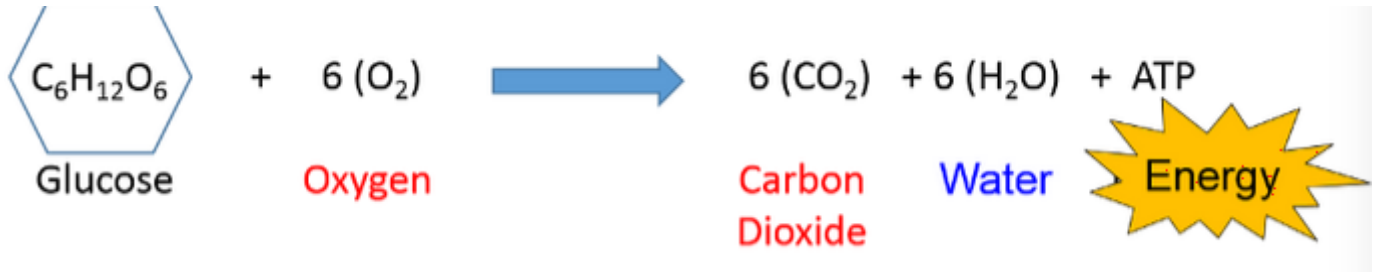


# Respiratory Health

All animals need oxygen to metabolize nutrients to generate cellular energy.



The above equation illustrates how nutrients (glucose) are converted to cellular energy in the form of adenosine triphosphate (ATP). Note carbon dioxide is produced as a by-product of metabolism.

The lungs are the interface between our blood stream and the external environment and the site where  $O_2$  is taken up and  $CO_2$  leaves the bloodstream to be expelled into the environment. The intimacy of this interface between our internal and external environment with the need to exchange air has a major impact on health for several reasons:

- Continual exposure of the respiratory tract to air from the environment provides an important portal for entry of viruses and bacteria that can cause infection.
- Disease processes that impede the mechanisms of ventilation (e.g. asthma and emphysema) can cause severe illness or death; these processes can also be triggered or exacerbated by substances in the air we breath.
- Air is a variable and complex mixture of many substances including particulate matter and chemicals that can have a detrimental effect on lung function; moreover many of these chemicals can be absorbed into the blood and cause a wide range of health problems.

## Learning Outcomes

1. Describe the function of alveoli with respect to exchange of oxygen and carbon dioxide
2. Describe the role of hemoglobin in oxygen transport and the adverse effects of CO
3. Explain how the occurrence and severity of chronic obstructive pulmonary disease (COPD) and asthma relates to environmental factors and be able to give examples of factors known to trigger asthma attacks
4. List the six criteria air pollutants and discuss the impact of air pollution on health
5. Discuss the impact of environmental tobacco smoke on health

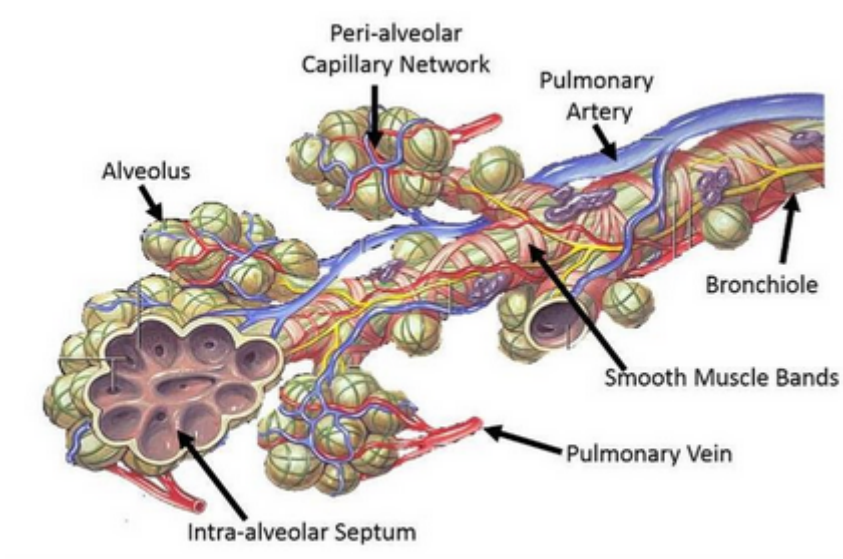
# The Respiratory Tract

Inspired air enters through the nose or mouth, passes through the pharynx (throat) and larynx (voice box) and then enters the tracheo-bronchial tree. The trachea bifurcates into the right and main stem bronchi which branch again and again into increasingly smaller conduits called bronchioles.

Respiration continually brings air from the environment in contact with the delicate cells in our lungs to provide oxygen and to expel carbon dioxide. The air must be warmed, moistened and filtered for the lungs. When harmful contaminants are carried in the air there are several mechanisms to mitigate the effects of these contaminants.

Nasal hairs and mucus can trap dust and other particulate matter, and goblet and ciliated cells work in tandem to remove particulate matter. Goblet cells create a mucus layer on the lining of the surface that protects the cells and traps dust and other foreign material while ciliated cells have hair-like projections that move rhythmically and sweep the mucus and particulate matter upwards where it can be swallowed or expectorated.

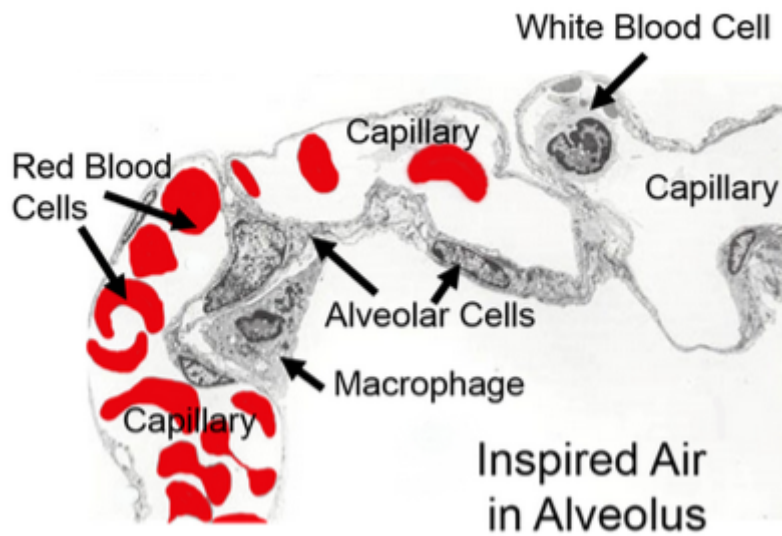
# Supplying Oxygen and Expelling CO<sub>2</sub>



The above figure shows a bronchiole terminating in several clusters of bronchiole. The bronchiole has a vascular supply of oxygenated blood (in blue) and nervous enervation (nerves in yellow) and the bronchiole is wrapped by smooth muscle cells that can contract or relax in response to physiologic conditions.

Contraction of smooth muscle narrows the airways, and relaxation increases their diameter. Abnormally severe contraction of this smooth muscle is of central importance to asthmatic attacks.

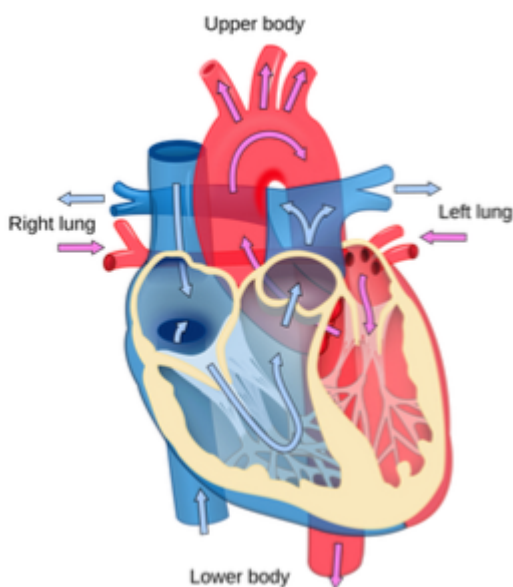
Eventually, the terminal bronchioles open into thousands of alveoli - delicate grape-like clusters of air sacs where gas exchange occurs. There are several types of alveolar cells: type 1, type 2, and macrophages.



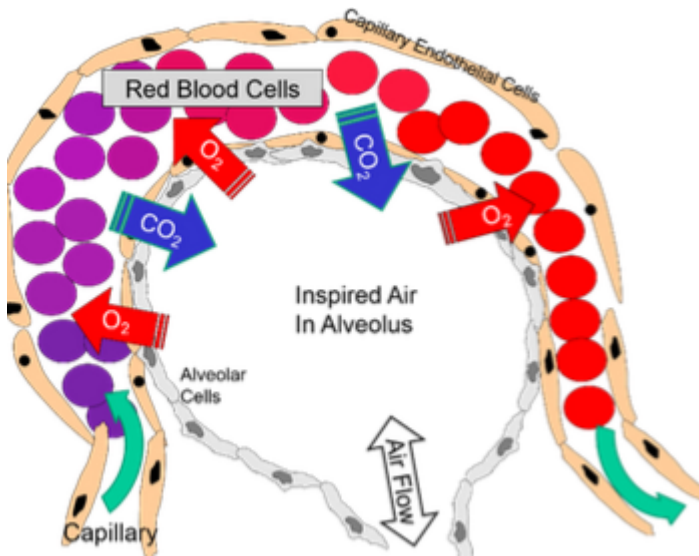
The above image focuses on the details in a single alveolus. Note the capillaries surrounding the alveolar cells are in very intimate contact, which facilitates the exchange of oxygen and carbon dioxide between the air in the alveolus and blood in the capillary.

The alveolus is lined with alveolar cells; type 1 are for exchange of  $O_2$  and  $CO_2$ , while type 2 can divide to give rise to new type 1 cells and also synthesize and secrete a substance called surfactant which reduces surface tension in the alveolus and prevents collapse during expiration.

Within the alveolus there are also macrophages (also called "dust cells") - phagocytic cells that engulf particulate matter then migrate up the bronchioles where the ciliated cells sweep them up into the pharynx where they are swallowed or expelled.



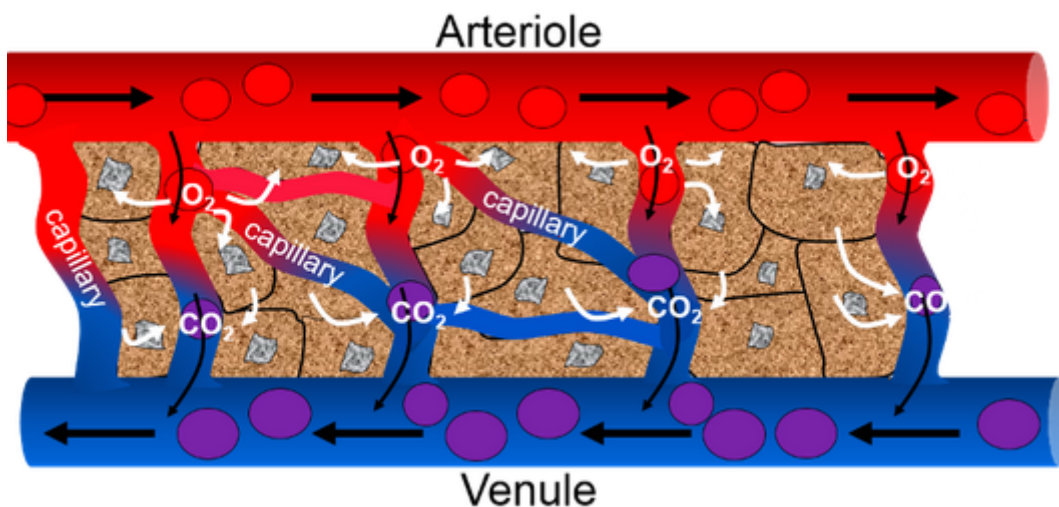
The graphic above illustrates that blood returning to the heart is de-oxygenated (in blue) and returns to the right atrium of the heart and then the right ventricle. When the heart contracts blood in the right ventricle is pumped to the lungs where it enters capillary vessels that circulate around the alveoli where gas exchange takes place. As blood circulates around the alveoli it becomes re-oxygenated and CO<sub>2</sub> moved from the pulmonary arterial blood into the alveolus to be exhaled. Blood returning to the left atrium of the heart then to the left ventricle is fully oxygenated and when the heart contracts it is pumped into the aorta to be distributed throughout the body via the arterial system.



Blood returning from the peripheral tissues has a relatively low concentration of oxygen but is rich in CO<sub>2</sub> as a result of cellular metabolism. As a result, the oxygen readily diffuses from the alveolus across the alveolar cells and into the capillary where it binds to the hemoglobin in red blood cells. Conversely, CO<sub>2</sub> diffuses from the capillary blood into the air in the alveolus which is exhaled.

## Cellular Gas Exchange

Cells use oxygen to metabolize, or create cellular energy from glucose or fatty acids. Arteries branch into arterioles which eventually branch into capillaries.



The image above shows an arteriole branching into smaller capillaries which supply nutrients and red blood cells to metabolizing cells. Capillaries are often so thin that often red blood cells can only pass one at a time.

# Smoking

Tobacco smoke is a complex mix of toxic and carcinogenic chemicals and particulate matter. Emission levels of 98 components in mainstream smoke constitute a human inhalation risk with potential to contribute to many adverse effects.

Below is a list of some of the known effects:

- Cancer of the bladder, blood, cervix, colon, esophagus, kidney, larynx, liver, oropharynx, pancreas, stomach, trachea, bronchus, or lung
- Generates free radicals that damage tissue membranes
- Increases blood pressure and clotting
- Promotes atherosclerosis
- Causes 2 to 4 fold increased risk of coronary heart disease; Including stroke and peripheral vascular disease
- 12 fold increased risk of COPD
- Heavy smokers have a 20 fold risk for lung cancer
- Many maternal/fetal effects
- Nicotine and free radicals kill osteoblasts - bone-making cells
- Older people who smoke experience significant bone loss
- Smoker's bones take longer to heal and may experience more complications during healing
- Second hand smoke puts non-smokers at risk

Since carbon monoxide from smoke binds to hemoglobin in red blood cells, effecting delivery of oxygen and causing platelets to become stuck together causing blood clots, thus every organ is effected by smoking. In addition, nicotine and CO can damage the inner lining of arteries. In coronary heart disease plaques can reduce or block flow of blood to the heart, causing chest pain. In more serious cases when the heart muscle is starved of oxygen for too long an area of the heart may die, causing a heart attack.

Smoking is the leading preventable cause of death in the US. More than 480,000 deaths per year can be attributed to cigarette smoking. Smoking causes 90% of lung cancer deaths. While COPD is more common in men, more women die from COPD annually. More women die from lung cancer each year than breast cancer. About 50-80% of all deaths from COPD caused by smoking.

# COPD

Chronic Obstructive Pulmonary Disease (COPD) is a global health problem that effects millions of people. COPD is one of the top 10 causes of death worldwide and the direct cost of treating it in the

US alone is ~\$30 Billion per year.

## Symptoms

- Shortness of breath
- Wheezing
- Chest tightness
- Difficulty with routine activities
- Weight loss
- Fatigue

COPD actually represents a spectrum of disease ranging from destruction of the alveoli and thickening of the terminal airways and impaired airflow (emphysema) to the thickening of the airways with chronic inflammation and repeated bouts of infection (chronic bronchitis). The hallmark of COPD is reduced airflow, which occurs as a result of one or more of the following:

- Loss of elastic recoil in the alveoli due to excessive breakdown of the protein elastin
- Destruction of the walls between the alveoli as a result of excessive action of enzymes called "proteases"
- Thickening of the walls of the airways due to inflammation
- Excessive secretion of mucus, which can clog airways.

While smoking is the leading cause of COPD, it can also be caused by genetic or environmental factors. Respiratory infections such as influenza do not cause COPD, but can make it much worse.

## Asthma

Asthma is a common, chronic syndrome characterized by intermittent episodes of symptoms which can be severe and life-threatening. The clinical episodes are triggered by antigens, viruses, exercise, or inhalation of irritating substances. Any of these stimuli can trigger a hyperactive allergic response which produces:

- Inflammation of the respiratory tract
- Bronchoconstriction
- Hypersecretion of mucus

These can cause varying degrees of airflow obstruction causing shortness of breath, wheezing, coughing, tightness in chest, and some times severe "air hunger" panic. Some episodes resolve spontaneously, while others require medical treatment.

The CDC estimates nearly 20 million Americans have asthma, and it is more common in children than adults, more common in women than men, and more common in black people than white people. The mortality from asthma rose in the 1980's, but then plateaued and declined since 1999 due to improved treatment.

## Why do some people have seasonal allergies?

Seasonal allergies are a hyper-sensitive immune response to something that's not actually harmful. Pollen or some allergen finds its way into the mucus membrane and the immune system attacks it. When the white blood cell attaches to the allergen it releases a chemical which stimulates nerve cells and cause blood vessels and the mucus membrane to swell and leak fluid; itchiness, sneezing, congestion, etc. An allergy can even bring on full anaphylaxis.

## Asthma Triggers

- Allergens (pollen, dust, molds, animal dander, bugs, etc)
- Tobacco smoke
- Exercise/activity (especially in cold air), as well as laughing, crying, or hyperventilating
- Cold air, wind, rain, and sudden changes
- Medications
- Air pollutants and irritants
- Sinusitis - respiratory tract infections including the flu and common cold
- Sulfites (preservatives added to some perishable foods)
- Emotional Stress

## Environmental Remediation for Asthma

The medical management of asthma and treatment of acute attacks has improved substantially, but the prevalence of asthma continues to rise in urban settings in industrialized countries. There is some evidence that interventions to reduce trigger exposures are effective, but the literature indicates that allergen reduction is difficult to achieve and the effectiveness is not as great as expected.

## Air Pollution

Air pollutants are the particles, vapors, and contaminants not found in pure air. These primarily come as a result of burning hydrocarbon fuels and releasing by-products into the atmosphere. Pollutants can be naturally occurring or the result of human activity (anthropogenic).

The energy humans require for energy is mostly derived by combustion. Combustion involves oxygen combining with hydrocarbons (gas, oil, propane, natural gas, wood, etc) to produce energy. The by-products are CO<sub>2</sub> and CO, water vapor, smoke, and ash. CO tends to be formed when there is insufficient oxygen for the hydrocarbon to burn completely.

Combustion of hydrocarbon fuels also produces "particulates" some of which are visible as smoke. These can pose threats to health and the environment. Nitrogen is the most abundant gas in the air we breathe, and it combines with oxygen during combustion to form a series of compounds called nitrogen oxides, sometimes referred to as NO<sub>x</sub>. Sulfur dioxide SO<sub>2</sub> is also formed at combustion of sulfur-containing fuels such as coal. Other pollutants can also be released by combustion, coal also contains concentrations of mercury which gets turned into vapor and returns

to our waterways driving concern about mercury in the ocean. Polycyclic aromatic hydrocarbons (PAH) represents a large family of molecules can also be produced when dirty fuel is burned, which cause tumors and birth defects.

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