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Morphological and Histological Comparative Study between the Lower Respiratory System of Pigeon (*Columba livia*) and Guinea Pig (*Cavia porcellus*)

Jehan Mahmood Rajab[1], Raghad Abdulmahdi Mohsin[2] and Nagham Saadi Mohammed[3]

[1-3]Department of Pharmacology and Toxicology, College of Pharmacy, Mustansiriyah University, Iraq.

E-mail: jehan@uomustansiriyah.edu.iq , raghad.abdulmahdi@uomustansiriyah.edu.iq , naghamsaadi@uomustansiriyah.edu.iq

ABSTRACT

The current study showed that there are morphological and anatomical differences between pigeons and guinea pigs. The trachea appeared in pigeons in the form of a long tube containing cartilaginous rings that were completely round and overlapping with each other, while the trachea appeared in the guinea pig in the form of a long tube with a diameter wider than that of the pigeon. It consisted of a group of cartilaginous rings that were not completely round. In both types, the lung consisted of left and right lobes. The lung in pigeons was rectangular in shape, fragile, and it has many blood vessels, it was closely attached to the ribs. The lung of the guinea pig was composed of a group of lobes pyramidal in shape, and the left lung was smaller than the right lung. Histologically, the trachea in both animals consisted of four tissue layers, which are mucosa, submucosa, and a layer of connective tissue that contains cartilage and is covered from the outside with a layer of covering tissue called the adventitia. The lung in the pigeons also consisted of connective tissue with wide holes that were uniformly distributed throughout the lung tissue. The lung in the guinea pig consists of connective tissue with many branches, which represent the branches of the bronchioles, and those branches end with air sacs in the form of clusters. The differences in the nature of the behavior of the two animals could be a major reason for the presence of morphological and histological differences in the structure of the respiratory system of both animals.

Keywords: **Guinea Pig, Histological, Lower Respiratory System, Morphological, Pigeon.**

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INTRODUCTION

The respiratory system is made up of the trachea, bronchi, larynx, nasal cavity, and lungs in general. In addition to facilitating gaseous exchange, the respiratory system of organisms also plays a role in creating sound, controlling body temperature, and detoxifying certain metabolites (Knudsen & Ochs, 2018). Birds' respiratory systems are distinct from mammals' respiratory systems in that they have syrinxes and air sacs (Dyce et al., 2010). The function of the air sacs in birds is to increase breathing efficiency by removing carbon dioxide from the body and providing the blood with a enough supply of oxygen (Dogan & Takici, 2018). The respiratory system birds also differ in that the tracheal rings are complete, unlike mammals, in which the tracheal rings are incomplete. Birds also do not have a diaphragm separating the thoracic cavity from the abdominal cavity. The trachea is divided into two primary branches. Each branch enters a lung to branch inside the lung

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into secondary and tertiary branches that end with alveoli in mammals, while in birds these branches end with parabronchus (Hsia et al, 2016). The rate of oxygen consumption in birds increases when flying at a rate greater than that of other animals (Asker & Al-Azawi, 2021). Therefore, birds need adaptations that increase the volume of gas in the lungs of birds, such as the presence of air sacs connected to the lungs, which are connected to each other through a network of tubes, which makes the total size of the respiratory system about twice what is found in mammals that have the same size (Butler, 2016).

Ethical approve

On January 07, 2022, this investigation was conducted in the animal house of the College of Science at Mustansiriyah University in Iraq, under the ethical approval number BCSMU/0122/00019Z.

MATERIALS AND METHODS

Five adult male pigeons and five adult guinea pigs were used for the purpose of the study. Animals were anesthetized with intramuscular injection of diazepam (1 mg/kg) and ketamine HCL (30 mg/kg). Animals were dissected using sharp dissecting scissors to obtain the lower respiratory organs (trachea, primary bronchi, and lungs). The organs were photographed by using a 12-megapixel Sony digital camera (Sony Corporation, Japan).

The samples were dried with a series of increasing concentrations of ethyl alcohol, and xylene was used for clearing. Filtration was done by using paraffin wax and xylene together, and finally the samples were embedding with pure wax with a melting point of 60-62 degrees Celsius, and a rotary microtome was used for the purpose of cutting in the form of serial sections 5 cm thick. Slides were stained with Harris hematoxylin and eosin stains for general histological structures. Hematoxylin stains the cell nucleus blue, and eosin stains the cytoplasm pink (Suvarna et al., 2019) Stained slides were examined by using a digital camera attached to an Olympus microscope.

RESULTS AND DISCUSSION

1- Morphological Description

1-1- The trachea, primary bronchi and lungs in guinea pig.

The trachea in guinea pigs showed as a pliable cylindrical tube hollow made up of hyaline cartilage rings with ligament and muscle (Fig.1). The tracheal rings were semi-circular in their cross-section. This finding didn’t like as trachea in the dog (Jackson & Krevans, 1984). The cervical and thoracic sections of the trachea are divided. There are differences in tracheal lengths and plate numbers across and within species. For example, dogs have 42 to 46 plates, whereas cats have 38 to 43 plates (Getty, 1975). The left and right bronchi make up the trachea. The apical, middle, auxiliary, and caudal lobes are the four major bronchi from which the right bronchus was constructed. This result was the same as that seen in cats: the right major bronchus supplies the right primary bronchus to the apical lobe (Fig. 1) (Nassar, 2012). The middle bronchus enters the middle lobe of the right lung. The caudal lobe is the target of the right caudal major bronchus (Fig. 1), and these findings are consistent with those of (Al-Anbaki, 2013), who examined the rabbit lung. The right primary bronchus, which divides into the secondary and tertiary bronchi, is the result of the right main bronchus. The caudal primary bronchus, middle primary bronchus, and left apical bronchus split out from the left main bronchus (Fig. 1). These results were in conflict with those found in the pig lung by (Schwarzkopf et al., 2010).

The lungs of guinea pigs resemble the thoracic cavity (Fig. 1) in domestic animals (Pasquini et al., 1997) and are paired, pink, spongy structures that encircle the heart. Each lung has caudal and ventral boundaries in addition to a dorsal, apical, and basal area. The dorsal boundaries were thick and round, while the ventral and caudal borders were flat and pointed. As seen in rabbits, the apex of the right lung was spherical and big, whereas the left lung was pointed and little (Fig. 1). The convex and thin diaphragmatic, medial, and costal surfaces of the lungs are similar to those of ruminants (Thrall, 2002). Interlobular fissures separated the lung into lobes, with the right lung having apical, middle, and caudal lobes (Fig. 1), similar to those reported in cats (Nassar, 2012) and goats (Habib & Mahammed, 2010). The right lung is bigger than the left due to the location of the heart. These outcomes correspond to the dog's outcomes (Legaspi, 2010). There are three lobes in the left lung as well: the caudal, middle, and apical (Fig. 1). These findings are in opposition to what is seen in cats, where the left lung is made up of a caudal lobe and a left apical lobe (Oliveira et al., 2001), as well as what is seen in hamsters (Kennedy et al., 1978), which has only one lobe.

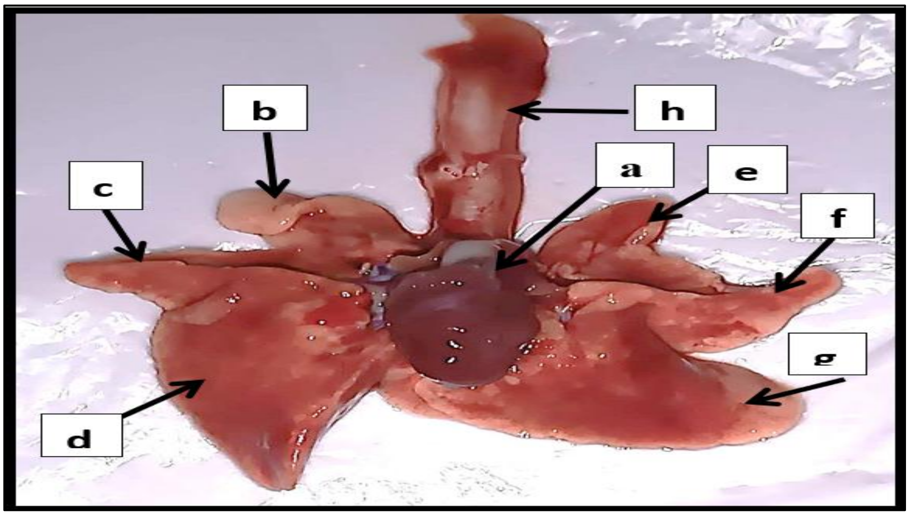

Figure 1: Photographic Picture of the Respiratory system in the guinea pig Shows, Heart (a), Right cranial lung lobe (b), Right medial lung lobe (c), Right caudal lung lobe (d), Left cranial lung lobe (e), Left medial lung lobe (f), Left caudal lung lobe (g), Trachea (h).

1-2- The trachea, primary bronchi and lungs in pigeon

The pigeon's trachea was a long tubular cartilaginous structure, comprising unfolded elastic rings and a series of fully cartilaginous rings. On the anterior side, the trachea was connected to the larynx. On the other side, the trachea was extended towards both the right and left lungs. Bifurcating main bronchi allow the trachea to reach the lungs (Fig. 2, 3). Between 67 and 70 complete rings of thin cartilage are seen on average (Fig. 2, 3). Our investigation confirmed what was stated by (Ibe et al., 2008), namely that the cervical trachea is linked to two ventral sides by the thyroid muscle. However, the results did not match the findings of (Ali & Mutlak, 2019), who claimed that the trachea comprises incomplete cartilage rings, with the number of rings being about 16–17. The pigeon's lungs were pink, spongy, and rectangular in shape. The lungs connected by ribs are located inside the thoracic cavity (Fig.2, 3). These results correspond with (Al-Mussawy et al., 2010) who wrote that lung shapes were elongated-triangular, pink in color, and extended inside a thoracic cavity from the 1st to 6th vertebral ribs in Turkey (Meleagris gallopava).

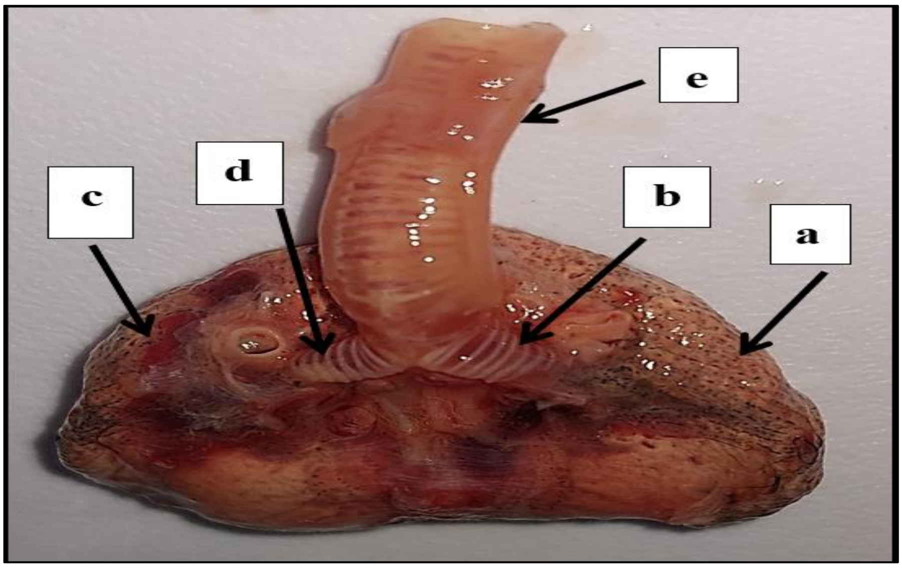

Figure 2: Photographic Picture of the Respiratory system (posterior view) in the pigeon Shows: Left lung (a), Left Primary bronchus (b), Right lung (c), Right primary bronchus (d), Trachea (e).

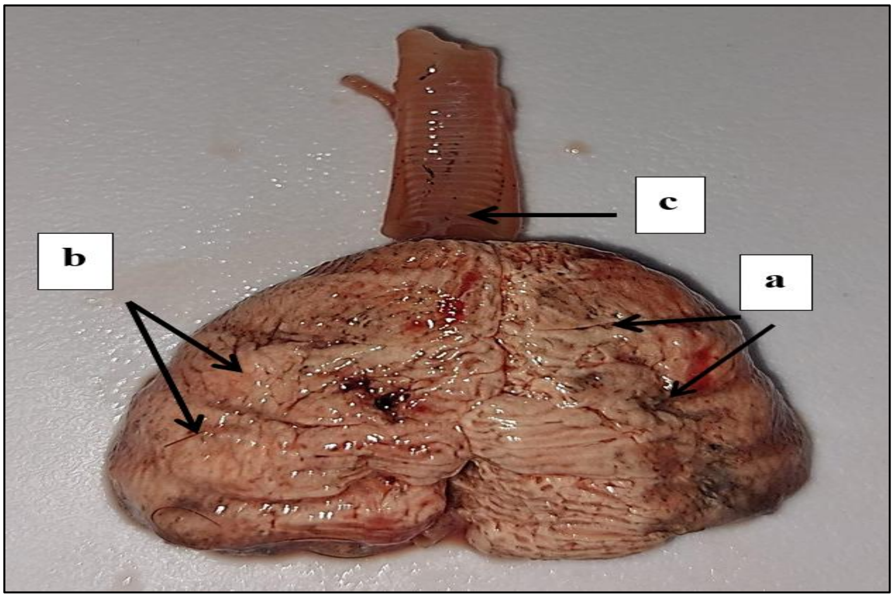

Figure 3: Photographic Picture of the Respiratory system (anterior view) in the pigeon Shows: Left lung lobes (a), Right lung lobes (b), Trachea (c).

2- Histological structure

2-1- The trachea, primary bronchi and lungs in guinea pig

In guinea pigs, the trachea is a hollow, tubular organ made up of adventitia, mucosa, submucosa, and muscle (stratum cartilaginous). As seen in caiman (Santos et al., 2011), the mucosa is composed of basal cells, goblet cells, and ciliated columnar cells that are resting on the foundation membrane (Figure 4). Similar to yak (Yang et al., 2010), the most prevalent cell types were long columnar cells with apical cilia extending into the tracheal lumen on their surfaces. Despite not reaching the lumen, basal cells had tiny triangular cells lying on the basement membrane (Habib & Mahammed, 2010). In goats, the tracheal epithelium was the same as observed in other laboratory animals (Reznik, 1990). The lamina propria, a thin layer of loose connective tissue composed of collagenous and elastic fibers, was not well developed. A few smooth muscle fibers and a very thin layer of muscularis mucosa are present in rabbits (Al-Anbaki, 2013).

The tunica submucosa observed a layer of loose connective tissue. Blood vessels have very few, small, tubular–acinar submucosal mucous glands (Fig.4, 5). The guinea pig revealed a unique character in the glands density this finding disagreed with that reported in rabbits, mice, and hamsters where the submucosal glands were absent (Widdicombe et al., 2001). The current study demonstrated low or very rare submucosal glands while camel were found a large number of submucosal glands (Raji & Naserpour, 2007). Many of tracheal glands secrete mucous lined by simple columnar to cuboidal cells or with large round basally situated nuclei and wide lumen (Fig.4, 5). This result agrees with (Widdicombe et al., 2001) Widdicombe in the horse, where it was founded mucus was found, where mucus has an important role in preventing dust accumulation (Thornton & Sheehan, 2004). Goblet cells produce mucus that is also secreted by the submucosal gland, whose function is to moisturize, lubricate, and provide normal mucociliary clearance (Buechner & Maxwell, 1993). The muscular cartilage layer is embedded with the perichondrium cartilage of the hyaline meniscus and fibrous tissue located between the cartilage rings. Hyaline cartilage contains chondrocytes in an amorphous matrix (Figure 4), a similar observation in ruminants by (Habib & Mahammed, 2010). The cartilaginous rings open dorsally, appear C-shaped, and are filled with tracheal smooth muscle and connective tissue connecting the inner side of the rings (Fig. 5), as observed in other species (Ibe et al ., 2011). The tunica adventitia with loose connective tissue covers the cartilage as shown in rabbits (Al-Anbaki, 2013).

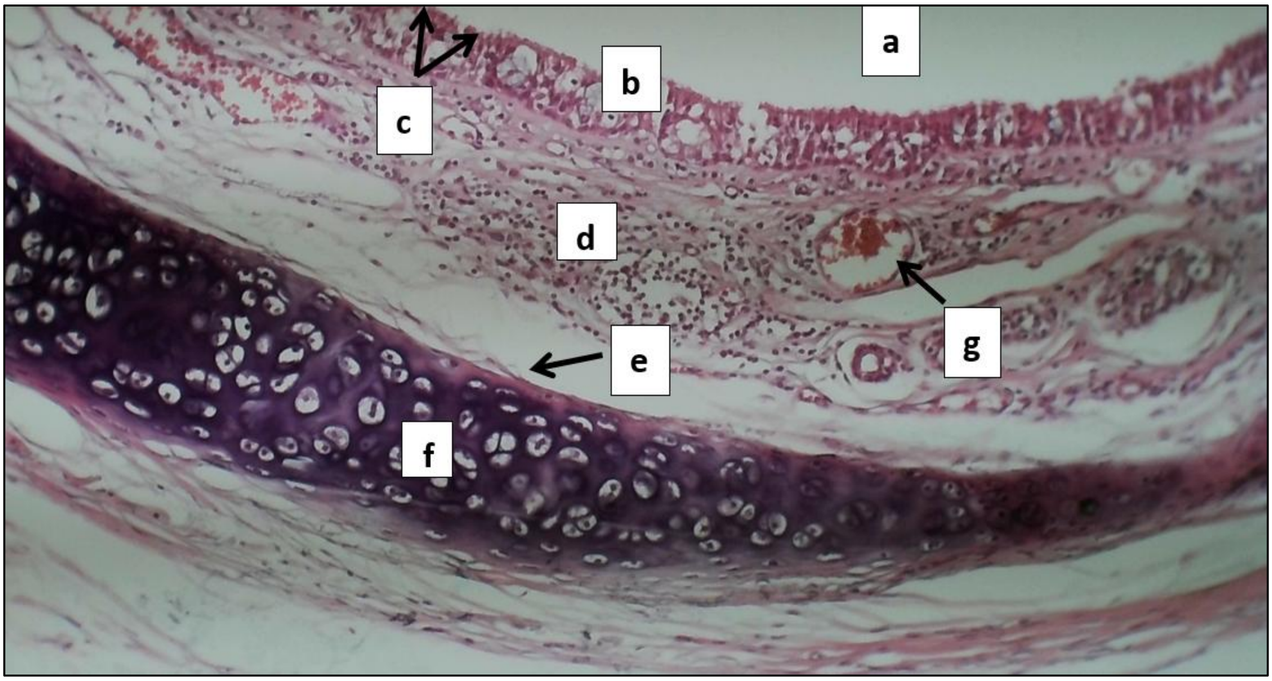

Figure 4: Cross section of the trachea wall in the guinea pigs shows: the tracheal lumen (a), ciliated pseudostratified columnar epithelium (b), goblet cells (c), submucosa (d), perichondrium (e), hyaline cartilage (f), blood vessel (g) H & E stain (X100).

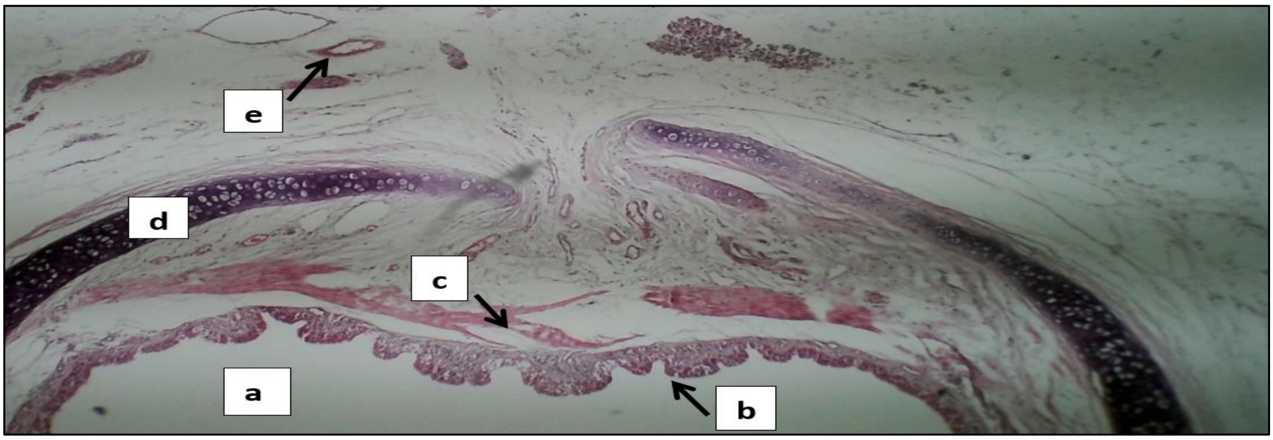

Figure 5: Cross section in the trachea of guinea pigs shows: the lumen of the trachea (a), tunica mucosa (b), tracheal muscle (c), hyaline cartilage (d), blood vessel (e) H & E (X40).

The lung was composed of alveoli with blood capillaries and interalveolar septum. The alveoli display as small spherical air spaces surrounded partly by simple squamous epithelium which formed the mainlining epithelium, type I pneumocyte which showed as squamous cells with a centrally located nucleus and the type II pneumocyte, which was observed as rounded or cuboidal cells scattered between the type I pneumocyte (Fig. 6). As shown in rats (Dahlin et al., 2004) and in goat (Carvalho & Gonçalves, 2011). Type I pneumocytes of alveoli and stated to be mainly accountable for an interface between the air and blood to permit gas exchange (Banks, 1993). Pneumocyte type II has secreted mucus, mucus works as lubrication of the epithelial layer resulting in a reduction in the surface tension and preventing alveolar collapse through the exhalation (Plopper & Adams, 1993). The pneumocytes type II and I types were found in the same species (Kahwa et al., 1997). The inter-alveolar septa were made up of one layer of epithelium, a very thin connective tissue layer composed of fine collagen, blood capillaries, and reticular, elastic fibers underlying the epithelium, this result was agreed in goats (Baba & Choudhary, 2008). Visceral pleura made up of thin connective tissue and a mesothelium, like the finding in a goat (Habib & Mahammed, 2010).

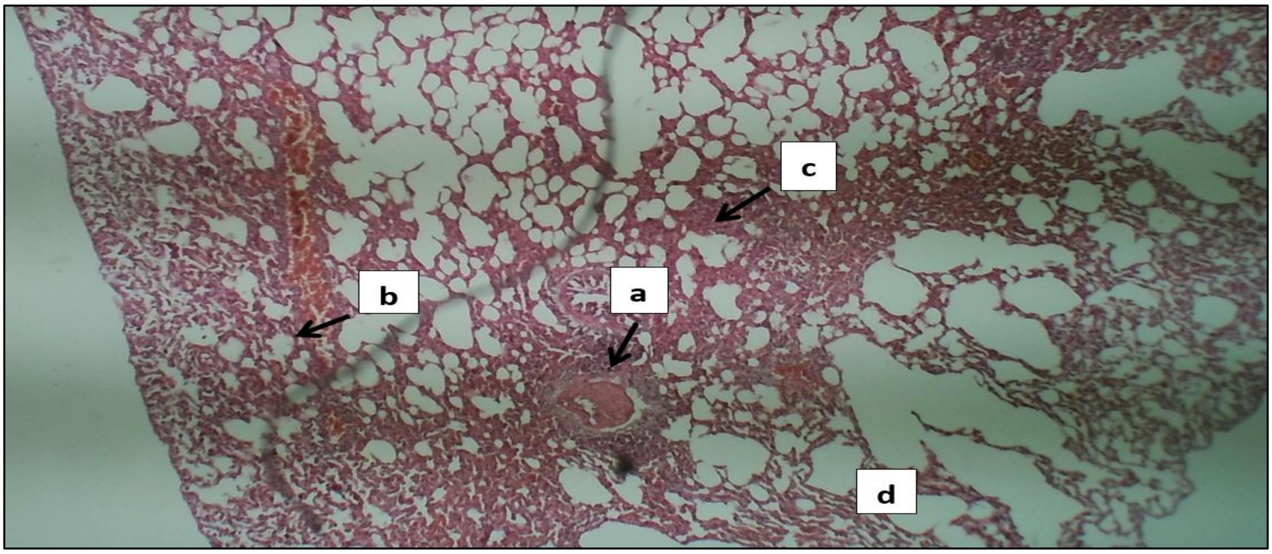

Figure 6: Cross section in lung of the guinea pigs shows: simple squamous epithelium (a), blood vessels (b), alveolar sac (c), alveolar duct (d) H&E stain (X100).

2-2- The trachea and primary bronchi and lungs in pigeon

The tunica mucosa, which is bordered by ciliated pseudostratified columnar epithelial cells with goblet cells, makes up the tissue layers of the trachea of Columba livia. and the lamina propria, a loose layer of connective tissue rich in blood vessels and containing collagen and elastic fibers. The next layer of mucosa is called the submucosa, and it includes a cartilaginous tracheal tube that is packed with mucous glands and blood arteries (Fig. 7, 8). The exterior layer of cartilage is covered with loose connective tissue and blood arteries, which make up the tunica adventitia. These findings supported the findings of Waad (Waad, 2015; Sabaa Khameas Abid et al., 2020), who observed that in guinea fowl and geese, the trachea was lined with ciliated pseudostratified columnar epithelium containing goblet cells.

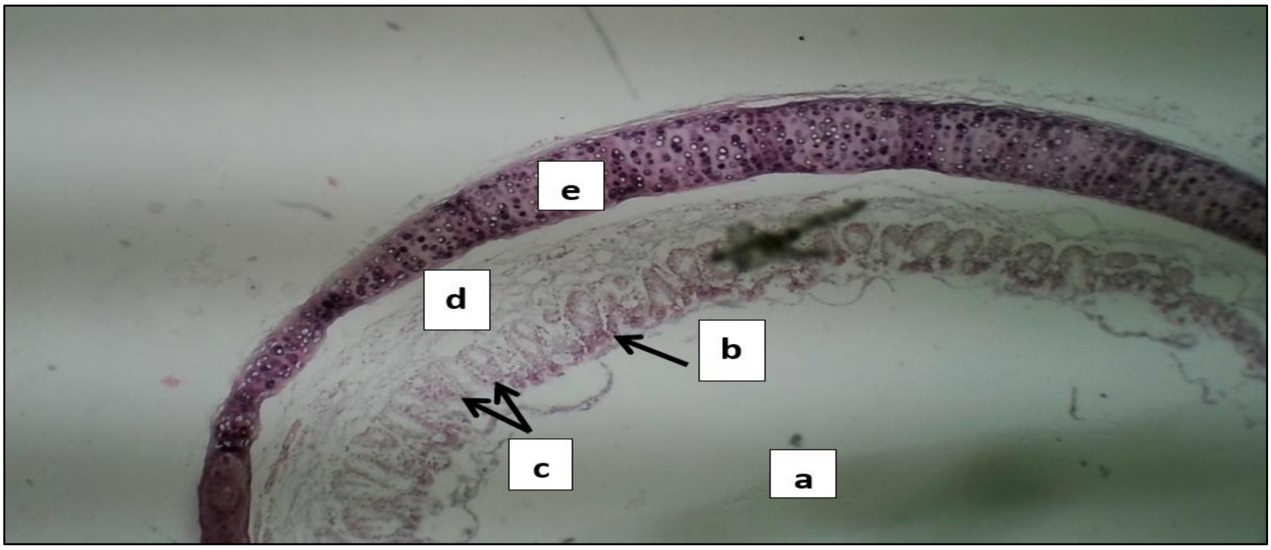

Figure 7: Cross section of the trachea wall in the pigeon shows: tracheal lumen (a), ciliated pseudostratified columnar epithelium (b), goblet cells (c), submucosa (d), tracheal hyaline cartilage (e) H & E stain (X40).

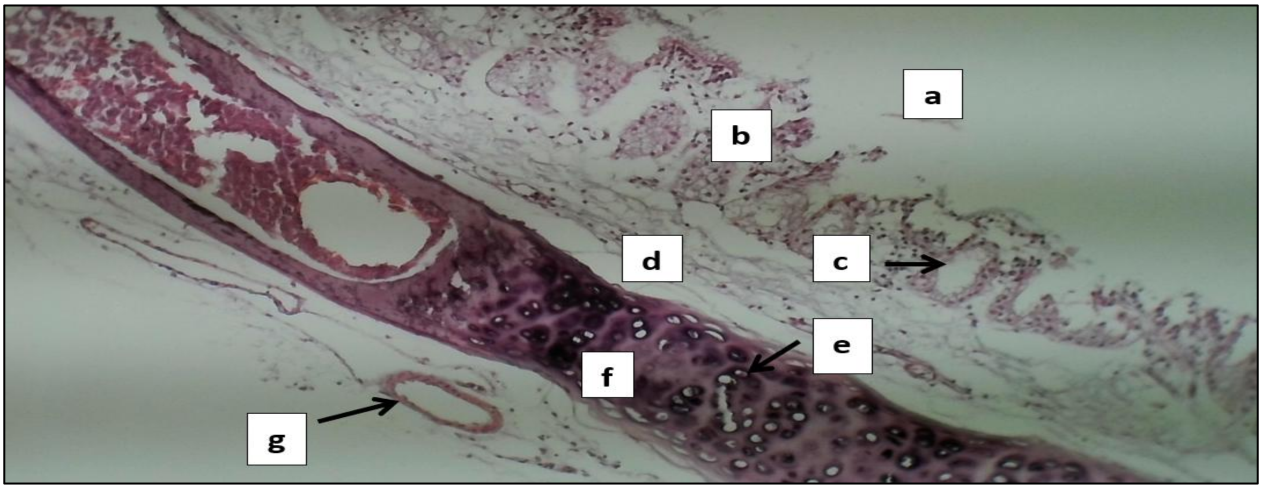

Figure 8: Cross section of the trachea wall in the pigeon shows: tracheal lumen (a) ciliated pseudostratified columnar epithelium (b) goblet cells (c), submucosa (d) perichondrium (e) hyaline cartilage (f) blood vessels (g) H & E stain (X100).

The study noted that the bronchi were lined with simple squamous epithelium to facilitate gas exchange within the lungs and blood vessels surrounded by connective tissue (Fig. 9). These observations agreed with Frandson (Frandson et al., 2009) who said that the bronchi were lined with squamous cells and separated by lobulated septa. The study also disagreed with Maina and Nathaniel (Maina & Nathanel, 2001) who reported that the septa between the bronchi were absent in the ostrich.

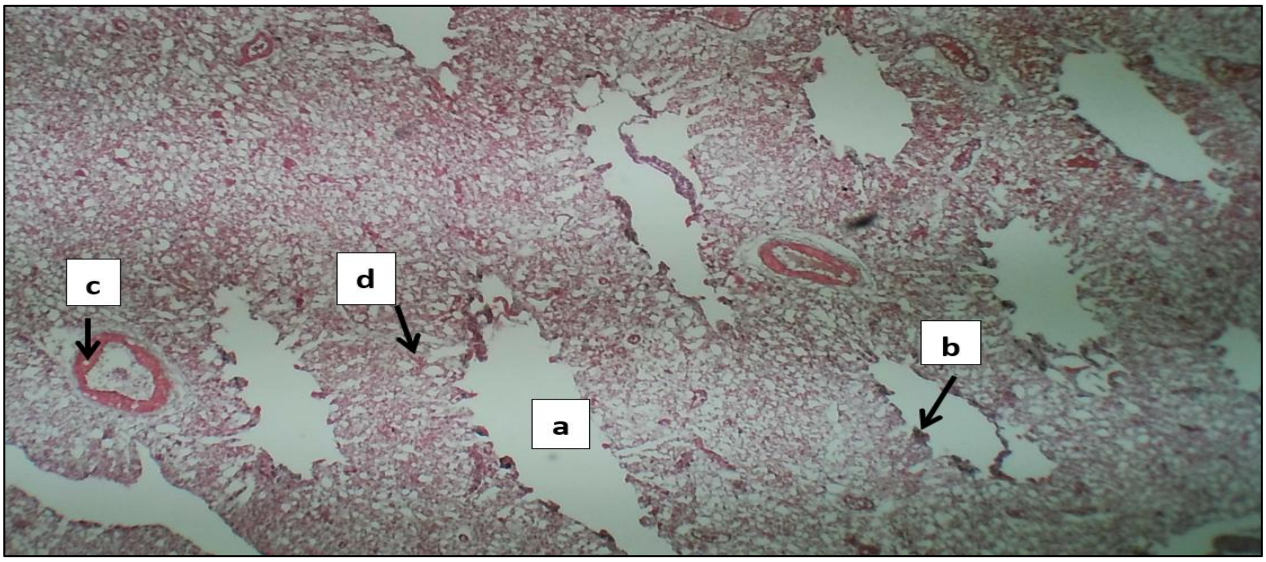

Figure 9: Cross section of pigeon lung shows: the para bronchial lumen (a), the simple squamous epithelium (b), blood vessels (c), air capillaries (d) H&E stain (X100).

CONCLUSION

The current study showed a significant difference in the shape and tissues of the posterior respiratory system between birds and mammals. This is due to the difference in the behavior of the two animals and their need for oxygen in quantities sufficient to provide the energy necessary to carry out the vital actions that contribute to the survival of the two animals, such as flying for pigeons and feeding for guinea pigs.

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Conflict of interest

The author has nothing to disclose and has no competing exist.

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