Chapter 23

Neural and Voluntary Control of Breathing
Neural Control of Breathing

• This topic is still “unsettled” science // exact mechanism for setting the rhythm of respiration remains unknown

• Currently, we understand there are three neural circuits (nuclei) within the brain stem which influence breathing
  – Dorsal respiratory group
  – Ventral respiratory group
  – Pontine respiratory group

• Higher brain centers may also influence these nuclei in the brain stem to modify breathing // cerebral cortex, limbic system, hypothalamus.
Neural Control of Breathing

• Medullary respiratory center located in the medulla oblongata // two nuclei form the MRC
  
  – Dorsal respiratory group – quiet during normal breathing / location for two nuclei that send impulses to diaphragm via phrenic nerves and external intercostal muscles via the intercostal nerves

  – Ventral respiratory group – location of the pre-Botzinger complex // generates the rhythm of breathing by sending action potentials to the DRG’s inspiratory neurons (2 seconds)
Neural Control of Breathing

• Pontine respiratory group
  – Located in the pons
  – Send signals to the DRG / modify breathing
  – Changes rate and force of both inspiration and expiration
  – Modify breathing for exercising, speaking, or sleeping, etc.
Neural Control of Breathing

• Breathing depends on repetitive stimuli from brain 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 inspiratory neurons during eupnea (3 sec)
  – Respiratory cycle = 12 breaths per minute
  – voluntary control provided by motor cortex // you can hold your breath!
  – Other factors // in order to maintain homeostasis // central chemoreceptors, peripheral chemoreceptors, proprioceptor lung stretch receptors (Hering-Breuer reflex), irritant reflex, limbic system, temperature, pain, stretching the anal spincter, blood pressure (minor)
Quiet Breathing / Normal Quiet Breathing (Know This)

Dorsal respiratory group (DRG)

Active

2 seconds

Diaphragm contracts and external intercostal muscles contract during their most active phase

Normal quiet inhalation

Inactive

3 seconds

Diaphragm relaxes and external intercostal muscles become less active and relax, followed by elastic recoil of lungs

Normal quiet exhalation
**Forceful Breathing / Breathing During Exercise**

1. **Dorsal respiratory group (DRG):**
   - Diaphragm contracts and external intercostal muscles contract during their most active stage.

2. **Ventral respiratory group (VRG) (forceful inhalation neurons):**
   - Accessory muscles of inhalation (sternocleidomastoid, scalene, and pectoralis minor muscles) contract.
   - Forceful inhalation

3. **Ventral respiratory group (VRG) (forceful exhalation neurons):**
   - Accessory muscles of exhalation (internal intercostal, external oblique, internal oblique, transversus abdominis, and rectus abdominis muscles) contract.
   - Forceful exhalation
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)
Respiratory Control Centers

- Cerebral cortex
- Limbic system
- Hypothalamus

Higher Centers

- Pneumotaxic center
- Apneustic center
- CSF CHEMORECEPTORS
- Medulla oblongata

Chemoreceptors and baroreceptors of carotid and aortic sinuses

- Stretch receptors of lungs
- Dorsal respiratory group (DRG)
- Ventral respiratory group (VRG)

KEY:
- Red = Stimulation
- Blue = Inhibition

Motor neurons controlling diaphragm

Diaphragm
Phrenic nerve

Motor neurons controlling other respiratory muscle
Respiratory Control Centers
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
  - **inflation (Hering-Breuer) reflex**
    - triggered by excessive inflation
    - protective reflex
    - inhibits inspiratory neurons to stop inspiration
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), or coughing
Central and Peripheral Input to Respiratory Centers (cont.)

- 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
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
    - bypassing brainstem
- limits to voluntary control
  - breaking point // when CO\textsubscript{2} levels rise to a point when automatic controls override one’s will
Threshold stimulations disrupt homeostasis by increasing the arterial blood $P_{CO_2}$ (or decreasing pH or $P_{O_2}$).

**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

**CONTROL CENTER**
Dorsal respiratory group in medulla oblongata

**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

Chronic Elevation of CO2 Levels

- Medullary Chemoreceptors Become Insensitive to High PCO2
  - PCO2 Increases
  - PO2 Decreases
  - No Increase In Respiration
  - Marked Decrease In O2 Levels
  - Very Low PO2 Stimulates Peripheral Chemoreceptors

- Inspiratory Muscles Stimulated

- Increased Respiration
- Remove CO2 / Take in O2

- PO2 Increases
- PCO2 Decreases

- Respiration Slows
Fourth week

Pharynx
RESPIRATORY DIVERTICULUM
TRACHEAL BUD
Esophagus

Pharynx
Trachea
BRONCHIAL BUDS
Esophagus
Fifth week:
- Trachea
- Right primary bronchus
- Right secondary bronchi

Sixth week:
- Left primary bronchus
- Left secondary bronchi
- Right tertiary bronchi
- Left tertiary bronchi