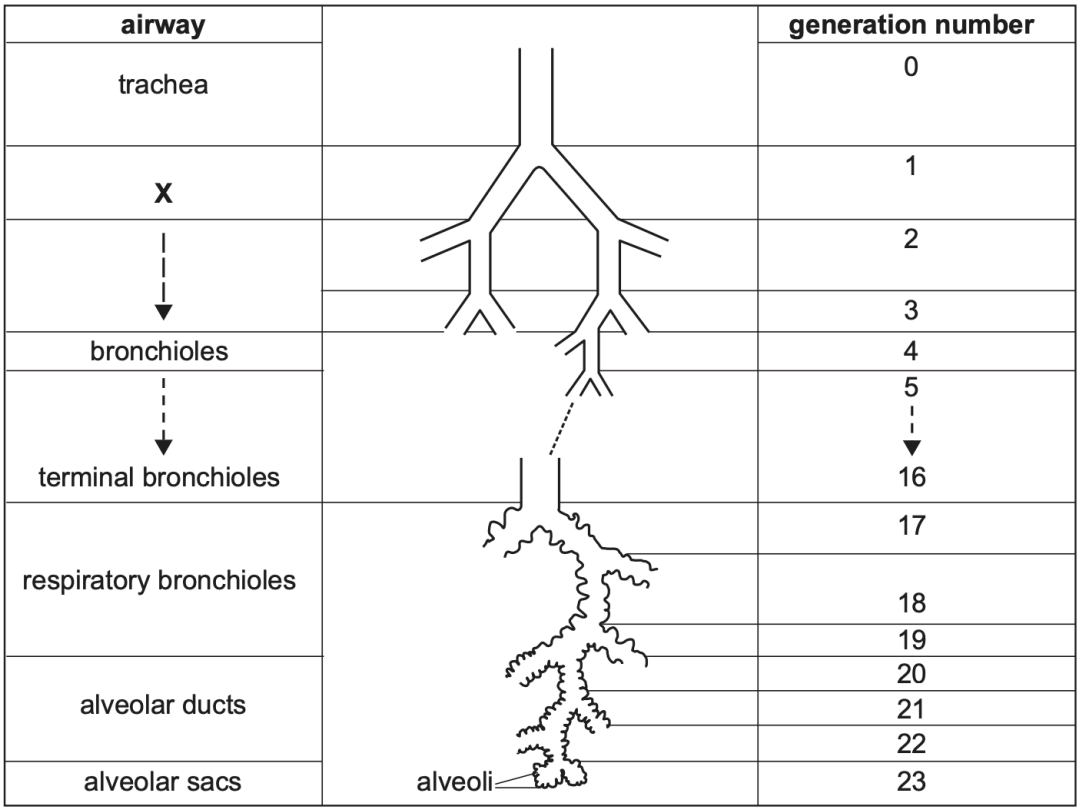
9. Gas exchange

1.

The Weibel Lung model was developed after an extensive study of the gas exchange system. The model includes detailed measurements of airway diameters (lumen diameters of the airways). In the model, different parts of the gas exchange system are identified with a generation number, as outlined in Fig. 6.1.



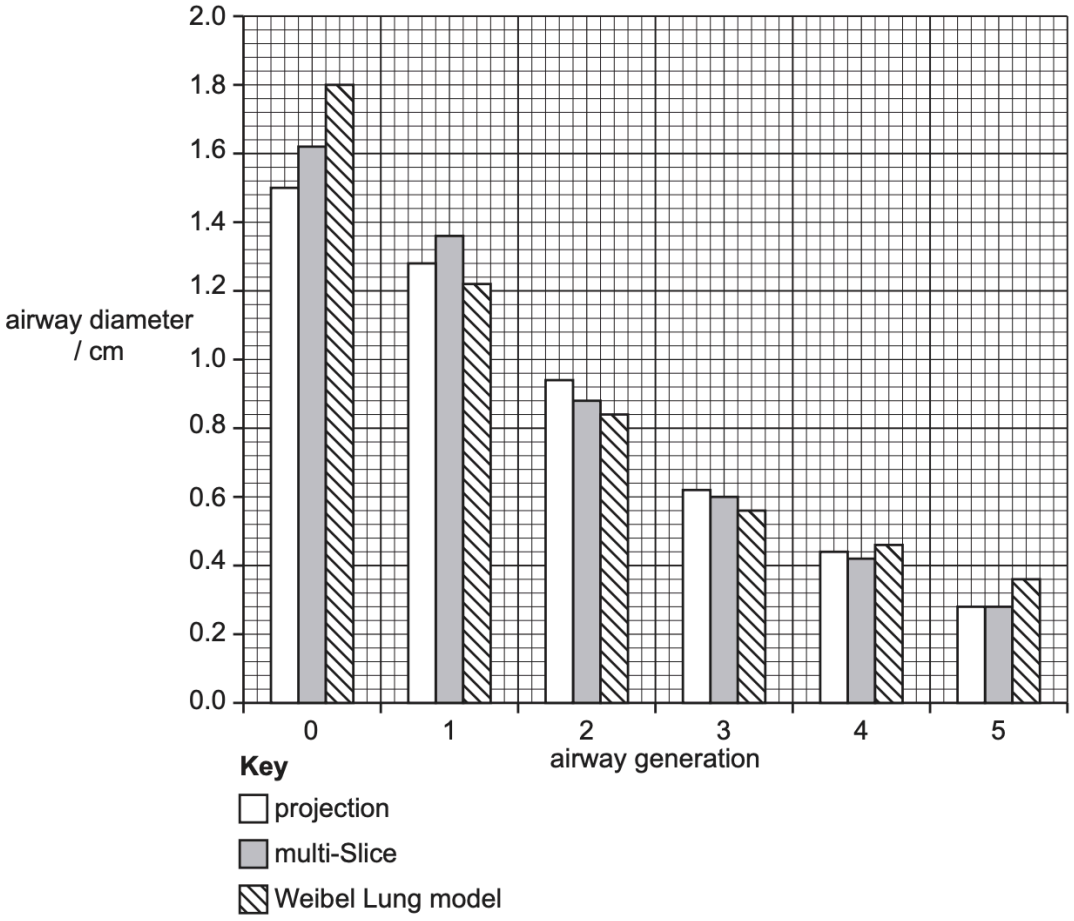
The airways are well supplied with blood. However, the airways from generation 0 to generation 16, shown in Fig. 6.1, are not able to carry out gas exchange. Suggest why the airways from generation 0 to generation 16 are not able to carry out gas exchange.

- diffusion distance too great // walls too thick for (efficient) diffusion
- many cell layers / a number of tissues to pass across, eg. presence of smooth muscle tissue, ciliated epithelium, layer of mucus on lining of gas exchange system
- time taken for diffusion to occur too long / diffusion rate too slow
- ventilation / fast air flow reduces time for correct gradient to be established for diffusion to occur
- blood supply is not from pulmonary artery / not pulmonary circulation / from a branch of the aorta / part of the systemic circulation
- systemic blood supply to the gas exchange organs is already oxygenated / not deoxygenated – low / no concentration gradient for oxygen / carbon dioxide in systemic blood supply to the gas exchange organs

(c) High-resolution computed tomography (HRCT) is an imaging technique that is used to obtain measurements of airway diameters in people with a pulmonary (lung) disease. Regular, repeated imaging must be avoided because it involves exposure to harmful radiation.

Scientists researched the use of a different technique, HP gas MRI, that does **not** involve harmful radiation. Two types of MRI image, known as projection and multi-Slice, were used to obtain measurements of airway diameters.

Fig. 6.2 shows the results of the HP gas MRI study compared with the Weibel Lung model, for generations 0 to 5. The Weibel Lung model was used as a standard reference for airway diameters.



- yes, useful: compared to Weibel Lung model measurements similar results / same trend / same relationship between airway generation and airway diameter
- data to support: projection / multi-Slice for at least one generation compared to Weibel
- no risk of harmful / radiation exposure
  can repeat / can use regularly (on same person)
  can follow progression of disease

2. The cartilage in the bronchi can be damaged in some people with TB. Suggest the effect that damage to cartilage may have on the bronchi.

- bronchi may collapse / lose structural support

3.

(ii) Table 2.1 shows four types of cell and three structures found in the gas exchange system.

Complete Table 2.1 to show the distribution of cell types in each structure of the gas exchange system.

Use a tick (✓) if the cell type is present in the structure and a cross (✗) if the cell type is **not** present.

Put a tick (✓) or a cross (✗) in every box.

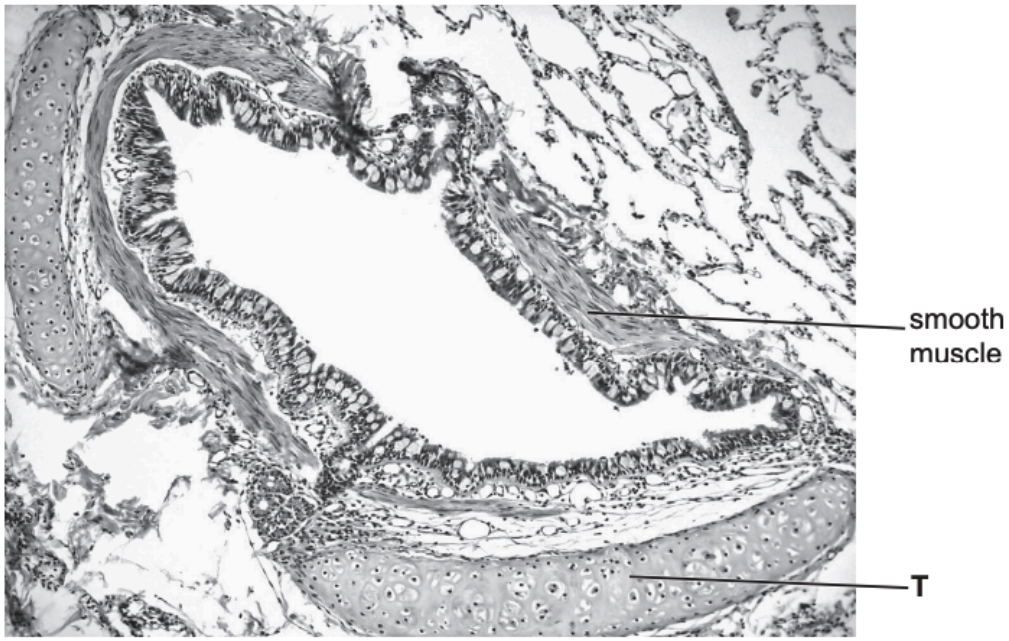
Table 2.1

cell type	alveolus	bronchus	trachea
ciliated epithelial cell			
goblet cell			
smooth muscle cell			
squamous epithelial cell			

cell type	alveolus	bronchus	trachea
ciliated epithelial cell	×	✓	✓
goblet cell	×	✓	✓
smooth muscle cell	×	✓	✓
squamous epithelial cell	✓	×	×

4.

Fig. 5.1 is a photomicrograph of a transverse section of a bronchus in the lungs.



Identify the tissue labelled T

- Cartilage

5. Describe the function of smooth muscle in the bronchus.
   - smooth muscle contracts and relaxes
   - changes diameter of the airway / controls size of the lumen
   - helps to regulate airflow into / away from gas exchange surfaces

6. Explain how blood flow through the alveolar capillaries helps to maintain steep diffusion gradients for gas exchange.
   - blood arriving is deoxygenated / has lower partial pressure of oxygen / has low concentrations of oxygen OR blood arriving has higher partial pressure of carbon dioxide
   - newly oxygenated blood is constantly/continually removed / passed to pulmonary vein

7. Ventilation of the lungs is the process of inhalation and exhalation. Ventilation helps to maintain steep diffusion gradients. Explain the role of elastic fibres in the alveolar wall during ventilation.
   - allow alveoli to expand / stretch on inhalation / inspiration / breathing in
   - prevent alveoli from overstretching / rupturing / bursting on inhalation / inspiration / breathing in
   - recoil to help exhalation / expiration / breathing out / force air out

8. P. jirovecii (a fungi) can adhere (attach) to squamous epithelial cells of the alveoli and to the network of fibrous proteins that support the alveolar wall, known as the extracellular matrix (ECM). Examples of proteins in the ECM are elastin and collagen.
   Adhesion (attachment) of P. jirovecii to alveolar epithelial cells and the ECM stimulates the growth of its population.
   One consequence of the pneumonia that results from P. jirovecii infection is a decrease in the quantity of oxygen that is delivered to body tissues. Explain why a severe P. jirovecii infection results in a decrease in the quantity of oxygen that is delivered to body tissues.
   - alveolar cells hindered / surrounded by P. jirovecii cells // alveolar wall becomes thicker
   - diffusion of oxygen impaired / decreased // distance for diffusion increased
   - between alveolus / alveolar air / alveolar space and capillary / blood / red blood cells
   - less oxyhaemoglobin formed // less oxygen binds to haemoglobin // less oxygen forms bonds with Fe^{2+} in haemoglobin
   - ability of elastic fibres t, stretch / recoil impaired due to decreased elasticity of alveoli
   - P. jirovecii infection damages alveolar capillaries

9. State the precise site in the mammalian body where haemoglobin molecules bind with oxygen.
   - Alveolar capillaries / capillaries around alveoli (in the lungs)

10. Describe how ciliated epithelium is adapted to its function in the gas exchange system.
    - goblet cells secrete / produce / release mucus
    - mucus covers ciliated epithelium to trap (named) particles
    - cilia / ciliated epithelial cells move mucus (and trapped material) upwards / towards mouth / towards throat

11. Explain how smooth muscle cells in the walls of the bronchioles contribute to the function of these airways.
    - contraction and relaxation
    - diameter / lumen size can be controlled / changed
    - controls / regulates flow of air / volume of air flowing
    - normally relaxed but can contract / cause constriction, when needed, to reduce air movement / prevent entry of contaminants

NOTE: proportionally more smooth muscle in the wall of the bronchiole than bronchus/ trachea

12. State the main effects of tar on the cells lining the gas exchange system that are related to lung cancer and to chronic bronchitis.

Lung cancer

- tar is a carcinogen
- acts as mutagen / causes mutations OR causes changes to sequence of bases / nucleotides in DNA
- tumour suppressor genes switched off and oncogenes switched on
- cell cycle checkpoints fail to function
- cell moves from, inactive state of cell cycle to G1 phase for mitosis
- no programmed death

Chronic bronchitis

- tar paralyses / destroys / damages cilia
- cilia cannot waft away mucus
- tar causes goblet cells / mucous glands to increase in size / enlarge
- more / excess mucus produced by goblet cells