Gas exchange and smoking

- The gas exchange system
- Smoking and smoking-related diseases

Learning objective:

Describe the structure of the human gas exchange system, including the microscopic structure of the walls of the trachea, bronchioles and alveoli with their associated blood vessels;

Describe the distribution of cartilage, ciliated epithelium, goblet cells and smooth muscle in the trachea, bronchi and bronchioles;

Describe the functions of cartilage, cilia, goblet cells, smooth muscle and elastic fibres in the gas exchange system;

Cartilage in the walls of the trachea and bronchi provides support and prevent the tubes collapsing when the air pressure inside them is low.

Ciliated epithelium is found lining the trachea, bronchi and some bronchioles. It is single layer of cells whose outer surfaces are covered with many thin extensions (cilia) which are able to move. They sweep mucus upwards towards the mouth, helping to prevent dust particles and bacteria reaching the lungs.

Goblet cells are found in the ciliated epithelium. They secrete mucus, which traps dust particles and bacteria.

Smooth muscle cells are found in the walls of the trachea, bronchi and bronchioles. This type of muscle can contract slowly but for long periods without tiring. When it contracts, it reduces the diameter of the tubes. During exercise it relaxes, widening thee tubes so more air can reach the lungs.

Elastic fibres are found in the walls of all tubes and between the alveoli. When breathing in, these fibres stretch to allow the alveoli and airways to expand. When breathing out, they recoil, helping to reduce the volume of alveoli and expel air out of the lungs.

Describe the process of gas exchange between air in the alveoli and the blood;

The air inside an alveolus contains a higher concentration of oxygen, and a lower concentration of carbon dioxide, than the blood in the capillaries. This blood has been brought to the lungs in the pulmonary artery, which carries deoxygenated blood from the
heart. Oxygen therefore diffuses from the alveolus into the blood capillary, through the thin walls of the alveolus and the capillary. Carbon dioxide diffuses from the capillary into the blood.

The diffusion gradients for these gases are maintained by:

- Breathing movements, which draw air from outside the body into the lungs, and then push it out again; this maintains a relatively high concentration of oxygen and low concentration of carbon dioxide in the alveoli;
- Blood flow past the alveolus, which brings deoxygenated blood and carries away oxygenated blood.
Describe the effects of tar and carcinogens in tobacco smoke on the gas exchange system;

- **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 lung cancer.
- **Carcinogens** are cancer-causing compounds. These cause mutations in the genes that control cell division.

Describe the signs and symptoms of lung cancer and chronic obstructive pulmonary disease (emphysema and chronic bronchitis);

**Lung cancer**

- Takes 20-30 years to develop
- Most of the growth of a tumour occurs before there are any symptoms
- Most common symptoms are: coughing blood as a result of the tissue damage
- Chest pain and people find it difficult to breath.
- It is rare for the cancer to be diagnosed before it reaches 1cm in diameter.

**Chronic obstructive pulmonary disease**

**Chronic bronchitis:**

- Infections such as pneumonia easily develop in the accumulated mucus. When there is an infection in the lungs, the lining becomes inflamed and this further narrows the airways. This damage and obstruction of the airways is chronic bronchitis. Sufferers have a severe cough, producing large quantities of phlegm, which is a mixture of mucus, bacteria and some white blood cells.

**Emphysema:**

- Smoking causes inflammation in the lungs. This involves the presence of increased numbers of white blood cells, some of which secrete chemicals that damage elastic fibres. This makes the alveoli less elastic. They may burst, resulting in larger air spaces. This reduces the surface area available for gas exchange. This is called emphysema. A person with emphysema had shortness of breath, meaning they struggle to breathe as deeply as they need to, especially when exercising.

Describe the effects of nicotine and carbon monoxide on the cardiovascular system;

- Nicotine is the drug in tobacco. It is absorbed very readily to the blood and travels to the brain within a few seconds. It stimulates the nervous system to reduce the
diameter of the arterioles and to release the hormone adrenaline from the adrenal glands. As a result, heart rate and blood pressure increase and there is a decrease in blood supply to the extremities of the body, such as hands and feet, reducing their supply of oxygen, nicotine also increases the risk of blood clotting. Nicotine is a highly addictive drug that influences reward centres in the brain. It stimulates nerve endings in the brain to release the transmitter substance dopamine, which is associated with reinforcing pleasurable experiences. This makes it very hard to give up smoking.

- Carbon monoxide diffuses across the walls of the alveoli and into the blood in the lung. It diffuses into red blood cells, where it combines with haemoglobin to form the stable compound carboxyhaemoglobin. This means that haemoglobin does not become fully oxygenated. The quality of oxygen transported in the blood may be 5-10% less in a smoker than in a non-smoker. Less oxygen is supplied to the heart muscle, putting a strain on it especially when the heart rate increases during exercise. Carbon monoxide may also damage the lining of the arteries.

**Explain the link between smoking and atherosclerosis, coronary heart disease and strokes;**

The nicotine and carbon monoxide in tobacco smoke increase the risk of developing atherosclerosis. Atherosclerosis is a thickening and loss of elasticity in the walls of arteries. It is caused by build-up of plaques in the blood vessel walls. The plaques contain cholesterol and fibres. They produce a rough surface lining the artery, which stimulates the formation of blood clots.

A blood clot may break away from the artery wall and get stuck in a narrow vessel elsewhere in the blood system, for example in the lungs or in the brain. This prevents blood passing through so cells are not supplied with oxygen and die. If this happens in the brain it is called a stroke.

The loss of electricity in an artery or arteriole also makes it more likely that the vessel will burst when high-pressure blood pulses through. This is another cause of stroke.

If atherosclerosis happens in the coronary arteries that supply the heart muscle with oxygenated blood, the person has coronary heart disease (CHD). Parts of the muscle may be unable to function properly as they did not have enough oxygen for aerobic respiration. The muscle may die. Eventually, this part of the heart may stop beating, causing a heart attack.

**Evaluate the epidemiological and experimental evidence linking cigarette smoking to disease and early death;**

Epidemiological evidence
This consists of data collected about people’s smoking habits and their health. Large numbers of people should be involved in the study. The researchers then look for correlations between smoking and particular diseases. Although this approach does not provide any definite evidence about a causal link between smoking and the disease, it can at least show whether there could be a causal relationship. If we then have physiological evidence to show how smoking might cause the disease, then this adds up to strong evidence that smoking does indeed cause the disease.

Experimental evidence

This consists of carrying out controlled experiments. For example, the independent variable could be whether or not a subject smokes (or how much they smoke) and the dependent variable could be some aspect of physiology. All other variables should be kept constant. This is not possible with humans, as it would be unethical to make people smoke. In the 1960s, dogs and other animals were used in such experiments. The result showed conclusively that smoking tobacco greatly increases the risk of developing lung cancer. Experiments can also be carried out using cells grown in tissue culture. Exposure of these cells to chemical found in tar shows that these chemicals can damage DNA.

Discuss the difficulties in achieving a balance between preventions and cure with reference to coronary heart disease, coronary by-pass surgery and heart transplant surgery;

The risk of developing CHD is increased by:

- Inheriting particular alleles of genes
- Eating a diet rich in saturated fats and cholesterol
- Not taking sufficient exercise
- Being obese
- Smoking

Server CHD can be treated with a coronary bypass, in which a piece of blood vessel is taken from another part of the body and sewn into places to provide an alternative route for oxygenated blood to flow from the aorta the heart muscle.

If the heart is damaged beyond repair, either by CHD or other conditions, then the only long – term option may be a heart transplant. The heart muscle must come from a person who has just died (often in an accident) and has a tissue type that is similar to the recipient. Even so, the recipient will still have to take immunosuppressant drugs for the rest of their life, to prevent their immune system from attacking the donor tissues and rejecting the transplant.

Prevention of CHD and other forms of heart disease is clearly much better than having to carry out complex surgery. Lifestyle choices can be made that reduced the risks listed about
(apart, of course, from the genes a person has). However, research shows that slightly obese people are more likely to recover well after heart surgery than thinner people.