Lungs in Vertebrates

Lungs are the primary respiratory organs of reptiles, birds and mammals though they help in respiration in amphibians in which the main respiratory organ is skin. Lungs show a change from a simple sac to highly spongy organs during the course of evolution. They are covered over by the visceral peritoneum.

Comparative anatomy of lungs

(a) Amphibians: Lungs in amphibians are pink coloured, hollow, simple thin walled sac like structures. They usually develop during metamorphosis. The lungs lie in the anterolateral portions of the pleuroperitoneal cavity on either side of the heart (the pleuroperitoneal cavity contains both the lungs and the abdominal viscera in all pulmonate vertebrates except mammals).

In caecilians (apoda), the left lung is highly reduced and the right lung has alveolic over its entire surface. In Urodels the lungs are elongated and the left lung is usually longer than the right. The inner surface of the lungs is smooth in some, with alveoli in others and the alveoli confined to the basal portion in still others. In anurans, the inner epithelium of the lungs is thrown into numerous radially arranged infundibular folds or septa which enclose the alveoli. The inner epithelium lining the lungs has mucous secreting cells which secrete mucous that keeps the inner surface of the lungs moist, a condition necessary for the exchange of gases. Outer to the inner epithelium is the middle layer or coat of connective tissue with blood capillaries and smooth muscle fibres. The muscle fibres provide considerable power of contraction & relaxation to the lungs. The outermost layer is of

the visceral peritoneum formed of simple squamous epithelial cells. The terrestrial forms have larger alveolar respiratory surface than the aquatic forms.

The salamander Plethodon lacks lungs and the adult respire only through skin + buccopharyngeal cavity. In some forms such as Necturus + Siren both gills (external) and lungs are present. Mainly, they respire through skin, gills are very less used by adults. They breathe through lungs in certain condition only ie in less oxygenated warm waters.

Mechanism of lung respiration

Amphibians: In frog, the respiratory mechanism involves three processes:

(1) Aspiration: The throat is moved up and down by the action of two muscles — (a) Sternohyal muscles (b) Petrohyal muscles.

The sternohyal muscles extend from the sternum to the ventral surface of the hyoid apparatus, embedded in the floor of the buccal cavity. Contraction of these muscles lowers down the throat. With the lowering of the throat, the buccopharyngeal cavity is enlarged. This reduces the pressure of air in this cavity. Since, the air moves from a place of higher pressure to a place of lower pressure, the fresh air from outside where the pressure is higher, immediately rushes into the buccopharyngeal cavity through external nares, nasal chamber and internal nares. This passage of air from outside into the buccopharyngeal cavity is known as aspiration. The incoming air mixes with the foul air staying in the buccopharyngeal cavity from the previous expiration. It loses some O_2 and gains some CO_2 from the buccopharyngeal lining.

(b) Inspiration: It involves taking in of air inside the lungs. During this, the mentomeckelian bones of the lower jaw are pushed upwards, this raises the premaxillae bones of the upper jaw, thereby closing the nostrils. The throat and the hyoid apparatus are also raised by the contraction of petrohyal muscles (Petrohyal muscles extend from the squamosal bone of the skull to the upper surface of the hyoid apparatus) This decreases the volume of the buccopharyngeal cavity and increases the pressure of air in this cavity. The bucco-pharyngeal cavity acts as a force pump, opens the glottis and passes air into the lungs. This passage of air into the lungs is called inspiration. There is further mixing of air in the lungs as it contains residual fowl air.

Exchange of gases: In the lungs, the exchange of gases takes place. O_2 from air dissolves in the mucous covering the inner surface of the alveoli. From here the O_2 diffuses into the blood flowing through the capillaries present in the walls of the alveoli. CO_2 from the blood diffuses into the air. The air in the lungs, thus becomes foul.

Expiration: After the exchange of gases is over in the lungs, the sternohyal muscles contract so that the throat is lowered. This creates a negative pressure or partial vacuum in the buccopharyngeal cavity. So, the foul air from the lungs opens the glottis and enters into the buccopharyngeal cavity. The contraction of the lungs and of the body wall muscles helps in the emptying of the lungs. Finally, due to the lowering of the mentomeckelian bones of the lower jaw + premaxillae bones of the upper jaw, the nostrils get opened, the throat gets raised, glottis gets closed and foul air expels i.e moves out through the nostrils. Mouth + oesophagus remain closed during pulmonary resp. Some foul air stays back in the buccopharyngeal cavity

Lungs in Reptiles: Reptilian lungs also lie in the anterolateral portions of the pleuroperitoneal cavity, one on either side of the heart. They are better developed than amphibian lungs. The lungs of lizards and snakes are asymmetrical. In some lizards eg Calotes, the right lung is larger and in some the left lung is larger. In snakes, left lung is either much smaller in size or altogether absent. Lungs of Sphenodon (living fossil) show the most primitive condition in reptiles. They are simple sacs with uniformally arranged septa or infundibula. In snakes, the septa or infundibula are generally restricted to the basal part of the lungs and they enclose alveoli.

In lizards, the inner lining of the lungs is raised into a network of septa enclosing small alveoli. In each lung, the anterior part is more sacculated i.e containing more alveoli and more vascularised i.e more blood vessels. The walls of lungs and alveoli have rich supply of blood. In Crocodilians, the bronchi form a bronchial intercom as in mammals i.e form secondary + tertiary bronchi + thus the lungs become spongy organs as in mammals.

In chamaeleon, thin walled air sacs arise from the posterior part of the lungs. These air sacs innervate the viscera and are inflatable (i.e they can be enlarged, they do this to threat other animals). They seem to foreshadow the air sacs of birds. (i.e indicating a future event i.e the formation of air sacs in birds).

Mechanism of breathing: In reptiles, ventilation of lungs is brought about by the ribs + their intercostal muscles (These muscles run between the ribs + sternum). Contraction of the outer intercostal muscles pulls the ribs outward + forward, thus enlarging the pleuroperitoneal cavity.

This causes the elastic lungs to expand and thus pressure of air in them falls. The fresh atmospheric air outside, being at a higher pressure, immediately rushes in through the respiratory tract to fill the lungs. This is known as insperation

Exchange of gases takes place in the alveoli through their thin moist walls. Soon, the air in the alveoli becomes foul & needs to be eliminated

Contraction of the inner intercostal muscles returns the ribs to their original position, Partly due to the pressure exerted on them by ribs and partly due to their own elasticity, the lungs contract. As a result the pressure of air inside the lung rises. The foul air, passes to the exterior again through the respiratory tract and ultimately goes out through the nostril

This is called expiration. This mechanism of respiration is characteristic of ~~land~~ reptiles living on land.

Lungs in Birds or Aves

The Avian lungs are the most efficient among the vertebrates. They are small as compared to the size of the body. They are solid, spongy and slightly distensible. They are not as elastic as the lungs of frogs and lizards. They are pinkish in colour and are highly vascular. They do not hang freely in the thoracic cavity, but are closely applied by their dorsal surface to the thoracic vertebrae and the ribs. Thus, the dorsal surfaces of the lungs do not have the covering of visceral peritoneum. The visceral peritoneum covers only the ventral surfaces of the lungs. In the lungs of the birds, the visceral peritoneum is modified into a thick, strong, fibrous sheet called the pulmonary aponeurosis or pleura. Small fan like costopulmonary or intercostal muscles arises from the junction of the vertebral and sternal portion of the ribs and are inserted into the pleura.

Bronchial intercom: Lungs have a very complex system of bronchi inside them. This is called bronchial intercom. The antero-ventral end of each lung is pierced by a bronchus. This bronchus is also termed as primary bronchus. This primary bronchus within the lung loses its cartilagenous rings and is called mesobronchus. The mesobronchus extends right upto the posterior end of the lung. On its way, the mesobronchus dilates into a vestibule and gives off a number of small branches called the secondary bronchi or lateral bronchi. The secondary bronchi are

distinguished into dorsibronchi and ventrobronchi depending upon their position (i.e if present on the dorsal side of the lung, then dorsibranchi & if present of the ventral side called ventrobronchi)

The secondary bronchi (dorsi or ventro) further branch into many tertiary or parabronchi. Very fine, branching and anastomising tubules, the air capillaries or bronchioles radiate from the parabronchi or teertiary bronchi. Each capillary opens at both the ends into a paraponchi; so, there is no blind end and no dead space in the lung from where the air does not flow. (See Fig 20).

Much of the lung is composed of parabronchi and their associated bronchioles which together form hexagonal units. Exchange of gases between the air and the blood takes place through the thin, vascular walls of the bronchioles or air capillaries

Oblique septa: A muscular membrane extends on each side from the dorsal body wall to the base of the pericardium (heart) It encloses or surrounds the ventral walls of both the posterior thoracic air sacs. The oblique septa seperate the pleural cavities that contains the lungs from the abdominal cavity (that contains rest of the organs) The oblique septa do not correspond to the diaphragm of the mammals nor do they play any role in respiration (See fig 17).

Also Add Air Sac - Str. & [illegible]
even add the mechanism — At rest
During flight)

Lungs in Mammals

The mammalian lungs are much better developed than other vertebrates.

The lungs of mammals are located in the thoracic cavity and are present on the sides of the heart. The thoracic cavity is an air tight chamber enclosed dorsally by the thoracic vertebrae + ribs; laterally by the ribs only and ventrally by both the ribs and the sternum and with these bones are the associated muscles. The thoracic cavity is closed posteriorly by the diaphragm and boland anteriorly by the root or base of the neck. Each lung is enclosed in two membranes, which are actually the layers of the peritoneum and are called pleurae. The inner membrane is called visceral pleura and covers the surface of each lung. The outer membrane is called parietal pleura and it lines or is attached to the inner surface of the thoracic cavity. A very narrow space called the pleural cavity exists between the two pleurae. This cavity contains the watery fluid called the pleural fluid. The pleural fluid lubricates the two pleurae so that they may slide over each other without friction as the lungs expand and contract during respiration. (Fig Pulmonary Pleurae)

Structure: The lungs are soft, spongy, elastic and pinkish organs. They are divided by clefts into lobes. In Rabbit, the left lung has two lobes: left anterior and left posterior. and the right lung has 4 lobes: the anterior azygous, right anterior, right posterior and posterior azygous lobes.

Number of lobes of the lungs vary in different species

Generally, the right lung has more lobes than the left. In man the right lung has 3 lobes and left has 2 lobes. In cat, right has 4 lobes and left has only 3. In rat right has 4 lobes and left has one. The elephant, Hyrax etc. have non-lobed lungs.

In mammals, the trachea divides into two bronchi before entering into the lungs. These bronchi are called primary bronchi. Within the lung, each primary bronchus divides into secondary bronchi which in turn divide into tertiary bronchi. From the tertiary bronchi, branch the bronchioles and these bronchioles lack the cartilagenous rings (All pry. sec & tertiary bronchi have cartilagenous rings). Each bronchiole divides into a few thinner branches, the alveolar ducts. Each alveolar duct opens into a blind chamber, the alveolar sac or infundibulum. The alveolar sac consists of a central passage giving off several small pouches, the alveoli or air sacs on all sides. These air sacs give the alveolar sac or infundibulum, the appearance of a small bunch of grapes. The alveolar sacs are generally separated from each other by interalveolar septa but are sometimes connected by minute alveolar pores. The walls of the alveoli are extremely thin composed of single layered, moist squamous epithelium and surrounded by fine network of capillaries. These alveoli provide surface area for gaseous exchange. It occurs by diffusion between the air in the alveoli and the blood passing through the capillaries surrounding the alveoli. The no. of alveoli found are enormous. The human lungs have about 750,000,000 alveoli. A group of alveolar sacs, that receive alveolar ducts from a single bronchiole form a lobule of the lung.

Each lung has innumerable such lobules. This makes the lungs spongy. (See Fig 5.29). + (Fig 22).

The mechanism of respiration in mammals involves 3 steps — (i) Inspiration (ii) Exchange of gases (iii) Expiration

(i) Inspiration: It involves the process of taking in of fresh air in the alveoli of the lungs. Here two types of muscles are involved.

(a) Pheneric muscles — These muscles extend from the diaphragm (dome-shaped muscle that separates the chest from abdomen) to ribs and vertebral column. When these muscles contract, the diaphragm is flattened. The flattening of the diaphragm pushes the viscera backward and enlarges the thoracic cavity anteroposteriorly.

(b) External Intercostal muscles: These muscles extend from the hind border of one rib to the front border of the rib behind. When these muscles contract, the ribs are pulled forward, downward and outward, so thoracic cavity increases laterally and dorsoventrally.

As both the types of muscles contract simultaneously, the thoracic cavity increases in all directions and since the lungs are held tightly against the thoracic wall, increase in the dimensions of thoracic cavity results in the expansion of lungs. This reduces the pressure of air in the lungs below the atmospheric pressure. As the air always moves from a place of higher pressure to lower pressure. Hence, the fresh air from outside, rushes into the lungs through respiratory tract till the pressure of air in the lungs becomes equal to the atmospheric pressure. On reaching the lungs, the fresh air is taken through the bronchi, bronchioles, and alveolar ducts to alveoli or air sac. This is called inspiration

(ii) Exchange of gases — Exchange of gases takes place in the alveoli. O_2 passes from the alveoli into the blood in the surrounding blood capillaries and the CO_2 passes from the

blood into the alveoli. The air in the alveoli thus becomes foul and needs renewal.

(iii) Expiration: It involves the expelling of the foul air from the body. Expiration is normally a less active process than inspiration, as it simply involves relaxation of inspiratory muscles ie phrenic and external intercostal muscles. The relaxing of phrenic muscles causes the abdominal viscera compressed during inspiration to push the diaphragm forward, making it convex anteriorly ie domeshaped again. The relaxing of the external intercostal muscles brings the ribs and the sternum to their original position. This is aided by the elastic recoiling (contraction) of the lungs and the thoracic wall which are stretched or expanded during inspiration. With the above two events the thoracic cavity becomes smaller.

But during the heavy or forceful breathing two expiratory muscles are involved:

(a) Abdominal muscles: They extend from the ribs to the abdominal organs. When these muscles contract, the abdominal visceral organs are pulled upward towards the diaphragm. So the diaphragm becomes more convex and thoracic cavity decreases anteroposteriorly

(b) Internal intercostal muscles: These muscles are arranged at right angles to the external intercostal muscles. When these muscles contract, the ribs are pulled backward and inward, so the thoracic cavity decreases laterally and dorsoventrally.

The decrease in the thoracic cavity, reduces the lungs and raises the pressure of the air in the lungs above atmospheric pressure. This pushes out the foul air from the lungs until the pressure of the air in the lungs falls to that of the atmospheric pressure

(See fig 24)

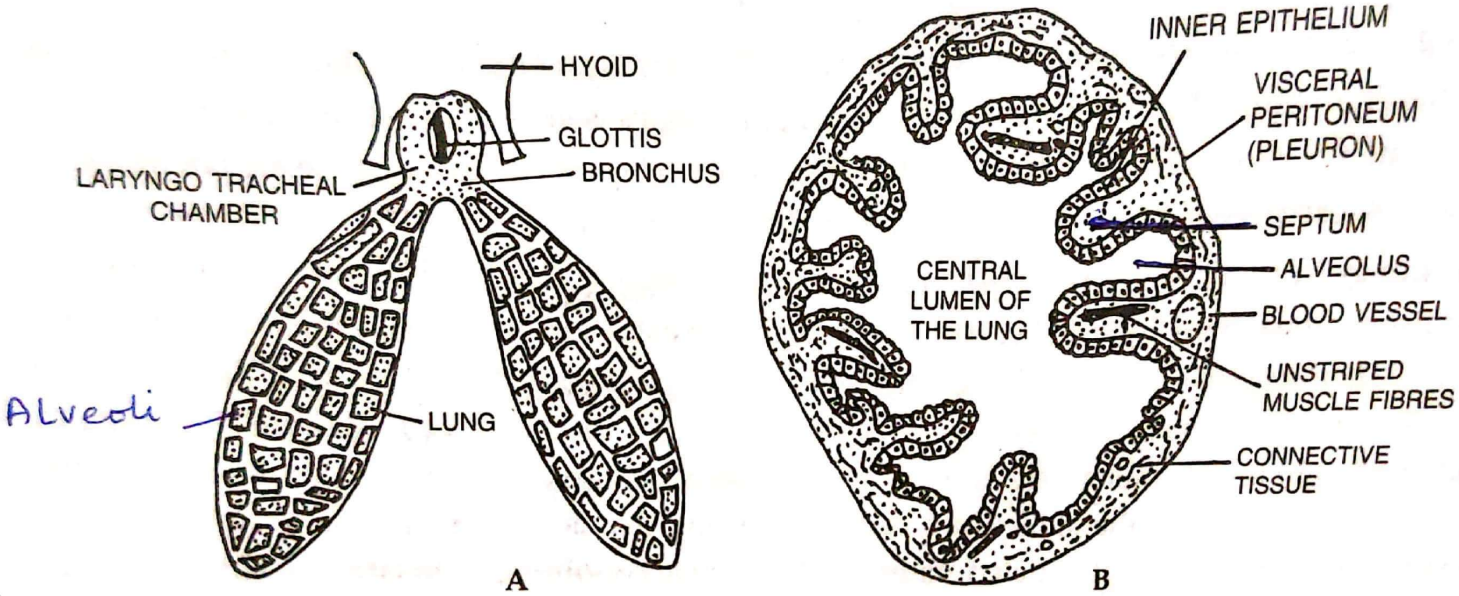


Fig. 15. Frog : **A.** Pulmonary respiratory system **B.** T.S. lung.

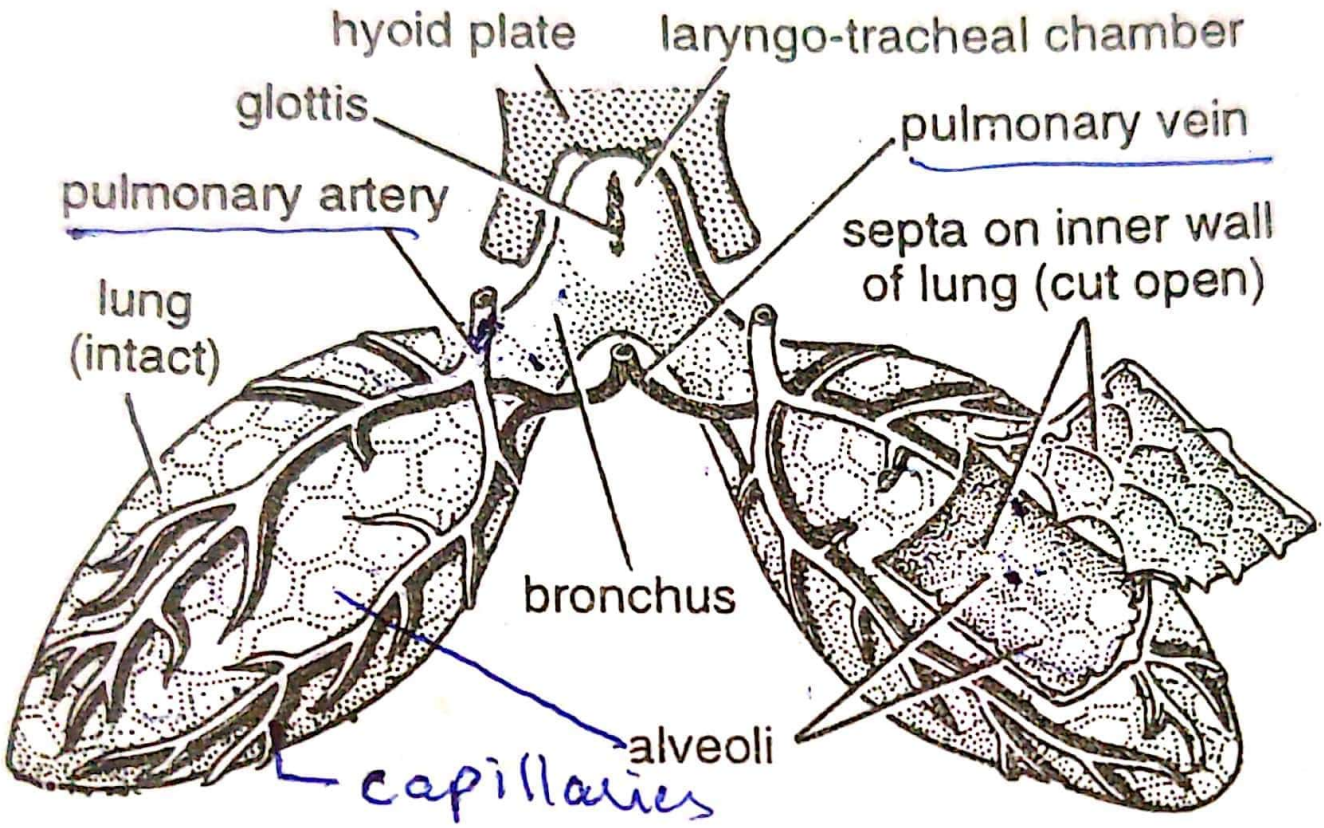


Fig. 15. Frog. Respiratory organs in dorsal view. Right lung partly cut open to show inner partitions and alveoli. (just for reference)

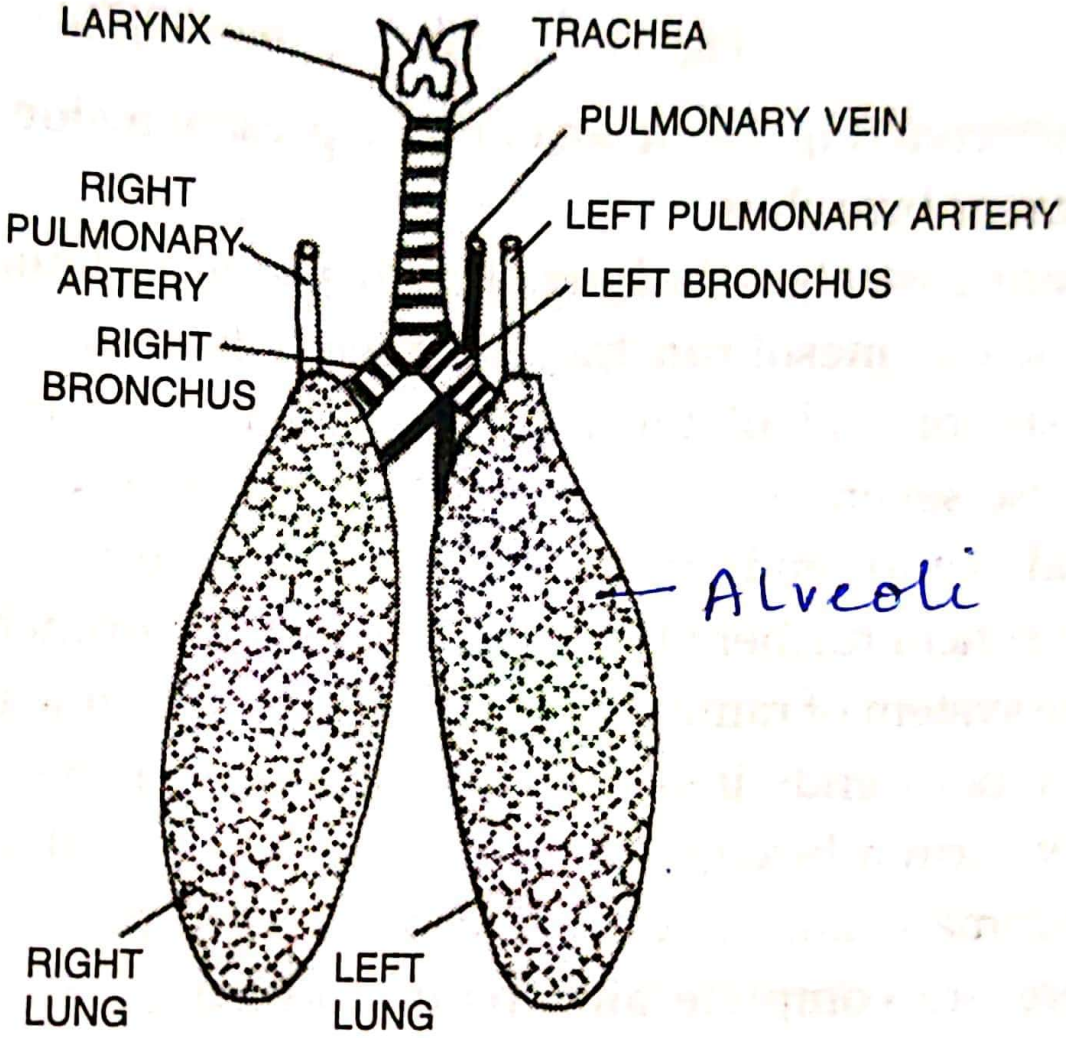


Fig. 16. Respiratory organs and tract of *Hemidactylus*. (Reptile)

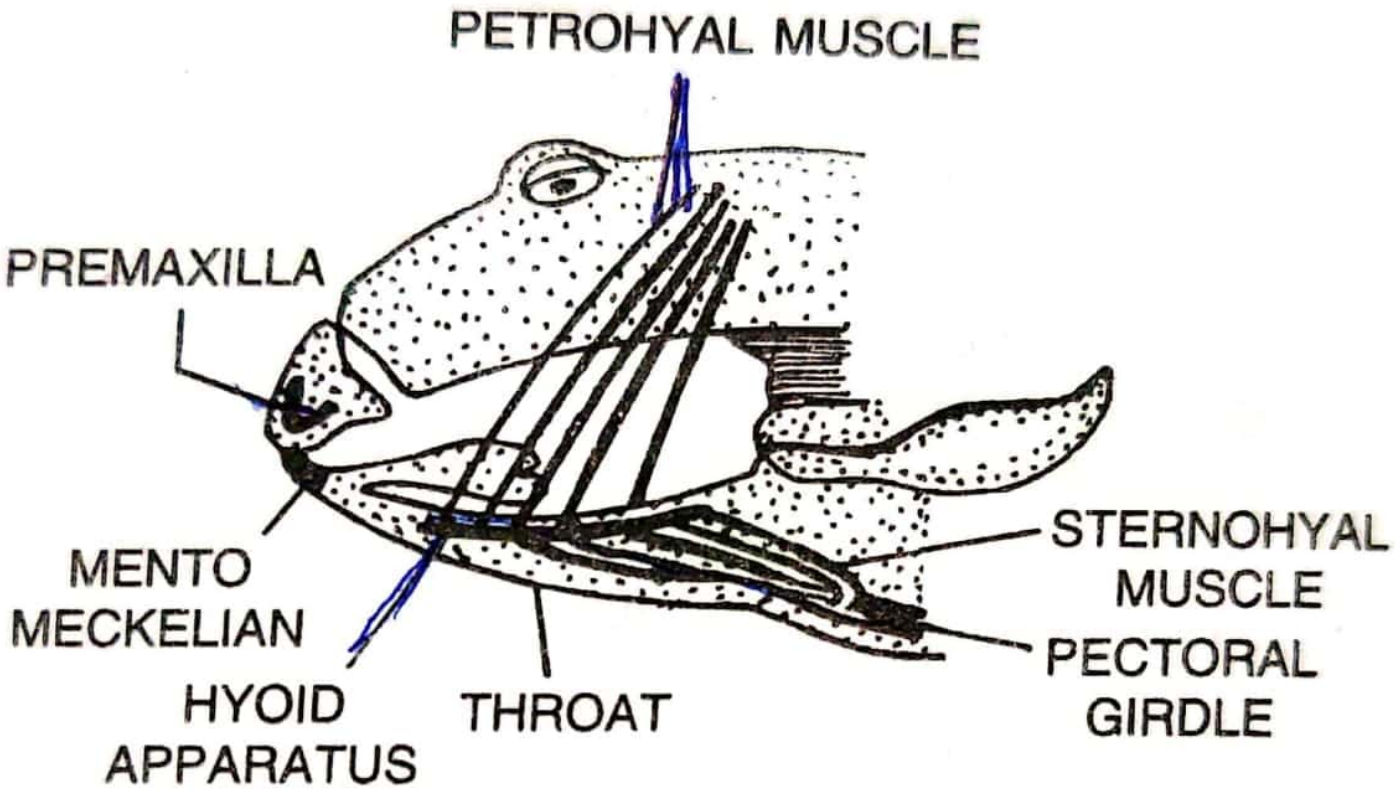


Fig. 22. Frog : Respiratory muscles.

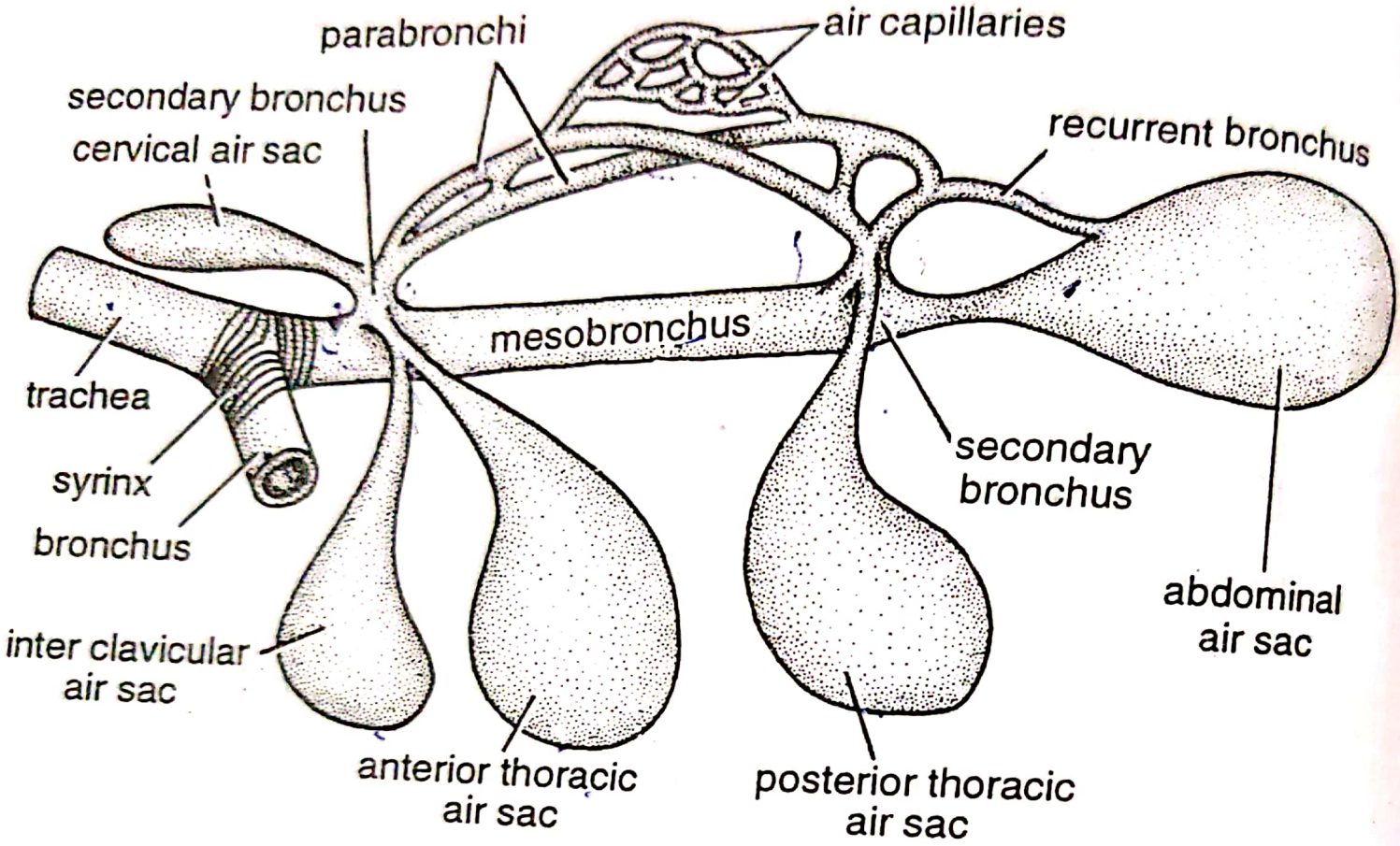


Fig. 20. Pigeon. Scheme of histological structure of a lung and origin of air sacs.

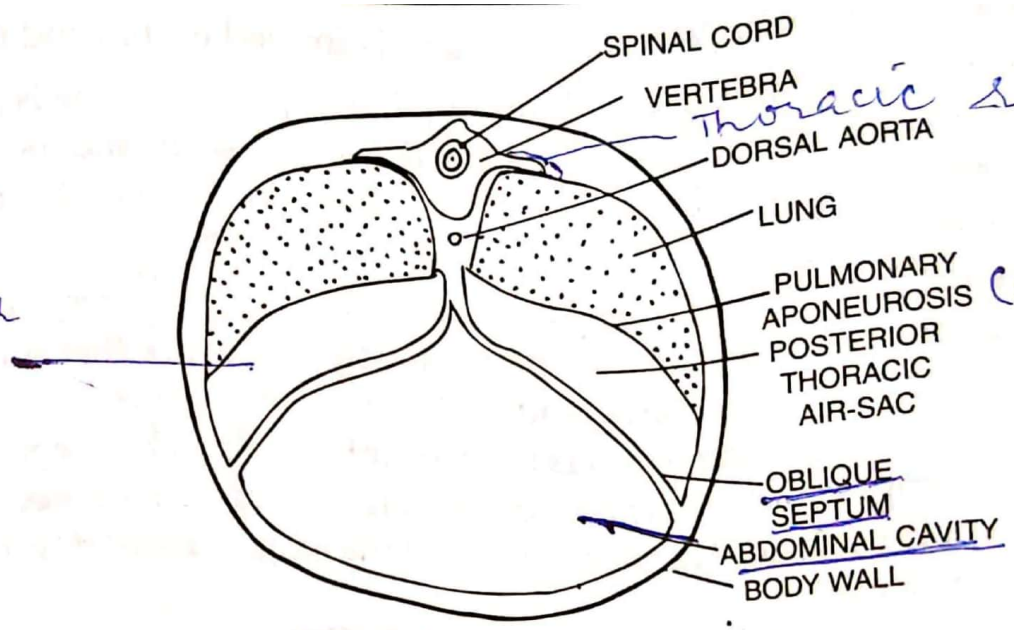


Fig. 17. Pigeon : T.S. through lungs.

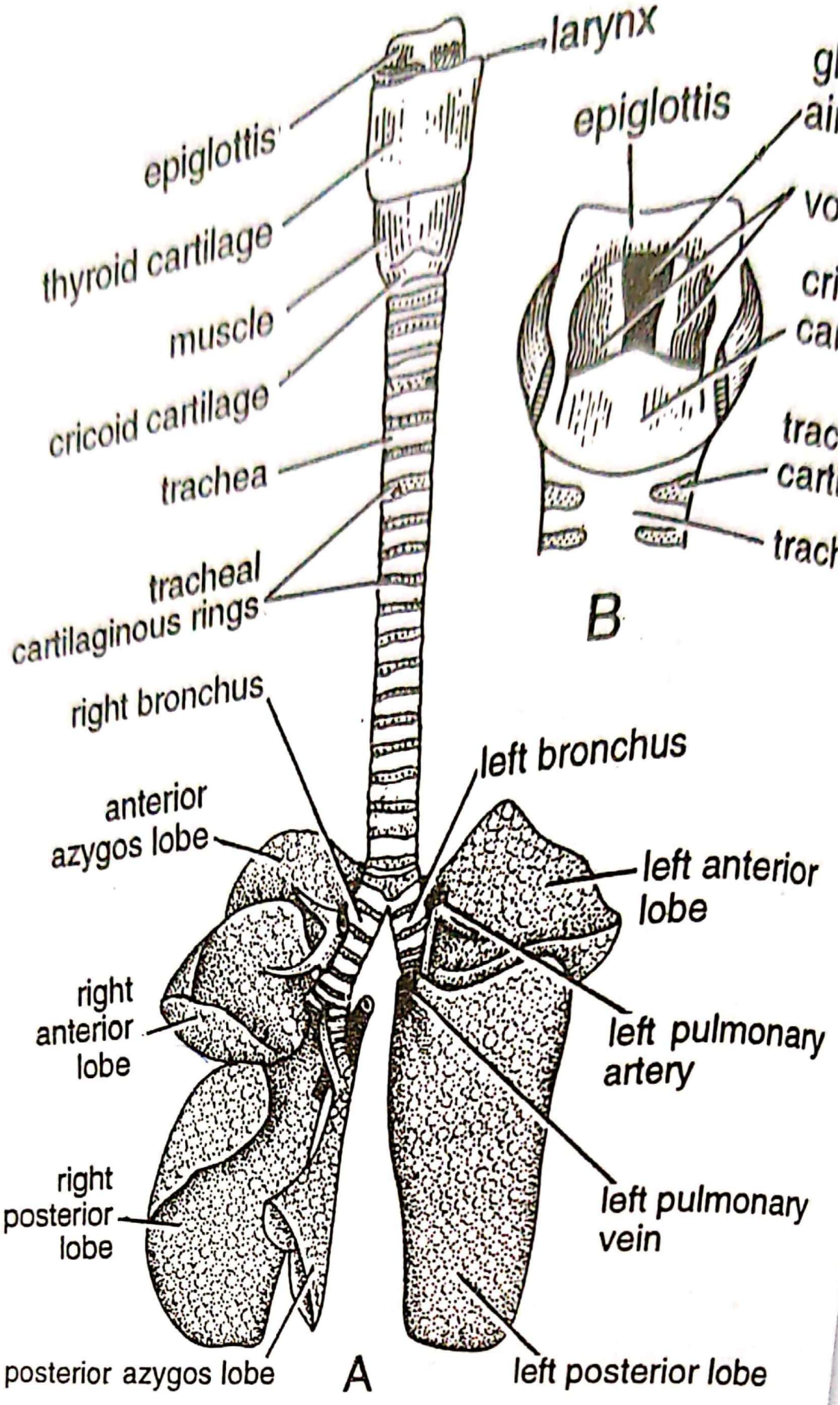


Fig. 22. Rabbit. A—Respiratory system in ventral view. B—Vocal cords in dorsal view of larynx.

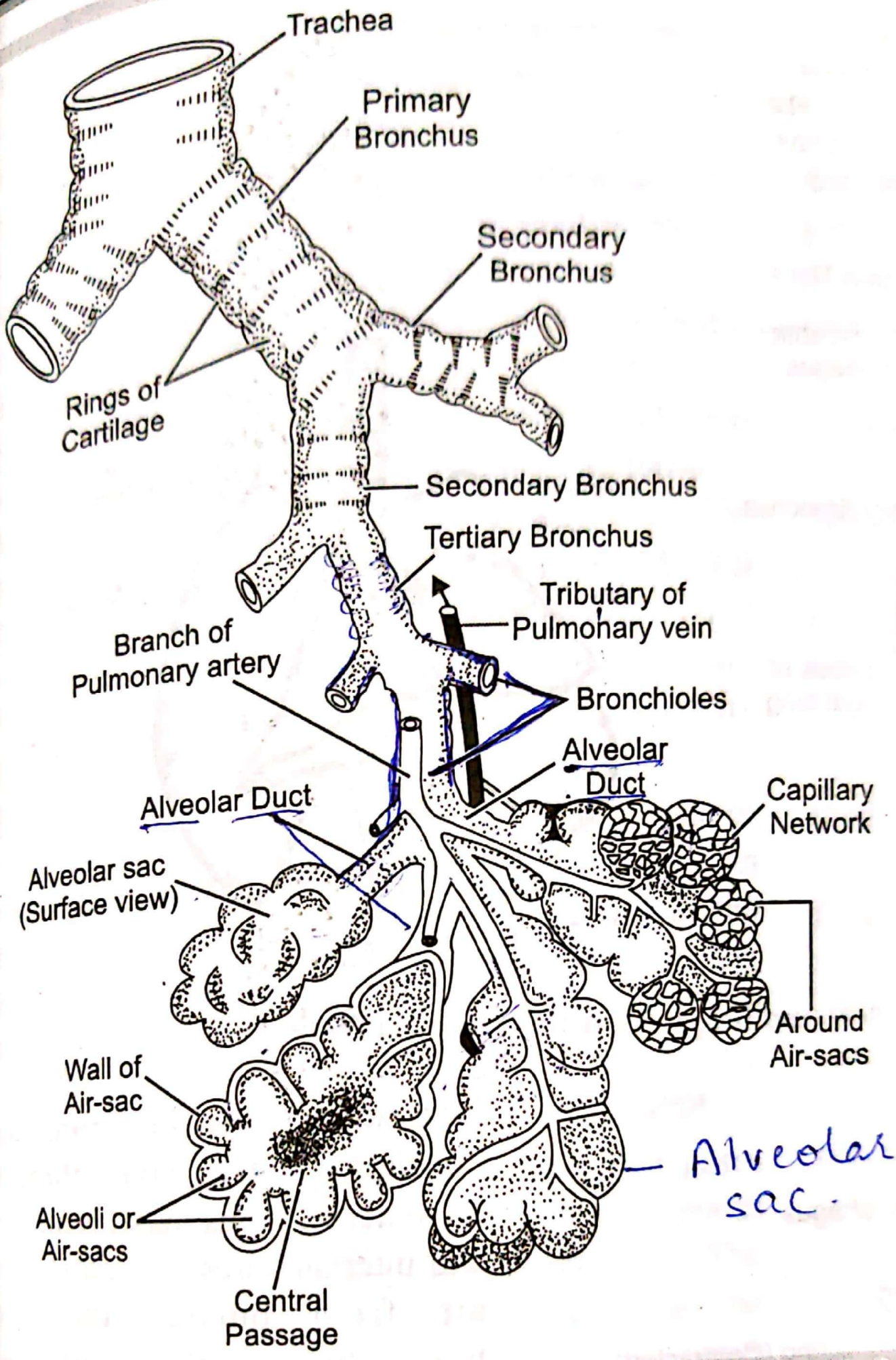


FIGURE 5.29. Branches of trachea and structure of infundibula.

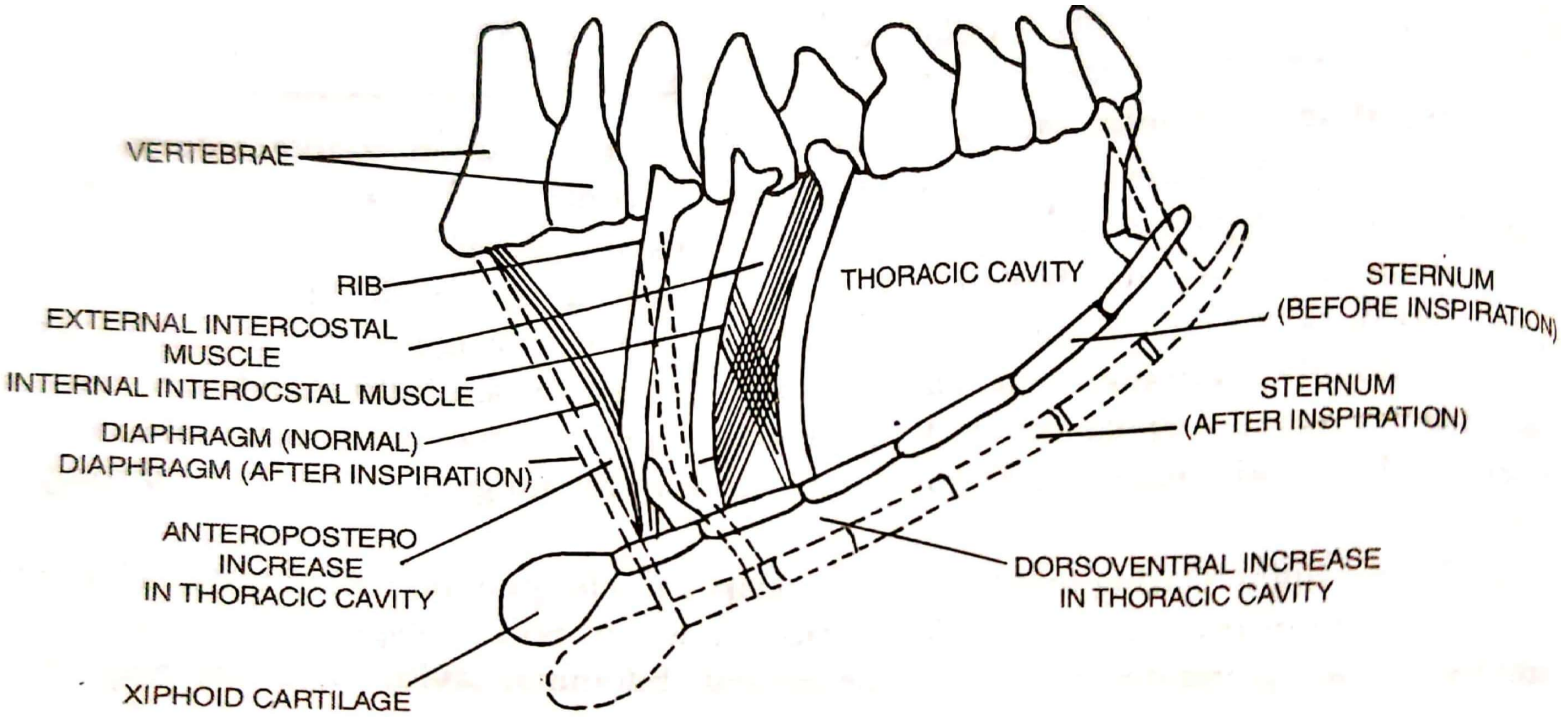
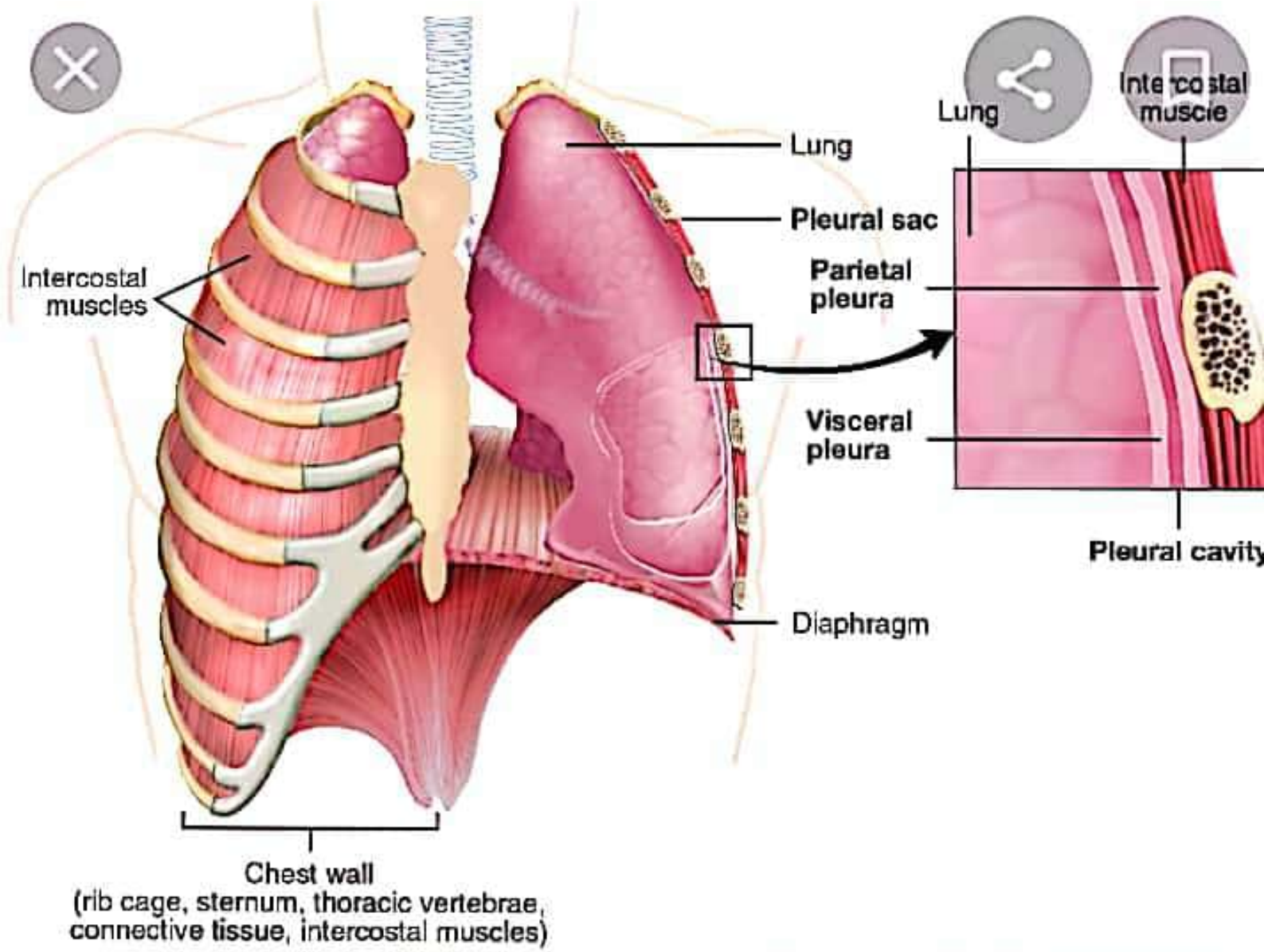


Fig. 24. ~~Rat~~ : Mechanism of breathing. in mammals



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