The respiratory system Part 2: trachea to alveoli

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Warmed and humidified inspired air continues its journey from the larynx into the lower respiratory tract (see the first part of this four-part series) and passes next through the trachea.

The trachea or windpipe

The trachea is a tube about 11cm long that extends from the larynx to the level of the fifth thoracic vertebra in the chest cavity (Law and Watson, 2005). Its main function is to allow the unobstructed passage of air to and from the lungs. The trachea is a fairly rigid structure and a good deal of force is required to squeeze it closed. It is held open because it consists of a stack of 15 to 20 C-shaped rings of cartilage with a small amount of soft tissue between them (Fig 1). The cartilage forms the front and side walls of the trachea while the back of the windpipe is muscular and slightly stretchy. This side lies next to the oesophagus and allows large boluses of food to move down the oesophagus easily.

The trachea is lined with mucosa, like the rest of the respiratory system, and the mucosal glands below the epithelium help to produce a blanket of mucus that is moved continuously upwards towards the pharynx. Like the structures of the upper respiratory tract, the trachea helps to filter, warm and moisten inspired air.

Although the trachea is a fairly wide tube, it can become blocked. Sometimes an individual inhales a piece of food or something else large enough to block the tube. It can also be closed by severe infection of the lymph nodes in the neck or by a tumour (Thibodeau and Patton, 2005). Complete obstruction of the trachea causes death in a matter of minutes because air cannot reach the lungs and thus oxygen cannot be exchanged and transported to the cells of the body.

At its lower end, the trachea divides into two (bifurcates) – the right and left main bronchi.

The bronchial tree

The two main bronchi may be thought of as the first branches of what is often called the respiratory or bronchial tree, although the right is shorter and wider than the left and lies in a more vertical

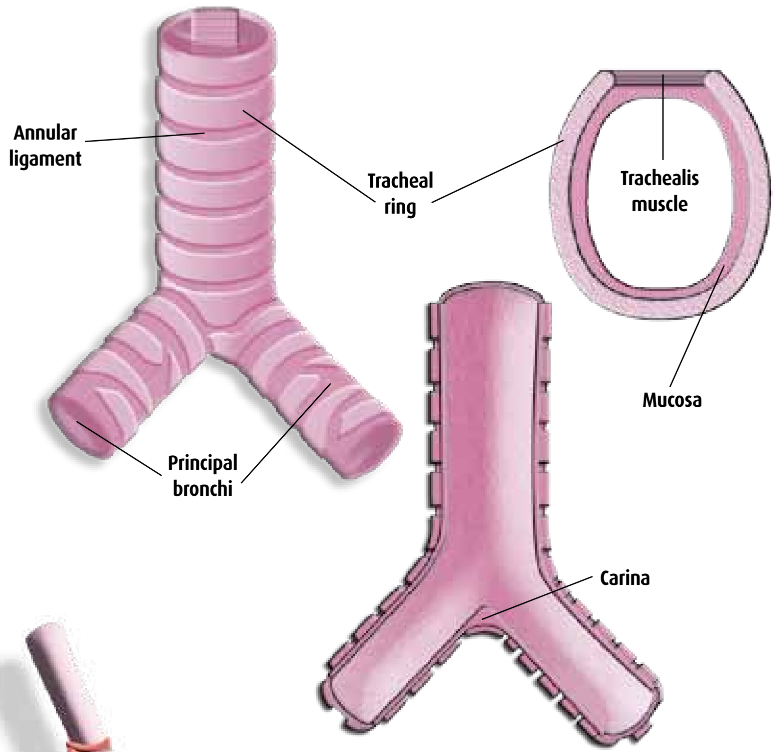

FIG 1. THE TRACHEA

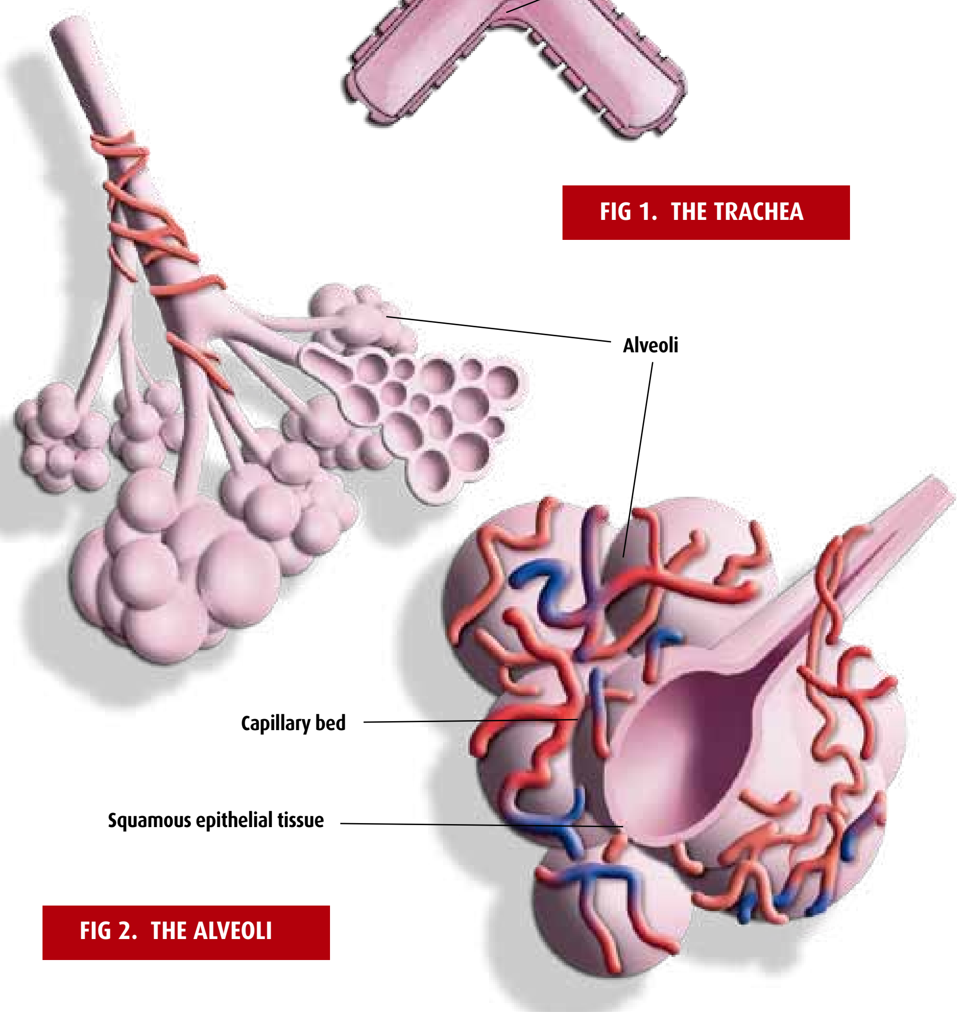

FIG 2. THE ALVEOLI

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position. This means that inhaled particles are more likely to be caught in the right bronchus. The bronchi enter the lungs at the hilum and branch again into secondary bronchi – the right main bronchus branches into three to supply the three lobes of the right lung and the left into two to supply the left lung's two lobes. The walls of the main and secondary bronchi are kept open by rings of cartilage to enable the free passage of air.

The bronchi continue to divide, very much like the branches of a tree, into smaller and smaller tubes. The tubes of each division contain a little less cartilage and a little more smooth muscle until eventually becoming tiny tubes containing only rings of smooth muscle – the terminal bronchioles, small structures less than 1mm in diameter. Because these tubes contain only muscle, they can be dilated as the muscle relaxes and constricted if the muscle contracts. Bronchodilation occurs in response to stimulation of the sympathetic nervous system (for example during exercise) or to drugs such as adrenaline, noradrenaline and salbutamol.

Bronchoconstriction occurs in response to parasympathetic nervous activity, acetylcholine, histamine and stimulation of receptors in the trachea and large bronchi by irritants such as smoke. Asthma is an exaggerated bronchoconstriction response to many physical, chemical and pharmacological agents (Law and Watson, 2005).

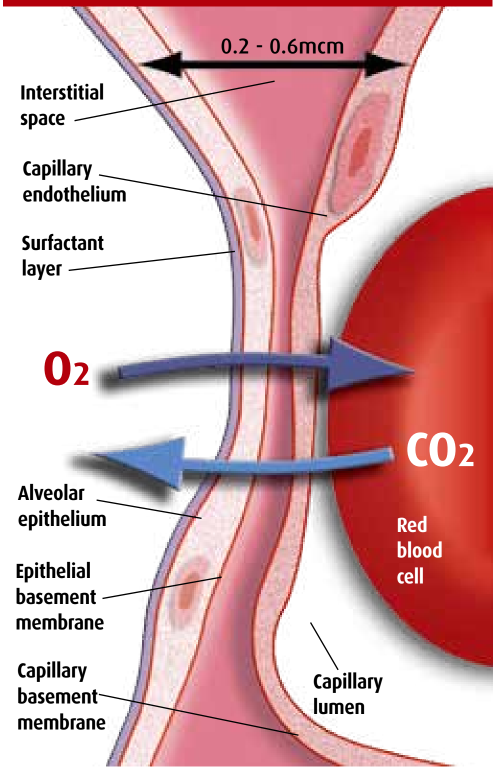
The terminal bronchioles further subdivide into an area called the respiratory exchange zone, minute tubes called respiratory bronchioles. These lead to alveolar ducts, which look like the stems on a bunch of grapes. Each of these ducts ends in several alveolar sacs, resembling small clusters of grapes, and the wall of each alveolar sac is made up of cup-shaped alveoli. As there is no cartilage in the walls of these structures, they are all liable to collapse.

Alveoli

There are approximately 300 million alveoli in the lungs and they are the 'business' area where the work of gaseous exchange takes place. Alveoli have very thin walls (far thinner than a sheet of tissue paper) and are surrounded by a rich network of blood vessels (Fig 2).

There are no cilia or mucus-producing cells in the alveolar epithelium – instead, the surface of the respiratory membrane inside the alveoli is covered with surfactant, a substance secreted by cuboidal cells within the membrane. Surfactant helps to reduce the surface tension inside the alveoli and stops them collapsing as air moves in and out of them during respiration. The ability to manufacture surfactant only fully develops very shortly before birth and the alveoli of premature babies are prone to collapse because they do not produce sufficient amounts of surfactant – this makes the effort of breathing much greater. Symptoms of respiratory distress soon develop (infant respiratory distress syndrome). Synthetic preparations of surfactant are now available and can be delivered to the baby's lungs via an endotracheal tube to correct this problem.

FIG 3. THE ALVEOLAR-CAPILLARY MEMBRANE



The alveolar-capillary membrane

It is in the respiratory exchange zone that oxygen diffuses out of the lungs and into the blood and carbon dioxide diffuses from the blood into the lungs to be expirated. In order for gases to exchange in this way, the gases have to cross cellular membranes. Within the lungs, only the surfaces of the alveoli, alveolar ducts and terminal bronchioles are sufficiently thin for rapid exchange to take place.

The blood vessels surrounding these structures also have extremely thin walls. Air and blood are brought into close proximity, with air on one side of the thin membrane and blood on the other, and diffusion of the gases takes place across the alveolar capillary membrane (Fig 3). In this way blood is supplied with all the oxygen needed to keep the body's cells functioning normally and the cells are able to rid themselves of their waste products, which are largely converted to carbon dioxide.

Owing to the tree-like structure of the respiratory airways, a vast surface area of approximately 50–100m^2 (more than 40 times the skin's surface area) is available for gaseous diffusion to take place. ■

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