuli of Visceral Origin

- Protective Reflexes
  - Cough reflex
    - forceful expiratory effort
  - Cessation of Respiration
    - closure of the glottis and bronchial constriction
  - Swallowing Reflex
    - closure of the glottis and inhibiting of inspiration

Neurogenic Stimuli of Visceral Origin

- Pulmonary Stretch Reflex (Hering-Breuer reflex)
- Thoracic chemoreflexes (Bezold-Jarisch reflex)
  - veratrum alkaloids, antihistamines, serotonin→ cessation of respiration, slowing of the heart, fall in BP.
- Circulatory factors
  - increase ABP stimulates pressoreceptors in the carotid sinus and in the aortic arch→ inhibition

Neurogenic Stimuli of Somatic Origin

- Reflexes from joints
  - increase the rate and occasionally the depth of breathing
- Effect of pain
  - either respiratory +- depending on the character, origin and intensity of the stimulus
  - generally increase rate of pulmonary ventilation
- Effect of temperature
  - increase body temp→ increase pulmonary ventilation
  - warming the medullary centers

Three Chemical Stimuli to the Respiratory Center

- Increase arterial pCO_2
  - increase ventilation
    - central chemoreceptors, peripheral chemoreceptors
- Decrease arterial PO_2
  - increase ventilation
    - carotid and aortic body chemoreceptors
    - no action on central chemo®
- Response to pH
  - decrease arterial blood pH stimulate ventilation
  - peripheral chemoreceptors

THE HERING BREUER REFLEX

- Components of the reflex arc
- Mechanism
- Mechanism of rhythmicity after double vagotomy

THE HERING BREUER REFLEX

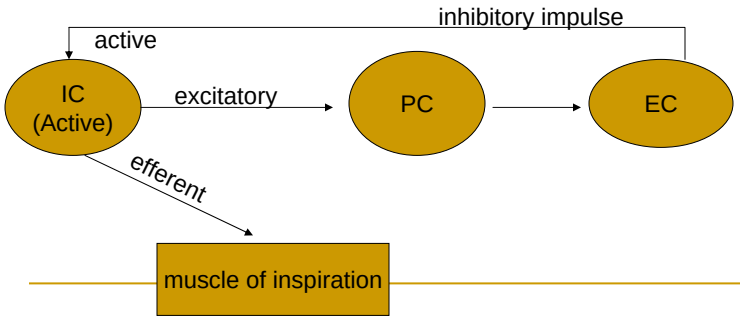
- Components of the reflex arc
  - Receptors- lungs (wall of alveolar ducts)
    - stretch receptors
    - deflation receptors
  - Afferents- vagus
  - Center- respiratory center
  - Efferents- the motor nerves to the muscle of inspiration
  - Effectors- muscles of inspiration

THE HERING BREUER REFLEX

- Mechanism
  - Inspiration inflates the lungs
  - Inhibitory impulses- vagus nerves
  - Inhibition of the center cut off impulses causing relaxation
  - Expiration deflates the lung
  - Excitatory impulses- vagus nerves
  - Excitation of the center sent impulse to inspiratory muscles

THE HERING BREUER REFLEX

- Mechanism of rhythmicity after double vagotomy
  - abolishes H-B reflex



PHYSIOLOGY OF EXERCISE

RESPIRATION IN EXERCISE

- Oxygen Consumption and Pulmonary Ventilation
- Oxygen Diffusing Capacity of Athletes
- Effect of Smoking on Pulmonary Ventilation in Exercise

Oxygen Consumption and Pulmonary Ventilation in Exercise

- Normal oxygen consumption - 250ml/min
- Pulmonary Ventilatio increase 20-fold

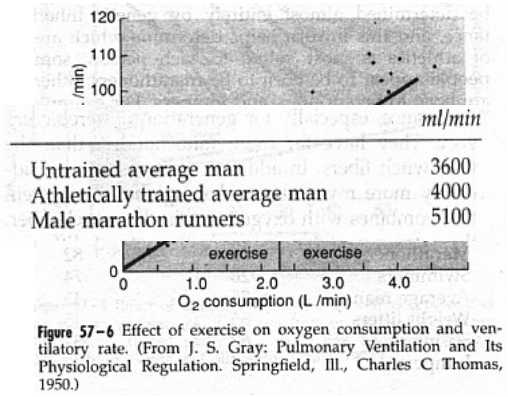


Figure 57–6 Effect of exercise on oxygen consumption and ventilatory rate. (From J. S. Gray: Pulmonary Ventilation and Its Physiological Regulation. Springfield, Ill., Charles C Thomas, 1950.)

Oxygen Diffusing Capacity of Athletes

- O2 diffusing Capacity?
- ml of O2/min for each mmHg difference between alveoli and pulmonary blood capillaries
- threefold increase
  - sluggish
  - increased blood flow through the lungs

Nonathlete at rest	23m/min
Nonathlete during maximal exercise	48ml/min
Speed skaters during maximal exercise	64ml/min
Swimmers during maximal exercise	71ml/min
Oarsmen during maximal exercise	80ml/min

Effect of Smoking on Pulmonary Ventilation in Exercise

- decrease athletes “wind”
- Reasons
  1. Nicotine cause constriction
  2. Irritating effects of smoke
  3. Nicotine paralyzes the cilia
- Chronic Smoking
  - Emphysema
    - Chronic Bronchitis
    - Obstruction of many of the terminal bronchioles
    - destruction of many alveolar walls

THANK YOU

FOR NOT LISTENING