Breathing in Humans

In mammals, the mechanism of breathing (ventilation) provides a continual supply of fresh air to the lungs and helps to maintain a large diffusion gradient for respiratory gases across the gas exchange surface. Oxygen must be delivered regularly to supply the needs of respiring cells. Similarly, carbon dioxide, which is produced as a result of cellular metabolism, must be quickly eliminated from the body. Adequate lung ventilation is essential to these exchanges. The cardiovascular system participates by transporting respiratory gases to and from the cells of the body. The volume of gases exchanged during breathing varies according to the physiological demands placed on the body (e.g. by exercise). These changes can be measured using spirometry.

Inspiration (inhalation or breathing in)

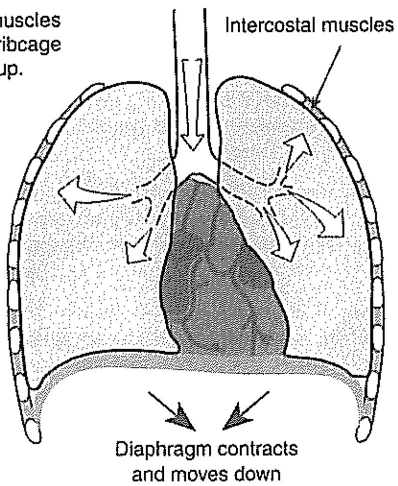
During quiet breathing, inspiration is achieved by increasing the space (therefore decreasing the pressure) inside the lungs. Air then flows into the lungs in response to the decreased pressure inside the lung. Inspiration is always an active process involving muscle contraction.

1a External intercostal muscles contract causing the ribcage to expand and move up.

1b Diaphragm contracts and moves down.

2 Thoracic volume increases, lungs expand, and the pressure inside the lungs decreases.

3 Air flows into the lungs in response to the pressure gradient.



Expiration (exhalation or breathing out)

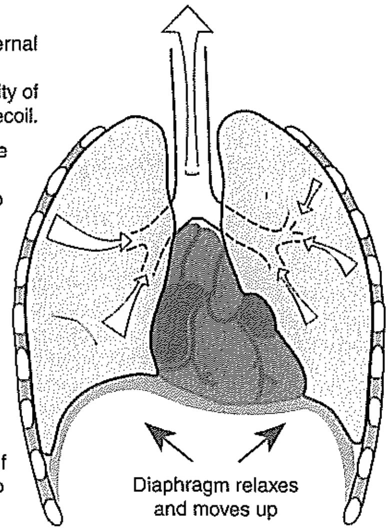
During quiet breathing, expiration is achieved passively by decreasing the space (thus increasing the pressure) inside the lungs. Air then flows passively out of the lungs to equalise with the air pressure. In active breathing, muscle contraction is involved in bringing about both inspiration and expiration.

1 In **quiet breathing**, external intercostal muscles and diaphragm relax. Elasticity of the lung tissue causes recoil.

In **forced breathing**, the internal intercostals and abdominal muscles also contract to increase the force of the expiration.

2 Thoracic volume decreases and the pressure inside the lungs increases.

3 Air flows passively out of the lungs in response to the pressure gradient.



1. Explain the purpose of breathing: ______________________________

2. (a) Describe the sequence of events involved in quiet breathing: ______________________________

   (b) Explain the essential difference between this and the situation during heavy exercise or forced breathing:

3. Identify what other gas is lost from the body in addition to carbon dioxide: ______________________________

4. Explain the role of the elasticity of the lung tissue in normal, quiet breathing: ______________________________

5. Breathing rate is regulated through the medullary respiratory center in response to demand for oxygen. The trigger for increased breathing rate is a drop in blood pH. Suggest why this is an appropriate trigger to increase breathing rate:

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The Human Respiratory System

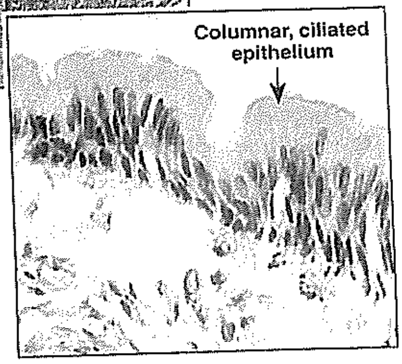
; paired lungs of mammals, including humans, are located ;hin the thorax and are connected to the outside air by way a system of tubular passageways: the trachea, bronchi, and ;nchioles. Ciliated, mucus secreting epithelium lines this ;tem of tubules, trapping and removing dust and pathogens 'ore they reach the gas exchange surfaces. Each lung is ided into a number of lobes, each receiving its own bronchus.

Each bronchus divides many times, terminating in the respiratory bronchioles from which arise 2-11 alveolar ducts and numerous **alveoli** (air sacs). These provide a very large surface area (around 70 m^2) for the exchange of respiratory gases by diffusion between the alveoli and the blood in the capillaries. The details of this exchange across the **respiratory membrane** are described on the next page.

Morphology of the Gas Exchange System

Photograph left: The nasal epithelium produces large amounts of mucus.

Photograph below: The epithelium of the trachea has many cilia. Mucus is produced from goblet cells.



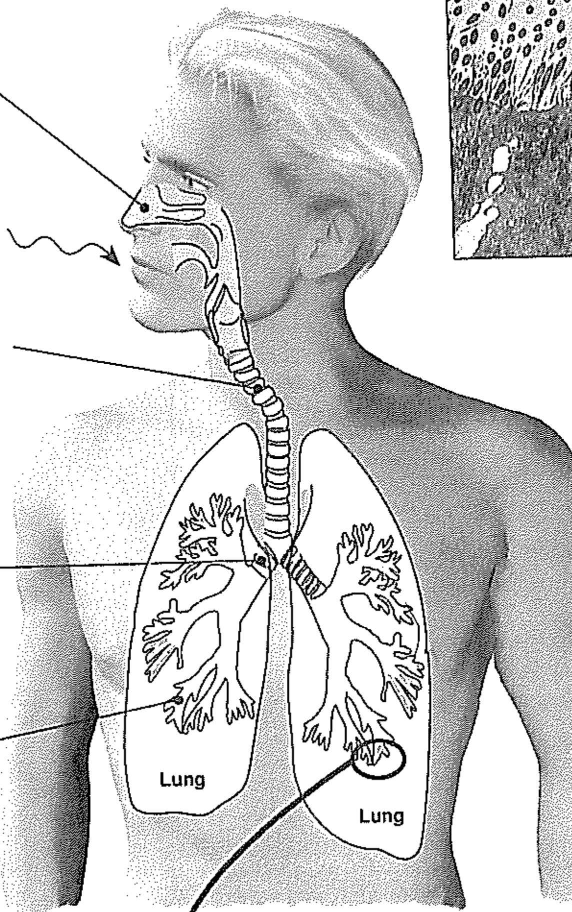
sal passages warm and ;isten the air entering through ; nostrils. Each nostril has a rder of hairs to trap particles d filter them out of the system.

· entering the body through ; mouth enters the pharynx d mixes with air from the ;sal passages.

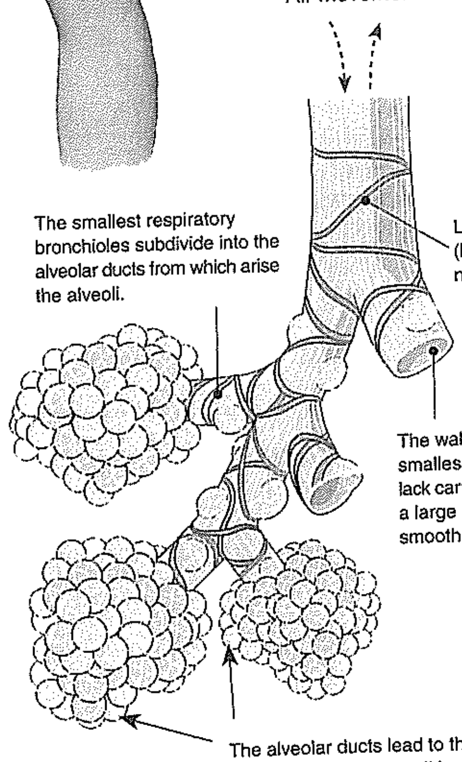
ıe **trachea** lies in front of the ;ophagus and extends into the ;orax. It is strengthened with C-ıaped bands of cartilage and ıed with ciliated epithelium.

ıe trachea splits into two **ronchi**. These are also ıpported by cartilage bands.

ironchioles branch off ıe bronchi and divide ıto progressively smaller ıranches. The cartilage is ;radually lost as the ıronchioles decrease in liameter.



Detail of a terminal bronchiole and its branches

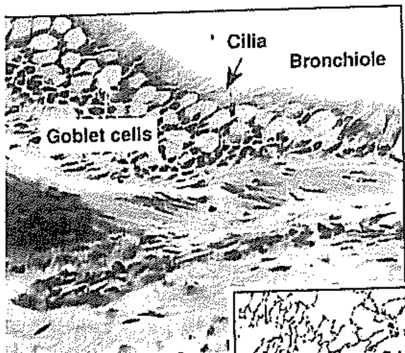


The smallest respiratory bronchioles subdivide into the alveolar ducts from which arise the alveoli.

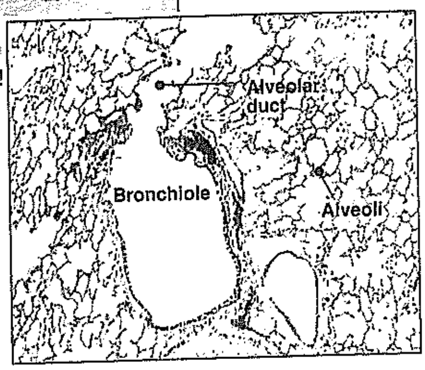
Lymph vessels (blood vessels not shown)

The walls of the smallest bronchioles lack cartilage but have a large amount of smooth muscle.

The alveolar ducts lead to the alveoli. The alveoli tend to recoil inward (deflate) after each breath out. A phospholipid **surfactant** helps to prevent collapse of the alveoli by decreasing surface tension.



Photograph above: The epithelial lining of the bronchioles is ciliated and lined with mucus-producing **goblet cells**.



Photograph right: Respiratory bronchiole and alveolar duct leading to alveoli. Note the thin alveolar walls.

The Respiratory System

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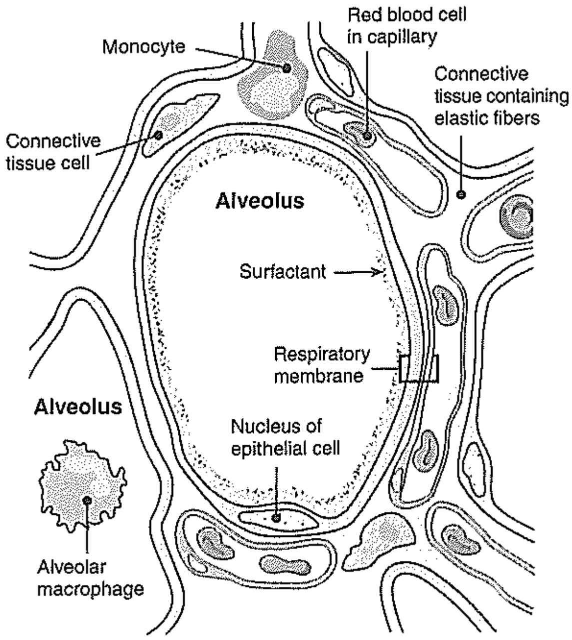
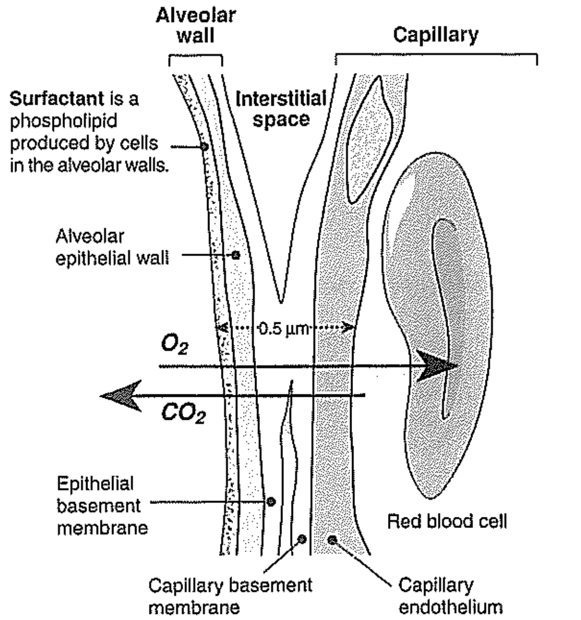
Related activities: Gas Transport in Humans

An Alveolus



The diagram above illustrates the physical arrangement of the alveoli to the capillaries through which the blood moves. Phagocytic monocytes and macrophages are also present to protect the lung tissue. Elastic connective tissue gives the alveoli their ability to expand and recoil.

The Respiratory Membrane



The **respiratory membrane** is the term for the layered junction between the alveolar epithelial cells, the endothelial cells of the capillary, and their associated basement membranes (thin, collagenous layers that underlie the epithelial tissues). Gases move freely across this membrane.

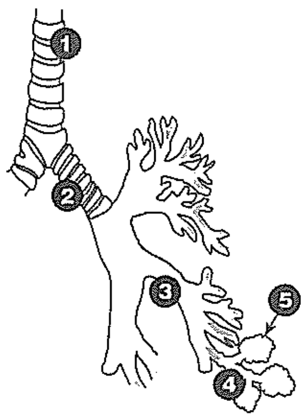
1. (a) Explain how the basic structure of the human respiratory system provides such a large area for gas exchange:

   (b) Identify the general region of the lung where exchange of gases takes place:

2. Describe the structure and purpose of the respiratory membrane:

3. Describe the role of the surfactant in the alveoli:

4. Using the information above and on the previous page, complete the table below summarizing the **histology of the respiratory pathway**. Name each numbered region and use a tick or cross to indicate the presence or absence of particular tissues.



	Region	Cartilage	Ciliated epithelium	Goblet cells (mucus)	Smooth muscle	Connective tissue
1						✓
2						
3		gradually lost				
4	Alveolar duct		✗	✗		
5					very little	

5. Babies born prematurely are often deficient in surfactant. This causes respiratory distress syndrome; a condition where breathing is very difficult. From what you know about the role of surfactant, explain the symptoms of this syndrome:

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Measuring Lung Function

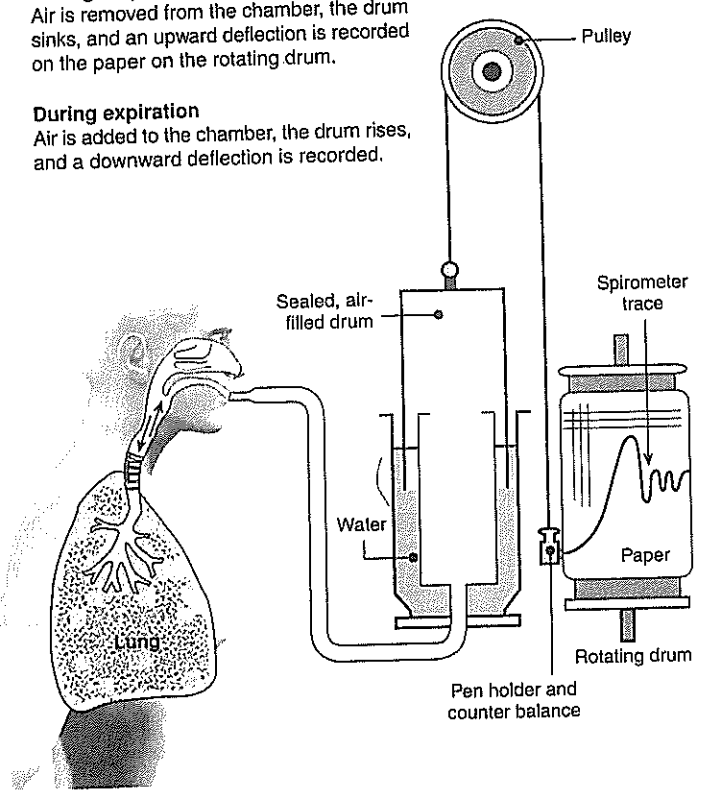
Changes in lung volume can be measured using a technique called **spirometry**. Total adult lung capacity varies between 4 and 6 litres (L or dm^3) and is greater in males. The **vital capacity**, which describes the volume exhaled after a maximum inspiration, is somewhat less than this because of the residual volume of air that remains in the lungs even after expiration. The exchange between fresh air and the residual volume is a slow process and the composition of gases in the lungs remains relatively constant. Once measured, the tidal volume can be used to calculate the **pulmonary ventilation rate** or PV, which describes the amount of air exchanged with the environment per minute. Measures of respiratory capacity provide one way in which a reduction in lung function can be assessed (for example, as might occur as result of disease or an obstructive lung disorder such asthma).

Determining changes in lung volume using spirometry

The apparatus used to measure the amount of air exchanged during breathing and the rate of breathing is a **spirometer** (also called a respirometer). A simple spirometer consists of a weighted drum, containing oxygen or air, inverted over a chamber of water. A tube connects the air-filled chamber with the subject's mouth, and soda lime in the system absorbs the carbon dioxide breathed out. Breathing results in a trace called a spirogram, from which lung volumes can be measured directly.

During inspiration
Air is removed from the chamber, the drum sinks, and an upward deflection is recorded on the paper on the rotating drum.

During expiration
Air is added to the chamber, the drum rises, and a downward deflection is recorded.



Lung Volumes and Capacities

The air in the lungs can be divided into volumes. Lung capacities are combinations of volumes.

DESCRIPTION OF VOLUME	Vol / L
Tidal volume (TV) Volume of air breathed in and out in a single breath	0.5
Inspiratory reserve volume (IRV) Volume breathed in by a maximum inspiration at the end of a normal inspiration	3.3
Expiratory reserve volume (ERV) Volume breathed out by a maximum effort at the end of a normal expiration	1.0
Residual volume (RV) Volume of air remaining in the lungs at the end of a maximum expiration	1.2
DESCRIPTION OF CAPACITY	
Inspiratory capacity (IC) = TV + IRV Volume breathed in by a maximum inspiration at the end of a normal expiration	3.8
Vital capacity (VC) = IRV + TV + ERV Volume that can be exhaled after a maximum inspiration.	4.8
Total lung capacity (TLC) = VC + RV The total volume of the lungs. Only a fraction of TLC is used in normal breathing	6.0

PRIMARY INDICATORS OF LUNG FUNCTION

Forced expiratory volume in 1 second (FEV_1)
The volume of air that is maximally exhaled in the first second of exhalation.

Forced vital capacity (FVC)
The total volume of air that can be forcibly exhaled after a maximum inspiration.

1. Describe how each of the following might be expected to influence values for lung volumes and capacities obtained using spirometry:

   (a) Height: ______

   (b) Gender: ______

   (c) Age: ______

2. A percentage decline in FEV_1 and FVC (to <80% of normal) are indicators of impaired lung function, e.g in asthma:

   (a) Explain why a forced volume is a more useful indicator of lung function than tidal volume:

   ______

   (b) Asthma is treated with drugs to relax the airways. Suggest how spirometry could be used during asthma treatment:

   ______

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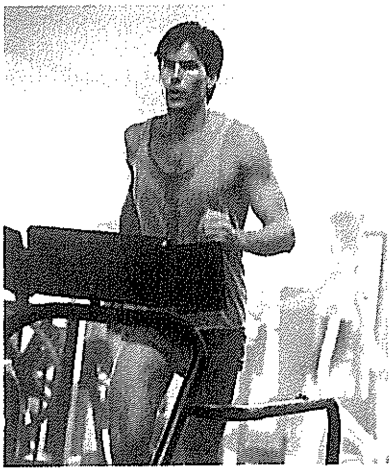
Related activities: The Human Respiratory System
Web links: Respiratory Basics Learning Activity

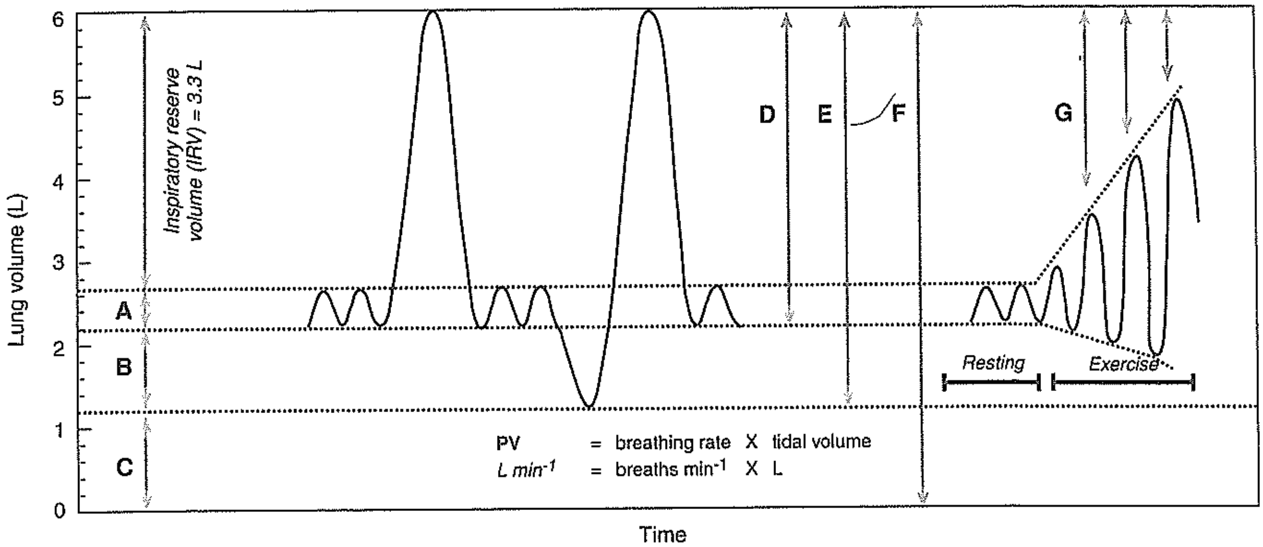


Respiratory gas	Approximate percentages of O_2 and CO_2		
	Inhaled air	Air in lungs	Exhaled air
O_2	21.0	13.8	16.4
CO_2	0.04	5.5	3.6

Above: The percentages of respiratory gases in air (by volume) during normal breathing. The percentage volume of oxygen in the alveolar air (in the lung) is lower than that in the exhaled air because of the influence of the **dead air volume** (the air in the spaces of the nose, throat, larynx, trachea and bronchi). This air (about 30% of the air inhaled) is unavailable for gas exchange.

Left: During exercise, the breathing rate, tidal volume, and PV increase up to a maximum (as indicated below).

Spirogram for a male during quiet and forced breathing, and during exercise



3. Using the definitions given on the previous page, identify the volumes and capacities indicated by the letters **A-F** on the spirogram above. For each, indicate the volume (vol) in liters (L). The inspiratory reserve volume has been identified:

(a) A: ______________________ Vol: ________ (d) D: ______________________ Vol: ________

(b) B: ______________________ Vol: ________ (e) E: ______________________ Vol: ________

(c) C: ______________________ Vol: ________ (f) F: ______________________ Vol: ________

4. Explain what is happening in the sequence indicated by the letter **G**: ______________________

5. Calculate PV when breathing rate is 15 breaths per minute and tidal volume is 0.4 L: ____________

6. (a) Describe what would happen to PV during strenuous exercise: ______________________

(b) Explain how this is achieved: ______________________

7. The table above gives approximate percentages for respiratory gases during breathing. Study the data and then:

(a) Calculate the difference in CO_2 between inhaled and exhaled air: ______________________

(b) Explain where this 'extra' CO_2 comes from: ______________________

(c) Explain why the dead air volume raises the oxygen content of exhaled air above that in the lungs: ____________

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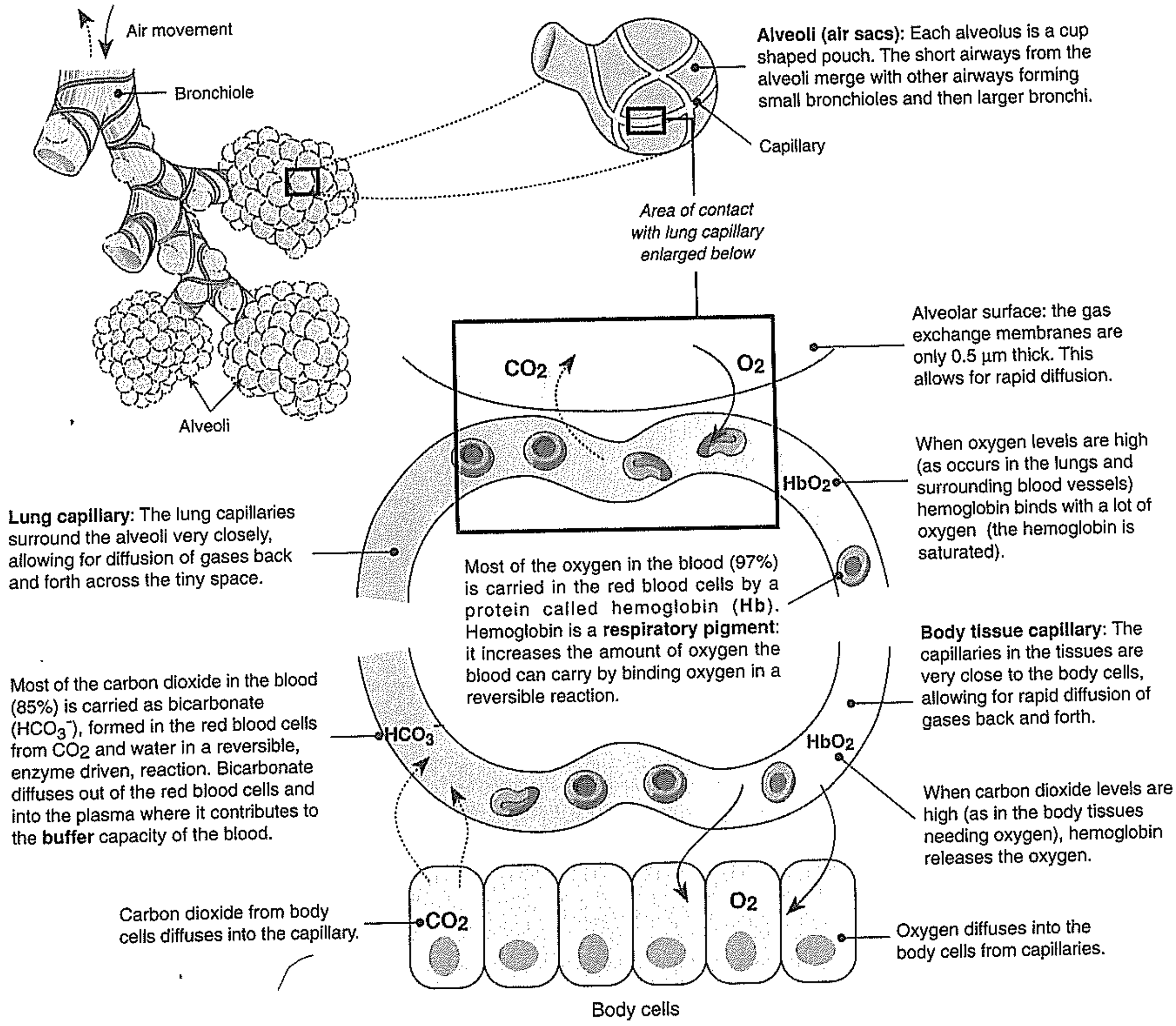
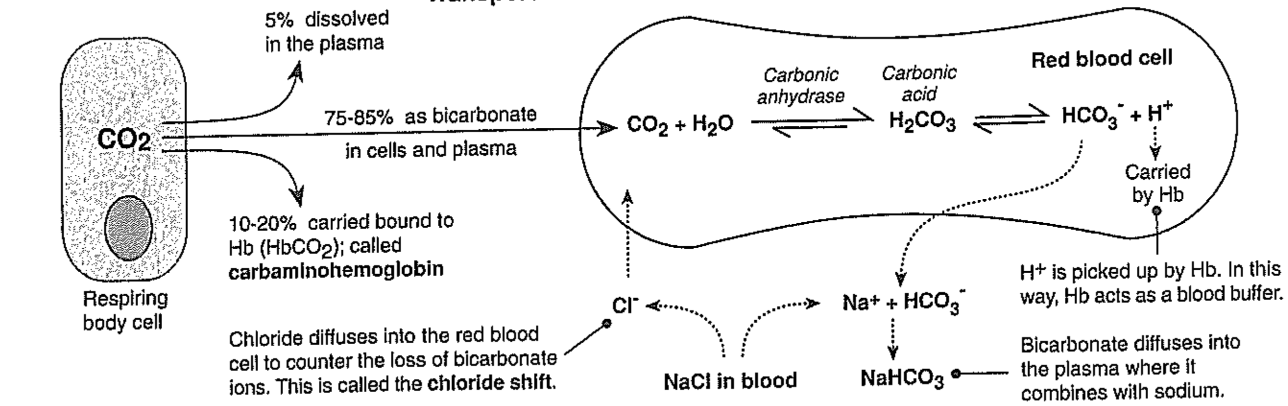
Gas Transport in Humans

he transport of respiratory gases around the body is the role
: the blood and its respiratory pigments. Oxygen is transported ıroughout the body chemically bound to the respiratory pigment **emoglobin** inside the red blood cells. In the muscles, oxygen om hemoglobin is transferred to and retained by **myoglobin**, a ıolecule that is chemically similar to hemoglobin except that it onsists of only one heme-globin unit. Myoglobin has a greater affinity for oxygen than hemoglobin and acts as an oxygen store within muscles, releasing the oxygen during periods of prolonged or extreme muscular activity. If the myoglobin store is exhausted, the muscles are forced into oxygen debt and must respire anaerobically. The waste product of this, lactic acid, accumulates in the muscle and is transported (as lactate) to the liver where it is metabolized under aerobic conditions.

Gas Exchange and Transport



Transport of Carbon Dioxide in the Blood



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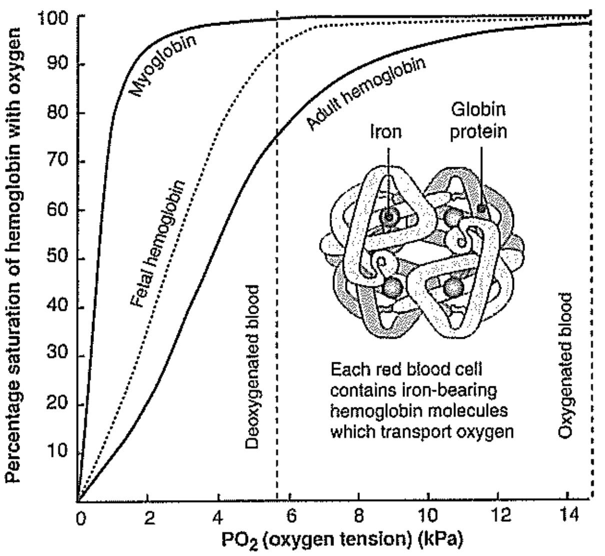
Related activities: The Human Respiratory System, Respiratory Pigments

Oxygen does not easily dissolve in blood, but is carried in chemical combination with hemoglobin (Hb) in red blood cells. The most important factor determining how much oxygen is carried by Hb is the level of oxygen in the blood. The greater the oxygen tension, the more oxygen will combine with Hb. This relationship can be illustrated with an oxygen-hemoglobin dissociation curve as shown below (Fig. 1). In the lung capillaries, (high O_2), a lot of oxygen is picked up and bound by Hb. In the tissues, (low O_2), oxygen is released. In skeletal muscle, myoglobin picks up oxygen from hemoglobin and therefore serves as an oxygen store when oxygen tensions begin to fall. The release of oxygen is enhanced by the **Bohr effect** (Fig. 2).

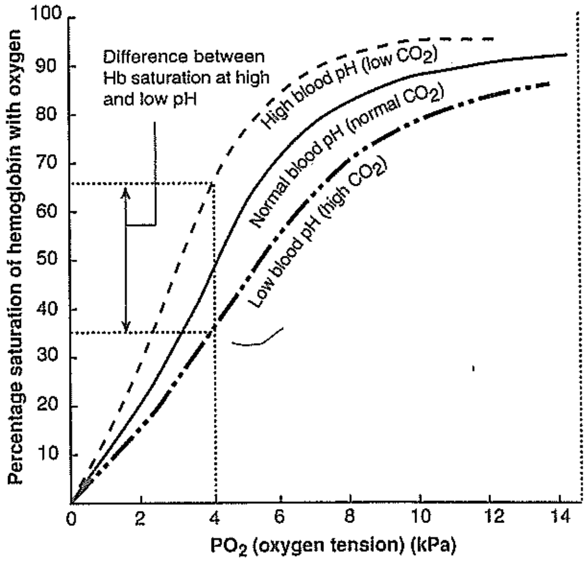
Respiratory Pigments and the Transport of Oxygen

Fig. 1: Dissociation curves for hemoglobin and myoglobin at normal body temperature for fetal and adult human blood.



As oxygen level increases, more oxygen combines with hemoglobin (Hb). Hb saturation remains high, even at low oxygen tensions. Fetal Hb has a high affinity for oxygen and carries 20-30% more than maternal Hb. Myoglobin in skeletal muscle has a very high affinity for oxygen and will take up oxygen from hemoglobin in the blood.

Fig. 2: Oxygen-hemoglobin dissociation curves for human blood at normal body temperature at different blood pH.



As pH increases (lower CO_2), more oxygen combines with Hb. As the blood pH decreases (higher CO_2), Hb binds less oxygen and releases more to the tissues (**the Bohr effect**). The difference between Hb saturation at high and low pH represents the amount of oxygen released to the tissues.

1. (a) Identify two regions in the body where oxygen levels are very high: ______

   (b) Identify two regions where carbon dioxide levels are very high: ______

2. Explain the significance of the **reversible binding** reaction of hemoglobin (Hb) to oxygen: ______

3. (a) Hemoglobin saturation is affected by the oxygen level in the blood. Describe the nature of this relationship:

   ______

   (b) Comment on the significance of this relationship to oxygen delivery to the tissues: ______

4. (a) Describe how fetal Hb is different to adult Hb: ______

   (b) Explain the significance of this difference to oxygen delivery to the fetus: ______

5. At low blood pH, less oxygen is bound by hemoglobin and more is released to the tissues:

   (a) Name this effect: ______

   (b) Comment on its significance to oxygen delivery to respiring tissue: ______

6. Explain the significance of the very high affinity of myoglobin for oxygen: ______

7. Identify the two main contributors to the buffer capacity of the blood: ______

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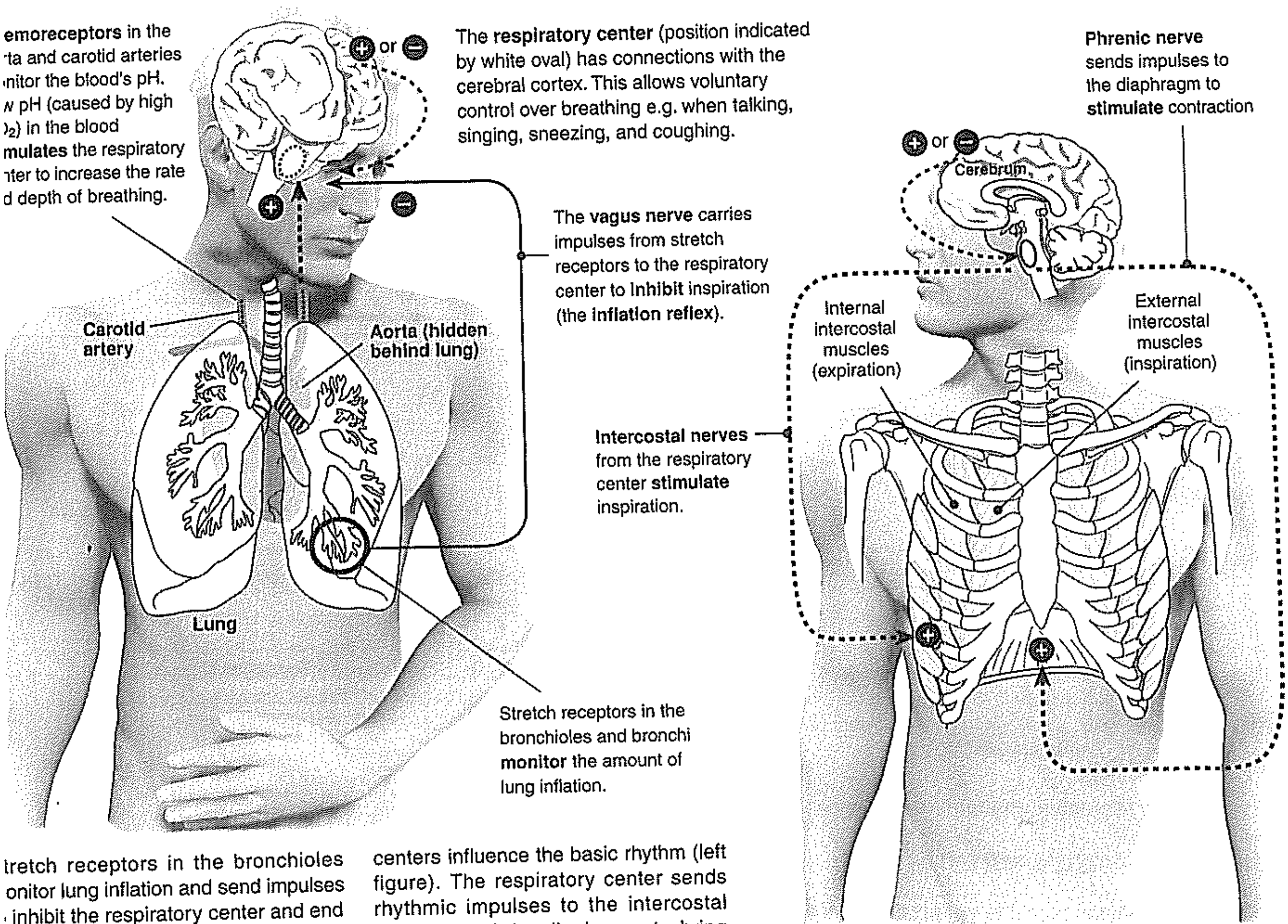
Control of Breathing

e basic rhythm of breathing is controlled by the **respiratory nter**, a cluster of neurons located in the medulla oblongata. This ·thm is adjusted in response to the physical and chemical changes that occur when we carry out different activities. Although the control of breathing is involuntary, we can exert some degree of conscious control over it. The diagram below illustrates these controls.

The Control of Breathing



ıtretch receptors in the bronchioles onitor lung inflation and send impulses · inhibit the respiratory center and end ıe breath in. Feedback from sensory ıceptors and input from the higher brain centers influence the basic rhythm (left figure). The respiratory center sends rhythmic impulses to the intercostal muscles and the diaphragm to bring about normal breathing (right figure).

. Explain how the basic rhythm of breathing is controlled: ______

!. Describe the role of each of the following in the regulation of breathing:

(a) Phrenic nerve: ______

(b) Intercostal nerves: ______

(c) Vagus nerve: ______

(d) Inflation reflex: ______

3. (a) Describe the effect of low blood pH on the rate and depth of breathing: ______

(b) Explain how this effect is mediated: ______

(c) Suggest why blood pH is a good mechanism by which to regulate breathing rate: ______

The Respiratory System

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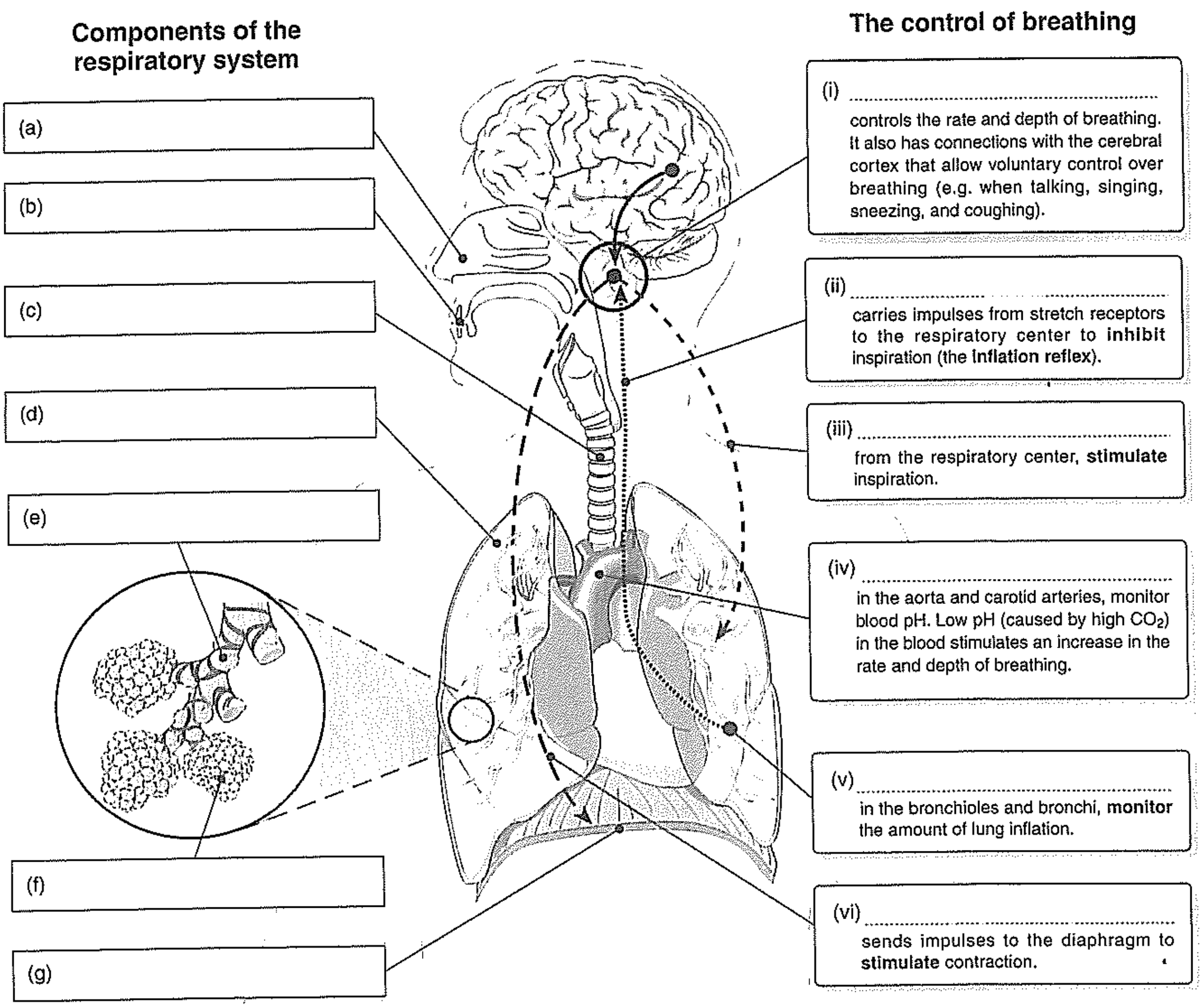
Related activities: Gas Transport in Humans

Review of Lung Function

The respiratory system in humans (and other air breathing vertebrates) includes the lungs and the system of tubes through which the air reaches them. Breathing (ventilation) provides a continual supply of fresh air to the lungs and helps to maintain a large diffusion gradient for respiratory gases across the gas exchange surface. The basic rhythm of breathing is controlled by the respiratory center in the medulla of the hindbrain. The volume of gases exchanged during breathing varies according to the physiological demands placed on the body. These changes can be measured using spirometry. The following activity summarizes the key features of respiratory system structure and function. The stimulus material can be found in earlier exercises in this topic.



1. On the diagram above, label the components of the respiratory system (a-g) and the components that control the rate of breathing (i - vi).

2. Identify the volumes and capacities indicated by the letters A - E on the diagram of a spirogram below.

A = ...

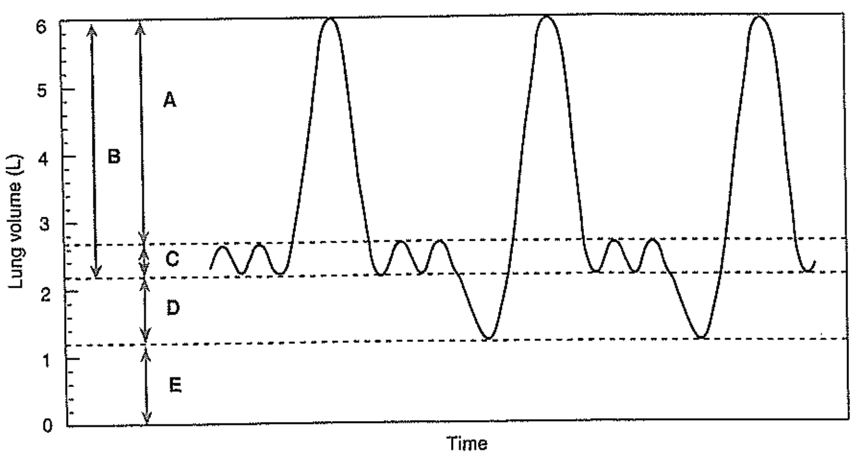
B = ...

C = ...

D = ...

E = ...

Spirogram for a male during quiet and forced breathing



Related activities: Breathing in Humans, The Human Respiratory System, Measuring Lung Function, Control of Breathing

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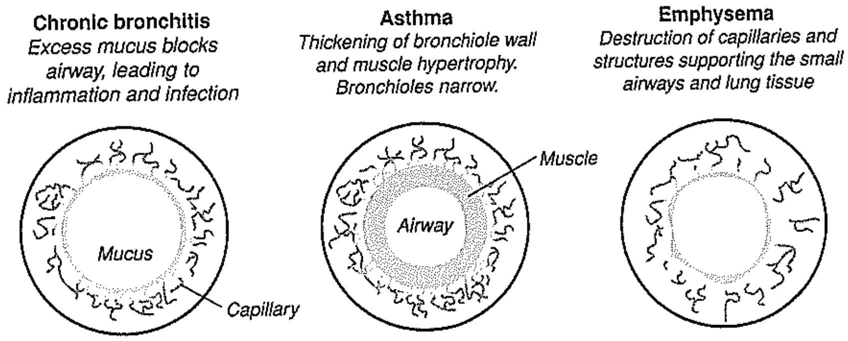
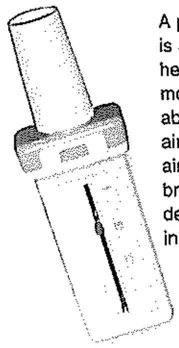
Respiratory Diseases

Respiratory diseases are diseases of the respiratory system, including diseases of the lung, bronchial tubes, trachea, and upper respiratory tract. Respiratory diseases include mild and self-limiting diseases such as the common cold, to life-threatening infections such as tuberculosis. One in six people in the US is affected by some form of chronic lung disease, the most common being asthma and chronic obstructive pulmonary disease (including emphysema and chronic bronchitis). Non-infectious respiratory diseases are categorized according to whether they prevent air reaching the alveoli (**obstructive**) or whether they affect the gas exchange tissue itself (**restrictive**).

Such diseases have different causes and different symptoms (below) but all are characterized by difficulty in breathing and the end result is similar in that gas exchange rates are too low to meet metabolic requirements. Non-infectious respiratory diseases are strongly correlated with certain behaviors and are made worse by exposure to air pollutants. Obstructive diseases, such as emphysema, are associated with an inflammatory response of the lung to noxious particles or gases, most commonly tobacco smoke. In contrast, scarring (**fibrosis**) of the lung tissue underlies restrictive lung diseases such as **asbestosis** and **silicosis**. Such diseases are often called occupational lung diseases.



Cross sections through a bronchiole with various types of obstructive lung disease



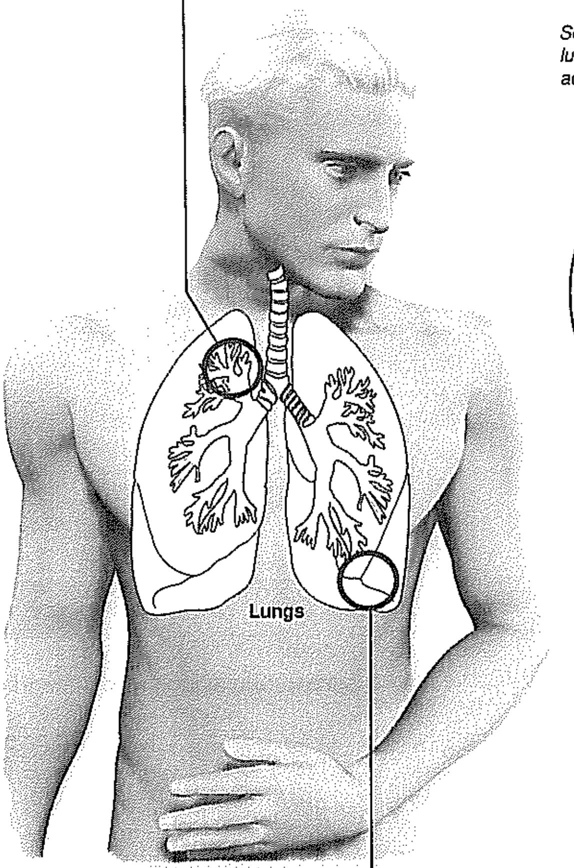
A peak flow meter is a small, hand-held device used to monitor a person's ability to breathe out air. It measures the airflow through the bronchi and thus the degree of obstruction in the airways.

Obstructive lung disease – passage blockage –

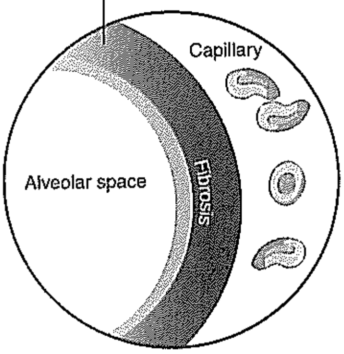
In obstructive lung diseases, a blockage prevents the air getting to the gas exchange surface.

The flow of air may be obstructed because of constriction of the airways (as in **asthma**), excess mucus secretion (as in **chronic bronchitis**), or because of reduced lung elasticity, which causes alveoli and small airways to collapse (as in **emphysema**). Shortness of breath is a symptom in all cases and chronic bronchitis is also associated with a persistent cough.

Chronic bronchitis and emphysema often occur together and are commonly associated with cigarette smoking, but can also occur with chronic exposure to air pollution.



Scarring (fibrosis) makes the lung tissue stiffer and prevents adequate gas exchange



Restrictive lung disease – scarring –

Restrictive lung diseases are characterized by scarring or **fibrosis** within the gas exchange tissue of the lung (above). As a result of the scarring, the lung tissue becomes stiffer and more difficult to expand, leading to shortness of breath.

Restrictive lung diseases are usually the result of exposure to inhaled substances (especially dusts) in the environment, including **inorganic dusts** such as silica, asbestos, or coal dust, and **organic dusts**, such as those from bird droppings or moldy hay. Like most respiratory diseases, the symptoms are exacerbated by poor air quality (such as occurs in smoggy cities).

SEM of asbestos fibers. Asbestos has different toxicity depending on the type. Some types are very friable, releasing fibers into the air, where they can be easily inhaled.

The Respiratory System

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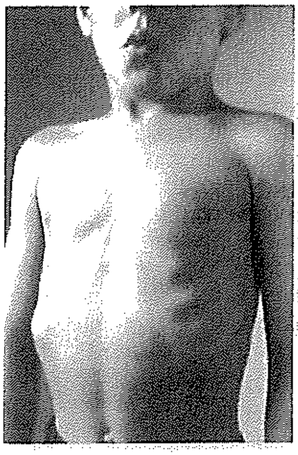
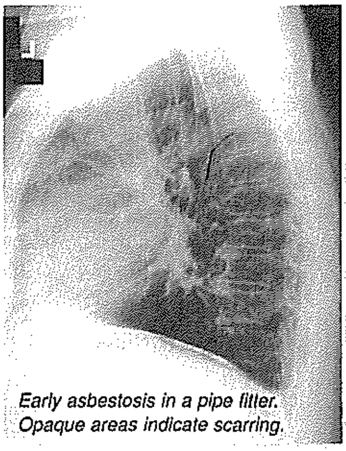
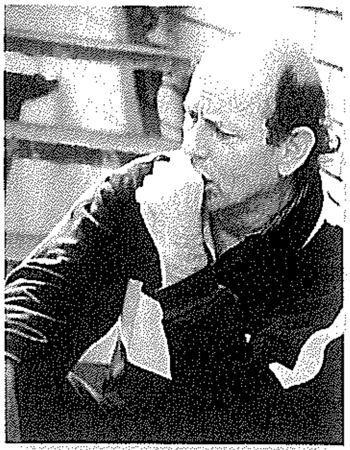
Related activities: Measuring Lung Function, Allergies and Hypersensitivity, Diseases Caused by Smoking **Web links:** What is Asthma?





Early asbestosis in a pipe fitter. Opaque areas indicate scarring.

Photo: Clinical Cases



Asthma is a common disease affecting millions of people worldwide (20 million in the US alone). Asthma is the result of a hypersensitive reaction to allergens such as house dust or pollen, but attacks can be triggered by environmental factors such as cold air, exercise, or air pollutants. During an attack, sufferers show labored breathing with overexpansion of the chest cavity (above left). Asthma is treated with drugs that help to expand the airways (bronchodilators). These are usually delivered via a nebulizer or inhaler (above).

Asbestosis is a restrictive lung disease caused by breathing in asbestos fibers. The tiny fibers make their way into the alveoli where they cause damage and lead to scarring. Other occupational lung diseases include silicosis (exposure to silica dust) and coal workers' pneumoconiosis.

Chronic bronchitis is accompanied by a persistent, productive cough, where sufferers attempt to cough up the sputum or mucus which accumulates in the airways. Chronic bronchitis is indicated using **spirometry** by a reduced FEV_1/FVC ratio that is not reversed with bronchodilator therapy.

1. Distinguish between obstructive and restrictive lung diseases, and provide some examples:

2. Physicians may use spirometry to diagnosis certain types of respiratory disease. Explain the following typical results:

   (a) In patients with chronic obstructive pulmonary disease, the FEV_1 / FVC ratio declines (to <70% of normal):

   (b) Patients with asthma also have a FEV_1 / FVC ratio of <70%, but this improves following use of bronchodilators:

   (c) In patients with restrictive lung disease, both FEV_1 and FVC are low but the FEV_1 / FVC ratio is normal to high:

3. Describe the mechanisms by which restrictive lung diseases reduce lung function and describe an example:

4. Suggest why many restrictive lung diseases are also classified as occupational lung diseases:

5. Describe the role of histamine in the occurrence of an asthma attack:

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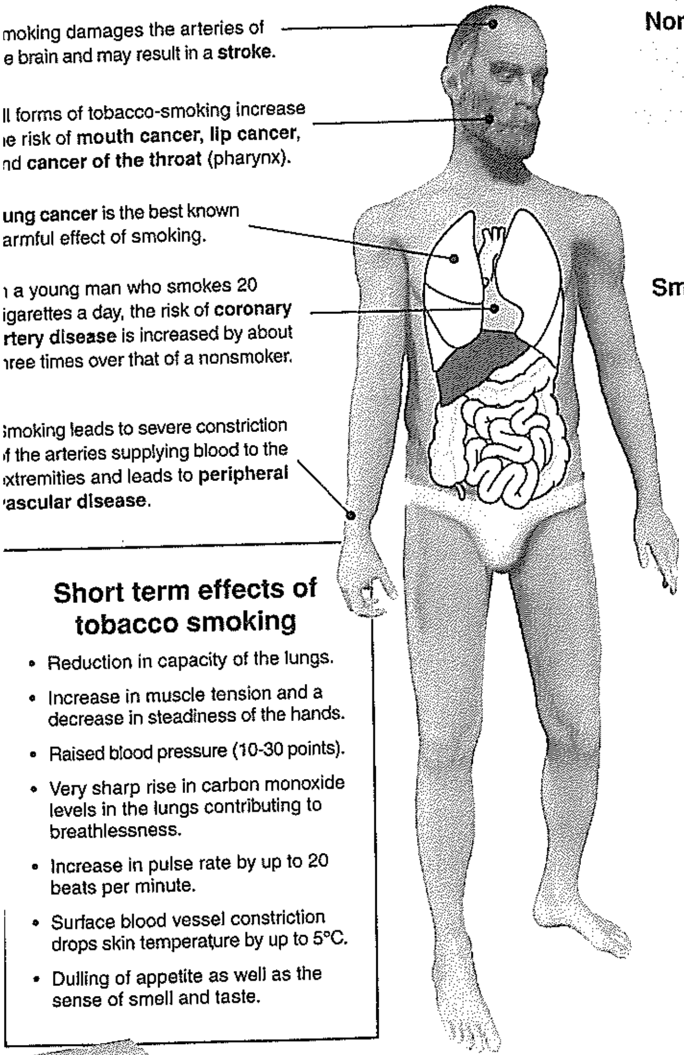
Smoking and the Lungs

bacco smoking has been accepted as a major health hazard ly relatively recently in historical terms, despite its practice in estern countries for more than 400 years, and much longer sewhere. Cigarettes became popular at the end of World War I cause they were cheap, convenient, and easier to smoke than pes and cigars. They remain popular for the further reason that ey are more addictive than other forms of tobacco. The milder noke can be more readily inhaled, allowing **nicotine** (a powerful ldictive poison) to be quickly absorbed into the bloodstream. **ing cancer** is the most widely known and most harmful effect of smoking; 98% of cases are associated with cigarette smoking. Symptoms include chest pain, breathlessness, and coughing up blood. Tobacco smoking is also directly associated with coronary artery disease, emphysema, chronic bronchitis, peripheral vascular disease, and stroke. The damaging components of cigarette smoke include tar, carbon monoxide, nitrogen dioxide, and nitric oxide. Many of these harmful chemicals occur in greater concentrations in sidestream smoke (as occurs as a result of **passive smoking**) than in mainstream smoke (inhaled) due to the presence of a filter in the cigarette.

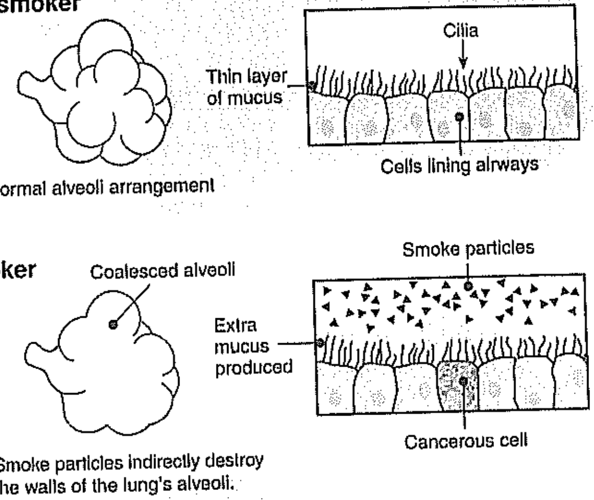
Long term effects of tobacco smoking

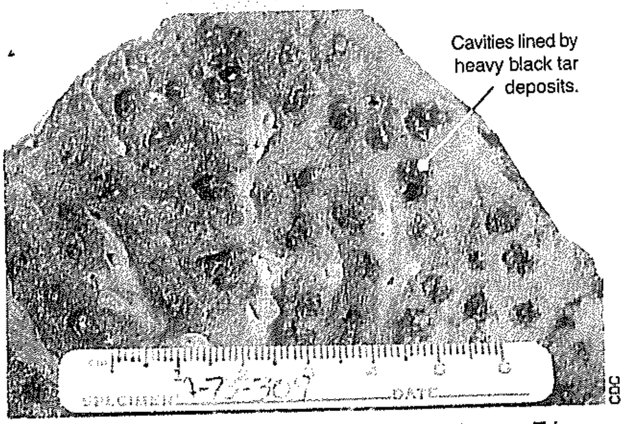


Short term effects of tobacco smoking

- Reduction in capacity of the lungs.
- Increase in muscle tension and a decrease in steadiness of the hands.
- Raised blood pressure (10-30 points).
- Very sharp rise in carbon monoxide levels in the lungs contributing to breathlessness.
- Increase in pulse rate by up to 20 beats per minute.
- Surface blood vessel constriction drops skin temperature by up to 5°C.
- Dulling of appetite as well as the sense of smell and taste.

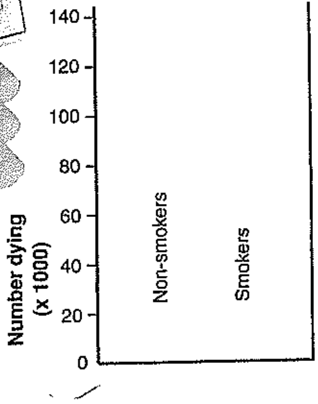
How smoking damages the lungs



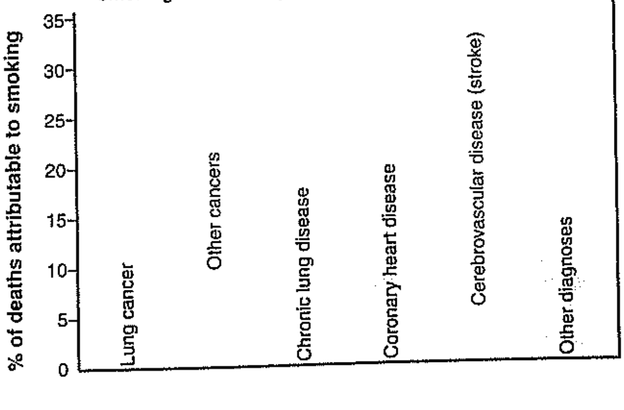


Gross pathology of lung tissue from a patient with emphysema. Tobacco tar deposits can be seen. Tar contains at least 17 known carcinogens.

Deaths from lung cancer in smokers and non-smokers (US, 2004)



Estimated annual percentage of deaths attributable to smoking in the US by cause (1997-2001 mortality data)



The Respiratory System

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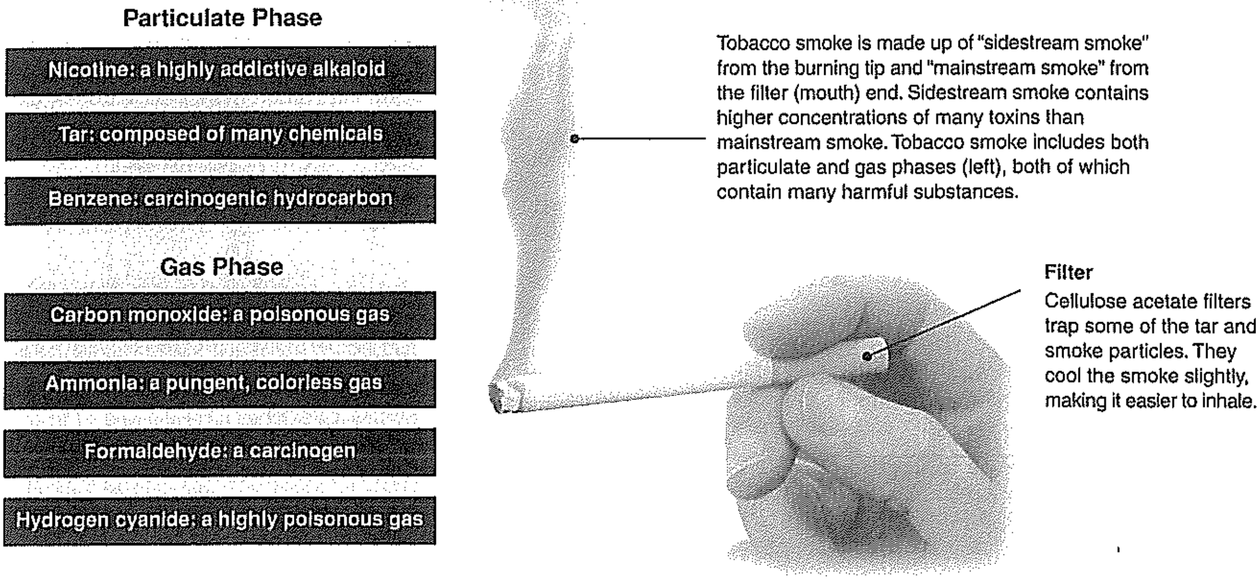
Related activities: Gas Transport In Humans, Cardiovascular Disease
Web links: CDC: The Health Consequences of Smoking

Components of Cigarette Smoke



1. Discuss the physical changes to the lung that result from long-term smoking:

2. Determine the physiological effect of each of the following constituents of tobacco smoke when inhaled:

   (a) Tar:

   (b) Nicotine:

   (c) Carbon monoxide:

3. Describe the symptoms of the following diseases associated with long-term smoking:

   (a) Emphysema:

   (b) Chronic bronchitis:

   (c) Lung cancer:

4. Evaluate the evidence linking cigarette smoking to increased incidence of respiratory and cardiovascular diseases:

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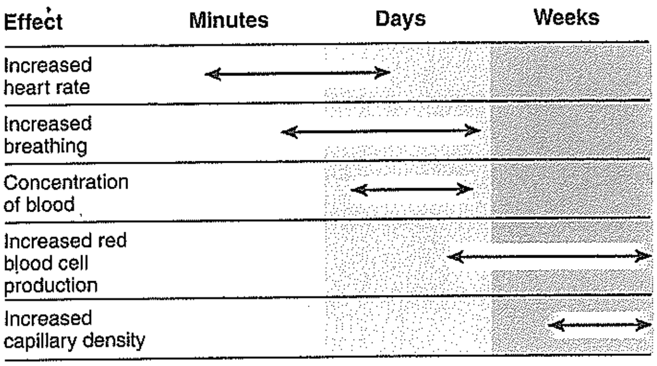
The Effects of High Altitude

The air at high altitudes contains less oxygen than the air at sea level. Air pressure decreases with altitude so the pressure (therefore amount) of oxygen in the air also decreases. Sudden exposure to an altitude of 2000 m would make you breathless on exertion and above 7000 m most people would become unconscious. The effects of altitude on physiology are related to this lower oxygen availability. Humans and other animals can make some physiological adjustments to life at altitude; this is called acclimatization. Some of the changes to the cardiovascular and respiratory systems to high altitude are outlined below.

Mountain Sickness

Altitude sickness or mountain sickness is usually a mild illness associated with trekking to altitudes of 5000 meters or so. Common symptoms include headache, insomnia, poor appetite and nausea, vomiting, dizziness, tiredness, coughing and breathlessness. The best way to avoid mountain sickness is to ascend to altitude slowly (no more than 300 m per day above 3000 m). Continuing to ascend with mountain sickness can result in more serious illnesses: accumulation of fluid on the brain (cerebral edema) and accumulation of fluid in the lungs (pulmonary edema). These complications can be fatal if not treated with oxygen and a rapid descent to lower altitude.

Physiological Adjustment to Altitude



The human body can make adjustments to life at altitude. Some of these changes take place almost immediately: breathing and heart rates increase. Other adjustments may take weeks (see above). These responses are all aimed at improving the rate of supply of oxygen to the body's tissues. When more permanent adjustments to physiology are made (increased blood cells and capillary networks) heart and breathing rates can return to normal.

People who live permanently at high altitude, e.g. Tibetans, Nepalese, and Peruvian Indians, have physiologies adapted (genetically, through evolution) to high altitude. Their blood volumes and red blood cell counts are high, and they can carry heavy loads effortlessly despite a small build. In addition, their metabolism uses oxygen very efficiently.

Llamas, vicunas, and Bactrian camels are well suited to high altitude life. Vicunas and llamas, which live in the Andes, have high blood cell counts and their red blood cells live almost twice as long as those in humans. Their hemoglobin also picks up and offloads oxygen more efficiently than the hemoglobin of most mammals.

1. (a) Describe the general effects of high altitude on the body: ______________________

   ____

   (b) Name the general term given to describe these effects: ______________________

2. (a) Name one short term physiological adaptation that humans make to high altitude: ______________________

   ____

   (b) Explain how this adaptation helps to increase the amount of oxygen the body receives: ______________________

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3. (a) Describe one longer term adaptation that humans can make to living at high altitude: ______________________

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   (b) Explain how this adaptation helps to increase the amount of oxygen the body receives: ______________________

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Related activities: Control of Breathing