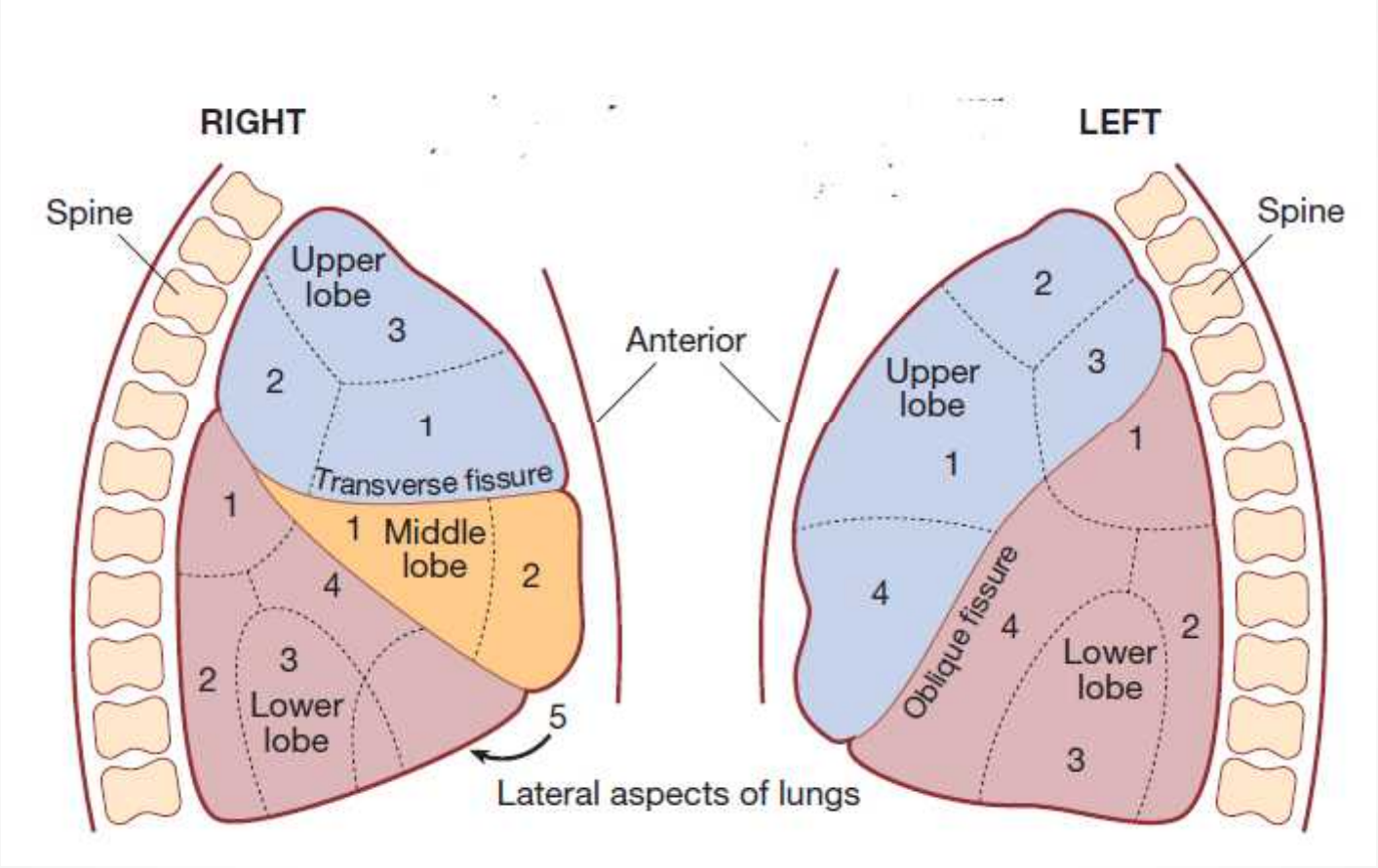
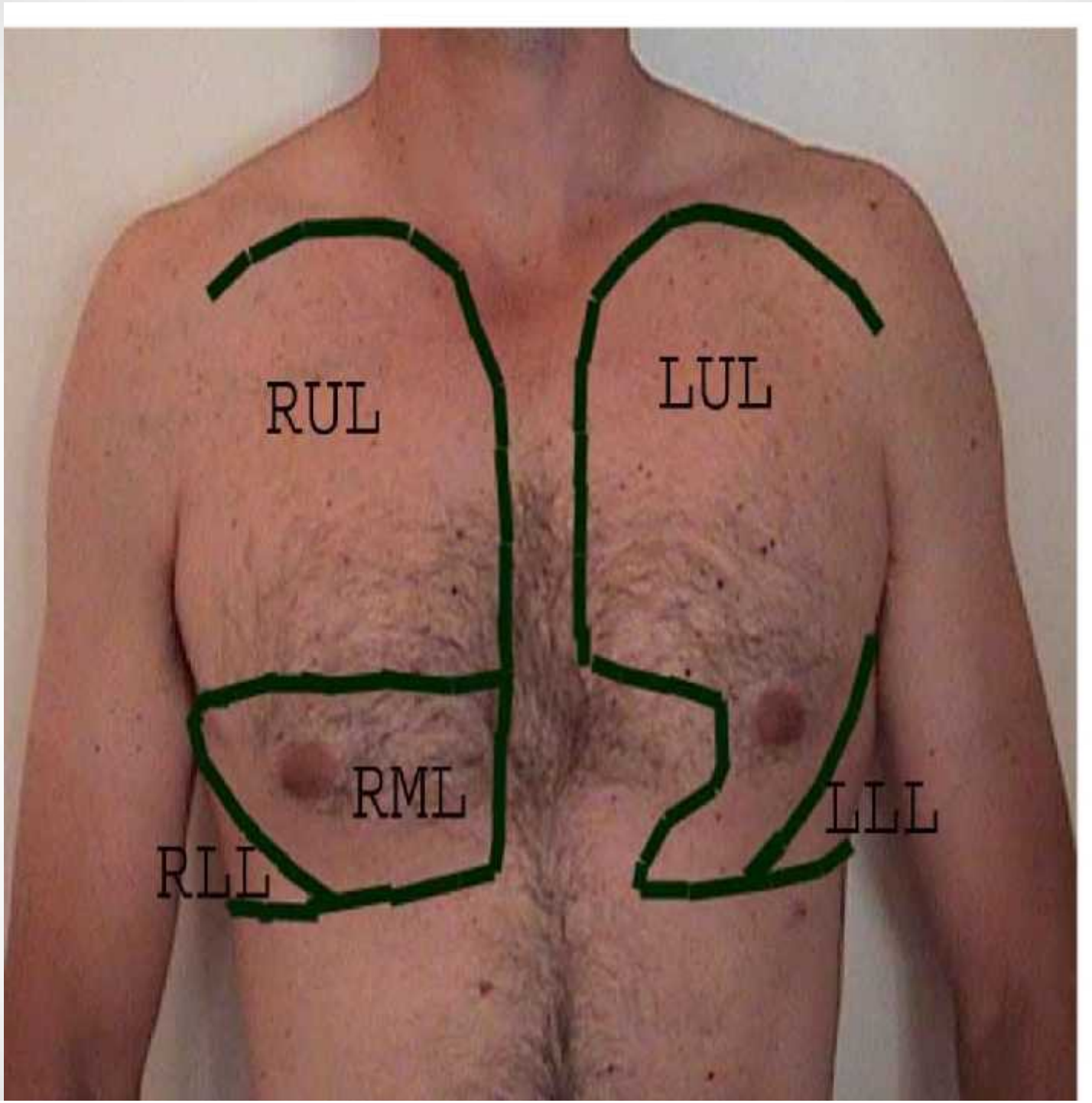
Respiratory system

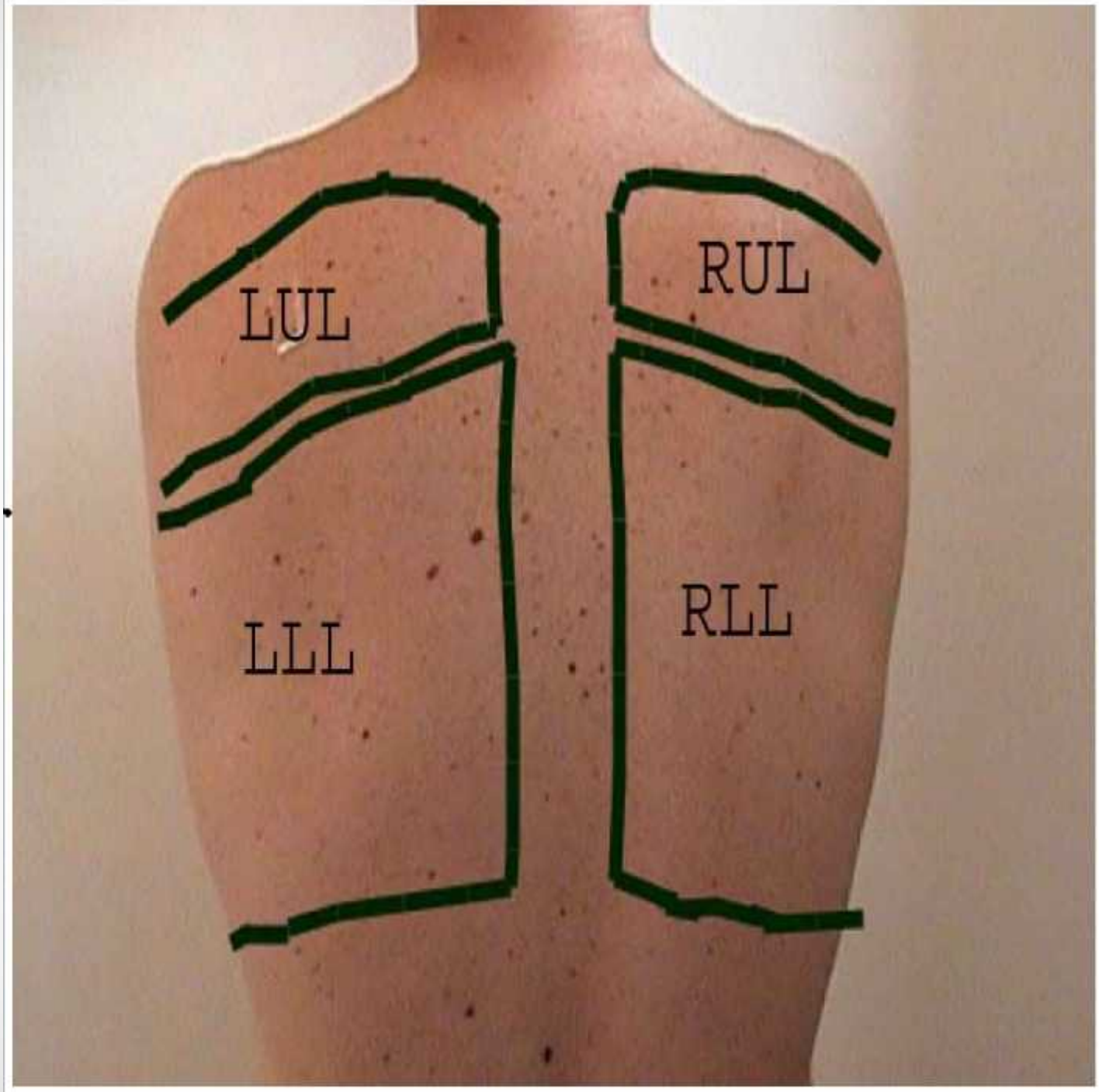
Functional anatomy and physiology

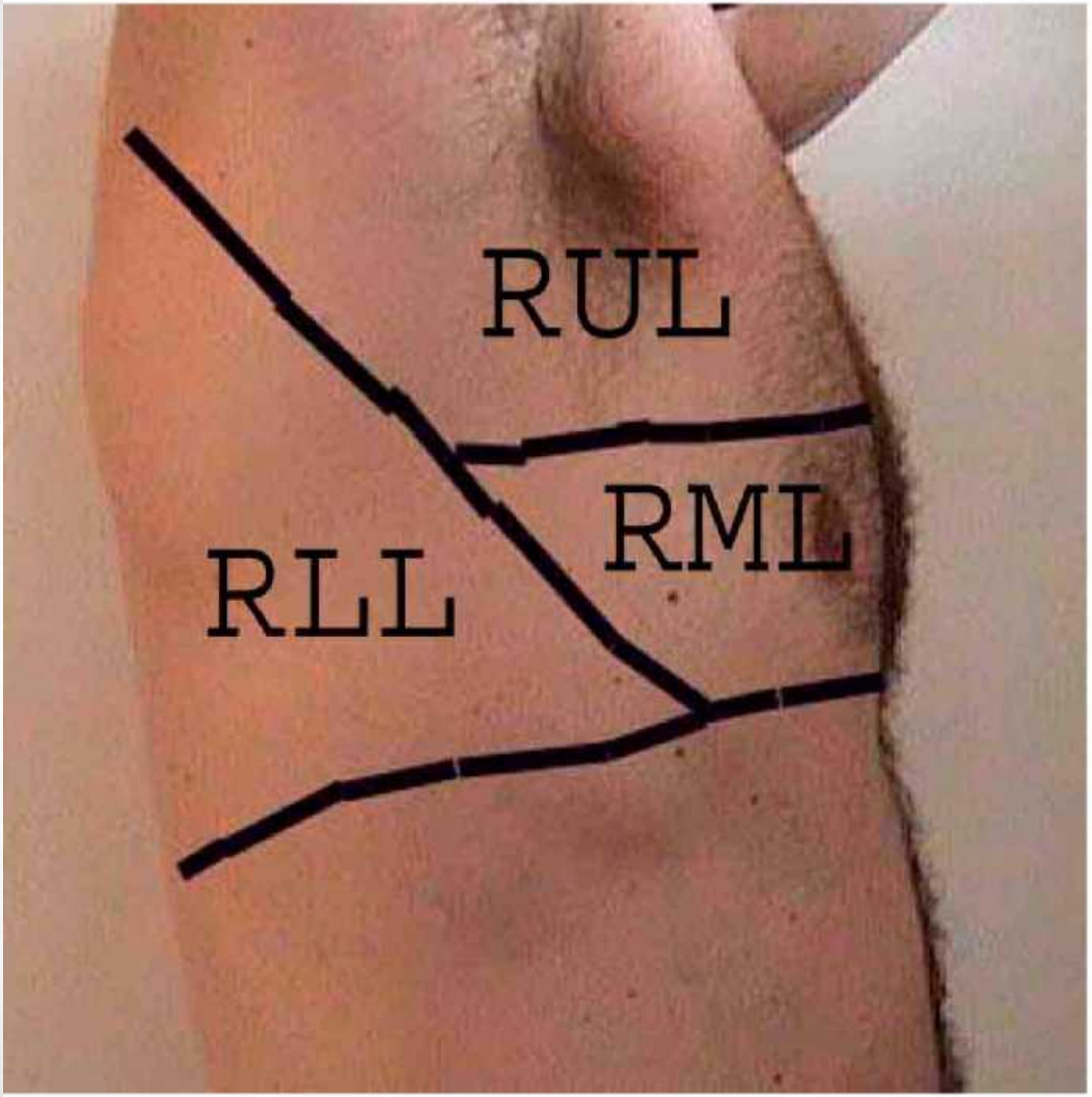
- **The trachea is 10-12 cm in length. It lies slightly to the right of the midline and divides at the carina into right and left main bronchi.**

- **The carina lies under the junction of the manubrium sterni and the second right costal cartilage.**


RIGHT
LEFT
Spine
Spine
Upper lobe
3
2
1
Transverse fissure
1
1
Middle lobe
2
4
2
3
Lower lobe
5
Anterior
2
3
Upper lobe
1
1
4
Oblique fissure
4
2
Lower lobe
3
Lateral aspects of lungs


RUL
LUL
RML
RLL
LLL


LUL
RUL
LLL
RLL


RUL
RML
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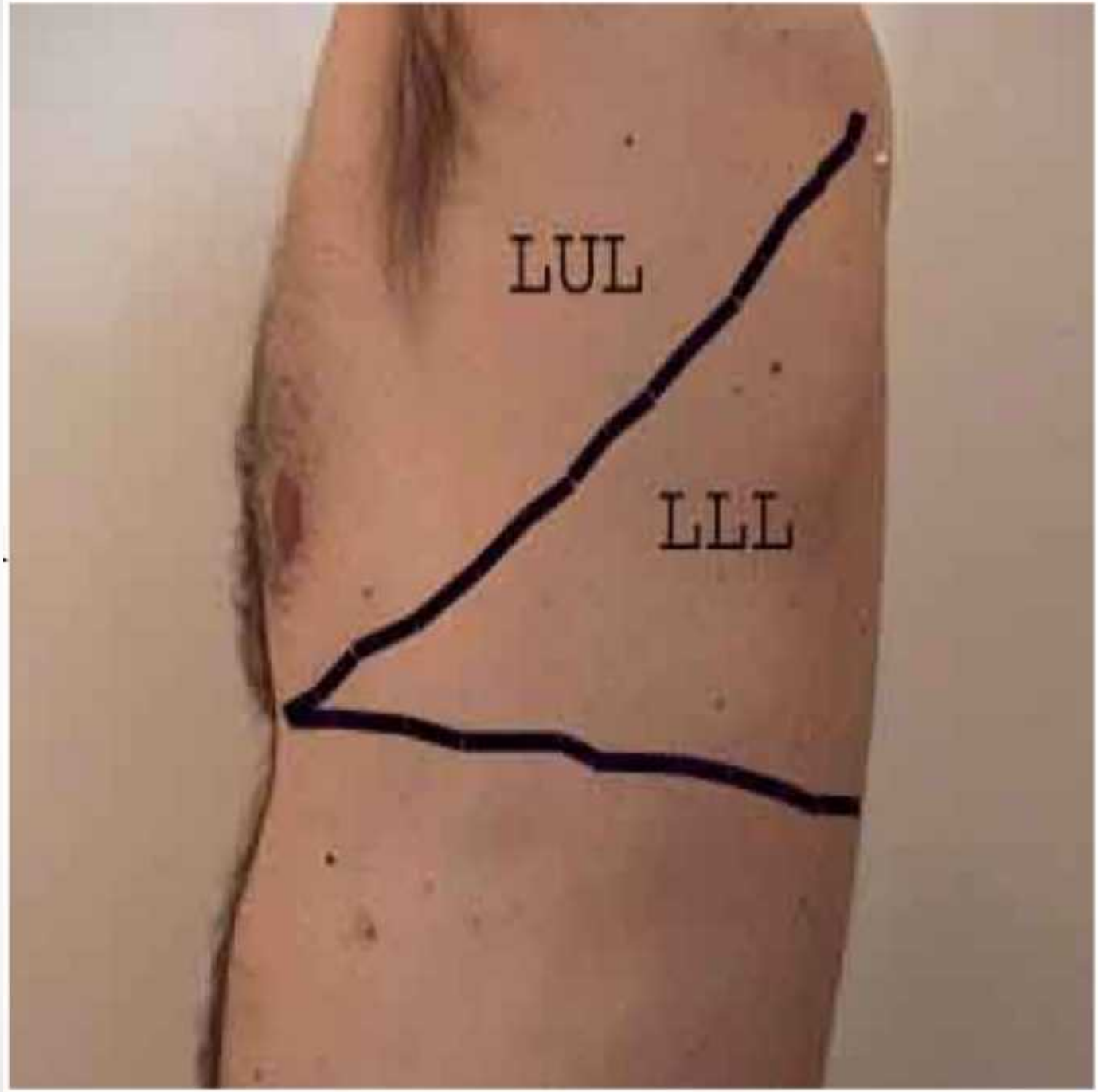
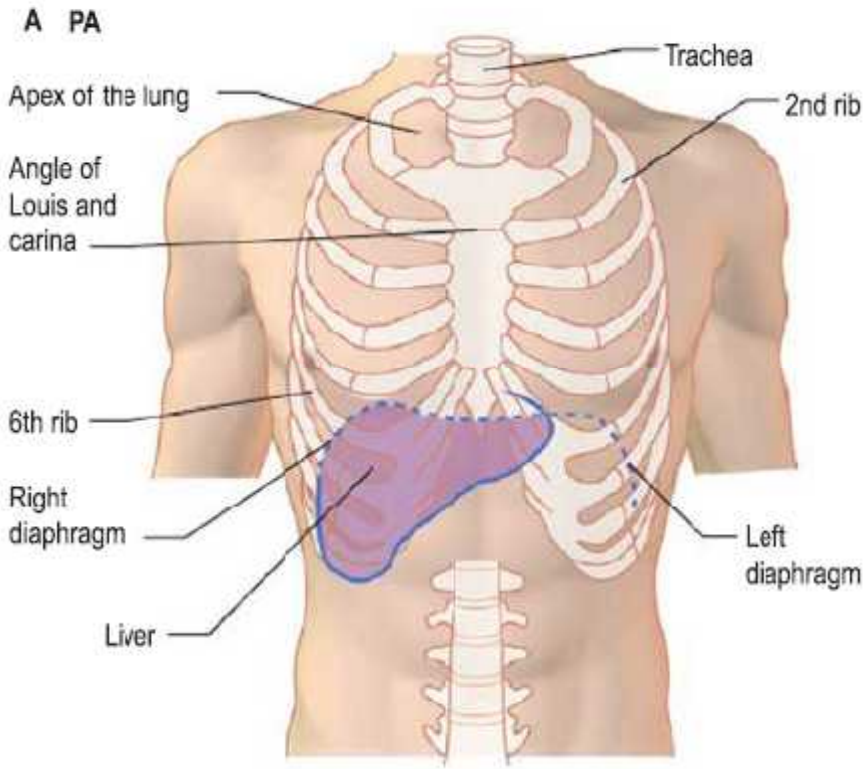
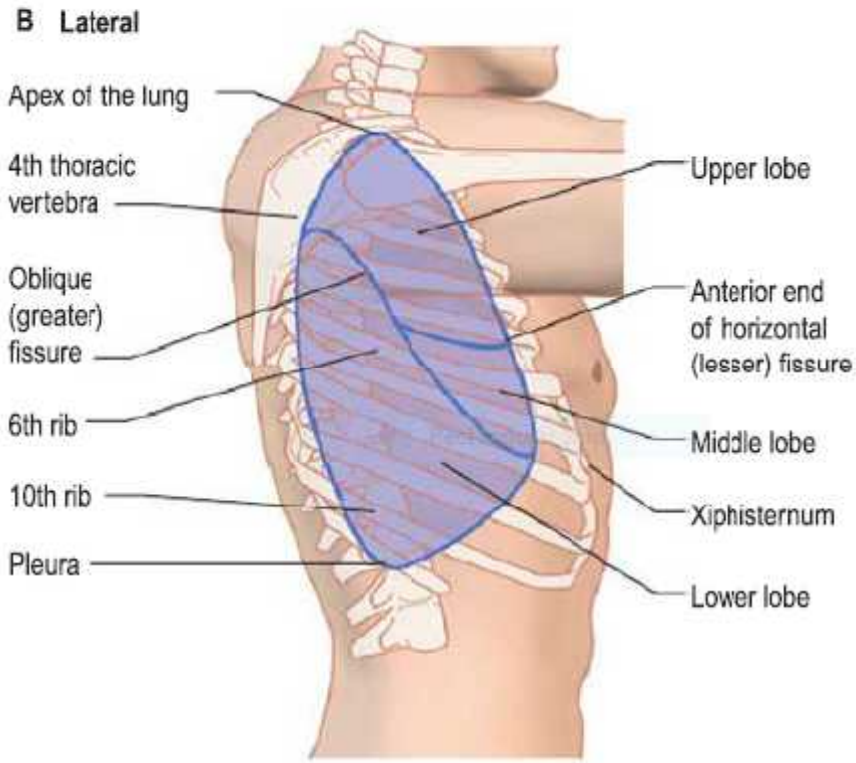

LUL
LLL


A PA
Trachea
Apex of the lung
2nd rib
Angle of
Louis and
carina
6th rib
Right
diaphragm
Left
diaphragm
Liver


B Lateral
Apex of the lung
4th thoracic
vertebra
Upper lobe
Oblique
(greater)
fissure
Anterior end
of horizontal
(lesser) fissure
6th rib
Middle lobe
10th rib
Xiphisternum
Pleura
Lower lobe

The lungs

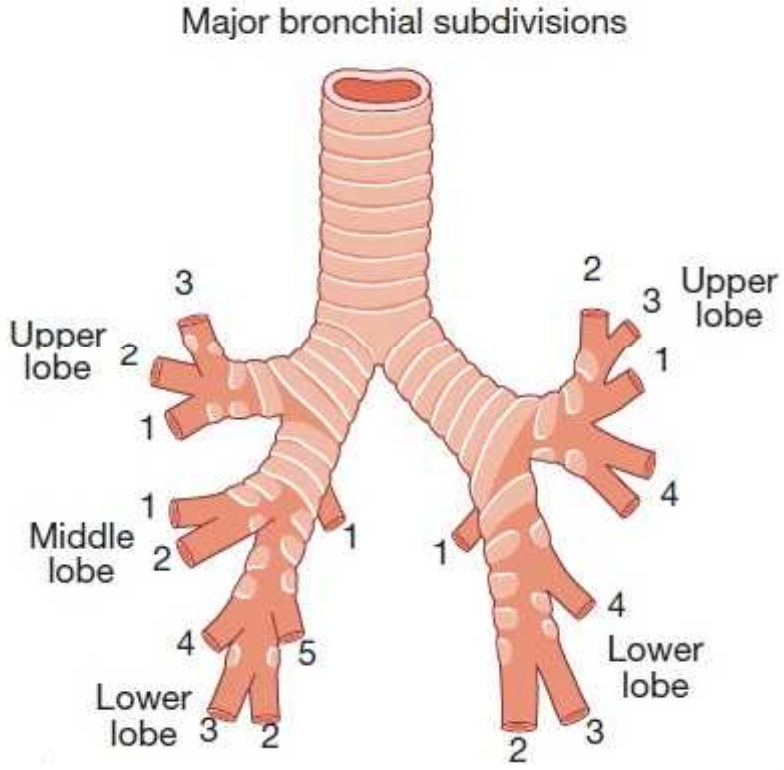
The lungs are separated into lobes by invaginations of the pleura, which are often incomplete.

The right lung has three lobes, whereas the left lung has two.

Each lobe is further subdivided into bronchopulmonary segments by fibrous septa that extend inwards from the pleural surface. Each segment receives its own segmental bronchus.

The bronchopulmonary segment is further divided into individual lobules approximately 1 cm in diameter.

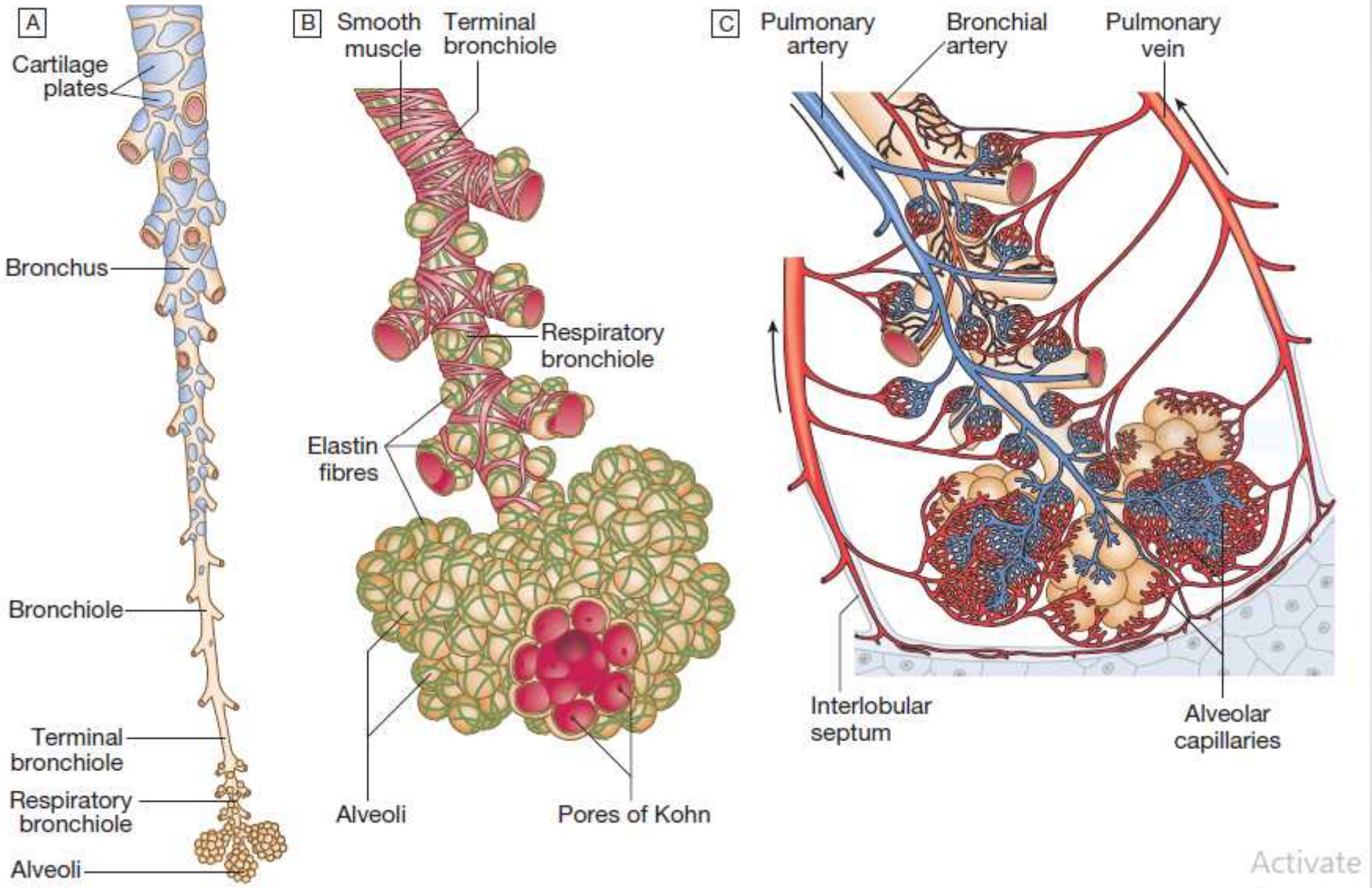
Within each lobule, a terminal bronchus supplies an acinus; within this structure, further divisions of the bronchioles eventually give rise to the alveoli.


Major bronchial subdivisions
Upper lobe
Middle lobe
Lower lobe
Upper lobe
Lower lobe

- **Bronchi**
- **The right main bronchus is more vertical than the left and, hence, inhaled material is more likely to end up in the right lung.**
- **The right main bronchus divides into the upper lobe bronchus and the intermediate bronchus, which further subdivides into the middle and lower lobe bronchi.**
- **On the left, the main bronchus divides into upper and lower lobe bronchi only.**
- **Each lobar bronchus further divides into segmental and sub-segmental bronchi.**

bronchi have:

- **walls consisting of cartilage and smooth muscle.**
- **an epithelial lining with cilia and goblet cells**
- **submucosal mucus-secreting glands**


A
Cartilage plates
Bronchus
Bronchiole
Terminal bronchiole
Respiratory bronchiole
Alveoli
B
Smooth muscle
Terminal bronchiole
Respiratory bronchiole
Elastin fibres
Alveoli
Pores of Kohn
C
Pulmonary artery
Bronchial artery
Pulmonary vein
Interlobular septum
Alveolar capillaries

- **<u>bronchioles</u> are a muscular layers, have no cartilage that progressively becomes thinner.**
- **Have a single layer of ciliated cells but very few goblet cells**
- **have granulated Clara cells that produce a surfactant-like substance.**
- **The bronchioles finally divide within the acinus into smaller respiratory bronchioles that have alveoli arising from the surface.**
- **Each respiratory bronchiole supplies approximately 200 alveoli via alveolar ducts.**
- **The term 'small airways' refers to bronchioles of <2 mm; the average lung contains about 30 000 of these bronchoiles.**

The alveoli

There are approximately 300 million alveoli in each lung.

Their total surface area is 40-8O m2•

The epithelial lining consists mainly of type I pneumocytes.

which only offers a thin barrier to gas exchange.

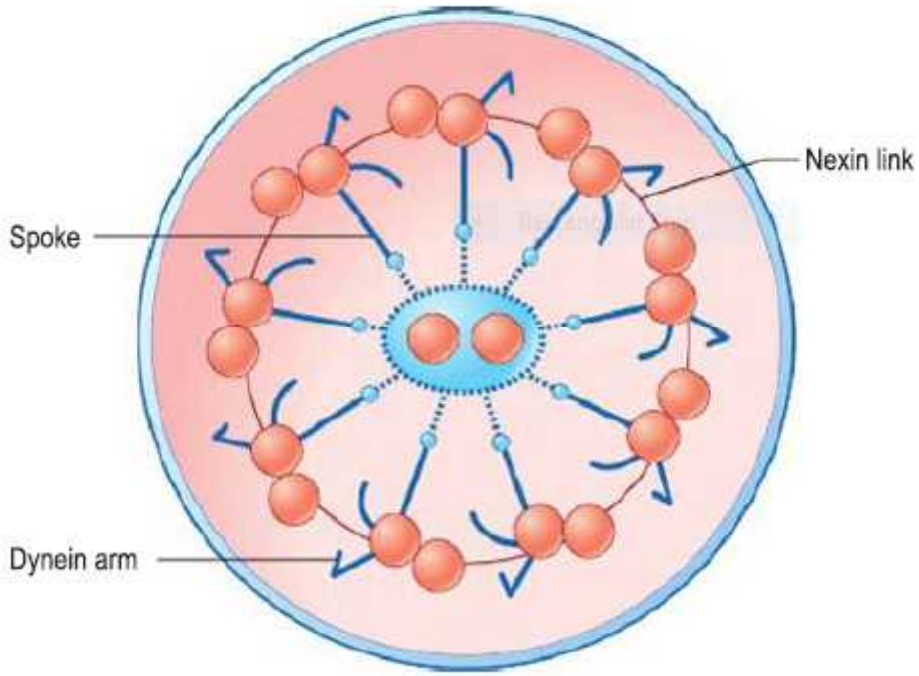
Type I cells are connected to each other by tight junctions that limit the movements of fluid in and out of the alveoli.

Alveoli are not completely airtight; many have holes in the alveolar wall, allowing communication between alveoli of adjoining lobules (pores of Kohn).

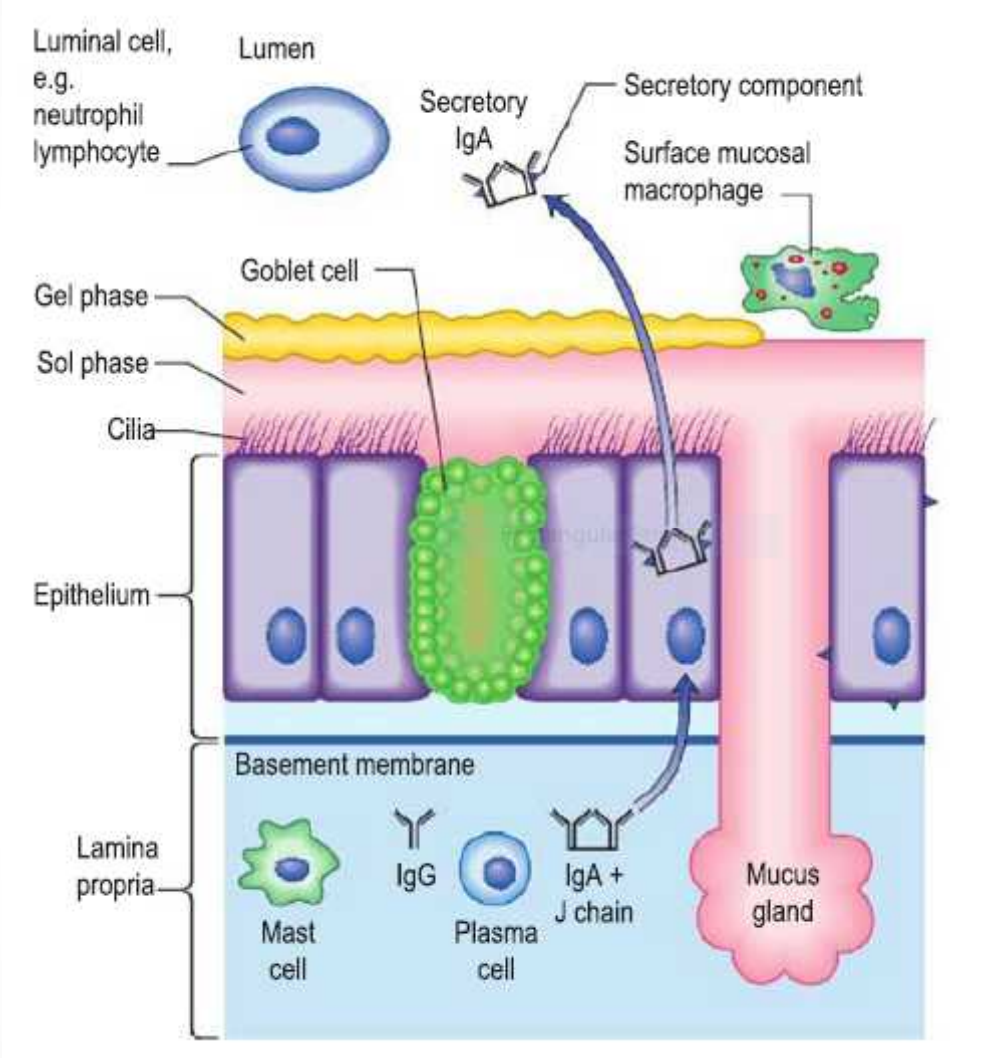
Type II pneumocytes are slightly more numerous than type I cells. They are found generally in the borders of the alveolus and contain distinctive lamellar vacuoles, which are the source of surfactant.

Type I pneumocytes are derived from type II cells.

Large alveolar macrophages are present within the alveoli and assist in defending the lung.


Nexin link
Spoke
Dynein arm

The ciliated epithelium is a key defence mechanism. Each cell bears approximately 200 cilia beating at 1000 beats per minute (b.p.m.) in organized waves of contraction. Each cilium consists of nine peripheral parts and two inner longitudinal fibrils in a cytoplasmic matrix . Nexin links join the peripheral pairs. Dyneinarms consisting of adenosine triphosphatase (ATPase) protein project towards the adjacent pairs. Bending of the cilia results froma sliding movement between adjacent fibrils powered by an ATPdependent shearing force developed by the dynein arms . Absence of dynein arms leads to immotile cilia. Mucus, which contains macrophages, cell debris, inhaled particles and bacteria, is moved by the cilia towards the larynx at about 1.5cm/min the ' mucociliary clearance'.


Luminal cell, e.g. neutrophil lymphocyte
Lumen
Secretory IgA
Secretory component
Surface mucosal macrophage
Goblet cell
Gel phase
Sol phase
Cilia
Epithelium
Basement membrane
Lamina propria
IgG
IgA + J chain
Mast cell
Plasma cell
Mucus gland

The pleura

The pleura is a layer of connective tissue covered by a simple squamous epithelium. The visceral pleura covers the surface of the lung, lines the interlobar fissures, and is continuous at the hilum with the parietal pleura, which lines the inside of the hemithorax.

The diaphragm

The diaphragm is covered by parietal pleura above and peritoneum below.

Its muscle fibres arise from the lower ribs and insert into the central tendon.

Motor and sensory nerve fibres go separately to each half of the diaphragm via the phrenic nerves.

PHYSIOLOGY OF THE RESPIRATORY SYSTEM

Gas exchange :

The major function of the lung is gas exchange between the lungs and the blood.
The alveolar and pulmonary capillary gases equilibrate across the thin blood-air barrier.

Inspiration is an active process: a negative intrapleural pressure is created by descent of the diaphragm and movement of the ribs upwards and outwards through contraction of the intercostal muscles.
During tidal breathing in healthy individuals, inspiration is almost entirely due to contraction of the diaphragm. More vigorous inspiration requires the use of accessory muscles of ventilation (sternomastoid and scalene muscles).
Respiratory muscles are similar to other skeletal muscles but are less prone to fatigue.
However, inspiratory muscle fatigue contributes to respiratory failure in patients with severe chronic airflow limitation and in those with primary neurological and muscle disorders.

At rest or during low-level exercise, expiration is passive and results from the natural tendency of the lung to collapse.

Forced expiration involves activation of accessory muscles, chiefly those of the abdominal wall, which help to push up the diaphragm.

The control of respiration

Coordinated respiratory movements result from rhythmical discharges arising in an anatomically ill-defined group of interconnected neurones in the reticular substance of the brainstem, known as the respiratory centre.

Motor discharges from the respiratory centre travel via the phrenic and intercostal nerves to the respiratory musculature.

Ventilation is controlled by a combination of neurogenic and chemical factors.

In healthy individuals, the main driver for respiration is the arterial pH, which is closely related to the partial pressure of carbon dioxide in arterial blood.

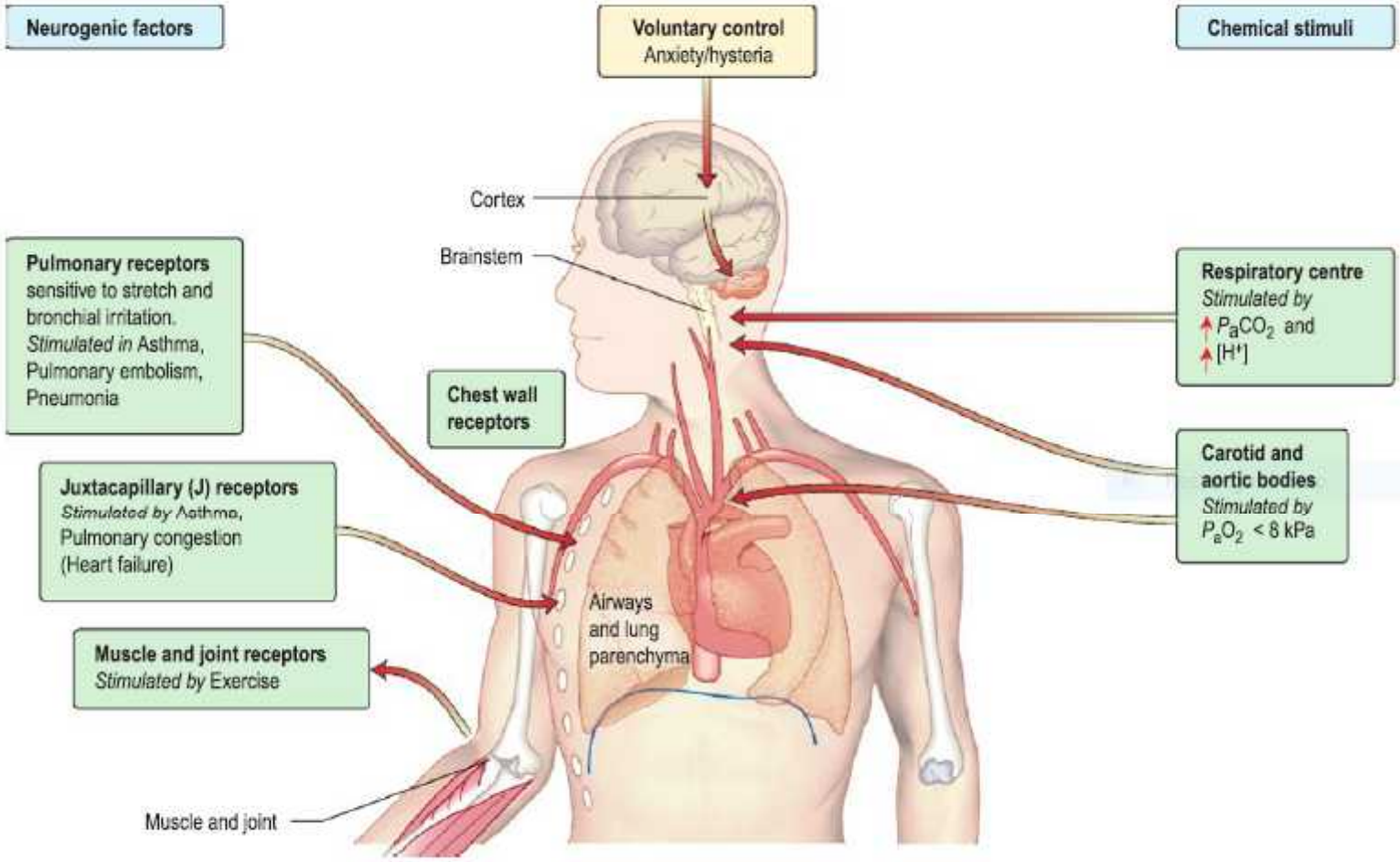


Figure 24.5 Chemical and neurogenic factors in the control of ventilation. The strongest stimulant to ventilation is a rise in P_aCO_2, which increases [H^+] in cerebrospinal fluid. ***Sensitivity*** to this may be lost in ***chronic obstructive pulmonary disease***. In these patients, hypoxaemia is the chief stimulus to respiratory drive; oxygen treatment may therefore reduce respiratory drive and lead to a further rise in P_aCO_2. An increase in [H^+] due to metabolic acidosis, as in diabetic ketoacidosis, will increase ventilation with a fall in P_aCO_2 causing deep sighing (Kussmaul) respiration. The respiratory centre is depressed by severe hypoxaemia and sedatives (e.g. opiates).

Control of airway tone

Bronchomotor tone is maintained by vagal efferent nerves and can be reduced by atropine or B-adrenoceptor agonists.

Adrenoceptors on the surface of bronchial muscles respond to circulating catecholamines;

there is no direct sympathetic innervation.

Airway tone shows a circadian rhythm, which is greatest at 04.00 and lowest in the mid-afternoon.

Defence mechanisms of the respiratory tract

Upper airway defences:

The nose

The major functions of nasal breathing are:

- **to heat and moisten the air**
- **to remove particulate matter.**

About 10 000 L of air are inhaled daily. The relatively low flow rates and turbulence of inspired air in the nose mean that only few particles>10 microns (.u.m) in diameter pass through the nose.

Nasal secretion contains immunoglobulin A (IgA) antibodies, lysozyme and interferons.

In addition, the cilia of the nasal epithelium move the mucous gel layer rapidly back to the oropharynx, where it is swallowed.

During cough, expiratory muscle effort against a closed glottis results in high intrathoracic pressure, which is then released explosively. The flexible posterior tracheal wall is pushed inwards by the high surrounding pressure, which reduces tracheal cross-section and thus maximizes the airspeed to achieve effective expectoration.

The larynx also acts as a sphincter, closing to protect the airway during swallowing and vomiting.

Lower airway defences

The innate response in the lungs is characterised by a number of non-specific defence mechanisms. Inhaled particulate matter is trapped in airway mucus and cleared by the. mucociliary escalator (clearance)

Cigarette smoke increases mucus secretion but reduces mucociliary clearance and predisposes towards lower respiratory tract infections, including pneumonia.

Defective mucociliary transport is also a feature of several rare diseases, including Kartagener's syndrome, Young's syndrome and ciliary dysmotility syndrome, Which are characterised by repeated sino-pulmonary infections and bronchiectasis.

Airway secretions contain an array of antimicrobial peptides (such as defensins, immunoglobulin A (IgA) and lysozyme), antiproteinases and antioxidants.
Many assist with the opsonisation and killing of bacteria and the regulation of the powerful proteolytic enzymes secreted by inflammatory cells.

Macrophages engulf microbes, organic dusts and other particulate matter. They are unable to digest inorganic agents, such as asbestos or silica, which cause their death and lead to the release of powerful proteolytic enzymes that damage the lung.

Neutrophil number….