The Respiratory System

Respiratory system functions mainly as gas exchange system for O_2 andCO_2

→ **cellular respiration** (energy production)

closely tied to circulatory system

General Functions of Respiratory System:

1. O_2 and CO_2 exchange between blood and air
2. speech and vocalization
3. sense of smell
4. helps control acid base balance of body
5. breathing movements help promote blood and lymph flow

Anatomy of the Respiratory System

Main Organs:

nose
pharynx
larynx
trachea
primary bronchi
lungs:
bronchioles
alveoli/respiratory membrane

these organs can also be subdivided into:

upper respiratory tract
nose→pharynx→larynx

lower respiratory tract
respiratory organs of the thorax

the lower respiratory tract fills most of the Thorax (Thoracic Cavity)

major portion is inside **lungs**

air passageways must be held open at all times

→nasal passageways and throat follow passages in skull bones and cartilage

→others held open by rings of cartilage

1. Nose

separated from mouth by hard and soft palate

cleft palate – bones don't unite completely
produces difficulties in swallowing

each nasal cavity is divided into 3 passageways by **turbinates**

→ creates narrow, turbulent passageways to insure that all air makes contact with mucous membranes

lined with ciliated mucous membranes containing **goblet cells**

membranes are heavily vascualrized

→ remove bacteria, debris and particles
mucous blanket: produces 125 ml/day
cilia move it 1-2 cm/min

→ warms and moisturizes air entering lungs

→ also contains receptors for smell

nasolacrimal ducts drain into nasal cavity

paranasal **sinuses** are accessory structures:
sound resonance (other animals)
warm and moisten air
lighten skull

2. Pharynx (throat)

from base of skull to junction with esophagus and trachea

5" long

made of muscle and lined with mucous membrane

junction between digestive and respiratory systems

divided into three regions:

a. Nasopharynx

behind nose to level of soft palate
includes uvula
tonsils (adenoids)
auditory tube (eustachian tube) drains here

b. Oropharynx

behind mouth
from soft palate to level of hyoid bone
palatine and lingual tonsils

c. Laryngopharynx

from hyoid bone to esophagus/larynx

3. Larynx (voice box)

enlarged beginning portion of trachea

composed of cartilage and muscles

opening into larynx = **glottis**

prevent food from entering lower respiratory system
sound → speech, singing, etc

9 cartilages (3 large, 6 small):

epiglottis –covers glottis when swallowing

in infants, the epiglottis is high in throat and touches the soft palate → allows infants to eat and breath at same time, epiglottis deflects foods away from glottis
this advantage is lost by age 2 when root of tongue becomes more muscular forcing larynx lower

thyroid cartilage

largest cartilage of larynx

testosterone stimulates the growth of the laryngeal prominence so it becomes larger in males than in females = **adam's apple**

cricoid cartilage

smaller cartilage below thyroid
connects larynx to trachea

two muscular folds within larynx:

upper: **(false) vocal cords**
(=vestibular folds)

close glottis during swallowing

lower: **(true) vocal cords**

wall of larynx are very muscular

→ some of these muscles help to control these two pairs of folds

4. Trachea

extends from larynx to bronchi

surrounded by "C" – shaped bands of cartilage ends joined by bands of muscle tissue

→holds walls open, prevents collapse

lined by pseudostratified ciliated columnar epithelium

tracheotomy

5. Bronchi

trachea divides into two branches = **bronchi** which enter each lung

bronchi resemble trachea in structure

→ also supported by C-shaped cartilages

also have lots of elastic connective tissue

each bronchus enters lung and continues to divide into smaller and smaller branches = **bronchi**, then into microscopic **bronchioles**

because of the extensive branching
= bronchial tree

6. Lungs

the remainder of the respiratory system is contained within the two lungs

left lung → 2 lobes
right lung → 3 lobes

all organs between the two lungs are located in the

mediastinum

mediastinum includes:

heart
heart is in its own sac = pericardium
esophagus
trachea
major blood vessels attached to heart

lungs are located in **pleura cavity**

visceral pleura covers outer surface of lungs

the pleurae and pleural fluid:

1. help reduce friction

act as a lubricant

pleurisy=pleurae are dry and inflamed

2. create a pressure gradient

as rib cage expands to draw air into the lungs

3. compartmentalization

surround each lung and isolate it from other and pericardial sac

prevent infections from spreading easily from one thoracic organ to another

7. Bronchioles

smallest branches of "respiratory tree"

<1mm diameter

no cartilage rings

but larger branches may have small patches of cartilage

lined with ciliated cuboidal epithelium and layer of smooth muscle

asthma affects the smallest terminal bronchioles

8. Alveoli

smallest bronchioles (respiratory bronchioles) have

clusters of tiny sacs branching off **= alveoli**

"grapelike clusters"

300-500 Million alveoli/lung

single cell layer thick (squamous epithelium)

enveloped by **capillaries**

alveoli are the "functional units" of the respiratory system

actual site of gas exchange with blood

alveoli increase in number and size until adolescence
after adolescence, can increase in size only and if damaged, have only limited ability to repair themselves

Physiology of Respiration

Pulmonary Ventilation

we move ~500 ml of air in and out of lungs with each breath

involves moving air down a **pressure gradient**

breathing involves 2 processes:
inspiration
expiration

1. Inspiration

an active **contraction** of diaphragm

→ innervated by phrenic nerve

may also involve contraction of the external intercostals

contraction of diaphragm lowers pressure in thoracic cavity:
outside pressure > pressure in lungs → lungs inflate

the "work" required for normal breathing is ~1-2% of body's total energy expenditure

during heavy exercise that may increase to 15% of energy expended

2. Expiration

normal expiration is mainly a passive process

→relaxation of diaphragm

volume of chest decreases, forcing air out of lungs

may also involve contraction of internal intercostals & muscles of abdominal wall

pressure in thoracic cavity is kept lower than pressure in outside air

→ keeps lungs inflated

pneumothorax
opening in chest cavity
eliminates pressure differential
causes lungs to collapse

Surface Tension also plays an important role in keeping the lungs inflated

outer surface of lungs and inner surface of alveoli are covered with thin film of water

water has a high surface tension (very "sticky")

on outer surface of lungs:

→ visceral pleura tends to stick to parietal pleura

creates slight negative pressure

helps to inflate lungs during inspiration

on inside of alveoli:

→ tends to cause the alveoli to collapse upon themselves

counteracted by:

a. lungs never completely deflated; always contain some air

b. secrete **surfactant**

reduces surface tension in alveoli

not produced until 8th month of pregnancy
→ respiratory distress syndrome

Respiratory Volumes

the volume of air exchanged in breathing is measured with a **spirometer**

provides information on pulmonary functions

eg. Tidal Volume (TV)
normal volume of air with each breath
small part of total lung capacity (~10%)
~500 ml

eg. Vital Capacity (VC)
largest volume of air that can be moved into or out of lungs

vital capacity is affected by:
a. overall size of individual, gender→ size of lungs
b. volume of blood in lungs → eg congestive heart failure
c. excess fluid in pleural or abdominal cavity
d. loss of lung elasticity → eg. emphysema
e. misc health related factors → eg. smoking, exercise, etc

eg. Residual Volume
air that cannot be removed from lungs
~1200 ml
removed in pneumothorax

Nonrespiratory Air Movements

speech → communication

cough → removes junk from lower resp passages, reflex
sneeze → clears upper resp. passages, reflex

laughing
crying } → emotional state

hiccup → spasmodic contraction of diaphragm

yawn, sigh → with shallow breathing, eventually surface tension can overcome surfactant and alveoli start to collapse; an occasional deep breath reinflates them → forces lungs open again since chest muscles are stronger than surface tension

Alveolar Gas Exchange

the exchange of gasses in the lungs takes place between alveolar air and venous blood

gas exchange occurs across the lining of the alveoli and capillaries (2 cell layers thick)

→ **respiratory membrane**

total surface area ~ 70 (60-80)m^2
(=760 ft^2 ~20'x38'; = tennis court)

Gas exchange is the result of simple diffusion down oxygen and carbon dioxide concentration gradients:

	Alveoli		Blood Entering Lungs
PO_2	105mmHg	→	40mmHg
PCO_2	39mmHg	←	46mmHg

The exchange of gasses in tissues is also by simple diffusion:

	Blood leaving lungs		Tissues
PO_2	104mmHg	→	≤40mmHg
PCO_2	40mmHg	←	≥45mmHg

Transport of Gasses in Blood

A. Oxygen

almost all hemoglobin in blood going through lungs manages to pick up oxygen

→ 98% saturation
versus ~70% saturation in venous blood

→ hemoglobin has a very **high affinity** for O_2

only ~2% of O_2 is carried dissolved in plasma

Hyperventilation doesn't increase P_{O_2} of blood

only slightly increases dissolved O_2 concentrations

→ may deliver a little more O_2 to tissues but not much

the amount of oxygen carried in the blood then is mainly dependent on the amount of hemoglobin in blood

4 O_2/hemoglobin → 250 Million Hb/RBC → 1 Billion O_2/RBC

anemia decreases oxygen transport

CO binds to Hemoglobin even more strongly than does oxygen

→ **CO poisoning** (takes very little, but continuous exposure)

2. Carbon Dioxide

transported in blood three major ways:

1. **10% dissolved in plasma**
→ >20x's more soluble than O_2

2. **20% bound to hemoglobin**
CO_2 binds to amino group of hemoglobin (O_2 binds to heme portion)
=carbaminohemoglobin

3. **70% converted to bicarbonate ions**

$$CO_2 + H_2O \xrightarrow{\text{carbonic anhydrase}} \underset{\text{carbonic acid}}{H_2CO_3} \longrightarrow H^+ + \underset{\text{bicarbonate ion}}{HCO_3^-}$$

this reaction occurs mainly inside RBC's
bicarbonate ions are then released into the plasma

oxygen release is enhanced by CO_2 loading

Regulation of Respiration

the heartbeat and breathing are the two most conspicuous rhythmic processes occurring in the body

the heart has its own pacemaker

the lungs do not → breathing depends on rhythmic

stimuli from the brainstem

breathing involves coordination of several groups of voluntary muscles

the lungs themselves are not actively involved in the process

normal breathing is automatic, rhythmic

controlled by respiratory reflex centers in brainstem

A. <u>Respiratory Reflex Centers</u>

Three reflex centers in brain that regulate breathing:

1. respiratory center: medulla

establishes basic rhythm of breathing

maintains automatic breathing rate
→ 12-15 breaths/min

2. apneustic: pons

3. pneumotaxic center: pons

the two centers in pons insure a smooth transition between inspiration and expiration

helps maintains rhythmicity of breathing

when connection between medulla and pons are cut breathing becomes abnormal
→ gasps

The Aging Respiratory System

pulmonary ventilation declines steadily after 20's
→ costal cartilages and joints become less flexible
→ lungs have less elastic tissue
→ fewer alveoli

decline in volume of inhaled air (TV) and Vital Capacity

also less capable of clearing lungs of irritants and pathogens and therefore more susceptible to respiratory infections

→ pneumonia causes more deaths in old age than any other infectious disease

Diseases of Respiratory System

Restrictive Disorders
→ stiffen lungs, reduce compliance and vital capacity

eg. pulmonary fibrosis
respiratory tissue is replaced by fibrous scar tissue

effect of TB and black lung disease

Obstructive Disorders
→ narrow the airway and interfere with airflfow

expiration requires more effort

eg. airway obstructions, bronchoconstriction, tumors or aneurysms that push on airways

chronic obstructive pulmonary diseases:
asthma
chronic bronchitis
emphysema

A. Diseases of inadequate ventilation

1. Pneumothorax

collapsed lung or lungs

2. paralysis of diaphragm muscle
due to injury to respiratory center of brainstem
eg. caused by polio which damages respiratory center
damage to nerves supplying diaphragm (phrenic nerve)

3. bronchial asthma
allergic reaction
excessive mucous secretions and constrictions of bronchioles

4. emphysema
progressive degenerative disease causing destruction of alveolar walls
may be due to chronic irritation (eg smoking)
loss of tissue elasticity

5. lung cancer
uncontrolled growth of cells
crowd out normal cells

B. Diseases of Poor Gas Exchange

1. emphysema

2. infections
viral or bacterial

eg. hay fever, bronchitis
cause lining of tubes to swell and become inflammed

2. pneumonia
more sever result of respiratory infection
bacterial or viral
alveoli fill with fluids

3. tuberculosis
tubercles formed to wall off bacterial infection
if infection is not controlled may invade more lung tissue causing fibrosis
causes extensive destruction of lung tissue

4. Respiratory Distress Syndrome
collapse of lungs in baby due to lack of surfactants