The Respiratory System

PROGRAM STUDI S1 KEPERAWATAN
FAKULTAS ILMU KESEHATAN UNIVERSITAS MUHAMMADIYAH MALANG
2014
5 Functions of the Respiratory System

1. Provides extensive gas exchange surface area between air and circulating blood
2. Moves air to and from exchange surfaces of lungs
3. Protects respiratory surfaces from outside environment
4. Produces sounds
5. Participates in olfactory sense
Components of the Respiratory System
Organization of the Respiratory System

- The respiratory system is divided into the **upper respiratory system**, above the larynx, and the **lower respiratory system**, from the larynx down.
The Respiratory Tract

• Consists of a conducting portion:
  • from nasal cavity to terminal bronchioles
• Consists of a respiratory portion:
  • the respiratory bronchioles and alveoli

Alveoli

• Are air-filled pockets within the lungs
  • where all gas exchange takes place
The Respiratory Epithelium
The Respiratory Epithelium

• For gases to exchange efficiently:
  • alveoli walls must be very thin (< 1 µm)
  • surface area must be very great (about 35 times the surface area of the body)
The Respiratory Mucosa

• Consists of:
  • an epithelial layer
  • an areolar layer

• Lines conducting portion of respiratory system
The Lamina Propria

- Underlies areolar tissue
- In the upper respiratory system, trachea, and bronchi:
  - contains mucous glands that secrete onto epithelial surface
- In the conducting portion of lower respiratory system:
  - contains smooth muscle cells that encircle lumen of bronchioles
Structure of Respiratory Epithelium

• Changes along respiratory tract
  • Alveolar Epithelium
    • Is a very delicate, simple squamous epithelium
    • Contains scattered and specialized cells
    • Lines exchange surfaces of alveoli
How are delicate respiratory exchange surfaces protected from pathogens, debris, and other hazards?
The Respiratory Defense System

• Consists of a series of filtration mechanisms
• Removes particles and pathogens
  * Components of the Respiratory Defense System
• Goblet cells and mucous glands: produce mucus that bathes exposed surfaces
• Cilia: sweep debris trapped in mucus toward the pharynx (mucus escalator)
• Filtration in nasal cavity removes large particles
• Alveolar macrophages engulf small particles that reach lungs
The Upper Respiratory System
The Nose

• Air enters the respiratory system:
  • through nostrils or external nares
  • into nasal vestibule

• Nasal hairs:
  • are in nasal vestibule
  • are the first particle filtration system
The Nasal Cavity

• The nasal septum:
  • divides nasal cavity into left and right

• Mucous secretions from paranasal sinus and tears:
  • clean and moisten the nasal cavity

• Superior portion of nasal cavity is the olfactory region:
  • provides sense of smell
Air Flow

• From vestibule to internal nares:
  • through superior, middle, and inferior meatuses

Meatuses

• Constricted passageways that produce air turbulence:
  • warm and humidify incoming air
  • trap particles
The Palates

• Hard palate:
  • forms floor of nasal cavity
  • separates nasal and oral cavities

• Soft palate:
  • extends posterior to hard palate
  • divides superior nasopharynx from lower pharynx
Air Flow

• Nasal cavity opens into nasopharynx through internal nares

The Nasal Mucosa

• Warm and humidify inhaled air for arrival at lower respiratory organs
• Breathing through mouth bypasses this important step
The Pharynx and Divisions

• A chamber shared by digestive and respiratory systems
• Extends from internal nares to entrances to larynx and esophagus
  • Nasopharynx
  • Oropharynx
  • Laryngopharynx
The Nasopharynx

• Superior portion of the pharynx
• Contains pharyngeal tonsils and openings to left and right auditory tubes

The Oropharynx

• Middle portion of the pharynx
• Communicates with oral cavity

The Laryngopharynx

• Inferior portion of the pharynx
• Extends from hyoid bone to entrance to larynx and esophagus
What is the structure of the larynx and its role in normal breathing?
Air Flow - From the pharynx enters the larynx: a cartilaginous structure that surrounds the glottis

Anatomy of the Larynx
Cartilages of the Larynx

• 3 large, unpaired cartilages form the larynx:
  • the thyroid cartilage
  • the cricoid cartilage
  • the epiglottis
The Thyroid Cartilage

- Also called the Adam’s apple
- Is a hyaline cartilage
- Forms anterior and lateral walls of larynx
- Ligaments attach to hyoid bone, epiglottis, and laryngeal cartilages
The Cricoid Cartilage

• Is a hyaline cartilage
• Form posterior portion of larynx
• Ligaments attach to first tracheal cartilage
• Articulates with arytenoid cartilages

The Epiglottis

• Composed of elastic cartilage
• Ligaments attach to thyroid cartilage and hyoid bone
Cartilage Functions

• Thyroid and cricoid cartilages support and protect:
  • the glottis
  • the entrance to trachea

• During swallowing:
  • the larynx is elevated
  • the epiglottis folds back over glottis

• Prevents entry of food and liquids into respiratory tract
3 pairs of Small Hyaline Cartilages of the Larynx
arytenoid cartilages, corniculate cartilages cuneiform cartilages

The Glottis
Cartilage Functions

- **Corniculate** and **arytenoid** cartilages function in:
  - opening and closing of glottis
  - production of sound
Ligaments of the Larynx

• Vestibular ligaments and vocal ligaments:
  • extend between thyroid cartilage and arytenoid cartilages
  • are covered by folds of laryngeal epithelium that project into glottis

1) The Vestibular Ligaments

• Lie within vestibular folds:
  • which protect delicate vocal folds
The Laryngeal Musculature

• The larynx is associated with:
  • muscles of neck and pharynx
  • intrinsic muscles that:
    • control vocal folds
    • open and close glottis

• Coughing reflex: food or liquids went “down the wrong pipe”
What is the structure of airways outside the lungs?

Anatomy of the Trachea
The Trachea

• Also called the windpipe
• Extends from the cricoid cartilage into mediastinum
  • where it branches into right and left pulmonary bronchi – karina

The Submucosa

• Beneath mucosa of trachea
• Contains mucous glands
The Tracheal Cartilages

• 15–20 tracheal cartilages:
  • strengthen and protect airway
  • discontinuous where trachea contacts esophagus

• Ends of each tracheal cartilage are connected by:
  • an elastic ligament and trachealis muscle
The Primary Bronchi

• Right and left primary bronchi:
  • separated by an internal ridge (the carina)

  1) The Right Primary Bronchus

• Is larger in diameter than the left
• Descends at a steeper angle
Structure of Primary Bronchi

- Each primary bronchus:
  - travels to a groove (hilus) along medial surface of the lung

Hilus-

- Where pulmonary nerves, blood vessels, and lymphatics enter lung
- Anchored in meshwork of connective tissue
The Root of the Lung

• Complex of connective tissues, nerves, and vessels in hilus:
  • anchored to the mediastinum
Gross Anatomy of the Lungs

Left and right lungs: are in left and right pleural cavities

The base: inferior portion of each lung rests on superior surface of diaphragm
Lobes of the Lungs

- Lungs have lobes separated by deep fissures

1) The Right Lung - Has 3 lobes:
   - superior, middle, and inferior
   - separated by horizontal and oblique fissures

2) The Left Lung - Has 2 lobes:
   - superior and inferior
   - are separated by an oblique fissure
Relationship between Lungs and Heart
Lung Shape

- Right lung:
  - is wider
  - is displaced upward by liver

- Left lung:
  - is longer
  - is displaced leftward by the heart forming the cardiac notch
The Bronchial Tree

- Is formed by the primary bronchi and their branches
  - Extrapulmonary Bronchi
- The left and right bronchi branches outside the lungs
  - Intrapulmonary Bronchi
- Branches within the lungs
Bronchi and Lobules

A Primary Bronchus

Branches to form secondary bronchi (lobar bronchi)
1 secondary bronchus goes to each lobe
Secondary Bronchi

- Branch to form tertiary bronchi, also called the segmental bronchi
- Each segmental bronchus:
  - supplies air to a single bronchopulmonary segment-
  - The right lung has 10
  - The left lung has 8 or 9
Bronchial Structure

• The walls of primary, secondary, and tertiary bronchi:
  • contain progressively less cartilage and more smooth muscle
  • increasing muscular effects on airway constriction and resistance
Bronchitis: Inflammation of bronchial walls: causes constriction and breathing difficulty

The Bronchioles
The Bronchioles

• Each tertiary bronchus branches into multiple bronchioles
• Bronchioles branch into terminal bronchioles:
  • 1 tertiary bronchus forms about 6500 terminal bronchioles
Bronchiole Structure

• Bronchioles:
  • have no cartilage
  • are dominated by smooth muscle

Autonomic Control

• Regulates smooth muscle:
  • controls diameter of bronchioles
  • controls airflow and resistance in lungs
Bronchodilation

- Dilation of bronchial airways
- Caused by *sympathetic* ANS activation
- Reduces resistance

Bronchoconstriction

- Constricts bronchi
- Caused by:
  - *parasympathetic* ANS activation
  - histamine release (allergic reactions)
Asthma

- Excessive stimulation and bronchoconstriction
- Stimulation severely restricts airflow
Pulmonary Lobules

• Are the smallest compartments of the lung
• Are divided by the smallest trabecular partitions (interlobular septa)

• Each terminal bronchiole delivers air to a single pulmonary lobule
• Each pulmonary lobule is supplied by pulmonary arteries and veins
Exchange Surfaces

- Within the lobule:
  - each terminal bronchiole branches to form several respiratory bronchioles, where gas exchange takes place
Alveolar Organization

Respiratory bronchioles are connected to alveoli along alveolar ducts. Alveolar ducts end at alveolar sacs: common chambers connected to many individual alveoli.
An Alveolus

- Has an extensive network of capillaries
- Is surrounded by elastic fibers

  Alveolar Epithelium
  - Consists of simple squamous epithelium
  - Consists of thin, delicate Type I cells
  - Patrolled by alveolar macrophages, also called dust cells
  - Contains septal cells (Type II cells) that produce Surfactant - an oily secretion which
    - 1) Contains phospholipids and proteins
    - 2) Coats alveolar surfaces and reduces surface tension
Respiratory Distress

• Difficult respiration:
  • due to alveolar collapse
  • caused when septal cells do not produce enough surfactant
Respiratory Membrane - The thin membrane of alveoli where gas exchange takes place

3 Parts of the Respiratory Membrane

- Squamous epithelial lining of alveolus
- Endothelial cells lining an adjacent capillary
- Fused basal laminae between alveolar and endothelial cells

- **Diffusion** - Across respiratory membrane is very rapid:
  - because distance is small
  - gases ($O_2$ and $CO_2$) are lipid soluble
Inflammation of Lobules

• Also called pneumonia:
  • causes fluid to leak into alveoli
  • compromises function of respiratory membrane
Blood Supply to Respiratory Surfaces

- Each lobule receives an arteriole and a venule
  1. respiratory exchange surfaces receive blood:
     - from arteries of pulmonary circuit
  2. a capillary network surrounds each alveolus:
     - as part of the respiratory membrane
  3. blood from alveolar capillaries:
     - passes through pulmonary venules and veins
     - returns to left atrium
Blood Supply to the Lungs

- Capillaries supplied by bronchial arteries:
  - provide oxygen and nutrients to tissues of conducting passageways of lung
- Venous blood bypasses the systemic circuit and flows into pulmonary veins
Blood Pressure

- In pulmonary circuit is low (30 mm Hg)
- Pulmonary vessels are easily blocked by blood clots, fat, or air bubbles, causing **pulmonary embolism**
Pleural Cavities and Pleural Membranes
Pleural Cavities and Pleural Membranes

• 2 pleural cavities:
  • are separated by the mediastinum

• Each pleural cavity:
  • holds a lung
  • is lined with a serous membrane (the pleura)

• Pleura consist of 2 layers:
  • parietal pleura -- rib
  • visceral pleura -- lung

• Pleural fluid:
  • lubricates space between 2 layers
Respiration

• Refers to 2 integrated processes:

  • External respiration- Includes all processes involved in exchanging $O_2$ and $CO_2$ with the environment

  • Internal respiration- Also called cellular respiration

  • Involves the uptake of $O_2$ and production of $CO_2$ within individual cells
3 Processes of External Respiration

1. Pulmonary ventilation (breathing)
2. Gas diffusion:
   • across membranes and capillaries
3. Transport of $O_2$ and $CO_2$:
   • between alveolar capillaries
   • between capillary beds in other tissues
Intrapulmonary Pressure

- Also called intra-alveolar pressure
- Is relative to $P_{atm}$
- In relaxed breathing, the difference between $P_{atm}$ and intrapulmonary pressure is small:
  - about $-1$ mm Hg on inhalation or $+1$ mm Hg on expiration
The Respiratory Pump

• Cyclical changes in intrapleural pressure operate the respiratory pump:
  • which aids in venous return to heart

   **Tidal Volume**

• Amount of air moved in and out of lungs in a single respiratory cycle
Injury to the Chest Wall

- **Pneumothorax:**
  - allows air into pleural cavity
- **Atelectasis:**
  - also called a collapsed lung
  - result of pneumothorax
What are the origins and actions of the respiratory muscles responsible for respiratory movements?
The Respiratory Muscles
The Mechanics of Breathing

• **Inhalation:**
  • always active

• **Exhalation:**
  • active or passive
3 Muscle Groups of Inhalation

1. **Diaphragm:**
   - contraction draws air into lungs
   - 75% of normal air movement

2. **External intracostal muscles:**
   - assist inhalation
   - 25% of normal air movement

3. **Accessory muscles** assist in elevating ribs:
   - sternocleidomastoid
   - serratus anterior
   - pectoralis minor
   - scalene muscles
Muscles of Active Exhalation

1. **Internal intercostal** and **transversus thoracis** muscles:
   - depress the ribs
2. **Abdominal muscles**:
   - compress the abdomen
   - force diaphragm upward
Modes of Breathing

• Respiratory movements are classified:
  • by pattern of muscle activity
  • into quiet breathing and forced breathing
Quiet Breathing (Eupnea)

• Involves active inhalation and passive exhalation

• **Diaphragmatic breathing or deep breathing:**
  • is dominated by diaphragm

• **Costal breathing or shallow breathing:**
  • is dominated by ribcage movements

**Elastic Rebound**

• When inhalation muscles relax:
  • elastic components of muscles and lungs recoil
  • returning lungs and alveoli to original position
Forced Breathing

- Also called hyperpnea
- Involves active inhalation and exhalation
- Assisted by accessory muscles
- Maximum levels occur in exhaustion
Respiratory Rates and Volumes

- Respiratory system adapts to changing oxygen demands by varying:
  - the number of breaths per minute (respiratory rate)
  - the volume of air moved per breath (tidal volume)
Respiratory Minute Volume

- Amount of air moved per minute
- Is calculated by:
  \[ \text{respiratory rate} \times \text{tidal volume} \]
- Measures pulmonary ventilation

Anatomic Dead Space

- Only a part of respiratory minute volume reaches alveolar exchange surfaces
- Volume of air remaining in conducting passages is anatomic dead space
Alveolar Ventilation

• Amount of air reaching alveoli each minute
• Calculated as:
  \[(\text{tidal volume} - \text{anatomic dead space}) \times \text{respiratory rate}\]
• Alveoli contain less \(O_2\), more \(CO_2\) than atmospheric air:
  • because air mixes with exhaled air
Alveolar Ventilation Rate

• Determined by respiratory rate and tidal volume:
  • for a given respiratory rate:
    • increasing tidal volume increases alveolar ventilation rate
  • for a given tidal volume:
    • increasing respiratory rate increases alveolar ventilation
Respiratory Volumes and Capacities

### Pulmonary Volumes

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital capacity</td>
<td>3300</td>
<td>1900</td>
</tr>
<tr>
<td>Inspiratory capacity</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Expiratory reserve volume (ERV)</td>
<td>1000</td>
<td>700</td>
</tr>
<tr>
<td>Residual volume</td>
<td>1200</td>
<td>1100</td>
</tr>
<tr>
<td>Functional residual capacity</td>
<td>6000 ml</td>
<td>4200 ml</td>
</tr>
</tbody>
</table>
Gas Exchange

• Occurs between blood and alveolar air
• Across the respiratory membrane
• Depends on:
  • partial pressures of the gases
  • diffusion of molecules between gas and liquid
Gas Content & Solubility in body fluids

• The actual amount of a gas in solution (at given partial pressure and temperature) depends on the solubility of that gas in that particular liquid

• CO₂ is very soluble
• O₂ is less soluble
• N₂ has very low solubility
How is oxygen picked up, transported, and released in the blood?

What is the structure and function of hemoglobin?
Gas Pickup and Delivery

• Blood plasma can’t transport enough O\textsubscript{2} or CO\textsubscript{2} to meet physiological needs

**Red Blood Cells (RBCs)**

• Transport O\textsubscript{2} to, and CO\textsubscript{2} from, peripheral tissues
• Remove O\textsubscript{2} and CO\textsubscript{2} from plasma, allowing gases to diffuse into blood
Oxygen Transport

- $O_2$ binds to iron ions in hemoglobin (Hb) molecules:
  - in a reversible reaction

- Each RBC has about 280 million Hb molecules:
  - each binds 4 oxygen molecules - saturated

- The percentage of heme units in a hemoglobin molecule:
  - that contain bound oxygen
Environmental Factors Affecting Hemoglobin
PO2 of blood, Blood pH, Temperature
Metabolic activity within RBCs

Oxyhemoglobin Saturation Curve
Oxyhemoglobin Saturation Curve

- Is a graph relating the saturation of hemoglobin to partial pressure of oxygen:
  - higher $P_{O_2}$ results in greater Hb saturation
- Is a curve rather than a straight line:
  - because Hb changes shape each time a molecule of $O_2$ is bound
  - each $O_2$ bound makes next $O_2$ binding easier
  - allows Hb to bind $O_2$ when $O_2$ levels are low
Oxygen Reserves

• $O_2$ diffuses:
  • from peripheral capillaries (high $PO_2$)
  • into interstitial fluid (low $PO_2$)
• Amount of $O_2$ released depends on interstitial $PO_2$
• Up to 3/4 may be reserved by RBCs

Carbon Monoxide

• CO from burning fuels:
  • binds strongly to hemoglobin
  • takes the place of $O_2$
  • can result in carbon monoxide poisoning
pH, Temperature, and Hemoglobin Saturation

(a) Effect of pH

(b) Effect of temperature
The **Oxyhemoglobin Saturation Curve**

- Is standardized for normal blood (pH 7.4, 37°C)
- **When pH drops or temperature rises:**
  - more oxygen is released
  - curve shifts to right
- **When pH rises or temperature drops:**
  - less oxygen is released
  - curve shifts to left
Fetal and Adult Hemoglobin

![Graph showing the comparison between Fetal and Adult Hemoglobin saturation with respect to oxygen partial pressure (P_{O_2})](image)
Fetal and Adult Hemoglobin

- The structure of fetal hemoglobin:
  - differs from that of adult Hb

- At the same $P_{O_2}$:
  - fetal Hb binds more $O_2$ than adult Hb
  - which allows fetus to take $O_2$ from maternal blood
KEY CONCEPT

• Hemoglobin in RBCs:
  • carries most blood oxygen
  • releases it in response to low $O_2$ partial pressure in surrounding plasma

• If $P_{O_2}$ increases, hemoglobin binds oxygen
• If $P_{O_2}$ decreases, hemoglobin releases oxygen

• At a given $P_{O_2}$:
  • hemoglobin will release additional oxygen
  • if pH decreases or temperature increases
How is carbon dioxide transported in the blood?
Carbon Dioxide Transport
Carbon Dioxide ($CO_2$)

- Is generated as a byproduct of aerobic metabolism (cellular respiration)

  $CO_2$ in the Blood Stream

- May be:
  - converted to carbonic acid
  - bound to protein portion of hemoglobin
  - dissolved in plasma

Bicarbonate Ions

- Move into plasma by an exchange mechanism (the chloride shift) that takes in $Cl^-$ ions without using ATP
CO$_2$ in the Blood Stream

- 70% is transported as carbonic acid (H$_2$CO$_3$):
  - which dissociates into H$^+$ and bicarbonate (HCO$_3^-$)
- 23% is bound to amino groups of globular proteins in Hb molecule:
  - forming carbaminohemoglobin
- 7% is transported as CO$_2$ dissolved in plasma
KEY CONCEPT

• CO$_2$ travels in the bloodstream primarily as bicarbonate ions, which form through dissociation of carbonic acid produced by carbonic anhydrase in RBCs
• Lesser amounts of CO$_2$ are bound to Hb or dissolved in plasma
Summary: Gas Transport
Control of Respiration

• Gas diffusion at peripheral and alveolar capillaries maintain balance by:
  • changes in blood flow and oxygen delivery
  • changes in depth and rate of respiration
Local Regulation of O₂ Transport (1 of 2)

- O₂ delivery in tissues and pickup at lungs are regulated by:
  1. rising P_{CO₂} levels:
     - relaxes smooth muscle in arterioles and capillaries
     - increases blood flow
  2. coordination of lung perfusion and alveolar ventilation:
     - shifting blood flow
  3. P_{CO₂} levels:
     - control bronchoconstriction and bronchodilation
Respiratory Centers of the Brain

• When oxygen demand rises:
  • cardiac output and respiratory rates increase under neural control
• Have both voluntary and involuntary components

Involuntary Centers

• Regulate respiratory muscles
• In response to sensory information
Voluntary Centers

• In cerebral cortex affect:
  • respiratory centers of pons and medulla oblongata
  • motor neurons that control respiratory muscles

•The Respiratory Centers

• 3 pairs of nuclei in the reticular formation of medulla oblongata and pons
Quiet Breathing

Inhalation (2 seconds):
- Inspiratory muscles contract
- Inspiration occurs
- Dorsal respiratory group active

Quiet Breathing

Exhalation (3 seconds):
- Passive expiration occurs
- Inspiratory muscles relax
- Dorsal respiratory group inhibited
Forced Breathing

Forced Breathing

INHALATION

Inspiratory muscles contract → Inspiration occurs → Expiratory muscles relax → DRG and inspiratory center of VRG active → Expiratory center of VRG inhibited → Active expiration occurs

EXHALATION

DRG and inspiratory center of VRG inhibited → Expiratory center of VRG active → Inspiratory muscles relax → Expiratory muscles contract
The Apneustic and Pneumotaxic Centers of the Pons

• Paired nuclei that adjust output of respiratory rhythmicity centers:
  • regulating respiratory rate and depth of respiration

An Apneustic Center

• Provides continuous stimulation to its DRG center

• Pneumotaxic Centers

• Inhibit the apneustic centers

• Promote passive or active exhalation
Respiratory Centers and Reflex Controls

Interactions between VRG and DRG:

Establish basic pace and depth of respiration

The pneumotaxic center: modifies the pace
5 Sensory Modifiers of Respiratory Center Activities

• Chemoreceptors are sensitive to:
  • $P_{CO_2}$, $P_{O_2}$, or pH
  • of blood or cerebrospinal fluid

• Baroreceptors in aortic or carotid sinuses:
  • sensitive to changes in blood pressure
5 Sensory Modifiers of Respiratory Center Activities

• Stretch receptors:
  • respond to changes in lung volume

• Irritating physical or chemical stimuli:
  • in nasal cavity, larynx, or bronchial tree

• Other sensations including:
  • pain
  • changes in body temperature
  • abnormal visceral sensations
Chemoreceptor Reflexes

- Respiratory centers are strongly influenced by chemoreceptor input from:
  - cranial nerve IX - The glossopharyngeal nerve:
    - from carotid bodies
    - stimulated by changes in blood pH or \( P_{O_2} \)
  
  - cranial nerve X - The vagus nerve:
    - from aortic bodies
    - stimulated by changes in blood pH or \( P_{O_2} \)

  - receptors that monitor cerebrospinal fluid:
    - Are on ventrolateral surface of medulla oblongata
    - Respond to \( P_{CO_2} \) and pH of CSF
Chemoreceptor Responses to $\text{PCO}_2$
**Hypercapnia** - An increase in arterial $P_{CO_2}$
  - Stimulates chemoreceptors in the medulla oblongata:
    - to restore homeostasis

**Hypoventilation** - A common cause of hypercapnia
  - Abnormally low respiration rate:
    - allows $CO_2$ build-up in blood

**Hyperventilation** - Excessive ventilation
  - Results in abnormally low $P_{CO_2}$ (*hypocapnia*)
  - Stimulates chemoreceptors to decrease respiratory rate
Baroreceptor Reflexes

• Carotid and aortic baroreceptor stimulation:
  • affects blood pressure and respiratory centers
• When blood pressure falls:
  • respiration increases
• When blood pressure increases:
  • respiration decreases
Protective Reflexes

• Triggered by receptors in epithelium of respiratory tract when lungs are exposed to:
  • toxic vapors
  • chemicals irritants
  • mechanical stimulation

• Cause sneezing, coughing, and laryngeal spasm
Apnea

- A period of suspended respiration
- Normally followed by explosive exhalation to clear airways:
  - sneezing and coughing

Laryngeal Spasm

- Temporarily closes airway:
  - to prevent foreign substances from entering
The Cerebral Cortex and Respiratory Centers

1. Strong emotions:
   • can stimulate respiratory centers in hypothalamus

2. Temporarily closes airway:
   • to prevent foreign substances from entering

3. Anticipation of strenuous exercise:
   • can increase respiratory rate and cardiac output
   • by sympathetic stimulation
Respiratory Performance and Age
3 Effects of Aging on the Respiratory System

1. Elastic tissues deteriorate:
   • reducing lung compliance
   • lowering vital capacity

2. Arthritic changes:
   • restrict chest movements
   • limit respiratory minute volume

3. Emphysema:
   • affects individuals over age 50
   • depending on exposure to respiratory irritants (e.g., cigarette smoke)
Integration with Other Systems

• Maintaining homeostatic $O_2$ and $CO_2$ levels in peripheral tissues requires coordination between several systems:
  • particularly the respiratory and cardiovascular systems
Coordination of Respiratory and Cardiovascular Systems

1. Improves efficiency of gas exchange:
   • by controlling lung perfusion

2. Increases respiratory drive:
   • through chemoreceptor stimulation

3. Raises cardiac output and blood flow:
   • through baroreceptor stimulation
The Respiratory System and Other Systems