The Respiratory System

Undergraduate - Graduate Histology Lecture Series

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Ventilation Mechanisms
- Thoracic cage (bony cavity)
- Intercostal muscles (respiration and expiration)
- Diaphragm (respiration only)
- Elastic components of lungs (lungs to partly deflate)

Natural Defenses of Our Respiratory System
- Large particles get trapped by nose hairs.
- Smaller particles are trapped in mucus that lines our respiratory system. The mucus keeps harmful particles out of the lungs.
- Coughing forcibly expels foreign particles trapped in our lungs and airways.
- Sneezing removes bacteria trapped in mucus from our nasal passages. Sneezes travel at about 100 miles per hour and remove 100,000 bacteria.
All higher animals require a mechanism to:

1. Obtain $O_2$ from the environment
2. and get rid of $CO_2$
The respiratory system exchanges these gases with the external environment.
Objectives

The histologic characteristics of the components of conducting portion and respiratory portion of the respiratory system.

How these characteristics allow each component to contribute to the overall function of the respiratory system.
Function?

Function of the respiratory system is “gas exchange”
**Gas Exchange?**

**Oxygen** diffuses out and **Carbon Dioxide** diffuses into the air space of the alveolus.

**Diffusion**: spontaneous process of equalization of physical states (e.g., heat spreading in a room)

**Diffuse**: to spread in all directions
The respiratory system has a direct conduit to the environment and brings air close to the blood. Capillary and alveoli walls are so thin that materials pass through them easily.
### Highest Flying Bird Found; Can Scale Himalaya

The bar-headed goose can reach nearly 21,120 feet, new study shows.

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Bird</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level</td>
<td>Canada goose</td>
<td>3280 ft</td>
</tr>
<tr>
<td></td>
<td>Songbirds</td>
<td>4,000 ft</td>
</tr>
<tr>
<td></td>
<td>Most ducks &amp; geese</td>
<td>7,000 ft</td>
</tr>
<tr>
<td></td>
<td>Bald eagle</td>
<td>10,000 ft</td>
</tr>
<tr>
<td></td>
<td>Light Aircraft</td>
<td>10,000 ft</td>
</tr>
<tr>
<td></td>
<td>Jet Aircraft</td>
<td>30,000 ft occasionally</td>
</tr>
<tr>
<td>20,000</td>
<td>Mt. McKinley</td>
<td></td>
</tr>
<tr>
<td>25,000</td>
<td>Mt. Everest</td>
<td></td>
</tr>
<tr>
<td>30,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35,000</td>
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</table>

Bar-headed geese (seen in a fly picture) can fly over the Himalayas in eight hours.
Ventilation Mechanisms

**Thoracic cage** (bony cavity)

**Intercostal muscles** (inspiration and expiration)

**Diaphragm** (inspiration only)

**Elastic components of lungs** (lungs to partially deflate)
Ventilation Mechanisms

Thoracic cage
Intercostal muscles
Diaphragm
Elastic and collagen components of lungs
Boyle’s law = states the inverse proportional relationship between the pressure and volume of a gas

Boyle’s law = as diaphragm is pulled down the volume is increased with a decrease in pressure (vacuum)
Breathing

What happens when I inhale?
- Your ribs come up.
- Your diaphragm drops down.

These movements increase volume and decrease pressure.

What happens when I exhale?
- Your ribs move down.
- Your diaphragm moves up.

These movements decrease volume and increase pressure.
Iron Lung

Positive pressure valve

Negative pressure valve

Leather diaphragm
Volumes of the Lung

- Dead space
- Residual volume
- Expiratory reserve volume
- Tidal volume
- Inspiratory reserve volume

Vital capacity

- Functional residual capacity
- Inspiratory capacity

Total lung capacity
Spirometer = Measures Lung Capacity

- 3.0 – 3.5 liters
- 2.0 – 2.5 liters
Routes of exposure to toxic materials in your environment

Ingestion (water and food)

Absorption (skin or eye)

Injection (bite, puncture, or cut)

Inhalation (air)
Routes of Environmental Exposure

Absorption

Inhalation

Injection

Ingestion
“Dose Makes the Poison”

1. Too much of a good thing is bad

2. A low enough dose of a poison does not hurt
The magnitude of risk is proportional to both the potency of the chemical and the extent (amount) of exposure.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Lethal Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar (sucrose)</td>
<td>3 quarts</td>
</tr>
<tr>
<td>Alcohol (ethyl alcohol)</td>
<td>3 quarts</td>
</tr>
<tr>
<td>Salt (sodium chloride)</td>
<td>1 quart</td>
</tr>
<tr>
<td>Herbicide (2, 4-D)</td>
<td>one half cup</td>
</tr>
<tr>
<td>Arsenic (arsenic acid)</td>
<td>1-2 teaspoons</td>
</tr>
<tr>
<td>Nicotine</td>
<td>one half teaspoon</td>
</tr>
<tr>
<td>Food poison (botulism)</td>
<td>microscopic</td>
</tr>
</tbody>
</table>
**Toxicology Terms**

**Toxicity** –
The *adverse effects* that a chemical may produce.

**Dose** –
The *amount* of a *chemical* that gains *access* to the body.
Toxicology Terms

**Exposure**

Contact providing opportunity of obtaining a poisonous dose.

**Hazard**

The likelihood that the toxicity will be expressed.
Exposure must first occur for the chemical to present a risk.
The magnitude of risk is proportional to both the potency of the chemical and the extent of exposure.

“The dose makes the poison” (amount of chemical at the target site determines toxicity).
The Respiratory System: Conducting portion
Respiratory portion

The Respiratory System

Nose
Pharynx
Epiglottis
Trachea
Larynx
Bronchus
Lung
Conducting Portion

- Cleans air
- Warms air
- Humidifies air
“Conditioning Air” by the Conducting Portion

Specialized respiratory epithelium
Numerous mucous and serous gland

• Traps particulate and gaseous impurities
• Prevents alveolar lining from desiccation

Rich superficial vascular network in lamina propria - warms blood in a counter current system (blood flows against inspired air)
Nasal septum

Vestibule

Wing of nose

Cartilage of nasal septum

Mobile part of nasal septum

Lateral crus

Medial crus

Lateral crus of major wing cartilage
Conditioning Air By The Conducting Portion

Nasal fossae
- Superior conchae - olfactory epithelium
  long cilia, nervous cells
- Middle conchae - respiratory epithelium
- Inferior conchae - respiratory epithelium

Swell bodies
- large venous plexus that direct air
  (occludes air way)
- Allergic reaction or inflammation restrict
  air flow
- counter current system warms air
The highly vascular nature of the lamina propria is important for conditioning inhaled air. A complex vasculature with loops of capillaries near the epithelial surface carries blood in a general direction counter to the flow of inspired air and releases heat to warm that air. Also, the swell bodies reduce the flow of air on either side of the nose and switches every 30 min to allow rehydration on one side as air flow is shifted to the other side.
Respiratory epithelium
Olfactory epithelium
Animal Respiratory (Olfactory) mucosa and nasal septum

- Bowman's glands
- Respiratory epithelium
- Highly vascular lamina propria
- Swell bodies
- Olfactory epithelium
- Bowman's glands

Histo 036 001
Histo 36 001: Respiratory (Olfactory) mucosa and nasal septum
Where do tears come from?

Almond-shaped lacrimal glands are located above the eyes, under the frontal bones. About a dozen ducts lead from each gland to the eye and eyelids. Tears are normally salty because they are derived from the circulatory system, which has a salt composition of about 0.9 percent. Tears are also sterile because they contain bacteria-destroying enzymes, which provide a measure of protection from infection. When you blink, tears bathe the eyes, keeping the cornea moist. The fluid drains down through the inside corner of the eye into a lacrimal sac and from there into the nasal cavity.
Beyond its important role as the collector of olfactory information – such as whiffs of smoke that warn of impending danger or smells that whet the appetite – the nose acts as an air conditioner for the respiratory system. Everyday, it treats approximately 500 cubic feet of air, the amount enclosed in a small room. It filters dust, traps bacteria from the air, brings air to the temperature of the body and also adds moisture. And then, the nose has some lesser-known functions. Among them it gives your voice resonance, adding a richness of tone that would otherwise be lacking.
Epithelium in the respiratory system

Respiratory epithelium

Olfactory epithelium

Stratified squamous

Pseudostratified columnar

Simple squamous

Olfactory
Epithelium in the respiratory system

- Nose
- Skin junction
- Nasal cavity
- Histo 36
- Respiratory epithelium
- Olfactory
- Ciliated simple columnar epithelium
- Conducting bronchiole
- Air sac

- Sphenoidal sinus
- Frontal sinus
- Nasal cavity
- Pharynx
- Larynx
- Trachea

Air sacs
Function of Mucus in the Respiratory System

Detoxifies gases

Has protein that presents odor chemicals to receptors of olfactory cells

Washes away current chemicals to allow one to smell the next chemical odor

Traps dust and washes it away

Contains IgA antibodies to guard against infection

Goblet cell in respiratory epithelium
Conducting Portion – Conduit to External Environment and Conditions Expired Air

Nasal cavity (nasal fossae)
Nasopharynx
Larynx
Trachea
Bronchi
Bronchioles
Terminal bronchioles
Larynx - Irregular Tube Connects Pharynx to Trachea

Cartilage
- Large: hyaline at thyroid, cricoid
- Smaller: elastic at epiglottis
Larynx - Irregular Tube Connects Pharynx to Trachea

Vocal cords
- False
- True
  - Vocal ligaments
  - Vocalis muscle - skeletal muscle
Hyaline cartilage provides flexible support in the respiratory system to hold the airway open.
Tracheal cartilages

Vocal cord muscles

Air space lumen

Cricoid cartilage

Thyroid cartilage

True vocal cords

The false vocal cords

Laryngeal ventricle
Larynx

Respiratory epithelium

Stratified squamous epithelium

Vocal cord muscles

Thyroid cartilage
How Vocal Cords Move to Produce Speech

These pictures show vocal cords at work. The slitlike opening between the cords is the glottis. Its size and shape change according to your activity. When you breathe, the cords draw apart, allowing passage of air to and from the lungs. If you speak or sing, the folds draw closer together. Speech is produced when you breathe out. The airflow through the glottis causes the vocal cords to vibrate, producing waves of sound. The tautness of the cords determines the frequency of the vibrations and the pitch of the sound.

Following from top to bottom, left to right, you can see vocal cords change in a one-second progression. In pictures 1 to 6, speech stops, cords gradually open. In pictures 7 to 9, speech resumes.
Larynx
(lower portion)

- Esophagus
- Cricoid cartilage
- Respiratory epithelium lining
- Tracheal cartilage

HISTO039
Esophagus and trachea, monkey - glands in trachea

- Trachea, whose lumen is lined with pseudostratified ciliated epithelium with goblet cells
- Thick hyaline cartilage bridged by smooth muscle bundle posteriorly
- Elastic fiber layer beneath the epithelium
- Submucosa with glands
Trachea, monkey

- Thick hyaline cartilage
- Submucosa with glands
- Trachea, whose lumen is lined with pseudostratified ciliated epithelium with goblet cells
Trachea, monkey

- Pseudostratified ciliated epithelium with goblet cells
- Thick basement membrane
- Rich vascular supply to warm air
- Goblet cell
- Plasma cells to produce antibodies
EM 8 trachea; 20630x

1. Mucous
2. Microvilli
3. Cilia
4. Goblet cell
Trachea

Thin walled tube

16-20 C-shaped rings of hyaline

Trachealis muscle
- Smooth muscle
- Allows for regulation of size of lumen for cough reflex
The bronchus has cartilage plates.
Bronchioles have NO cartilage plates.
The air-conducting tubes of the respiratory system can be thought of as a series of ducts which carry air to the sites of gaseous exchange - the alveoli.
19714 lung macrophages
On Slide 432, identify the characteristics of the bronchus: 1) pseudostratified ciliated columnar epithelium with goblet cells; 2) smooth muscle band between the lamina propria and the cartilage. Notice that the smooth muscle is not continuous around the bronchus. This is because there are two layers of muscle which follow a left- and right-handed spiral path, respectively, down the bronchi. 3) A change from cartilage rings to cartilage plates surrounding the tube; 4) Glands in the submucosa.
Macrophages in Air Space of Alveoli
Lung with bronchus

**Bronchus:**
1) pseudostratified ciliated columnar epithelium with goblet-cells;
2) smooth muscle band between the lamina propria and the cartilage. The smooth muscle is not continuous around the bronchus as it spirals.
3) a change from cartilage rings to cartilage plates surrounding the tube;
4) glands in the submucosa.

**Bronchioles:**
1) have a ciliated columnar epithelium;
2) do not have cartilage plates or glands;
3) have well organized muscle layers.
Cells in the respiratory portion

Histo 41

TERMINAL BRONCHIOLE
CLARE CELLS

Smooth muscle

Ciliated cells

Respiratory BRONCHIOLE

Elastic fibers

Smooth muscle cells
Cells in the respiratory portion

- Type I cells
- Type II cells
- Endothelium
- Macrophages

Histo41
Slide Histo 41 and Histo 42: Lung

- Mesothelium and connective tissue of lung capsule
- Type I & Type II pneumocytes
- Capillary endothelial cells and fibroblasts
- Alveolar macrophage
Respiratory Portion - Site Of Gases Exchange

- Respiratory bronchioles
- Alveolar ducts
- Alveoli

The Respiratory System
  Conducting portion
  Respiratory portion
Air

Blood

Capillaries

Alveolus

A

Air

Type I alveolar cell

Basal laminae

Capillary endothelial cell

Blood

Erythrocyte

B
Histo 42: Lung (mast cells)
Mast cells function in the localized release of many bioactive substances with roles in the local inflammatory response, innate immunity, and tissue repair.

Mast cell granules normally contain: heparin, histamine, serine proteases, eosinophil and neutrophil chemotactic factors, cytokines, etc.
1. Type I pneumocyte
2. Type II pneumocyte
Type II pneumonocyte (EM 18c).
1. Nucleus
2. Surfactant bodies
Type II pneumocytes

Surfactant bodies in Type II cells

36722
Respiratory Physiology

Surfactant functions in reducing surface tension, reduces work of breathing, and helps keep alveoli open and may have a bactericidal effect.

Hyaline membrane disease - premature infants cannot get or make sufficient surfactant.

Bronchoalveolar fluid - cleared by ciliary action toward oral cavity (contain lysosome, collagenase, glucuronidase, and antibodies).

Macrophages - contain hemosiderin, produce lytic enzymes in bronchoalveolar fluid.
Normal Airways

The bronchial tubes normally allow air to flow easily to reach the alveoli and to be returned and exhaled. To protect the lungs from inhaling poisonous particles and gases, the lining of the bronchial tubes is very sensitive. When the sensitivity is too high, the bronchials respond to particles and gases that are not poisonous. This is why about two-thirds of asthma cases occur in children whose sensitivity is much higher than many adults.

Obstructed Airways

When you have asthma, pollutants and allergens cause an increase in the production of mucus in the lining of the bronchials, and often cause the muscle surrounding the bronchials to constrict. When you have bronchitis, pollutants cause irritation and inflammation. This condition causes swelling of the bronchials, which narrows the air passageways. In older people, who have less mucus protecting the lining of the bronchials, an asthmatic constriction may occur with bronchitis.
Figure 42-5. Pulmonary changes in pneumonia and emphysema.
Emphysema - destruction of alveolar wall
Means too much air in the lungs.
Macrophage from non-smoker
Macrophage from Smoker
Small pieces of lungs from a non-smoker and from a smoker.
The Lungs on the left have Empysema. The one on the right has cancer - both from Smoking.
“Dose Makes the Poison”

The Lungs on the left have Empyema. The one on the right has cancer - both from Smoking
Natural Defenses of Our Respiratory System

Large particles get trapped by **nose hairs**.

Smaller particles are trapped in **mucus** that lines our respiratory system. The mucous keeps harmful particles out of the lungs.

**Coughing** forcibly expels foreign particles trapped in our lungs and airways.

**Sneezing** removes bacteria trapped in mucus from our nasal passages. Sneezees travel at about 100 miles per hour and remove 100,000 bacteria.
Respiratory System

• Conduction
  o Maintenance of an open lumen
  o Ability to accommodate expansion and contraction,
  o Warming, moisturizing and filtering of the inspired air

• Respiration
  o Rapid exchange of atmospheric gases
  o Alveolar wall cells secrete surfactant

• Structure
  o Skeletal components (cartilage, etc.)
  o Vascularization
  o Glands in lamina propria
In summary

Function of the Respiratory System

All higher animals require a mechanism to:
1. Obtain O₂ from the environment
2. and get rid of CO₂

This “gas exchange” is the function of the respiratory system.

Oxygen diffuses out and Carbon Dioxide diffuses into the air space of the alveolus.
Questions on the Respiratory System

The conducting portion of the respiratory system modifies the air in the following way(s):

a. warms
b. cleans
c. dries
d. a and b
e. a, b, and c

Which of the following are involved in both inspiration and expiration? Contraction of

a. intercostal skeletal muscle between the ribs
b. diaphragm
c. smooth muscle
d. a and b
e. a, b, and c

Variation in the epithelium lining the respiratory system facilitates varied functions.
Which epithelium-function does not match?

a. simple squamous - alveolar ducts
b. goblet cells - humidifies air
c. stratified squamous - false vocal cords
d. ciliated cells - move dust-laden mucus
e. hair follicle - filtration of air
Many illustrations in these VIBS Histology YouTube videos were modified from the following books and sources: Many thanks to original sources!

- Internet images and videos on biological presentations