Respiratory System
Module 1
Structure and Defense Mechanisms

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Also, if you have any questions, please let me know at lopez@upei.ca

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**Quiz**

At the end of this module, there is a simple Quiz to test your knowledge on this subject. It is a Quiz just for you, and nobody gets to see your answers.
The respiratory tract is divided into three independent but continuous systems:

1. **Conducting system** consists of the nasal cavity, sinuses, larynx, trachea and bronchi. The mucosa of the conducting system is lined primarily by ciliated epithelium and goblet cells.

2. **Transitional system** consists exclusively of the bronchioles which are lined by Clara cells, non-ciliated secretory cells, and only a few ciliated cells. Healthy bronchioles do not have goblet cells.

3. **Exchange system** consists of alveoli that are lined by epithelial type I (membranous) and type II pneumonocytes.

Each of 3 these systems has a specific susceptibility to injury and a particular type of host response and repair.
In addition to oxygenation, the respiratory system also plays an important role in several physiological functions:

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Like any other body system that is in direct contact with the external environment, the mucosa of the proximal respiratory tract harbors a healthy population of bacteria known as the nasal flora.

If a sterile swab is inserted into the nasal cavity of any healthy animal, and the swab is sent for microbiological culture, many species of bacteria will grow.

These organisms constitute the normal flora of the respiratory tract.
Mannheimia haemolytica and Bordetella bronchiseptica are normal nasal flora, yet both bacteria are also responsible for "Shipping Fever" in cattle and "Atrophic Rhinitis" in pigs respectively.

Isolation of bacteria from a dead animal is sometimes erroneously incriminated by veterinarians as the causative agents of disease.
The nasal flora is only present in the most proximal regions of the conducting system; that is the nasal cavity, the nasopharynx, larynx, and trachea.

The bronchi, bronchioles and alveoli are considered to be essentially sterile.
The bacteria present in the nasal flora, including some potentially important pathogens, are continuously being carried into the lung by inspired air. However, the organisms are rapidly destroyed and do not establish as flora.

In spite of this continuous bacterial bombardment, the alveoli and bronchioles remain essentially sterile due to the extraordinary defense mechanisms of the respiratory tract.
Aerobiology and Defense Mechanisms

The cleanest atmospheric air contains zillions of particles including pollen, bacteria, viruses, yeasts, mites, silica, carbon, dust, vapors and gasses.

Imagine the number of suspended particles in a dusty feedlot or barn.

Yet the respiratory tract remains healthy because of the effective defense mechanisms.

Microorganisms are destroyed, particles are removed and toxicants and neutralized.
Particle Deposition in the Respiratory Tract

- **> 10 microns**: Nasal Deposition
- **10-2 microns**: Bronchial Deposition
- **2 µm or less**: Alveolar Deposition
Defense Mechanisms

**Non specific**
- Air turbulence
- Particle trapping in mucus
- Mucociliary clearance
- Cough
- Sneezing

**Specific**
- Antibodies
- Secretions
- Cellular immunity
- Phagocytosis
- Inflammation
Particles 10 microns or larger are filtered out in the nasal cavity. Note narrow spaces (arrows) between dorsal (D), ventral (V) and ethmoid (E) conchae. These tight spaces are known as meatuses.

Also, the coiled shape (*asterisks*) of the conchae create vortexes that result in the impaction of air particles in the nasal mucosa.
Histological example of a pollen particle (arrow) trapped in the nasal meatus
Particles 10 to 2 microns collide on the bronchial bifurcation due to the sudden change in the air direction (red oval circle) and impact on the bronchial mucus of the ciliated epithelium.

BALT (bronchial associated lymphoid tissue).

- Inhaled particles

- 100-200 cilia/cell
- 1,000 ciliary beats/minute

Metachronous pulse of the cilia propels mucus out of the airways like a wave propel surfers to the beach.
Particles 2 microns or smaller reach the alveoli but are rapidly taken by the pulmonary alveolar macrophages. Bacteria and viruses are examples of respirable particles in this size particle.

Pulmonary Alveolar Macrophage (PAM)

Alveoli do not have cilia or mucus. PAMs reach the mucociliary escalator where the movement transport them into the nasopharynx where are finally swallowed.
How effective are the pulmonary defense mechanisms?

To answer this question, scientists developed an experimental model known as Pulmonary Bacterial Clearance, in which animals are exposed to an aerosol of bacteria and the number of bacteria in the lung is calculated over time after the aerosol exposure.

When a healthy animal is exposed to *Mannheimia haemolytica*, the number of bacteria in the lung decreases exponentially, by 24 hours all bacteria are destroyed as shown in this graph.

The healthy animal rapidly kills inhaled bacteria including some pathogenic organisms such as *Mannheimia haemolytica*, and *Pasteurella multocida* and *Bordetella bronchiseptica*, among many others.
**Q:** If bacteria are normally killed in the lung then why are animals susceptible to bacterial pneumonia?

**A:** Viral infection suppress the defense mechanisms allowing bacteria can colonize and multiply in the lung. *See graphic*

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**This experimental model demonstrates two facts:**

1. Healthy lungs rapidly eliminates inhaled bacteria.

2. Viruses such as IBR, BRSV, PI-3, EVR, FHV, distemper inhibit the pulmonary defense mechanisms thus predisposing the lungs to secondary bacterial pneumonia.

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Note in this graph the rapid elimination of inhaled bacteria given by aerosol to a normal animal (---).

In contrast note that the number of inhaled bacteria increases with time in viral infected animals (----).
Besides viruses the following factors can also impair pulmonary bacterial clearance:

- Lung Edema
- Stress
- Dehydration
- Uremia
- Ammonia
- Immuno-deficiency
The mucosa lining the conducting system is largely a pseudo-stratified ciliated epithelium. This epithelium has ciliated cells and interspaced goblet cells (long arrows) and some glands (arrowheads).

The proportion of goblet cells to ciliated cells decreases towards the distal portions of the conducting system.

The submucosa is highly vascularized with many blood vessels (bv).

Because of this abundant vascularization, the nasal cavity is unusually prone to hyperemia (active), congestion (passive) and hemorrhage (next slide).
• Epistaxis: medical term that describes a nose bleed.
• Hemoptysis: coughing up blood or presence of blood in mouth, saliva or sputum.
Common Causes of Epistaxis

- Inflammation
- Neoplasia
- Foreign body
- Trauma
- Pulmonary hemorrhage
IMPORTANT NOTE

The color of blood in feces varies depending on the site of bleeding; dark in gastric bleeding (digested blood) and fresh blood in colonic bleeding.

In epistaxis, the blood always looks the same regardless if bleeding is in the nasal cavity or deep in the lung. In other words, blood coming through the nostrils always looks fresh even if originates in the lungs.

Digested: Dark in gastric bleeding
Undigested: Fresh in colonic bleeding

Same color: Naso-pulmonar
Nasal congestion and hemorrhage occur in bloat, toxemia, sepsis, inhalation of irritant gasses and inflammation.

Epistaxis is also a common indicator of nasal trauma or nasal neoplasia.

In cattle, epistaxis-hemoptysis often results from ruptured pulmonary vessels (aneurysm).

In horses, epistaxis occurs in “Exercise-induced pulmonary hemorrhage” and Ethmoid hematoma.

Careful examination of the respiratory tract is required to localize the source of bleeding.
Equine Ethmoid Hematoma

The Ethmoid Hematoma occurs in older horses and it is clinically characterized by chronic, progressive and usually unilateral nasal bleeding.

Grossly, an ethmoidal hematoma appears as a pedunculated (tumor-like) soft mass (arrows) arising from the ethmoid conchae. It can be readily seen by endoscopy.

Microscopically, the mass is composed of a thinly encapsulated mass of connective tissue containing many blood vessels, red blood cells, a large number of siderophages and a few leukocytes.

The ethmoidal hematoma can be surgically removed.
• Remember that nasal mucosa is well vascularized, and therefore submucosal vessels can easily engorge with blood during inflammation (hyperemia) or circulatory failure (congestion).

• Nasal congestion or nasal hemorrhage is commonly seen following exposure to irritant gases such as ammonia, hydrogen sulfide (H₂S), nitrogen dioxide (NO₂), ammonia, etc. It also results from shock, bloat, and of course in rhinitis.
Before reviewing the inflammatory process in the nasal cavity, rhinitis, let’s first review how the nasal mucosa reacts to injury and how the damaged mucosa is repaired.

To illustrate the mechanisms of injury and host response let’s use an example of the common cold. When you become infected with the virus of the common cold (rhinovirus), the infected cells degenerate and exfoliate by detaching from the basal lamina. After cellular detachment then there is mild inflammation of the nasal mucosa causing pain, runny nose and eyes, and finally, through mitosis and cell migration, the necrotic cells are replaced by new epithelial cell.

The entire process takes 10-14 days.
Injury and Repair of the Nasal Mucosa
(Summary)

- Ciliated epithelium
- ~250 cilia/cell
- Highly vascularized
- Abundant glands
- Degeneration
- Loss of attachment
- Necrosis
- Exfoliation
- Repair
- Pre-ciliated cells
- Mitosis
- Cell differentiation
- Healed epithelium
- Normal function
The respiratory system consists of 3 independent but continuous compartments.

1. The conducting system extends from the nostrils to the bronchi;
2. The transitional system is composed by the bronchioles;
3. The exchange system is composed of millions of alveoli.

The conducting system is lined largely by pseudostratified ciliated epithelium and its main defense mechanism is the trapping and removal of particles by mucociliary action.

The transitional system is lined with ciliated and non-ciliated (secretory) epithelium and its main defense mechanism is provided by locally produced secretions.

The alveoli is lined by alveolar type I (membranous) and II pneumocytes (pneumonocytes) and the main defense mechanism is provided by the pulmonary alveolar macrophage (PAM). In addition, the lung has defense mechanisms against toxins, circulating organisms and locally produced free radicals.

The mucosal surface of the proximal conductive contains a vast population of organisms which constitute the nasal flora. Organisms of the nasal flora are carried into lung by inhaled air but these organisms are promptly eliminated by the defense mechanisms.

The healthy lungs can be exposed to bacterial aerosols but within 24 hours all bacteria are destroyed and removed from the lung.

Virus, stress, dehydration, lung edema, uremia, ammonia and several forms of immunodeficiency reduce the pulmonary defense mechanisms and predispose the lung to secondary bacterial pneumonia.
✓ The nasal mucosa is highly vascularized, and the blood vessels are quickly engorged with blood often resulting in hyperemia or hemorrhage.

✓ Nasal congestion and hyperemia are common in bloat, toxemia, sepsis and rhinitis

✓ Nasal hemorrhages are common in domestic animals.

✓ Nosebleed is referred to as epistaxis and presence of blood in saliva or sputum is called hemoptysis.

✓ In epistaxis and hemoptysis, the blood in the nostrils looks the same if blood originates in the nasal mucosa or deep in the lung.

✓ Important causes of epistaxis in horses are Ethmoid Hematoma and the Exercise Induced Pulmonary Hemorrhage.

✓ In all species, nasal tumors and rhinitis are also sources of epistaxis.

✓ The nasal mucosa has remarkable ability to repair. Injured cells degenerate, exfoliate and then become replaced by new cells within 14 days as long as the basement membrane remains intact.
I hope that you enjoyed this module, but most important, that you learned something about respiratory pathology.

If you have any critiques or found mistakes, please let me know at lopez@upei.ca.

For a quick Quiz, please go to the next slide.

Thank You.
Click or “copy and paste” the link into your browser

http://people.upei.ca/lopez/respiratory/1_quiz_defense/1a_structure_defense%20-%20Presenter%20output/presentation.html
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