CHAPTER 7

THE RESPIRATORY SYSTEM

GOALS FOR THIS CHAPTER:

1. Explain how the upper respiratory tract filters, moistens, and directs air.
2. Describe the composition, structure, and function of the lower respiratory system.
3. Describe how the mechanical action of breathing moves gases into and out of the lungs.
4. Explain how gases are exchanged between the respiratory system and the environment.

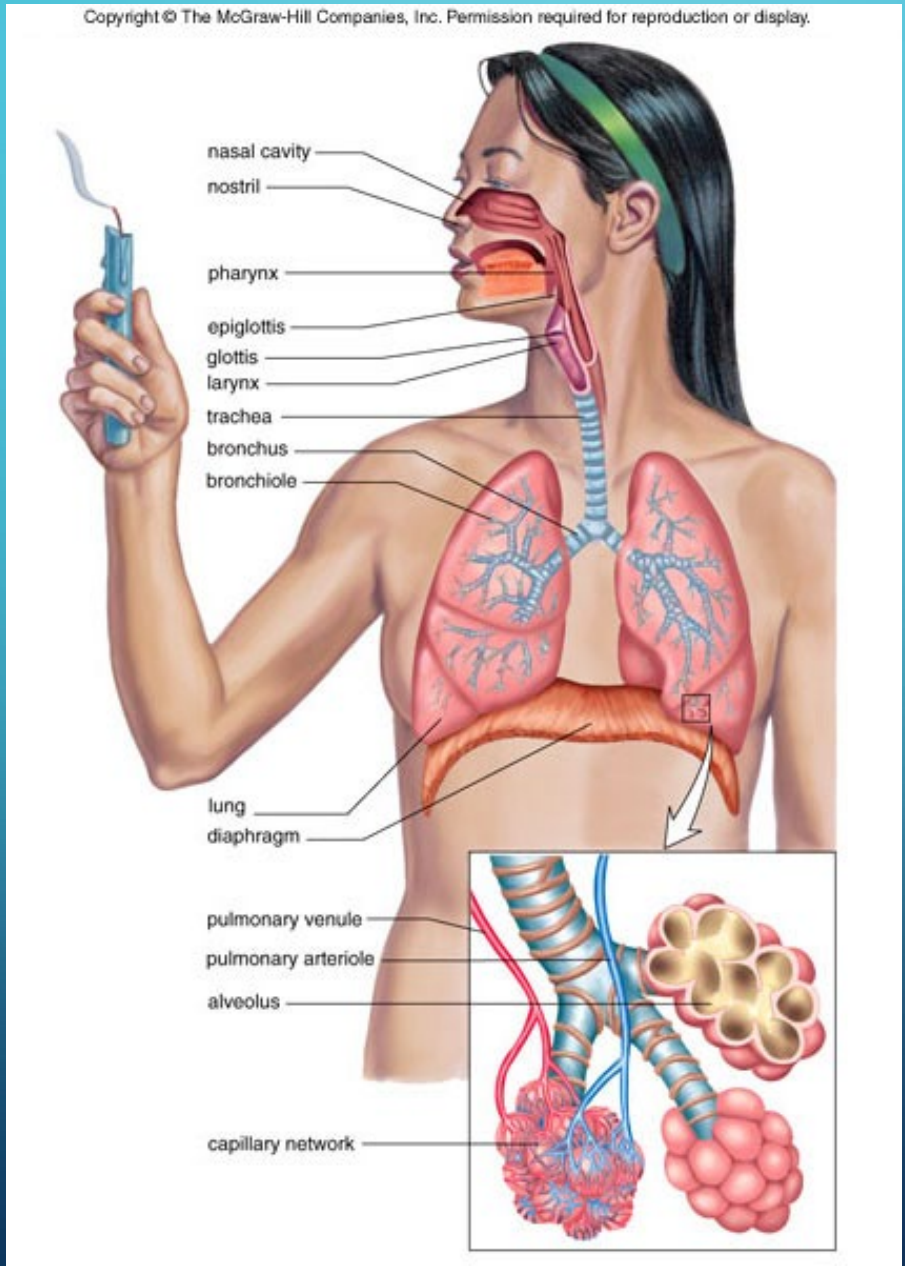
5. Identify factors that affect the rate of respiration.
6. Identify diseases that are associated with the respiratory system.
7. Identify technologies used to identify and treat diseases and disorders of the respiratory system.

7.1 – STRUCTURES OF THE RESPIRATORY SYSTEM

- Respiration actually involves a 4-stage process:

1. Breathing – the movement of air into & out of the lungs
2. External respiration – the exchange of oxygen and carbon dioxide within the lungs
3. Internal respiration – the exchange of oxygen and carbon dioxide within the blood and body tissues
4. Cellular respiration – the oxidation of glucose for energy

RESPIRATORY STRUCTURES



Parts introduction

How your lungs work. TED

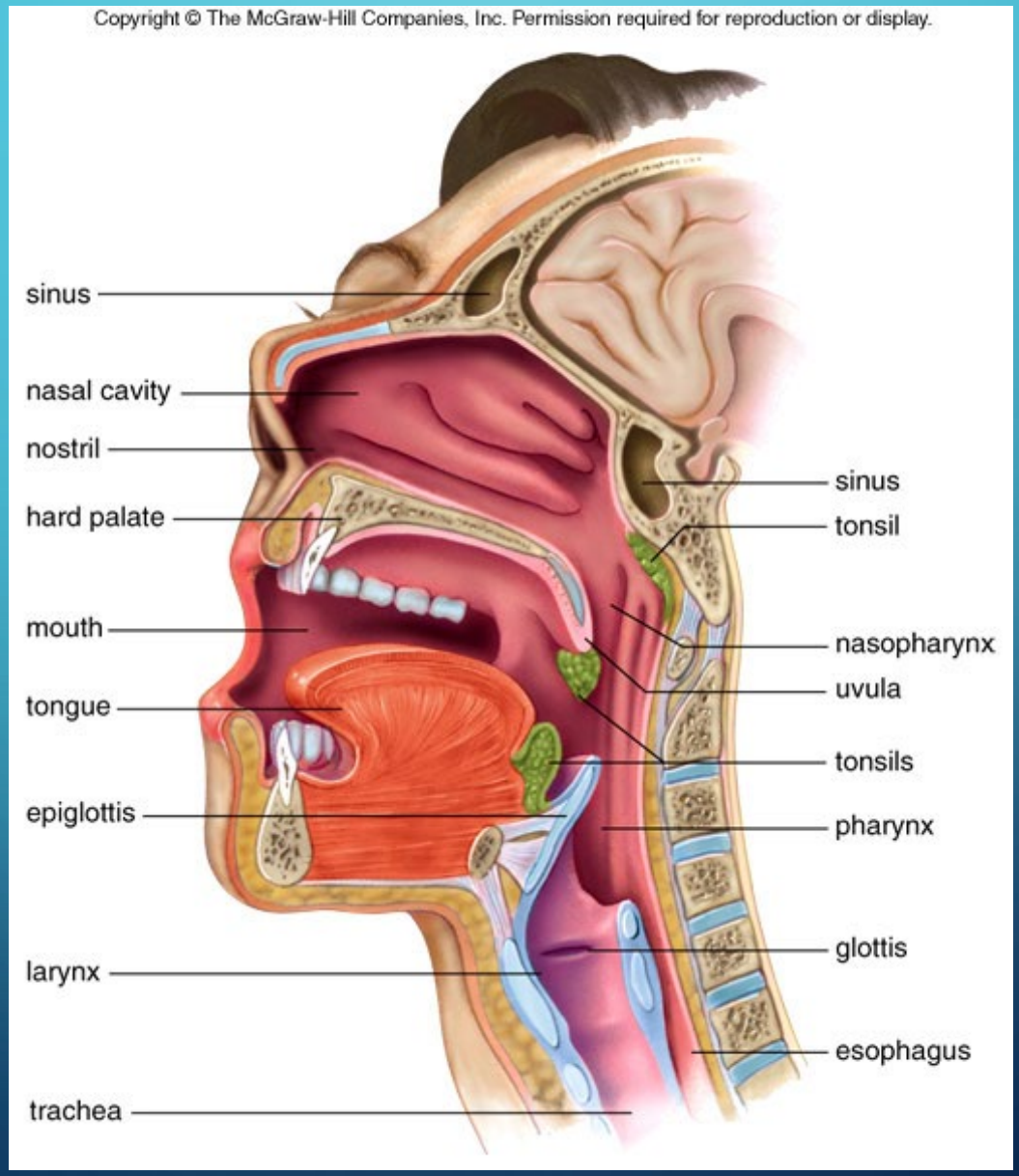
THE NOSE

- Part of upper respiratory tract
- Contains 2 nasal cavities
  - Lined by mucous membrane (traps foreign debris)
  - Functions:
    - Warms air – heat from large amount of blood vessels
    - Cleanses air – coarse hairs (cilia) and mucus
    - Humidifies air – wet surfaces of membrane
  - Olfactory receptors – on cilia high up in cavities

THE PHARYNX

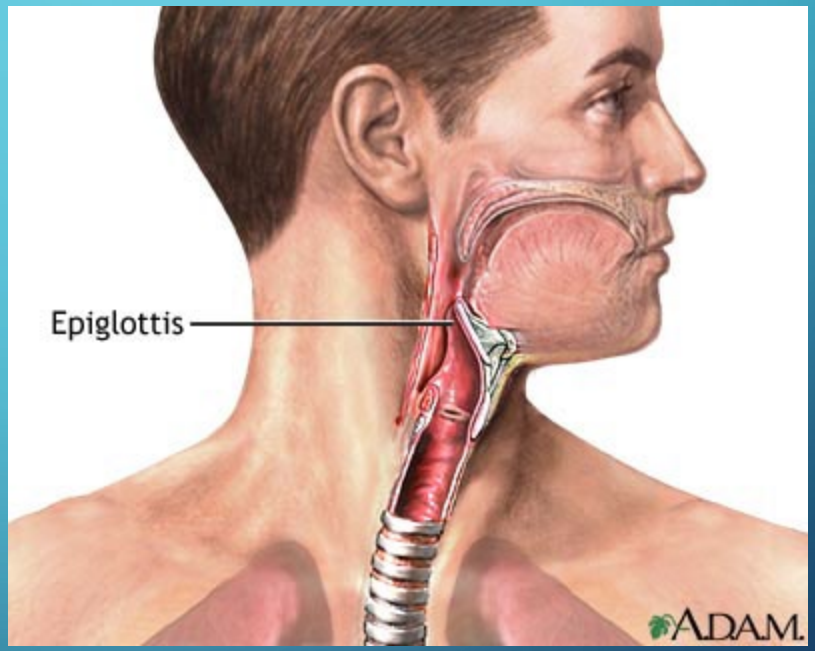
- Connects nasal and oral cavities to larynx
- 3 divisions
  - Nasopharynx
    - Nasal cavities open posterior to soft palate
  - Oropharynx
    - Where oral cavity opens
    - Uvula projects into oropharynx
  - Laryngopharynx
    - Opens into larynx
- Tonsils form a protective ring
- Larynx and trachea are normally open
- Esophagus is normally closed

THE PATH OF AIR



EPIGLOTTIS

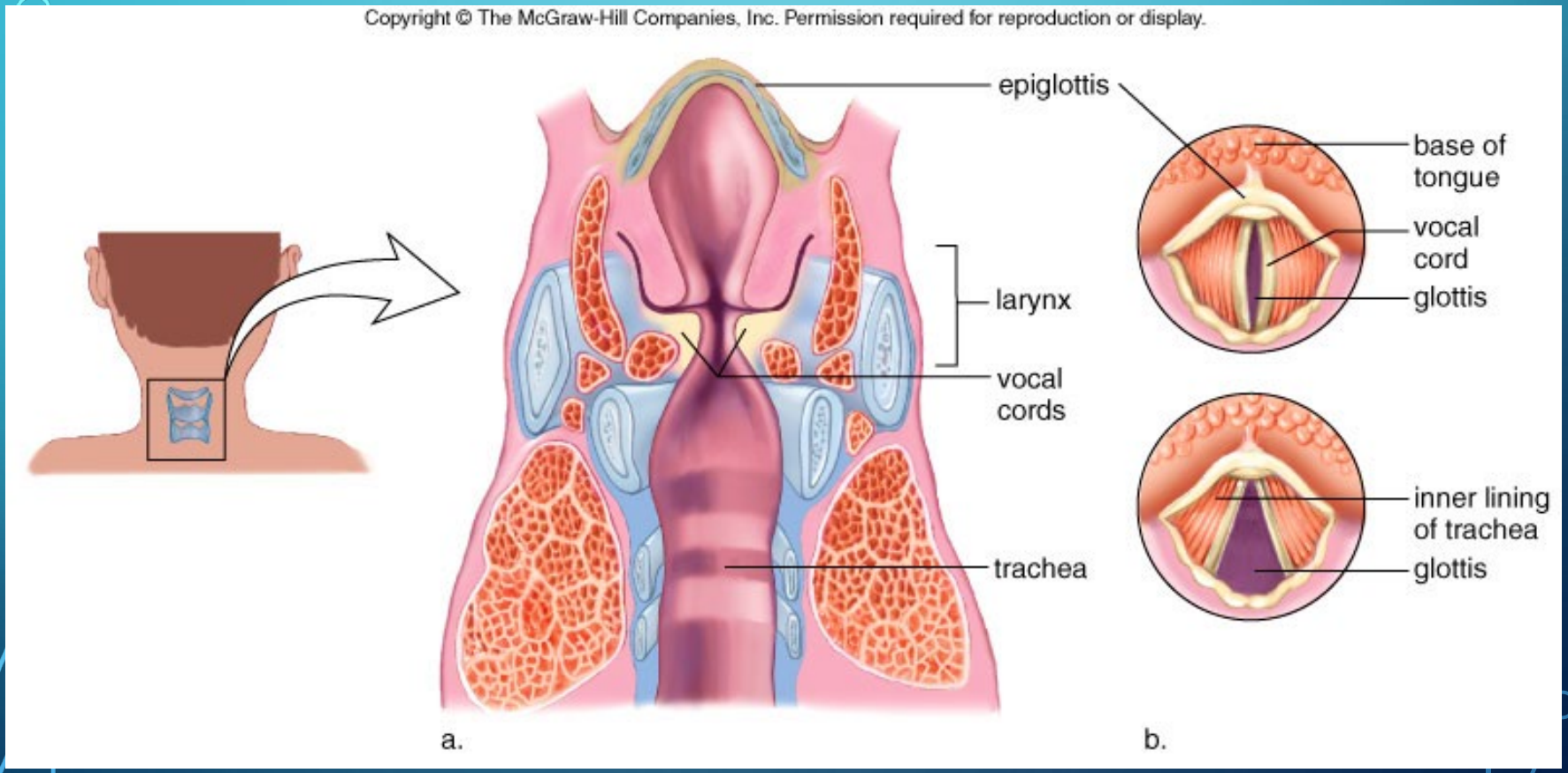
- When eating, an enlarged flap of cartilage called the epiglottis covers the trachea to prevent food from entering
- Food and drink that enter the trachea stimulates cilia that lines the respiratory tract, producing a cough



LARYNX

- Passageway for air between pharynx and trachea
- Vocal cords Steven Tyler - Aerosmith
  - Folds of membrane supported by sheets of elastic ligaments
  - Glottis - opening between folds
  - Vibrate during exhalation
    - Pitch controlled by tension (higher tension - higher pitch)
    - Loudness controlled by amplitude of vibration
- Males have thicker vocal cords, which results in a deeper voice

PLACEMENT OF THE VOCAL CHORD



Pitch

TRACHEA

- Connects larynx with primary bronchi
- Supported by C-shaped cartilage rings
  - Keeps trachea sturdy yet flexible
- Lined with:
  - Cilia
  - Goblet cells – produce mucous
  - ➢ Combined action – mucociliary apparatus
    - Mucus traps debris Smoking Vaping
    - Cilia sweeps mucus and debris upward
    - Smoking paralyzes the mucociliary apparatus
- Tracheostomy – artificial opening to open airway

THE BRONCHIAL TREE

- Right and left primary bronchi
  - Resemble trachea in structure (cartilage rings, cilia)
- Branch to secondary bronchi
  - ➢ Eventually lead to bronchioles
- Bronchioles have smaller airways, walls become thinner
  - Lack cartilage rings and can have diameter changed by smooth muscle
- Each bronchiole leads into terminal (respiratory) bronchioles
  - Respiratory bronchioles surrounded by alveoli (air sacs)

ALVEOLI

- Surrounded by blood capillaries
  - Gas exchange occurs across alveolar wall and capillary wall
    - Oxygen diffuses into blood
    - Carbon dioxide diffuses into alveoli
  - Alveoli must stay open to receive air
    - Surface tension has tendency to make them collapse
    - Surfactant – soapy-like lipoprotein
      - Produced in lungs
      - Lowers surface tension
      - Prevents collapse
    - Infant respiratory distress syndrome – premature babies
      - Lack surfactant; alveoli prone to collapse

Premature Babies

BRONCHIOLES & ALVEOLI

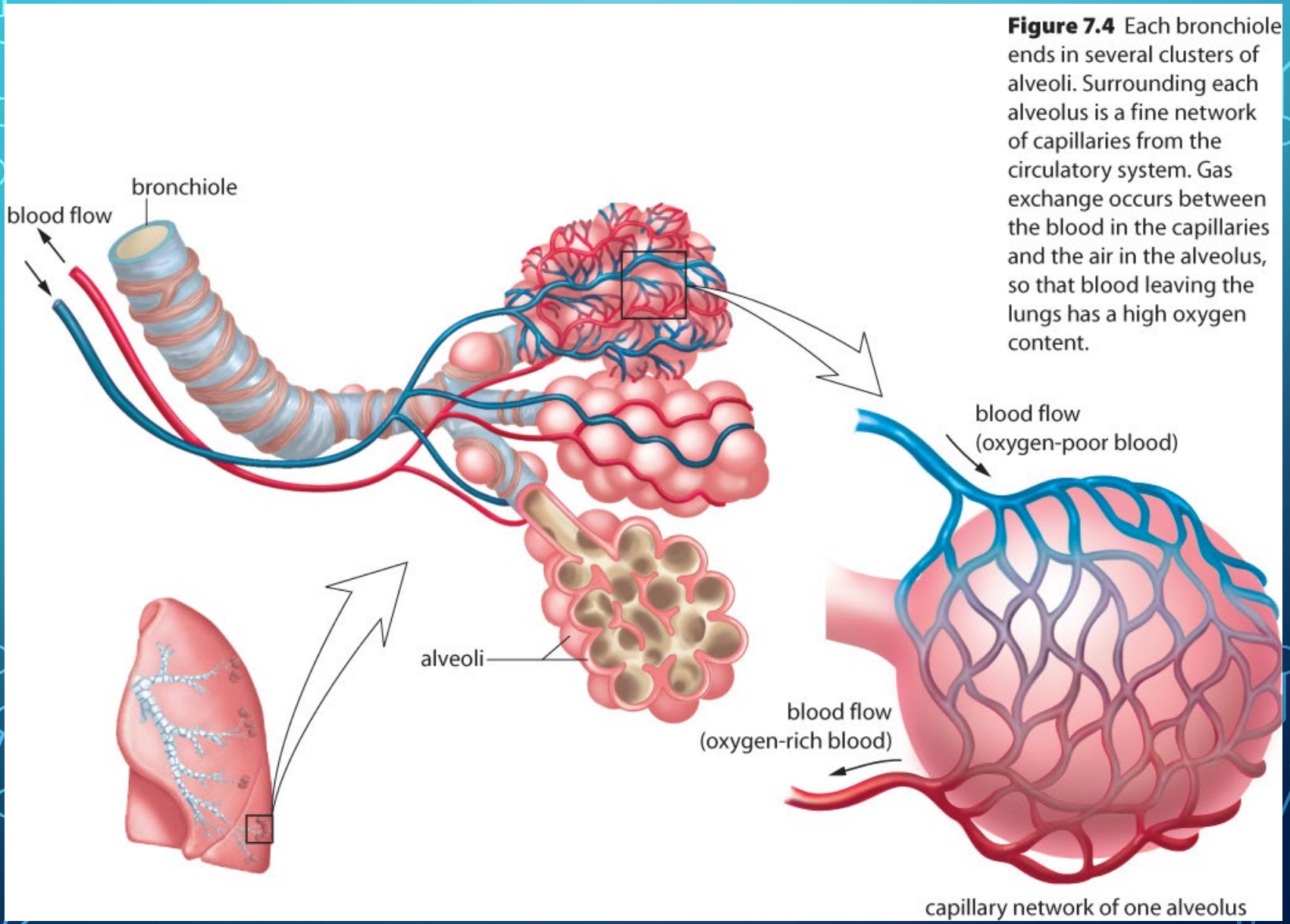


Figure 7.4 Each bronchiole ends in several clusters of alveoli. Surrounding each alveolus is a fine network of capillaries from the circulatory system. Gas exchange occurs between the blood in the capillaries and the air in the alveolus, so that blood leaving the lungs has a high oxygen content.

GAS EXCHANGE

- The alveoli walls are very thin and are surrounded by capillaries
- Carbon dioxide and oxygen transfer between the alveoli and capillaries through diffusion
- You have about 150 million alveoli, whose total combined surface area could cover a tennis court!

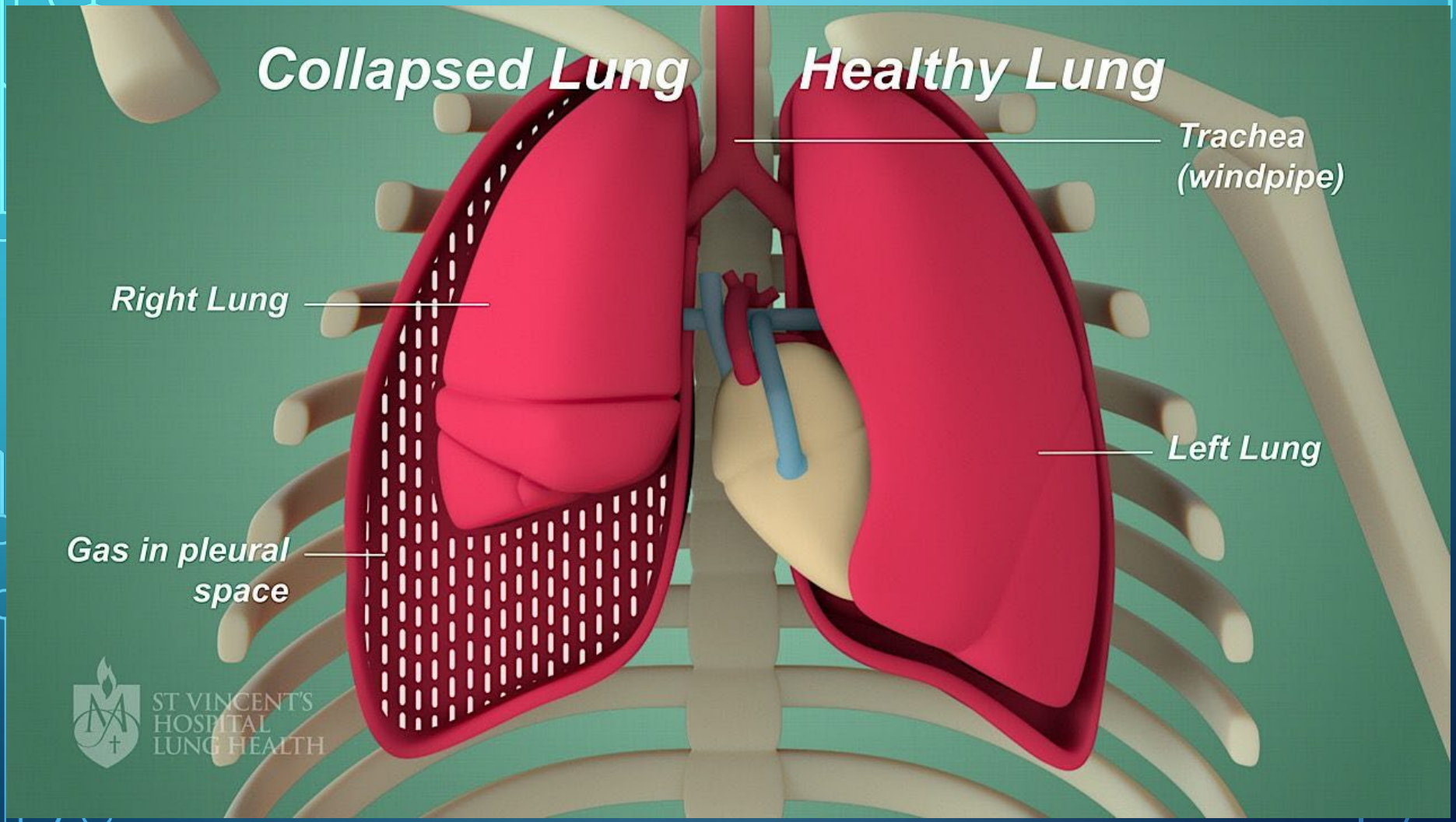
Gas Exchange

THE LUNGS

- Divided into lobes
  - Right lung has 3
  - Left lung has 2
- Each lobe is divided into lobules
  - Lobule has a bronchiole serving many alveoli
- Lungs are covered by pleural membrane
  - Double-layered
  - Visceral pleura-on lung surfaces
  - Parietal pleura-on walls of thoracic cavity
  - Surface tension holds the 2 pleural layers together

Lungs CC review Part 1 #31

PNEUMOTHORAX



Pneumothorax

SECTION 7.2 – BREATHING AND RESPIRATION

- Recall that breathing and respiration are different
- Breathing is the mechanical action that brings air into the lungs
- Respiration is the exchange of gases

MECHANISM OF BREATHING

- Inspiration and Expiration
  - To understand ventilation (breathing), it is important to remember the following:
    - Continuous column of air from pharynx to alveoli
    - Lungs lie in the sealed-off thoracic cavity
      - Rib cage forms top and sides
        - Intercostal muscles are between ribs
      - Diaphragm forms the floor
      - Lungs adhere to the thoracic wall due to surface tension between pleural membranes

INSPIRATION

- Active phase (uses energy)
  - Diaphragm contracts and flattens
  - External intercostal muscles contract and elevate rib cage
  - Increases volume of thoracic cavity
  - Lungs and alveoli expand
  - Creates partial vacuum
- Intra-alveolar pressure drops below atmospheric pressure (lung volume goes up → lung pressure goes down)
- Air flows from atmosphere into lungs down pressure gradient (high to low pressure)

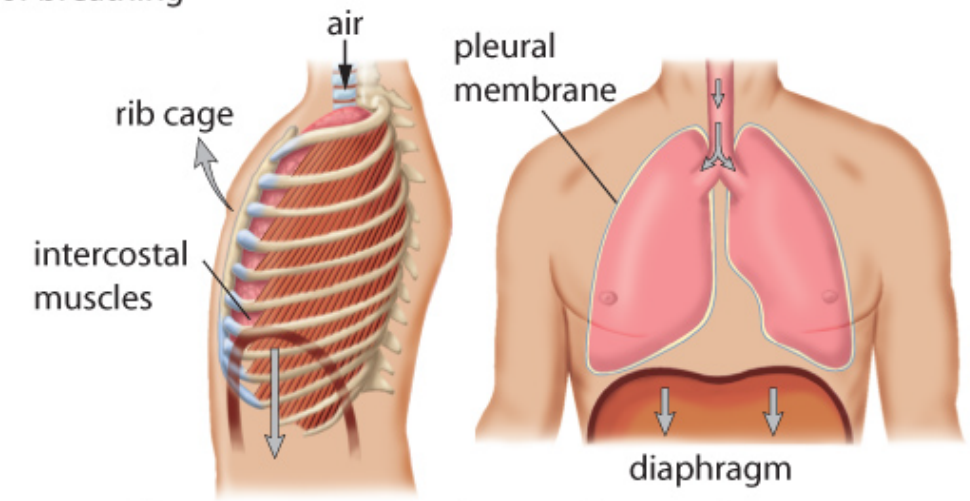
Inhaling and exhaling

EXPIRATION

- Passive phase (no energy needed – muscles just relaxing)
  - Diaphragm relaxes and returns to dome shape
  - External intercostal muscles relax, causing rib cage to drop
  - Decreases volume of thoracic cavity
  - Intra-alveolar pressure rises above atmospheric pressure
  - Air rushes out
- Forced exhalation
  - Abdominal muscles contract
  - Internal intercostal muscles contract, pulling ribcage down and in
  - Pushes air out

THE MECHANICS OF BREATHING

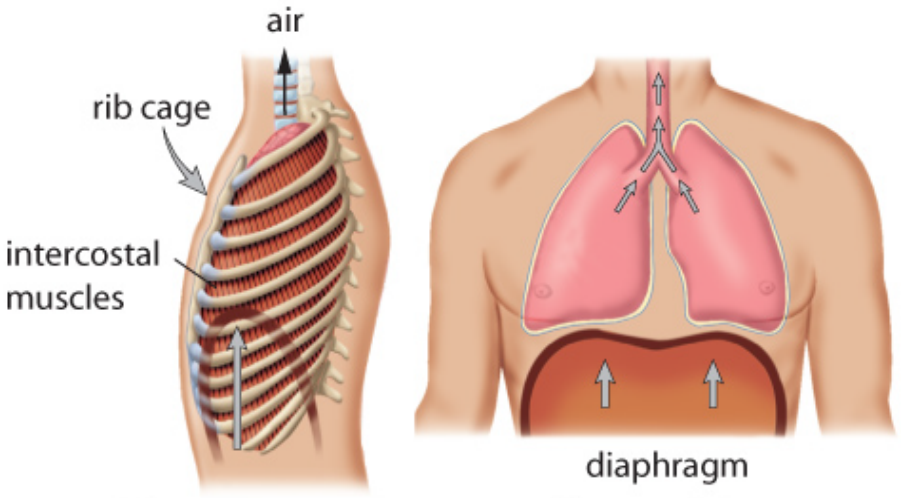
Figure 7.5 The mechanics of breathing



Rib cage moves up and out. Diaphragm contracts and moves down.

Pressure in lungs decreases, and air comes rushing in.

A Inhalation The intercostal muscles contract, lifting the rib cage up and out. At the same time, the diaphragm contracts and pulls downward. As the lungs expand, air moves in.



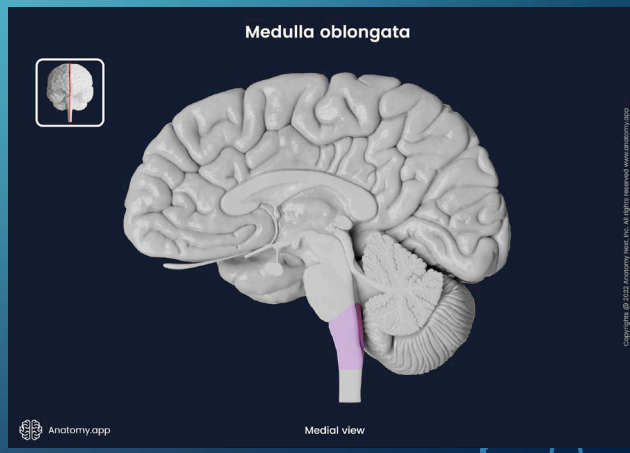
Rib cage moves down and in. Diaphragm relaxes and moves up.

Pressure in lungs increases, and air is pushed out.

B Exhalation The intercostal muscles relax, allowing the rib cage to return to its normal position. The diaphragm also moves upward, resuming its domed shape. As the lungs contract, air moves out.

CONTROL OF BREATHING

- Normal breathing rate – 12-20 breaths per minute
- Controlled by medulla oblongata region of brain
  - Inspiration
    - Sends out impulses to diaphragm and external intercostals, causing them to contract
  - Expiration
    - Stops sending impulses to those muscles
    - Muscles relax



- Medulla oblongata is activated / deactivated by both chemical and neural input

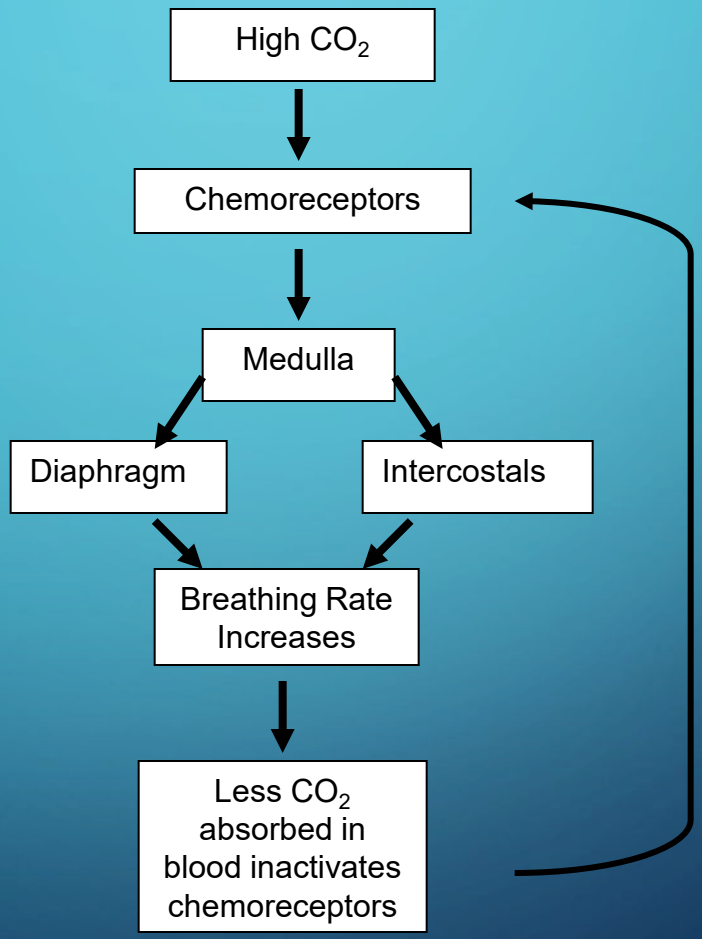
CHEMICAL RECEPTORS

- Medulla oblongata has chemical receptors that are:
  - Directly sensitive to CO_2 and H^+
  - When concentrations rise in the blood, the respiratory center of the medulla will have more activated receptors
  - Activates a nervous response which then sends signals to increase breathing movements
  - ➢ increases rate and depth of breathing

WHAT HAPPENS WHEN CO_2 LEVELS INCREASE?

- Chemoreceptors sense increase in CO_2
- the diaphragm and intercostal muscles' activity increases (stimulated by medulla oblongata)
- this increases breathing movements and therefore increases the amount of CO_2 being exhaled
- when CO_2 levels fall, the chemoreceptors become inactive and breathing rates return to normal

NEGATIVE FEEDBACK LOOP



WHAT HAPPENS WHEN CO_2 LEVELS INCREASE?

- Drugs like morphine and barbiturates (aka downers/depressants) can make the medulla less sensitive to CO_2 levels and as a result, breathing rate decreases which could eventually cause death

- Why can't you hold your breath forever?
- Why do people breathe into paper bags when having an anxiety attack?

NEURAL INPUT

- Medulla oblongata is indirectly responsive to O_2 concentrations
  - Chemoreceptors in the carotid artery and aorta are sensitive to oxygen levels in blood
    - When O_2 levels decrease, nervous impulses are sent to respiratory center of medulla oblongata
      - Medulla then signals for an increased breathing movements, rate, and depth of breathing

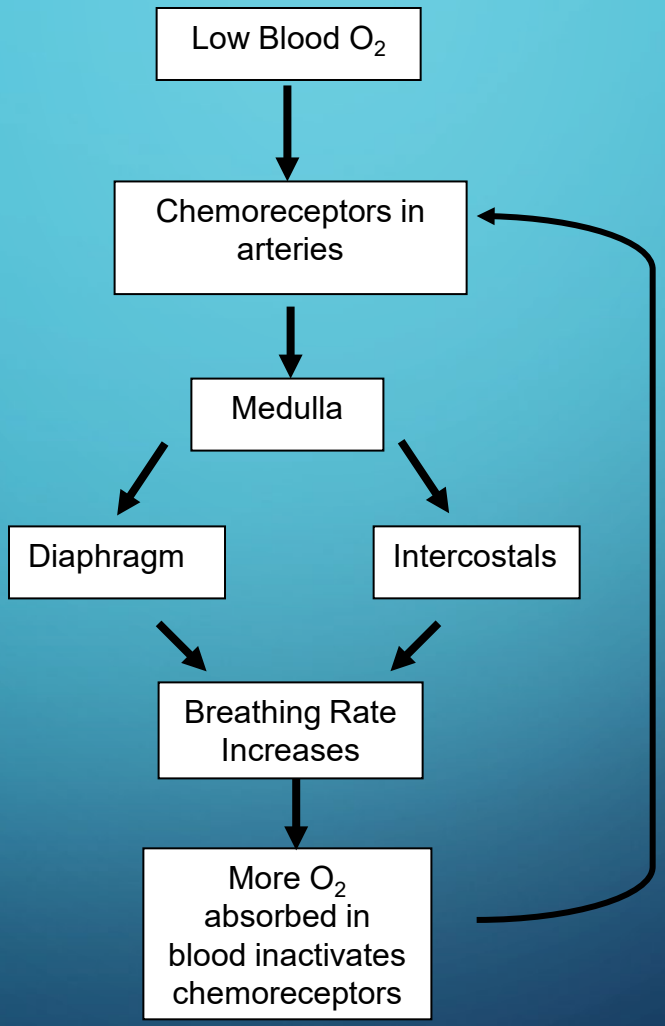
WHAT HAPPENS WHEN O_2 LEVELS ARE LOW?

- Oxygen chemoreceptors called the **carotid** and **aortic bodies** detect when O_2 levels are low and become stimulated
- A nervous impulse message is sent to the medulla oblongata
- the medulla sends nerve impulses to the diaphragm and the intercostal muscles to begin breathing movements
- this will increase the amount of oxygen in the blood
- **the O_2 receptors are only called into action when O_2 levels fall and CO_2 levels remain in the normal range**

WHAT HAPPENS WHEN O_2 LEVELS ARE LOW?

- Some examples:
  - When you hold your breath, your O_2 levels drop while the CO_2 levels increase and the high CO_2 levels will initiate breathing movements
  - In high altitudes where there is less O_2 present, the opposite will happen. Low levels of O_2 is not accompanied by high CO_2 levels, the oxygen chemoreceptors initiate breathing movements
  - When carbon monoxide poisoning occurs, CO (carbon monoxide) competes with O_2 on the binding sites of the hemoglobin molecules in the blood. This reduces the O_2 levels in the blood, stimulating the oxygen chemoreceptors to initiate breathing movements

NEGATIVE FEEDBACK LOOP



RESPIRATORY VOLUMES

- Tidal volume
  - Amount of air moving in and out with each breath
  - Average is 500 ml
- Vital capacity
  - Maximum volume moved in and moved out in a breath
  - Illness can affect vital capacity
- Inspiratory Reserve volume
  - Forced inhalation
  - Amount of air brought in above tidal volume
  - Normally about 2,900 ml

RESPIRATORY VOLUMES

- Expiratory reserve volume
  - Forced exhalation
  - Air exhaled beyond tidal volume
  - Normally about 1,400 ml
- Residual volume
  - Amount of air always remaining in lungs
  - Normally about 1,000 ml
  - Not useful for gas exchange
    - Oxygen depleted
- The vital capacity = tidal volume + inspiratory reserve volume + expiratory reserve volume

RESPIRATORY VOLUMES

- 30% of inspired air never reaches alveoli
  - Fills respiratory tree
    - Nasal cavities, trachea, bronchi, bronchioles
  - Dead space air
- To increase respiratory efficiency
  - Increase depth and not rate of breathing
  - Slow, deep breaths
  - Maximizes air reaching alveoli

A SPIROGRAPH:

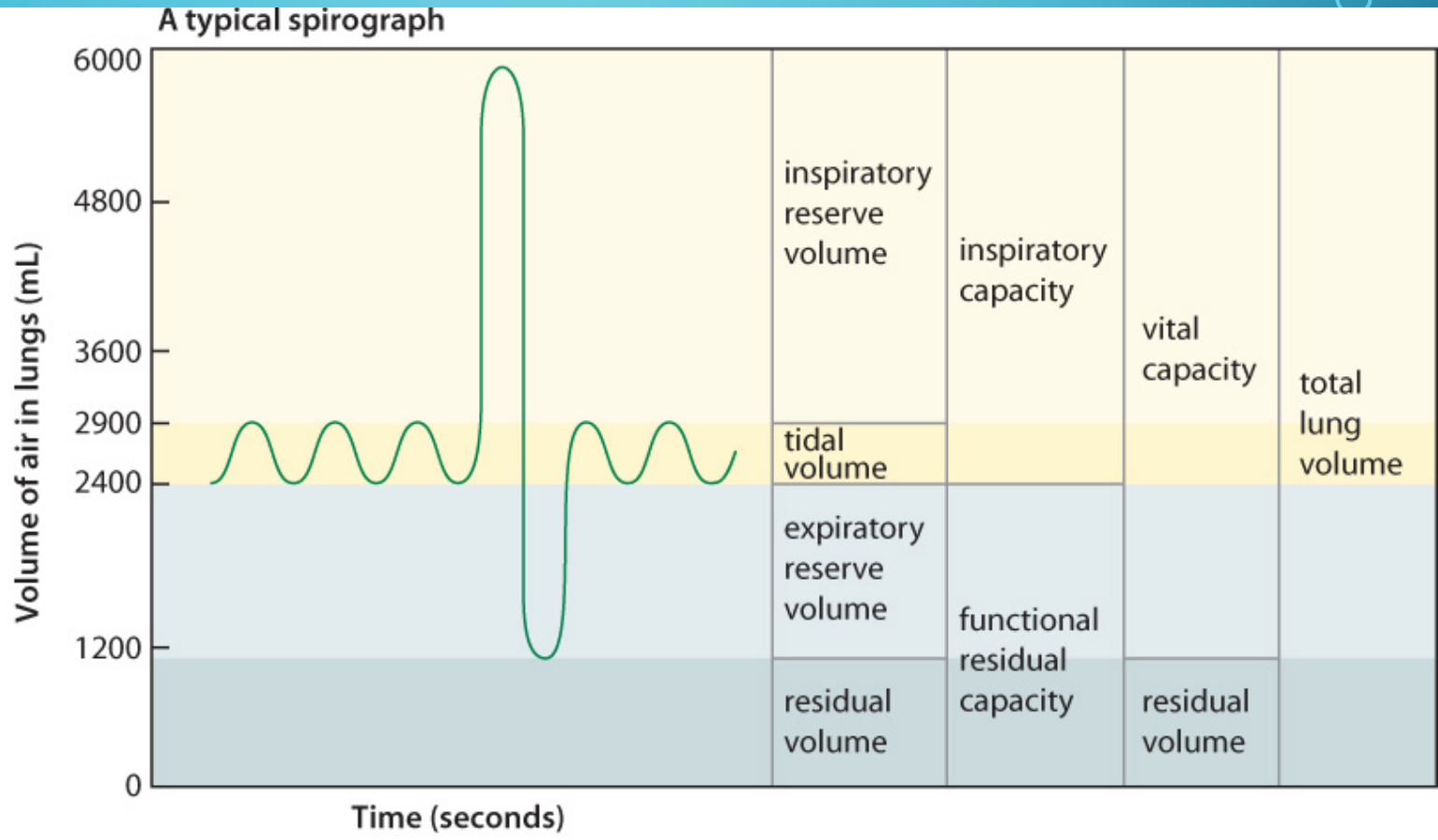
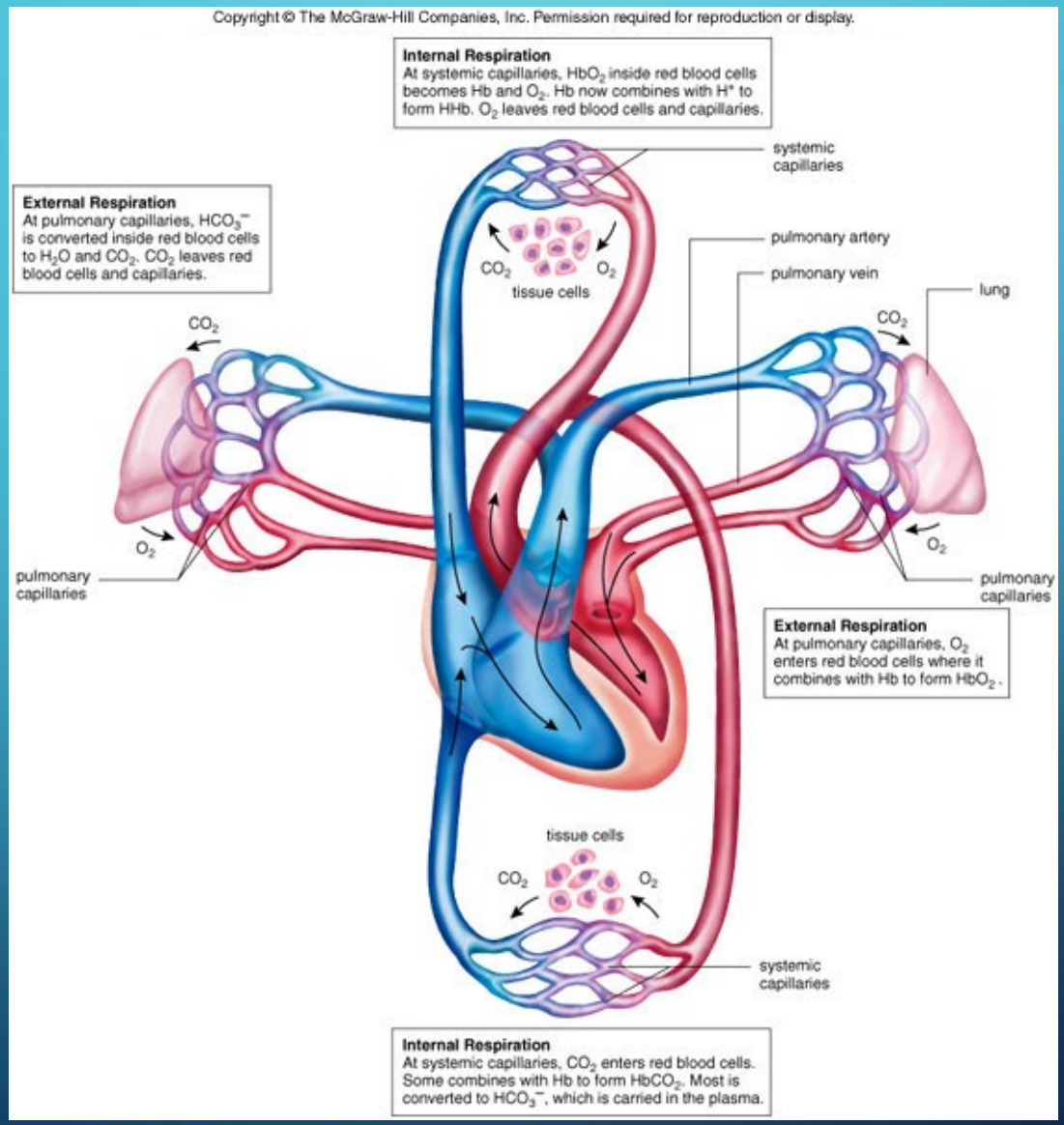


Figure 7.6 This graph shows typical values for human vital capacity: the maximum volume of air that can be moved into and out of the lungs during a single breath. The pattern of this graph is called a spirograph.

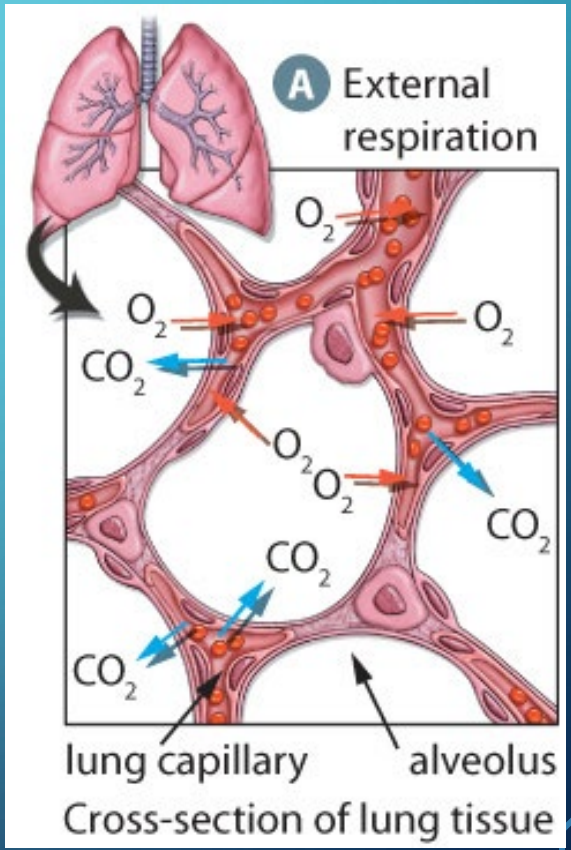
Lung volume and capacity

EXTERNAL AND INTERNAL RESPIRATION



GAS EXCHANGES IN THE BODY

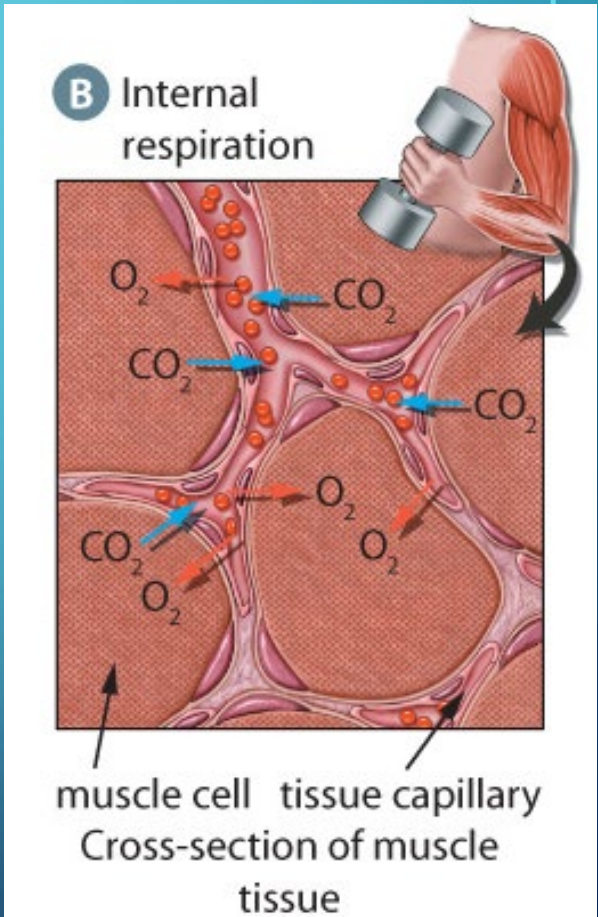
- External respiration
  - Gases are exchanged between the air in the alveoli and the blood of the capillaries in lungs
  - O_2 will diffuse out of the alveoli and into the capillary while CO_2 moves from the capillary to the alveoli



Partial pressure and respiration

GAS EXCHANGES IN THE BODY

- Internal Respiration
  - Within tissues, CO_2 and O_2 are also exchanged
  - O_2 leaves the blood and diffuses into the tissue
  - CO_2 diffuses out of the tissue and into the blood



COMPONENTS OF BLOOD

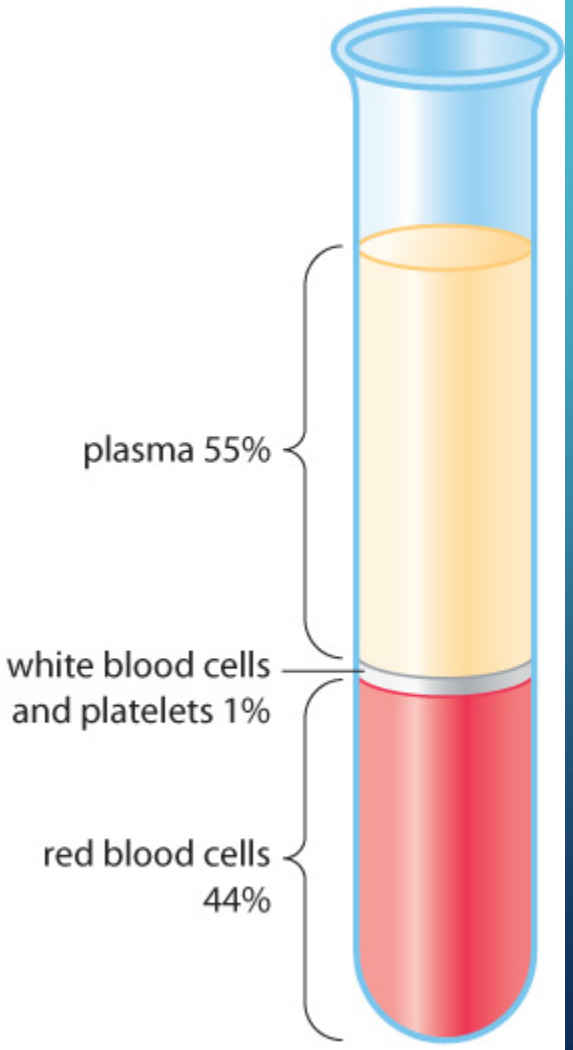


Figure 8.15 The three main components of blood can be separated using a special medical device called a blood centrifuge. When the blood is separated, it briefly settles into layers, as shown here.

O_2 AND CO_2 TRANSPORT IN THE BLOOD

- Oxygen Transport:
  - O_2 in the alveoli diffuses into the extracellular fluid (fluid around cells) surrounding the capillary bed
  - O_2 then diffuses through the capillary walls and into the blood plasma and the oxygen binds on the hemoglobin molecules in the red blood cell – called HbO_2
  - Only 1% of O_2 in the blood is dissolved in blood plasma
  - 99% of the O_2 is bonded to hemoglobin molecules
  - Hemoglobin allows red blood cells to carry 70 times more oxygen than cells without hemoglobin
  - You would only be able to maintain life for about 4.5 seconds without hemoglobin (we can go without oxygen for about 5 minutes!)

O_2 AND CO_2 TRANSPORT IN THE BLOOD

- Carbon Dioxide Transport:
  - 23% of CO_2 is carried on hemoglobin – called CO_2Hb
  - 7% is carried (dissolved) in plasma
  - 70% of CO_2 (from cellular respiration in tissues) is carried in the form of dissolved bicarbonate ions (HCO_3^-)
  - CO_2 enters the red blood cells from tissues / cells and, in order to maintain blood pH, is chemically converted to carbonic acid (H_2CO_3) in a reaction that is catalyzed by carbonic anhydrase (an enzyme)
    - carbonic acid molecules dissociate forming bicarbonate ions and hydrogen ions (which bind to hemoglobin to form HHb)
    - bicarbonate diffuses out of RBC into the plasma

O_2 AND CO_2 TRANSPORT IN THE BLOOD

- When blood rich in CO_2 reaches the lungs, the CO_2Hb loses its CO_2 and the gas dissolves into the alveoli.
- Bicarbonate ions recombine with hydrogen ions (released from HHb), reforming carbonic acid
  - carbonic acid decomposes, forming water and CO_2 which diffuses out of the blood and into the alveoli
- when present in normal amounts, the ratio of carbonic acid to bicarbonate creates an acid-base balance in the blood, helping to keep the pH at a level where the body's cellular functions are most efficient

REACTION SUMMARY

- At tissues:

$CO_2 + H_2O \xrightarrow{\text{carbonic anhydrase}} H_2CO_3$ (carbonic acid) — In RBC

$H_2CO_3 \longrightarrow HCO_3^- + H^+$ — In RBC then to plasma

(bicarbonate)

- At lungs:

$HCO_3^- + H^+ \longrightarrow H_2CO_3$ — In RBC

$H_2CO_3 \xrightarrow{\text{carbonic anhydrase}} CO_2 + H_2O$ — In RBC

THE FUNCTION OF HYDROGEN IONS

- The H^+ ions help to dislodge O_2 from the hemoglobin causing O_2 to diffuse into the tissues
- By removing H^+ ions from the plasma, the hemoglobin acts as a buffer (resisting pH change)
- When the deoxygenated blood from the veins reaches the lungs, O_2 dislodges the H^+ from the hemoglobin
- This is called blood buffering, it helps to maintain blood pH

RESPIRATORY HEALTH

- Respiratory health problems can be identified as conditions that affect either the upper respiratory tract, or the lower respiratory tract
- Many disorders are preventable – particularly those that are caused by smoking

UPPER RESPIRATORY INFECTIONS

- Tonsillitis:
  - Inflammation of the tonsils. This is caused by bacterial or viral infections. Typically, bacterial infections are treated with antibiotics.
    - ➢ Tonsillectomy – removal of tonsils (fewer done today)
- Laryngitis:
  - Inflammation of the larynx. Caused by infection, allergies, or straining of the voice. As a result, the vocal cords become inflamed and do not vibrate properly.
    - ➢ voice sounds hoarse

LOWER RESPIRATORY TRACT DISORDERS

- Bronchitis:
  - This is an inflammation of the bronchi. It causes mucus cells of the respiratory pathway to secrete more mucus. Tissue swelling occurs and air passages narrow, restricting breathing in and out
  - It can be classified as acute (usually a bacterial infection) or chronic (caused by irritants).
  - Characterized by deep cough and expulsion of mucous
  - During chronic bronchitis, the cilia lining the bronchi can become damaged.
  - The most common cause of chronic bronchitis is smoking.

LOWER RESPIRATORY TRACT DISORDERS

- Pneumonia:
  - This is an infection of the lungs.
  - It can be classified as viral or bacterial
  - Alveoli and bronchioles fill with fluid
  - Characterized by high fever, chills, chest pain, coughing

LOWER RESPIRATORY TRACT DISORDERS

- Pleurisy:
  - Temporary inflammation of the pleural membranes.
  - Caused by membranes rubbing together, moving lubricating fluid away
  - Results in a fluid buildup elsewhere and exhaling becomes more difficult
  - May be caused by infection, blood clots, or cancer
  - Characterized by a localized sharp, stabbing pain

4. Emphysema

- Emphysema is a loss of elasticity in the alveoli wall
- As a result, the surface area for absorption is reduced
- Most cases of emphysema are associated with smoking

5. Cystic Fibrosis

- Genetic condition that prevents the formation of sodium channels in cell walls
- This disrupts the water balance in the lung cells
- As a result, the normally runny mucus in the lungs becomes very thick and cannot be expelled

6. Asthma

- This is a chronic obstructive disease which reduces the diameter of the bronchi & bronchioles
- Environmental triggers and stress can often cause asthma attacks
- Bronchial dilators are used to treat asthma
- Most of these drugs are administered through inhalers which produce a mist or fine powder that contains the drug

7. Exercise Induced Bronchospasm

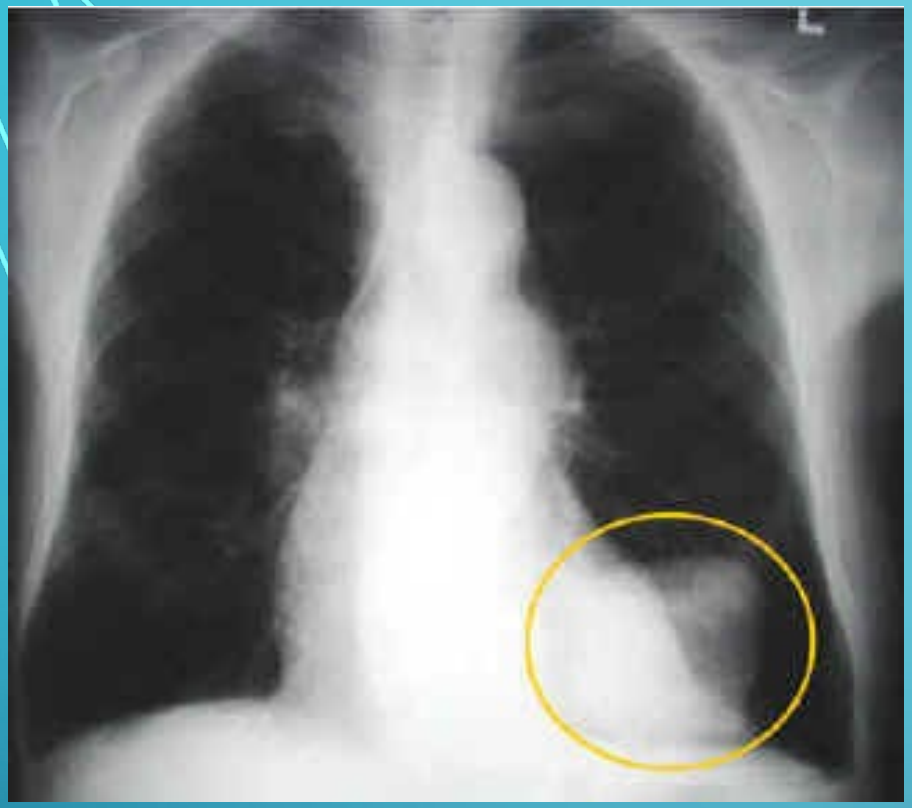
- This condition produces symptoms similar to asthma which are only brought on by exercise
- In most cases, dry, dusty and cold environments trigger this condition
- Patients with EIB can use bronchial dilators before exercise to avoid symptoms

8. Lung Cancer

- This (like all cancers) is an uncontrolled, abnormal growth of invasive cells
- The tumors that form reduce the available volume of the lung for gas exchange
- Often carcinogens (chemicals that cause cancer) trigger the production of tumors in the lungs
- Carcinogens are found in cigarette smoke, but also include asbestos and radon

TECHNOLOGIES FOR DETECTION AND TREATMENT OF LUNG DISORDERS

- Diagnosis of disorders such as cancer, and some other infections (such as inhalational anthrax and tuberculosis) are typically done using X-rays and CT scans



http://www.lakeridgehealth.on.ca

- Lung Cancer

http://www.ecosur.mx/tuberculosis/Tuberculosis-4.jpg

- Tuberculosis

- DNA analysis can be used to identify if genes for cancer are present
- Cancers can be treated in several ways, including radiation therapy and chemotherapy
- In some cases, liposomes (small, hollow sacks of lipids) are filled with cancer-fighting drugs
- These liposomes follow the spread of the cancer cells and attack them before they start new growth in a new area of the body