9 Gas exchange and smoking

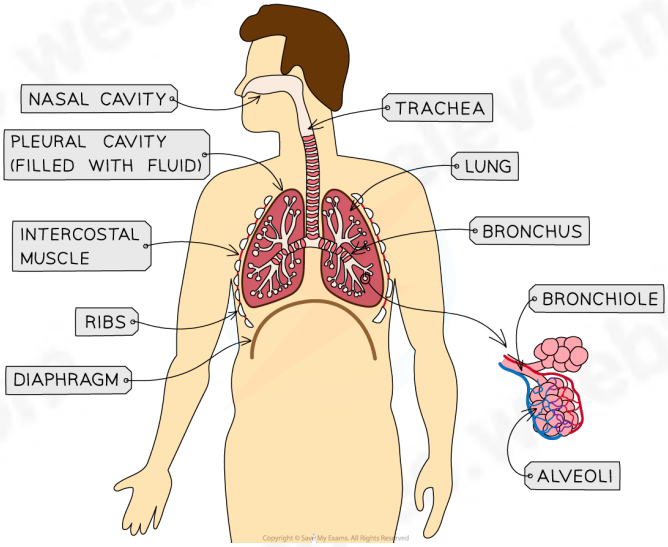
9.1 The gas exchange system

The gas exchange system is responsible for the uptake of oxygen into the blood and the excretion of carbon dioxide.

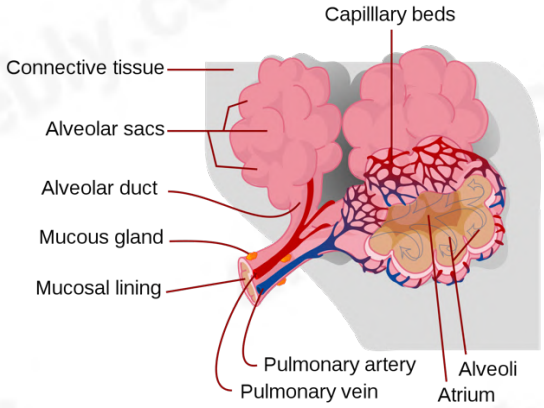
The gas exchange surface in the lungs is extensive, very thin, well supplied with blood and well ventilated.

The trachea and bronchi provide little resistance to the movement of air to and from the alveoli.

Gross structure of the human gas exchange system



- in single-celled organisms, oxygen can simply diffuse from fluid outside the cell through the cell surface membrane into the cytoplasm
- however, for multicellular organisms such as humans, most cells are at considerable distances from the external environment from which oxygen is obtained
- therefore, they need specialised gas exchange surfaces (alveoli) where oxygen can diffuse into the body, and carbon dioxide can diffuse out



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STRUCTURE	SUMMARY
trachea	• airway that leads from the throat to the bronchi • lined with goblet cells and cilia
lungs	• present in the thoracic cavity surrounded by pleural membranes • contains pleural fluid to allow friction free movement between the lungs, and diaphragm and ribs
bronchi	• located at the base of the trachea and have a similar structure to it albeit narrower • each bronchus divides many times to forms smaller bronchioles • terminal bronchioles divide to form even narrower respiratory bronchioles that supply alveoli with air
bronchioles	• very narrow tubes (<1mm) that carry air from the bronchi to the alveoli • do not contain cartilage unlike the trachea and bronchi and so can collapse
alveoli	• main site of gas exchange in the lungs • essentially are tiny sacs with many structural adaptations to enable gas exchange
capillary network	• an extensive network of capillaries surrounds the alveoli • they are also an extensive exchange surface between the lungs and the blood

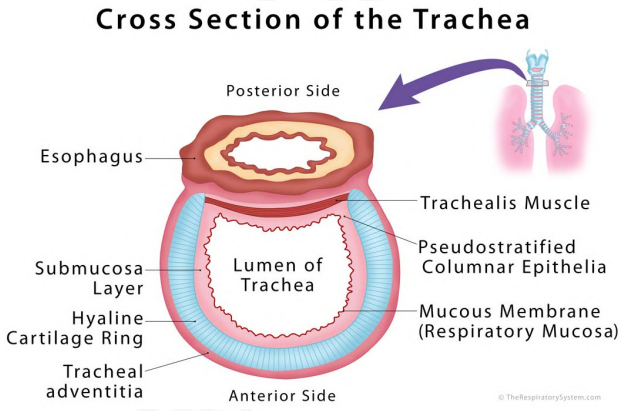
Trachea → bronchi → bronchioles

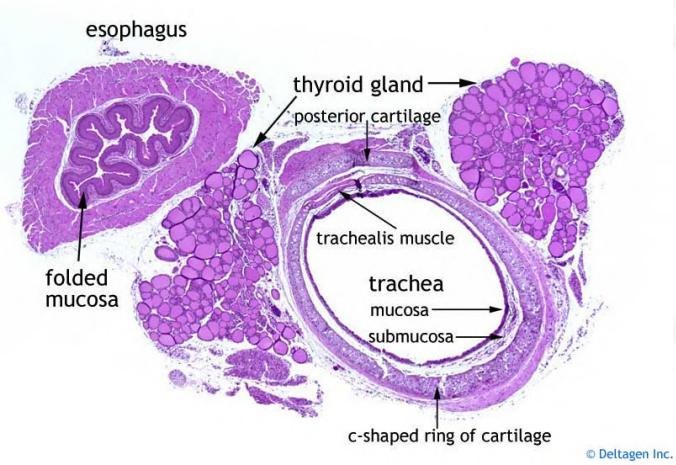
Cartilage

Cartilage is a flexible connective tissue of which the main cell type are chondrocytes.

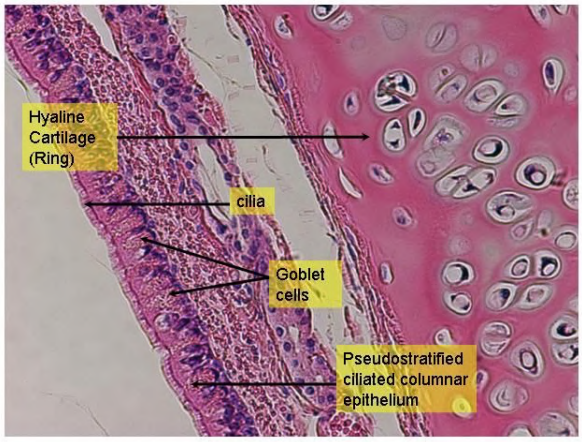
- cartilage in the trachea and bronchi keep the airways open and air resistance low
- also prevents the airways from collapsing/bursting as air pressure changes during breathing
- the structure of the cartilage differs slightly in the bronchi and trachea

a) Trachea





- cartilage here is present in a **regular arrangement of C-shaped rings**
- the trachea as a whole is supported by these rings of cartilage



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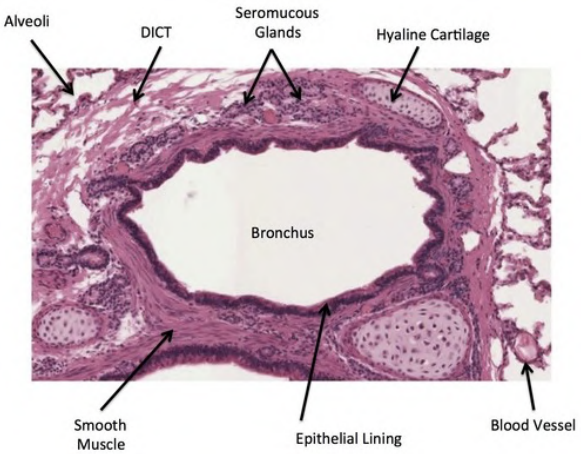
- the lining is comprised of ciliated epithelium *(ciliated cells + goblet cells)* which rests on a basement membrane of protein fibres
- beneath the epithelium is an area of loose tissue with blood vessels and mucous glands

b) Bronchi *(singular 'bronchus')*



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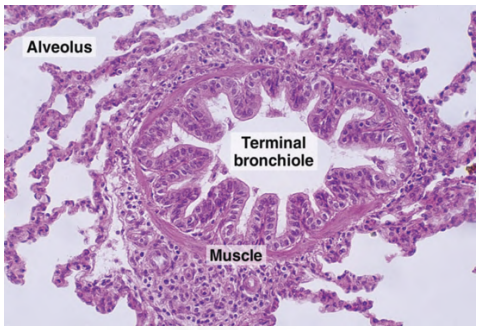
- cartilage here is present in **irregular blocks**
- there are fewer goblet cells per cm^2 than in the trachea and the epithelial cells are not as tall
- beneath the epithelium, there are elastic fibres

c) Bronchioles

Image: https://i.pinimg.com/

- surrounding the epithelium is smooth muscle which can contract or relax to adjust diameter
- there is no cartilage (to make such adjustments to diameter possible
- around the bronchiole are some alveoli



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Outline the function of cartilage in the human gas exchange system

1) keep airways open
2) provides support
3) allow flexibility
4) rings allow widening during inspiration

Outline the function of smooth muscle in the human gas exchange system

1) contraction and relaxation
2) changes diameter of trachea, bronchus, bronchioles
3) controls air flow in bronchioles

Warming and cleaning the air

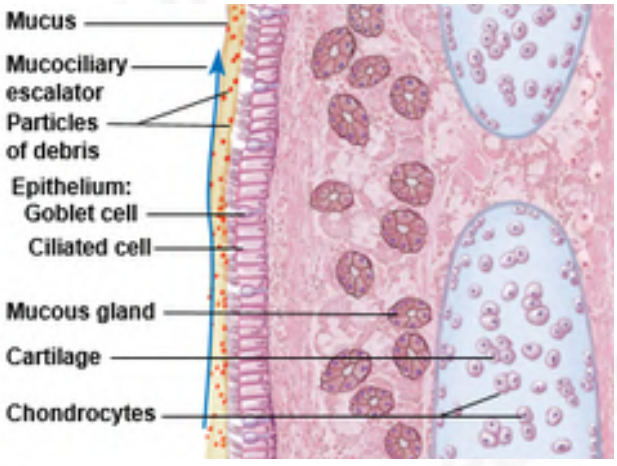
- air is warmed to body temperature and moistened in the nose and trachea to prevent delicate areas in the lungs from desiccation (drying out)
- protection is also needed against the suspended matter carried in the air which may include dust, sand, pollen, fungal spores, bacteria, and viruses
- there are both mechanical and chemical barriers to protect against these particles which are all potential threats to the functioning of the lungs

MECHANICAL
hairs inside the nose
(catch particles >5-10μm)

CHEMICAL
mucus lining nasal passages + other airways

Mucus

- mucus is produced by goblet cells of the ciliated epithelium
- the upper part of each goblet cell is swollen with mucin droplets which have been secreted by the cell
- mucus is a slimy solution of mucin which is composed of glycoproteins with many carbohydrate chains that make them sticky and able to trap inhaled particles
- mucus is also made by mucous glands beneath the epithelium



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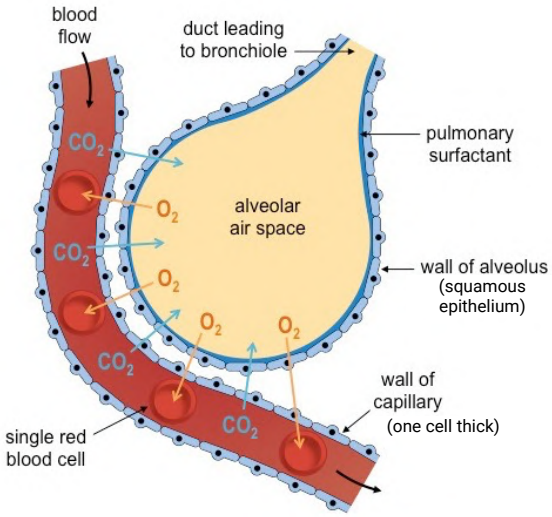
- some chemical pollutants like SO_2 and NO_2 can dissolve in mucus to form an acidic solution that irritates the airway lining

Goblet cells and ciliated cells

- between goblet cells, there are ciliated cells
- ciliated cells have cytoplasmic extensions which beat rhythmically to move mucus up the throat
- when mucus is at the top of the trachea, it's swallowed – pathogens are destroyed by stomach acid

Alveoli *(singular 'alveolus')*

At the end of the pathway between the atmosphere and the bloodstream are the alveoli. They are the main site of gas exchange.



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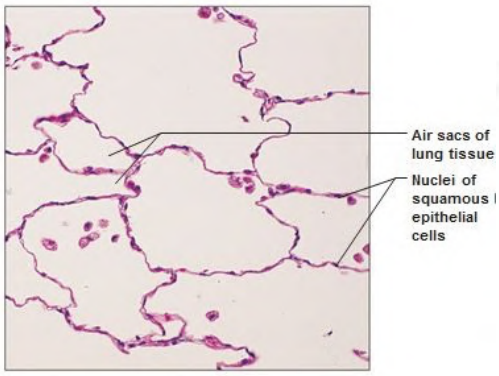
How alveoli are adapted for gas exchange

1) squamous epithelium is one cell thick



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2) for short diffusion distance
3) collectively many so large surface area for gas exchange
4) surrounded by a network of capillaries
5) so, RBC can come very close to air maintaining diffusion gradient

Elastic fibres in alveoli walls

- stretch during inspiration
- recoil during expiration
- elasticity allows alveoli to expand according to volume of air breathed in
- it is the elastic abilities of alveoli which enable them to have such a large surface area

Process of gas exchange between air in the alveoli and blood

- oxygen and carbon dioxide are exchanged in a process of simple diffusion – passive movement from high to low concentration
- the air in the alveoli contains a high concentration of oxygen
- the blood in the capillaries has a relatively low concentration of oxygen and a high concentration of carbon dioxide
  - the oxygen diffuses from the alveoli into the blood capillaries, before being carried away to the rest of the body for aerobic respiration
  - the carbon dioxide diffuses from the blood into the alveoli and is then exhaled

Summary of structures in the gas exchange system

	CARTILAGE	GOBLET CELLS	SMOOTH MUSCLE	CILIA
TRACHEA	✓	✓	✓	✓
BRONCHUS	✓	✓	✓	✓
TERMINAL BRONCHIOLE	✗	✗	✓	✓
RESPIRATORY BRONCHIOLE	✗	✗	✗	✓
ALVEOLI	✗	✗	✗	✗

9.2 Smoking

Tobacco smoke

- composed of **'mainstream'** smoke (from the filter or mouth end) and **'side stream'** smoke (from the burning tip)
- when a person smokes, about 85% the smoke released is side stream smoke
- many of the toxic ingredients are in a higher concentration in side stream than mainstream smoke
- these are breathed in by **passive smokers**

Main components of cigarette smoke

1) tar
   - tar is a mixture of compounds that settles on the lining of the airways in the lungs and stimulates a series of changes that may lead to obstructive lung diseases and cancer
   - tar contains carcinogens (cancer-causing compounds) which can cause mutations in the genes that control cell division
2) **carbon monoxide** – binds with haemoglobin resulting in the formation of carboxyhaemoglobin, decreasing the oxygen carrying capacity of red blood cells
3) **nicotine** – addictive

Effect of nicotine on the cardiovascular system

1) blood pressure increases
2) heart rate increases
3) platelets become sticky (increased risk of thrombosis)
4) endothelium damaged
5) blood vessels constrict
6) decreased blood flow to extremities

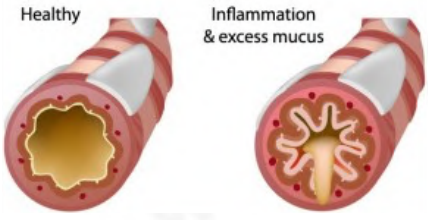
Lung diseases

- very small particles (<2μm) can reach the alveoli and stay there
- such deposits make lungs susceptible to airborne infections such as influenza, pneumonia, and in some people, can cause an allergic reaction leading to asthma
- **chronic** (long-term) **obstructive pulmonary diseases (COPD)** such as asthma, chronic **bronchitis**, and **emphysema** are now common in many countries
- atmospheric pollution from vehicle and industrial emissions and tobacco smoke are linked with these diseases

Chronic bronchitis

Tar –

1) stimulates goblet cells and mucous glands to enlarge and secrete more mucus
2) inhibits the cleaning action of ciliated epithelium that lines airways
3) consequently, mucus and the pathogens in it accumulates in bronchioles and obstructs them. this causes smoker's cough, an attempt to move mucus up airways
4) the damaged epithelia are replaced by scar tissue
5) smooth muscle surrounding bronchioles and bronchi become thicker causing airway to narrow and making it difficult to breathe
6) infections develop in accumulated mucus causing the lining to become inflamed, further narrowing the airway



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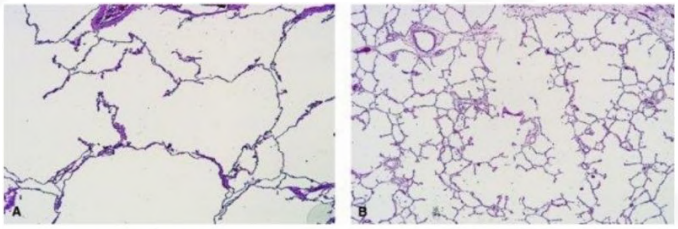
Emphysema

1) inflammation of constantly infected lungs causes phagocytes to line airways
2) they release elastase which destroys elastin in alveoli walls to reach lungs from capillaries
3) elastin is responsible for recoil of alveoli during expiration
4) with less elastin, alveoli cannot stretch and recoil, so bronchioles collapse during expiration trapping air and causing alveoli to burst
5) surface area for gas exchange is reduced and blood as a result is not oxygenated properly, leading to a rapid breathing rate
6) blood vessels become resistant to blood flow in lungs, to compensate, blood pressure in pulmonary artery increases and overtime, right side of the heart enlarges



emphysema normal lung

Image: https://i.pinimg.com/

Symptoms of emphysema

1) shortness of breath
2) wheezing (on inspiration)
3) rapid breathing rate
4) chest tightness/pain
5) cyanosis / bluish appearance to skin
6) fatigue
7) barrel chest

Describe the role of macrophages in the lungs. [3]

1) prevention of infections
2) prevents pathogens from entering rest of body/blood
3) carry out phagocytosis
4) engulf pathogens
5) macrophages are antigen presenting cells (APCs)

Signs and symptoms of COPD

1) fatigue/weakness
2) persistent cough
3) rapid breathing
4) cough produces much mucus
5) barrel-shaped chest
6) bluish colour to skin

Effect of COPD on the heart

1) increase in power of contraction
2) increase in systolic bp
3) right ventricle increases in thickness
4) insufficient oxygen received by cardiac muscles
5) heart failure/attack