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Comparative Gross Anatomical Studies of the Lungs in the Domestic Duck (Anas platyrhynchos) and Migratory Duck (Anas acuta)

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Abstract

There is no literature regarding the comparative descriptive variations of the lungs in the non-flying and flying ducks that could adapt various functions, such as flying and running. This study was conducted to reveal a gross morphological description of the lungs and bronchial system of adult ducks (domestic and migratory) of both sexes, Pekin ducks (Anas platyrhynchos) and Pintail ducks (Anas acuta). The anatomy of the domestic and migratory duck's lungs was studied macroscopically and by corrosion cast technique. In all birds under study, medio-ventral secondary bronchi were the largest followed by laterodorsal secondary bronchi then lateroventral and posterior secondary bronchi were the smallest. Results obtained by this study may be used as the basis of a structural and functional study of avian respiratory. Understanding the morphological characteristics of the lungs of the ducks, especially the migratory ducks, might have a crucial role in the distribution of avian influenza virus and can be responsible for avian flu in the Middle East region.

Keywords: Anas platyrhynchos, Anas acuta, Anatomy, Bronchi, Duck, Lungs, Pekin, Pintail

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1. Introduction

Birds can breathe at much higher elevations than mammals because of their more efficient and complicated lung structure, which takes two inspiratory and two expiratory cycles for the inspired air (Fedde, 1980; Maina, 2003). The structural arrangement of gas-exchanging tubes facilitates unidirectional airflow including three orders of branching before the air capillaries is reached: primary bronchus, secondary bronchi, and parabronchi. Although the basic structure of the avian lung is similar, differences exist fine in the details, particularly regarding the arrangement of the secondary bronchi, the extant of development of the parabronchi, and the location, connection, number of air sacs (Maina and West, 2005). After they stem from the trachea, the primary bronchi pass ventral to the lung as extrapulmonary primary bronchi (EPPB) before entering the respective hilus where each continues inside its parenchyma as intrapulmonary primary bronchus (IPPB). Medio-ventral (MV) secondary bronchi arise close to the entry of the IPPB, while the latero-dorsal (LD), latero-ventral (LV), and posterior (PO) secondary bronchi arise from the caudal curved portion of the IPPB (Makanya et al., 2014; Lucy and Karthiayini, 2022).

Migratory birds including ducks play a significant role in the ecology, circulation, and transmission of zoonotic pathogens in the Middle East region inducing human and animal illnesses and causing economic losses to the poultry industry(NABIL and YONIS, 2019). The white Pekin duck (Anas platyrhynchos) is a flightless domestic variety of mallard. Its restricted movements and conspicuous coloration facilitate observation in the field and make it readily distinguishable from wild ducks (Cobb, 1987). In Egypt, it is among the most popular breeds kept in Egypt, reared both in backyards and on homesteads across the country, and is primarily favored for meat production. Meanwhile, Pintail ducks (Anas Acuta) are winter visitors migrating with a large number from Russia, WC Siberia via Egypt toward Netherlands, France, Great Britain North Africa, and Senegal delta(Wernham, 2002; Veen et al., 2005). In Egypt, Pintail birds migrate in autumn throughout the country along the north coast of Sinai and the Nile Delta.

In contrast to the total lack of information on the anatomy of the lungs of the migratory ducks, documentation on the domestic ducks are in abundance(Akester, 1960; Mennega and Calhoun, 1968; Bretz and Schmidt-Nielsen, 1971; Makanya et al., 2014; Scott et al., 2015; Firdous et al., 2020; Lucy and Karthiayini, 2022) stated that the O2 uptake efficiency of birds that fly at high altitudes extremely increases than that of non-flying or low-level flying ones. Given this background, serious attention is given to the gross morphology and bronchial architecture of the lungs in migratory ducks.

This study aims to compare the gross morphological description of the lungs and bronchial system of adult Pekin duck (Anas platyrhynchos) and Pintail duck (Anas acuta). Also, describe the morphological characteristics and differences of the bronchial system of the lungs in adult Pekin and Pintail ducks using the casting technique..

2. Materials and Methods

Sampling and Processing

Collection of samples:

All procedures were conducted according to guidelines approved by the Ethics Committee of the Faculty of Veterinary Medicine, Damanhour University, Egypt by number (DMU/VetMed-2024/002). Ten adult healthy ducks of both sexes were used in this study including 5 white Pekin ducks (Anas platyrhynchos) and 5 Pintail ducks (Anas acuta). The Pekin ducks were purchased from a private farm in Alfayom governorate while the Pintail ducks were captured in New Valley governorate. All birds were brought to the Laboratory of Anatomy and Embryology, Faculty of Veterinary Medicine Damanhour University. The ducks were housed in separate cages and allowed for free access to water and food for a few days until the processing of the experiments.

Dissection and analysis of the structural components of the lung

All ducks were slaughtered by cutting arteries on each side of the neck, skinned, and then dissected by opening the coelomic cavity using a sharp dissecting scissor.

The abdominal viscera were removed but the rib cage including the trachea and lungs with their coelomic attachment were left for topographical examination. All specimens were fixed in formalin 10% for 72 hrs. Trunk muscles were dissected to reveal the ribs and intercostal spaces to project the right and left lungs to the external surface of the ducks. The two lungs were released carefully from their musculotendinous attachment with the trachea and transferred for further gross morphological studies. Special consideration was given to the courses of the secondary bronchi under the coelomic membrane in all the investigated specimens of the two species. On the ventral aspect of each lung, a longitudinal cut was made along the entire length of the IPPB i.e. from the hilus to the abdominal opening to reveal its internal architecture and the exits of all secondary bronchi.(Makanya et al., 2014).

Gross photos were taken using digital cameras, and the magnification bar was strictly illustrated in each.

Cast of the Lungs of Pekin and Pintail ducks

For the cast preparation of lungs, commercially available latex was inserted into the 4 lungs (two lungs of both ducks) through a trachea cannulated with a plastic tube. The lungs were kept in a hanging position overnight. Then, the latex-embalmed lungs were put in 15% of KOH for 3wks. The fleshy part of the lungs got dissolved leaving behind the cast of the lungs. The casts were removed from KOH, cooled down, and washed and observations were recorded. According to (Makanya et al., 2014; Firdous et al., 2020).

Anatomical Latin names are used according to the obligatory nomenclature provided in the works of (Makanya et al., 2014)

3. Results

1. Topography of the lungs of the Pekin and Pintail ducks:

The topography of the lungs of the adult Pekin and Pintail ducks is demonstrated in (**Fig. 1**). The lungs were contained in the craniodorsal half of the coelomic cavity extending dorsally on each side of the thoracic vertebrae and cranio-caudally between the first intercostal space to about 0.3 cm behind the caudal border of the 8^{th} rib in three Pekin ducks (**Fig. 1A**) and others extend from the first rib to the cranial border of the 8^{th} rib in Pekin ducks, and between the caudal borders of the 1^{st} to the 8^{th} ribs in four Pintail ducks (**Fig. 1B**) and in one pin tail duck the lungs extend from the 1^{st} rib to less than 0.5cm behind the caudal border of the 8^{th} rib. On both sides of the two species, the line of attachment of the ventrolateral edges of the lungs with the medial surfaces of the ribs was clearly projected. The deepest limit of this curved line was located at the level of the 4^{th} intercostal space in the two species.

2. ***Gross morphology of the lungs:***

The lungs of the adult Pekin and Pintail ducks were bright pink in color, spongy in nature, flattened, not lobed, and trapezoid in shape **(Fig. 2,3)** respectively. In all birds under study, the caudal end of the lungs was broader than the cranial end. Each investigated lung presented three surfaces, namely dorsolateral (costal), ventral, and medial surfaces, and four borders, namely dorsomedial, craniolateral, caudolateral, and caudal borders. The dorsomedial border was blunt, ran parallel to the vertebral column, and divided into eight intercostal torus separated by seven deep costovertebral grooves in three Pekin ducks and divided into seven intercostal torus separated by six deep costovertebral grooves in two Pekin duck **(Fig. 2)**. In Pintail ducks it was divided into seven intercostal torus separated by deep costovertebral grooves in all of the examined Pintail lungs **(Fig. 3)** except in one lung of the Pintail duck (sample of the corrosion cast) divided into eight intercostal torus separated by seven deep costovertebral grooves **(Fig. 6A)** which were firmly anchored by the proximal fourth of the 2^{nd} to the 8^{th} vertebral ribs. The costal surface of the lungs of the two species was convex and close contact with the thoracic wall to which it is attached through thick fibromuscular sheets. This surface presented the main trunks of LD secondary bronchi which more obvious in Pintail ducks than Pekin ducks **(Fig. 3A, 2A)**. The ventral surface of the lungs was slightly concave, covered by a thin double membrane of pleura, and rested on the horizontal septum lying immediately above the heart, stomach, and intestine. After they stem from the syrinx, each EPPB passed ventral to the lung for about 3.6 cm in Pekin ducks and 2.9 cm in Pintail ducks before entering the respective hilus. In Pekin ducks, the hilus was located at about the middle of the ventral surface, meanwhile, it was found at the junction of the cranial two-thirds of the lung in Pintail ducks. In both species, the main trunks of MV secondary bronchi were presented on the ventral surface of the lung **(Fig. 2C, 3C)**.

3. ***Bronchial system of the Pekin and Pintail ducks:***

After entering the hilus, the IPPB passed dorsolaterally to the lung surface where it turned caudally in a dorsally curved course until it opened into the abdominal air sac at the angle formed between the caudal and caudolateral borders of the lung. (**Fig. ٤)** demonstrates the openings of the secondary bronchi emanating from the IPPB in both Pekin and Pintail ducks. The MV and LD were the most grossly obvious in the lung bronchi, and they were almost identical in both the right and left lungs in terms of their origin and distribution.

In Pekin and Pintail ducks, The MV secondary bronchi arose from the cranial aspect of the proximal one-third of IPPB (**Fig. ٤)** and their terminal parts were discernible superficially positioned just below the parietal pleura on the ventral surface of each lung **(Fig. 2C, 3C).** The origin, courses, and branches of the MV secondary bronchi were demonstrated in (**Fig. 5A)** in Pekin ducks and (**Fig. 6B)** in Pintail ducks. The 1^{st} MV bronchus arose just after the hilus and was directed craniomedially giving several branches along the cranial half of the ventral aspect of the lung (area above the hilus). The 2^{nd} MV bronchus was directed dorsally then branched to medial and lateral branches. The 3^{rd}MV bronchus was directed caudally toward the angle formed between the caudal and dorsomedial borders. The 4^{th} MV bronchus is divided into a horizontal lateral branch directed toward the lateral border and a medial caudal branch directed with the 3^{rd} MV bronchus. In an exceptional case in Pekin ducks, the 5^{th} MV bronchus was noticed as a very small opening in the right lung.

In Pekin and Pintail ducks, LD secondary bronchi arose from the dorsal wall of the caudal aspect of the IPPB (**Fig. ٤)**, and their terminal parts were clearly discernible superficially positioned just below the parietal pleura on the costal surface of each lung **(Fig. 2A,3A)**. The origin, courses, and branches of the LD secondary bronchi were demonstrated in (**Fig. 5B)** in Pekin ducks and (**Fig. 6A)** in Pintail ducks. In Pekin Ducks (**Fig. 5B)**, the 1^{st} LD bronchus arose at the level of the 4^{th} torus and directed craniomedially. The 2^{nd} LD bronchus arose at the level of the 4^{th} torus and directed craniomedially and gave off 3 branches. The 3^{rd} LD bronchus arose at the level of the 4^{th} sulcus and directed obliquely. The 4^{th} LD bronchus arose at the level of the 5^{th} torus and gave off three branches. The 5^{th} LD bronchus arose at the level of the 5^{th} torus and directed caudomedially. The 6^{th} LD bronchus arose at the level of the 5^{th} sulcus. The 7^{th} LD bronchus arose at the level of the 6^{th} torus. Pintail ducks **(Fig. 6A)**, 1^{st} LD arose at the level of the 4^{th} torus and directed craniomedially then branched from both sides medial and lateral .The 2^{nd} LD arose at the level of the 4^{th} torus. The 3^{rd} LD arose at the level of the 5^{th} torus and directed medially and gave many branches. The 4^{th} LD arose at the level of the 5^{th} torus and directed caudomedially. The 5^{th} LD arose at the level of the 5^{th} sulcus and was directed caudomedially. The 6^{th} LD arose at the level of the 6^{th} torus and was directed caudomedially. The 7^{th} LD arose at the level of the 6^{th} sulcus and was directed caudomedially. The 8^{th} LD arose at the level of the 7^{th} torus.

LV secondary bronchi (1-4) arise from the ventral wall of the IPPB on the opposite side of the LD, The 1^{st} LV supplied the lateral margin of the lung, the 2^{nd} LV connected directly with the posterior thoracic air sac and the 3^{rd} LV directed caudally parallel to caudo lateral border. PO secondary bronchi were observed on the lateral wall of IPPB scattered between those of the LD and LV (**Fig. ٤)**.

In all investigated specimens of the two species, MV secondary bronchi were the largest followed by LD secondary bronchi, then LV secondary bronchi and PO secondary bronchi were the smallest and uniform in diameter.

No major branches were found along the ventral aspect of the caudolateral quarter of the ventral surface. The LD and VM secondary bronchi anastomosed with one another by numerous parabronchi, which were discernible on the dorsolateral and ventromedial parts of the two lungs.

The number of the secondary bronchi of the investigated species. We found (4-5) MV, (7-9) LD, (2-4) LV, and (36-40) PO secondary bronchi In the Pekin duck, 4 MV, 10 LD, 4 LV, and (38-44) PO secondary bronchi in the Pintail duck (**Fig. ٤**).

In Pekin ducks, the IPPB length and diameter measured about 4.7cm while in Pintail length was 2.7cm. Table 1

Discussion:

The difficulties in understanding the avian lung function emerge partly from poor understanding of the lung structure and partly due to the plenteous distorted information in the literature **(Makanya *et al.*, 2011)**

Regarding the location, the lungs were contained in the craniodorsal half of the coelomic cavity extending dorsally on each side of the thoracic vertebrae and cranio-caudally between the first intercostal space to about 0.3 cm behind the caudal border of the 8th rib in three Pekin ducks and other extend from the first rib to the cranial border of the 8th rib in Pekin ducks, and between the caudal borders of the 1st to the 8th ribs in four Pintail ducks and in one pin tail duck the lungs extend from the 1st rib to less than 0.5cm behind the caudal border of the 8th rib. Our findings contradict **(Firdous *et al.*, 2020)** who found the lungs of swans, ducks, and fowl located between the 1-6 ribs.

The two lungs were connected at the medial surface by a sheet of connective tissue, which in turn was attached dorsally to the ventral surface of the thoracic vertebrae by a thick tendentious sheet in both ducks. The costal surface of the lungs of the two species was convex and in close contact with the thoracic wall to which it is attached through thick fibromuscular sheets. The lungs of the birds under study, which were deeply indented by the ribs in the thoracic cavity especially in Pintail represented as a rigid immobile system of tubes as supported by **(Duncker, 1974)**in domestic fowl. Similar findings were reported in Kuttanad duck, swan, and fowl A strong, horizontal, tendinous sheet arising from the ventral crests of the thoracic vertebrae was fused to the ventral surface of the lung **(Firdous *et al.*, 2020)**

Regarding the shape of the lungs, The lungs of the adult Pekin and Pintail ducks were bright pink in color, spongy in nature, flattened, not lobed, and trapezoid in shape similar findings were reported in Kuttanad duck, swan, and domestic fowl **(Makanya *et al.*, 2014)** (**Kandyel et al., 2022)** **(Firdous *et al.*, 2020; Ahmad, 2022)**

The LD secondary bronchi are more obvious in the costal surface of Pintail than in Pekin ducks.

In the present study, minor differences were found in the number of the secondary bronchi of the investigated species. We found (4-5) MV, (7-9) LD, (2-4) LV, and (36-40) PO secondary bronchi In the Pekin duck, on the other hand, we found four MV, ten LD, four LV, and (38-44) PO secondary bronchi in the Pintail duck. **(Ahmad, 2022)** found 6 MV, 9 LD, 9 LV, and(40-47)PO secondary bronchi in Bewick swan, 4 MV, 9 LD, 9 LV, and (35-40)PO secondary bronchi in duck.

In both ducks, IPPB gave rise to 4 medio-ventral, 9 latero-dorsal, 9 latero-ventral, and (35-40) posterior secondary bronchi. In domestic fowl, a total of about (27-30) secondary bronchi as caudolateral or posterior secondary bronchi arising from the primary bronchus were present, and a total of about thirty secondary bronchi as caudolateral or posterior secondary bronchi arising from the posterior half of the primary bronchus in domestic fowl (**King and Cowie 1969**). **Gerrit and Clark (1972**) recorded 4 medio-ventral secondary bronchi, 6 dorso lateral secondary bronchi and posterior secondary bronchi as discrete secondary branches of the mesobronchus in common crackle. **Ahmad, (2022)** recorded 6 medio-ventral, 9 dorsolateral, 9 latero-ventral, and (40-47) posterior secondary bronchi arising from the IPPB in Bewick swan.

In all birds under study, medio-ventral secondary bronchi were the largest followed by laterodorsal secondary bronchi then lateroventral and posterior secondary bronchi were the smallest. In Kuttanad ducks, the medioventral secondary bronchi were the largest secondary bronchi, the Dorsolateral secondary bronchi were the second largest secondary bronchi and the posterior secondary bronchi were the smallest among all secondary bronchi **(Ahmad, 2022)**

In both ducks, the 3rd MV bronchus is directed caudally toward the angle formed between the caudal and dorsomedial borders. The 4th MV bronchus is divided into a horizontal lateral branch directed toward the lateral border and a medial caudal branch which directed toward the 3rd MV bronchus. Our findings are similar to **(Makanya *et al.*, 2014)** and contradict **(Mennega and Calhoun, 1968)** who found the 3rd MV turns ventromedial and bifurcates whereas its lateral branch arises near the hilus of the lung, the medial branch supplies air to a triangular area caudo medial to the hilus. The 4th MV turns the caudal to supply air to the ventral part of the lung in an area just lateral to that supplied by the 3rd MV. the 5th MV bronchus was noticed as a very small opening in the right lung similar finding was reported in white Pekin duck **(Mennega and Calhoun, 1968; Makanya *et al.*, 2014)**.

The 1st LV arises from the ventral wall of IPPB and supplies the lateral margin of the lung our finding contradicte**(Makanya *et al.*, 2014)** who found 1st LV emerging from 4th MV.

The MV, LD, LV and posterior secondary bronchi anastomosed with one another by numerous parabronchi, which were discernible on the dorsolateral and ventromedial parts of the two lungs. **Jaafar Ali and Zghair, (2023)** reported that the parabronchi were running between MV and LD secondary bronchi and together formed paleopulmonic lung. Caudo-ventrally and caudodorsally, the lung contained networks of parabronchi arising from laterodorsal and lateroventral secondary bronchi anastomosing with each other and with the other two groups of secondary bronchi. This part was very small and constituted a very small portion of the lungs in all birds under study and formed the neopulmonic lung. **Ahmad (2022)** reported that the lungs in Kuttanad ducks contained networks of parabronchi arising from laterodorsal and lateroventral secondary bronchi anastomosing with each other and with the other two groups of secondary bronchi Caudo-ventrally and caudo-dorsally. This part was very small and constituted a very little portion of the lungs in Kuttanad ducks and formed.

The lung possesses certain exceptional structural and functional attributes compared to other organs. It is the only organ in the body that receives the total cardiac output, a quantity that increases several times between exercise and rest **(Maina, 2017)**. The avian lung is the most complex and efficient gas exchanger between the respiratory organs **(King and McLelland, 1984)**. It takes two inspiratory and two expiratory cycles for the inspired air **(Fedde, 1980; Maina, 2003)**.

Conclusion

We hope that the generated data may provide valuable contributions to the morphology of the lung and the bronchial system in domestic and migratory ducks. Further studies are needed to explain the accurate distribution of the parabronchi and morphometric analysis of the bronchial system of both ducks.

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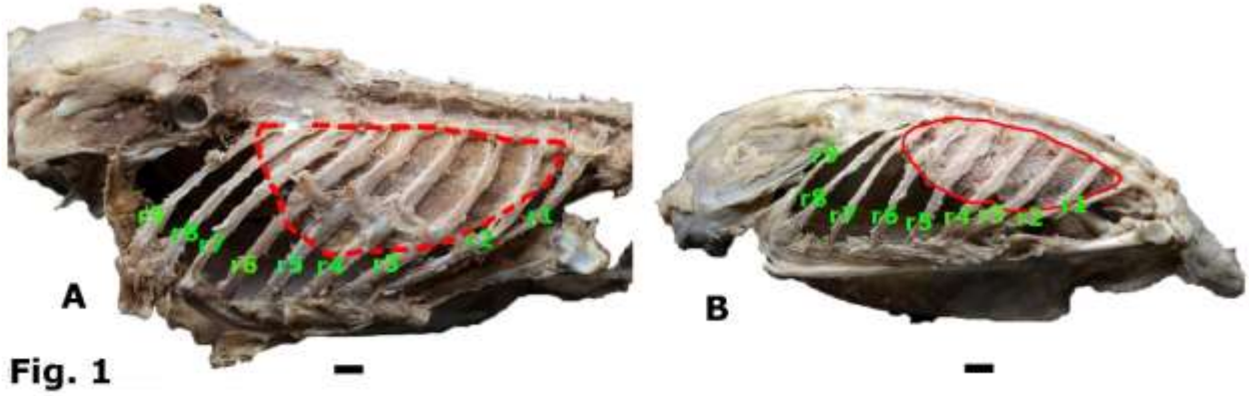

Fig.1 Topography of the right lateral view of the lungs of the Pekin (A) and Pintail ducks(B) , Length of scale bar 1cm
Right lung (RL), r1-9 (rib1-9)

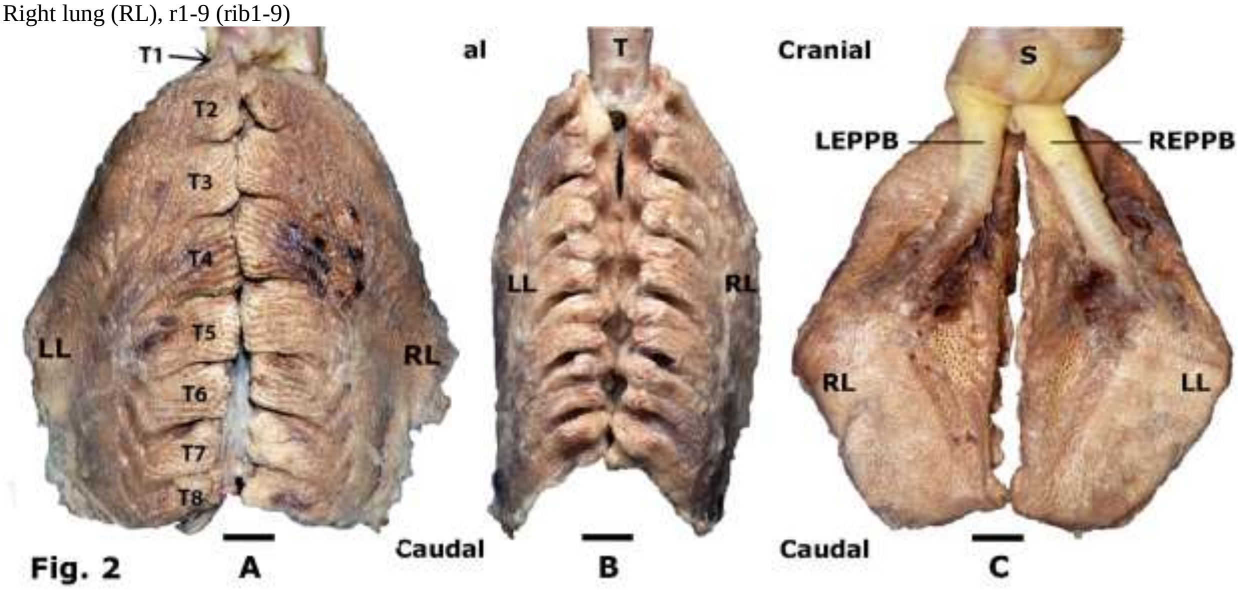

Fig 2. Gross morphology of the Pekin lungs. (A) Dorsolateral surface, (B) dorsomedial surface,(C) ventral surface. Right lung (RL), Left Lung (LL), Trachea (T), S(Syrinx), T1-8 (Torus 1-8), Right Extrapulmonary Primary Bronchi (REPPB), Left Extrapulmonary Primary Bronchi (LEPPB). **Length of scale bar 1cm**

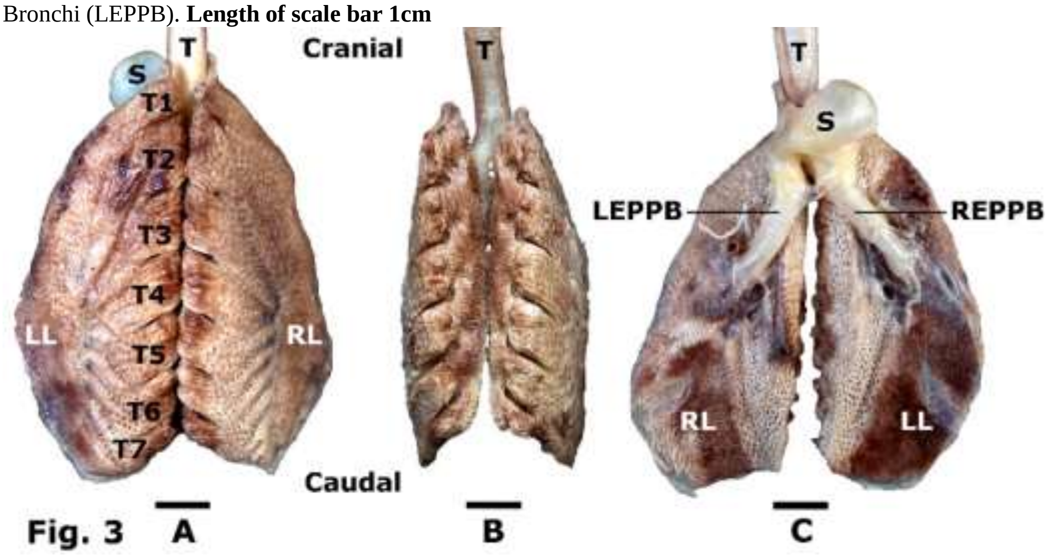

Fig.3 Gross morphology of the Pintail lungs. (A) Dorsolateral surface, (B) dorsomedial surface,(C) ventral surface. Right lung (RL), Left Lung (LL), Trachea (T), Syrinx (S), T1-7 (Torus 1-7), Right Extrapulmonary Primary Bronchi (REPPB), Left Extrapulmonary Primary Bronchi (LEPPB). **Length of scale bar 1cm**

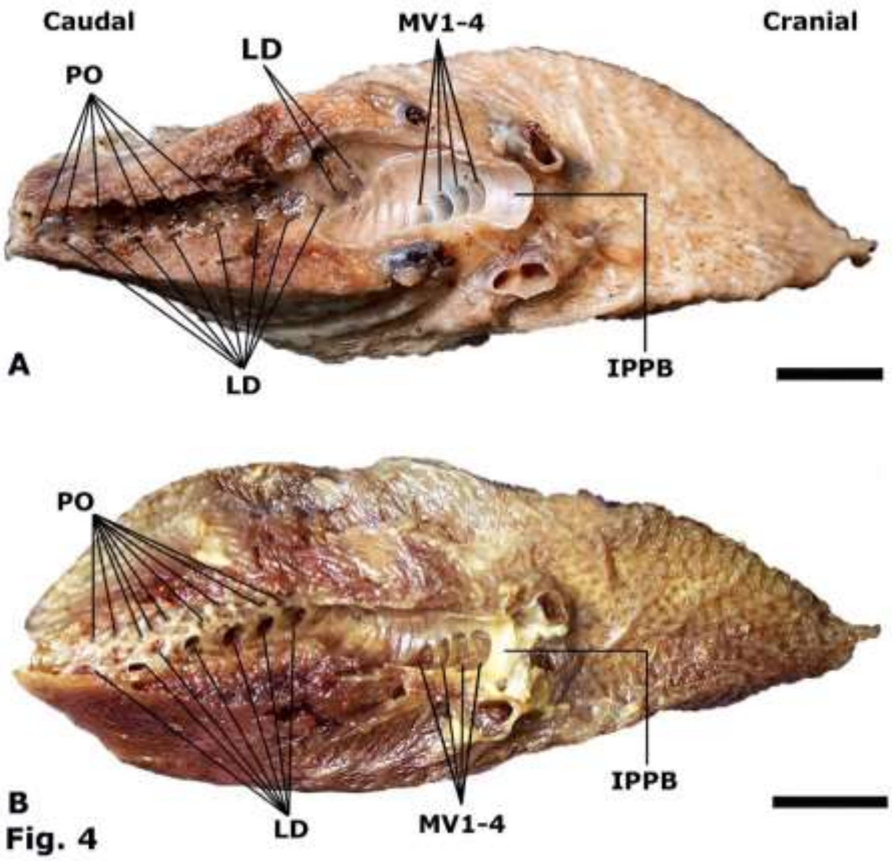

Fig.4 Illustrate the openings of the secondary bronchi emanating from the intrapulmonary primary bronchus (IPPB) in both Pekin(A) and Pintail (B) ducks. Medio-ventral (MV1-4) secondary bronchi, medio-dorsal (MD), latero-ventral (LV), Posterior (PO) and latero-dorsal (LD) secondary bronchi. **Length of scale bar 1cm**

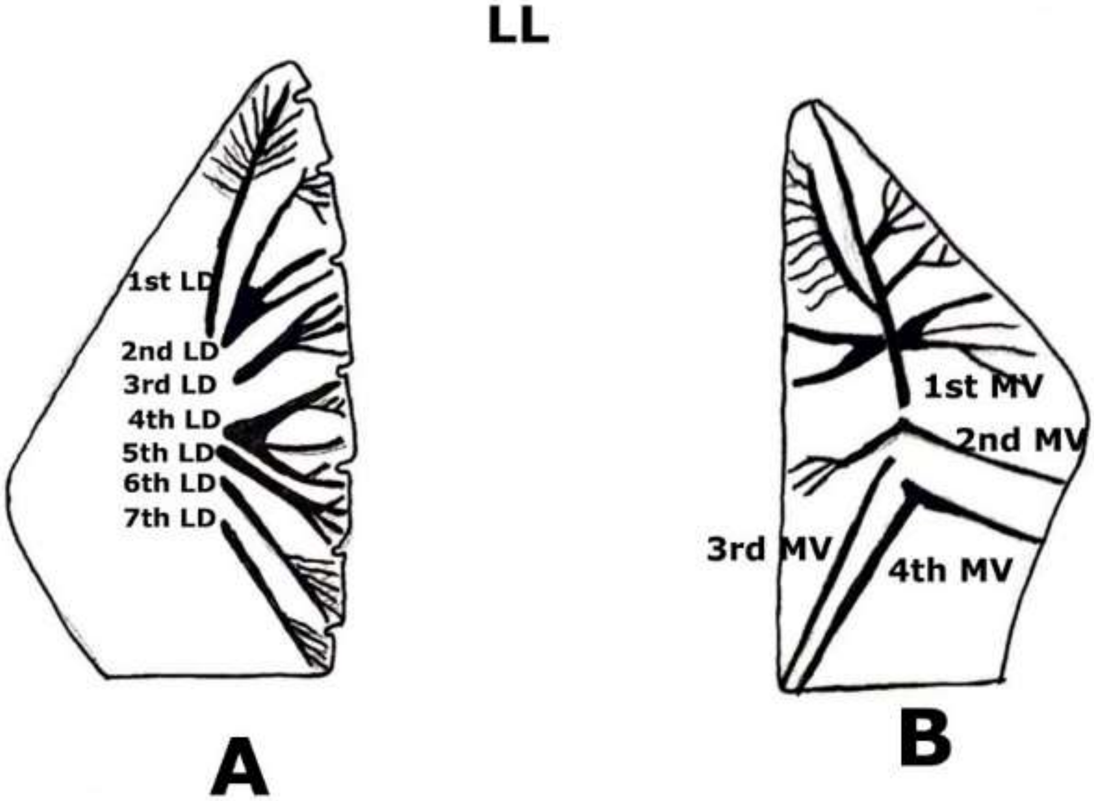

Fig.5 Drawings of corrosion cast of lungs in Pekin duck. (A) dorsolateral surface, (B)Ventral surface, Left Lung (LL), medio-ventral (MV1-4) and latero-dorsal (LD1-7) secondary bronchi.

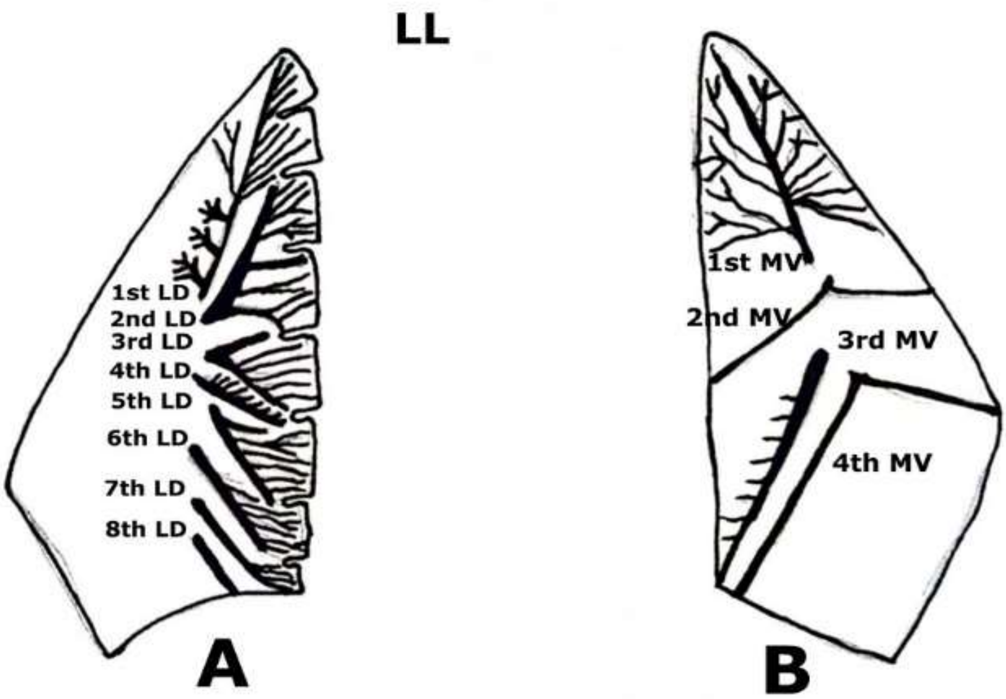

Fig.6 Drawings of corrosion cast of lungs in Pintail duck. (A)dorsolateral surface, (B) ventral surface, Left Lung (LL), medio-ventral (MV1-4) and latero-dorsal (LD1-8) secondary bronchi**.**

Table 1;

	Pekin Ducks	**Pintail Ducks**
Topography (Majority)	first intercostal space to about 0.3 cm behind the caudal border of the 8^{th} rib	caudal borders of the 1^{st} to the 8^{th} ribs
Special case Topography	first rib to the cranial border of the 8^{th} rib	1^{st} rib to less than 0.5cm behind the caudal border of the 8^{th} rib
Shape	flattened, not lobed, and trapezoid in shape	flattened, not lobed, and trapezoid in shape
Number of torus	8	7
Number of grooves	7	6
Clarity of LD secondary bronchi on costal surface	More	Less
Length of EPPB	3.6 Cm	2.9 Cm
Site of hilus	at about the middle of the ventral surface	at the junction of the cranial two-thirds of the lung
Number of MV	4-5	4
Number of LD	7-9	10
Number of LV	2-4	4
Number of PO	36-40	38-44
Length of IPPB	4.7cm	2.7cm