Gross anatomy of the heart in Ostrich (*Struthio camelus*)

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Summary

Today, with emphasis on the mechanical heart and heart transplantation from one human to another and one species to another, a knowledge of the anatomy of the bird's heart could contribute to these accomplishments. Eight male adult ostriches were used to study the heart macroscopically. This study revealed that the ostrich heart has some different features from the other birds. In the ostrich, fibrous pericardium as sternopericardial ligament attaches along the thoracic surface of the sternum. The central edge of muscular valve hangs down into the right ventricle and gives attachment to its rough parietal wall by a thick muscular stalk. The left and right pulmonary veins enter the left atrium independently and their openings were completely separated from each other by a septum. In the heart of the ostrich, the moderator bands were found in both the right and left ventricles in different locations. The right ventricle presents one tendinous moderator band near the base of the ventricle that extends from septum to the muscular valve. Also the moderator bands as tendinous thread like or flat sheet are usually present at about apex of the right ventricle that extends from septum to the parietal wall. In the left ventricle, there were some tendinous moderator bands close to the apex that extends from septum to the parietal wall and between trabeculae carneae of the parietal wall.

Key words: Heart, Ostrich, Gross anatomy

Introduction

There is some literature on the macroscopic anatomy of avian heart (Lewis, 1916; Kaupp, 1918; Kisch, 1951; Mcleod *et al*., 1964). Also anatomy of the heart in domestic fowl (Bradley, 1950; Ede, 1970; King and Mclelland, 1975), fowl and turkey (Nickel *et al*., 1977) and duck (Rigdon and Frolich, 1970; Koch, 1973) were recorded. There are scanty reports about the heart of ostrich. Bezuidenhout (1983) reported the origin of right atrioventricular valve in ostrich and fowl hearts. Ostrich heart and its associated arteries and veins (Mac Alister, 1864; Glenny, 1965; Bezuidenhout, 1981) and ostrich heart coronary circulation (Bezuidenhout, 1984) were also studied. There is not enough information on the gross anatomy of the heart in ostrich, therefore this study was conducted to determine the anatomical details of some features of the ostrich heart.

Materials and Methods

Eight hearts from healthy adult male ostriches (1.5–2-year-old and 122.1 ± 3.9 kg body weight) were obtained from the slaughterhouse immediately after slaughter. Before removing the hearts, their anatomical positions were studied inside the thorax. Each heart was washed by normal saline and the pericardium was investigated. After removal of the pericardium, the weight of heart and its long axis from middle of base to apex and circumferential length at the level of coronary groove were measured. The walls of the heart were opened, the blood were washed and then submerged in 10% buffered formalin solution for 72 h. After hardening the hearts, the shape and

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surface topography of them were considered. Also each heart was dissected and its compartments with all their components were studied in detail.

Results

This research revealed that the heart in ostrich is located opposite to the lateral wall of the thorax, from the first to third intercostal space (Fig. 1). Its shape is conical and has bluish-red colour and weight of 1054.33 ± 172.34 g. It's long axis and circumferential length were 19.33 ± 1.05 cm and 35.66 ± 1.04 cm, respectively. It lies obliquely and its long axis is directed ventrally and caudally. It is enclosed by the pericardium which is a fibro-serous sac. The fibrous pericardium is tough and attached dorsally to large vessels at the base of the heart and is continued ventrally as sternopericardial ligament along the thoracic surface of the sternum. Then by passing between left and right hepatoperitoneal cavities, it leads to the inner layer of left post-hepatic septum where it passes over the gizzard. The serous pericardium is a closed sac, consisting of two layers. The parietal layer lines the fibrous pericardium, to which it is tightly attached. The visceral layer also termed epicardium covers the heart and parts of the large vessels. The pericardial cavity is next to dorsal hepatic peritoneal cavity (Figs. 2 and 3).

The heart is attached at its base by the large vessels, but it is entirely free in the pericardial cavity. The base is directed cranio-dorsally and the apex lies dorsal to the caudal of sternum (Fig. 2).

The heart of the ostrich has a convex sternal or cranioventral surface, a flattened hepatic or caudodorsal surface and a pulmonary surface that is the same base. Its borders are the right border which is convex and nearly vertical and the left border which is oblique. The surfaces are marked by grooves which indicate the division of the heart into four chambers, the two atria dorsally and two ventricles ventrally. A distinct coronary groove filled with fat separates the atria from ventricles and the longitudinal grooves are present on the sternal and hepatic surfaces. The grooves are occupied by the coronary vessels (Figs. 4 and 5).

The right atrium has a greater volume than the left one and is separated from the left atrium by interatrial septum. Right atrium consists of muscular ridges, the so-called pectinate muscles which are arranged in net-like fashion and terminate on a stout transverse arch, crista terminalis. Also a distinct sinus venosus is a part of the typical adult ostrich heart. The sinus venosus is a small triangular shaped chamber and has thin wall and its slit-like aperture is guarded by the right and left sinuatrial valves. In the ostrich, there are two right and left cranial vena cava that terminate in the right atrium. The last part of caudal vena cava is buried in liver tissue (Fig. 6). The floor of the right atrium leads into the crescent-shaped right atrioventricular orifice that is guarded by interventricular septum medially and a thick muscular valve laterally. The peripheral edge of the valve is attached to the fibrous ring at the atrioventricular orifice and the central edge hang down into the ventricle and not only is fixed to the septum by a short left septal attachment, but also gives attachment to rough parietal wall of the ventricle by a thick muscular stalk (Figs. 7 and 8).

The right ventricle lies against the left ventricle in the form of a pouch and makes a curve towards the apex of the heart. It extends only about two thirds of the way from the base to the apex. The apical third of the heart is formed by the left ventricle alone (Fig. 4). The thickness of the right ventricular wall was 0.96 ± 0.25 cm and the parietal wall of the right ventricle bears low muscular ridges, so-called trabeculae carneae which are prominent in the region of the apex (Figs. 8 and 9). There were no papillary muscle and chordae tendineae in the right ventricle.

The moderator bands are found in different locations of right ventricle. There was a variation in the shape and number of these bands. It presents one tendinous moderator band about the base of the ventricle that extends from the septum to the muscular valve (Fig. 10). Also the moderator bands as tendinous thread-like or flat sheet (partly muscular and partly tendinous) are usually present at about the apex of the right ventricle that extend from

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septum to parietal wall. Some of them are as a strong muscular band that gives fibrous branches for attachment to parietal wall (Figs. 8, 9 and 10).

At the left side of the base of the right ventricle there was the funnel shaped region as conus arteriosus leading to the pulmonary trunk (Fig. 6). The pulmonary orifice was circular and was guarded by the pulmonary valve composed of three semicircular cusps. The wall of the trunk formed a pouch opposite to each cusp so called pulmonary sinuses (Fig. 11). The pulmonary trunk divided into the right and left pulmonary arteries (Fig. 5).

The left atrium forms the caudal part of the base of the heart and lies dorsal to the left ventricle. The cavity of the left atrium is smooth, with exception of its dorsal part, in which the pectinate muscles are present. The pectinate muscles are uniform and insert to a round stout muscular ridge. The left and right pulmonary veins enter the dorsal wall of the left atrium independently and their openings were completely separated from each other by a septum (Fig. 12). The floor of the left atrium has round left atrioventricular orifice that was supported by the left atrioventricular valve. It has three membranous cusps, dorsal, septal and left which the septal one is the largest (Fig. 13).

The left ventricle extends from the left atrioventricular opening toward the apex. The thickness of the left ventricular wall is 3.33 ± 0.29 cm that is three times thicker than that of the right ventricle (1.02 ± 0.16 cm). The cavity of the left ventricle resembles an elongated, fluted cylinder and is characterized by the large longitudinal trabeculae carneae projecting into the lumen. Each cusp of the left atrioventricular valve receives chordae tendineae from each of two adjacent papillary muscles. The cusps and chordae tendineae were very thick (Fig. 13). In the left ventricle there were some tendinous moderator bands close to the apex. Some of them extend from septum to parietal wall in the form of irregular branches that anastomose to each other and some of these were as thin threads like band between trabeculae carneae of the parietal wall (Figs. 14 and 15).

The vestibule of the aorta was the space between the septal cusp of the left atrioventricular valve and interventricular septum from which aorta arises. The aortic orifice is guarded by the aortic valve, composed of three semilunar cusps: right, left and septal. They were thick, strong and similar to those of the pulmonary cusps and constitute aortic sinuses (Fig. 11). Proximal to the right and left aortic sinuses, there were openings leading to the right and left coronary arteries, respectively (Fig. 16).

Interventricular septum in ostrich heart was a very thick muscular partition between the left and right ventricles and had 2.36 ± 0.15 cm thickness. It bulges far into the lumen of the right ventricle (Figs. 6, 7 and 9).

Discussion

The avian heart is relatively large

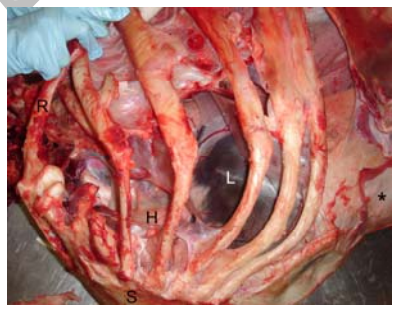

Fig. 1: Topography of the heart and thorax in the ostrich. H) heart, S) sternum, R) first rib, *) gizzard and L) liver

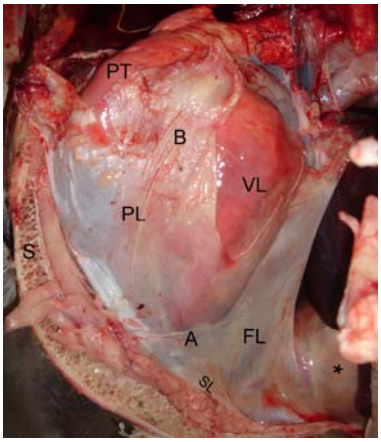

Fig. 2: Heart of ostrich with pericardium. S) sternum, *) gizzard, PT) pulmonary trunk, PL) parietal layer of serous pericardium, FL) fibrous pericardium, VL) visceral layer of serous pericardium, SL) sternopericardial ligament, A) apex of heart and B) base of heart

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(Nickel *et al*., 1977) and much larger than that of mammals. This relatively large size is associated with a relatively great cardiac output (King and Mclelland, 1975). In the ostrich, the heart has 1054.33 g weight that is 0.73% of body weight, while in the fowl it accounts for 0.5-1.42% of body weight, in

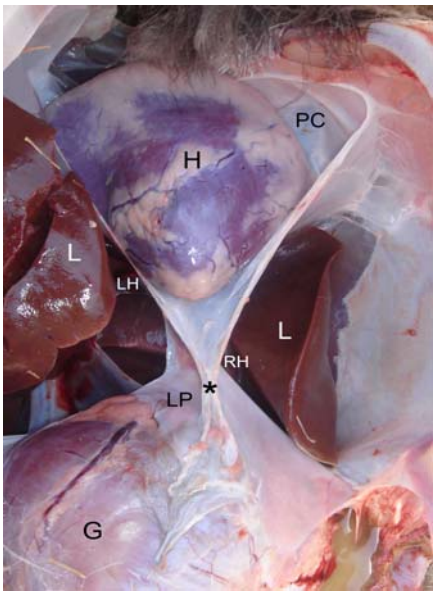

Fig. 3: Dissection revealing heart of ostrich in the thorax. G) gizzard, H) heart, L) liver, LH) left hepatic peritoneal cavity, RH) right hepatic peritoneal cavity, *) fibrous pericardium, LP) left post hepatic septum and PC) pericardial cavity

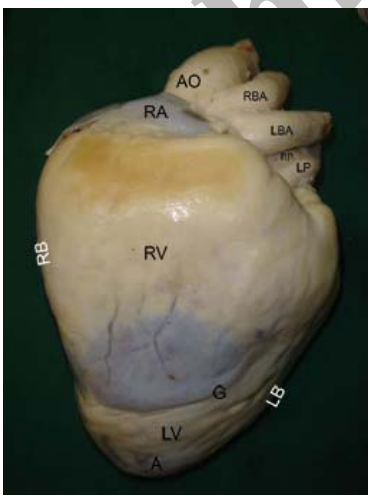

Fig. 4: Heart of ostrich, cranioventral surface. RV) right ventricle, LV) left ventricle, RA) right atrium, A) apex of heart, RB) right border, LB) left border, G) longitudinal groove, AO) aorta, RBA) right brachiocephalic artery, LBA) left brachiocephalic artery, RP) right pulmonary artery and LP) left pulmonary artery

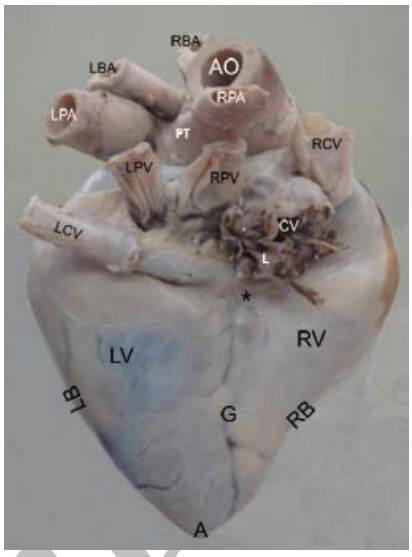

Fig. 5: Heart of ostrich, caudodorsal surface. LB) left border, RB) right border, A) apex of heart, G) longitudinal groove, *) coronary groove, LV) left ventricle, RV) right ventricle, AO) aorta, CV) caudal vena cava, RCV) right cranial vena cava, LCV) left cranial vena cava, LPV) left pulmonary vein, RPV) right pulmonary vein, RBA) right brachiocephalic artery, LBA) left brachiocephalic artery, A) apex of heart, #) pulmonary trunk, RPA) right pulmonary artery and LPA) left pulmonary artery

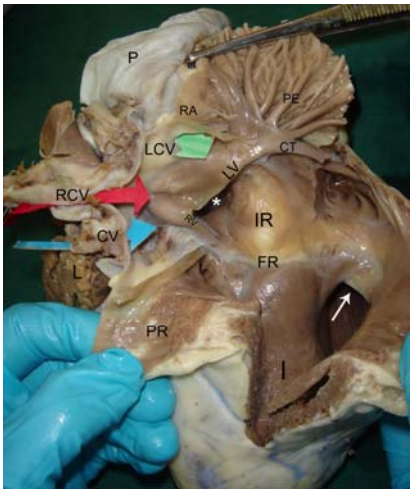

Fig. 6: Right side of heart in ostrich, opened by reflecting of wall. I) interventricular septum, white arrow) conus arteriosus, IR) interatrial septum, *) sinus venosus, LV) left sinoatrial valve, RV) right sinoatrial valve, FR) fibrous ring of right atrioventricular orifice, P) pericardium, CV) caudal vena cava, RCV) right cranial vena cava, LCV) left cranial vena cava, PR) parietal wall of right ventricle, RA) right atrium, PE) pectinate muscle, CT) crista terminalis and L) liver

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the turkey for 0.5%, in the duck and goose for 0.8% and in the pigeon, which is a good flier, for 1.1-1.4% of the body weight (Nickel *et al*., 1977). The ostrich heart resemble to some species including the domestic fowl (Kaupp, 1918; King and Mclelland, 1975) lies within the thorax. The conical heart of ostrich is enclosed by the pericardium whose fibrous pericardium is continued ventrally as sternopericardial ligament and attach to sternum that is similar to fowl, duck, goose, turkey and pigeon (Nickel *et al*., 1977).

The ostrich heart has three main surfaces that their features are similar to domestic fowl (Getty, 1975). In ostrich the sinus venosus is similar to fowl (Getty, 1975; King and Mclelland, 1975) and other birds (Nickel *et al*., 1977). In the ostrich the right atrium has greater volume than the left one and the thickness of left ventricle is about three times greater than that of the right one which these features are similar to fowl and turkey (Getty, 1975; Nickel *et al*., 1977), and duck (Rigdon and Frolich, 1970). The left ventricle provides the power for the high pressure systemic circulation and so has a

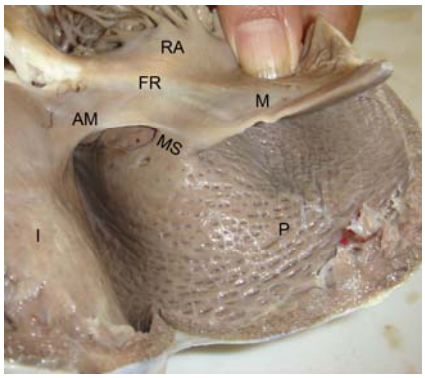

Fig. 7: Showing guarding of right atrioventricular orifice with valve. I) interventricular septum, M) muscular valve, MS) muscular stalk, P) parietal wall of right ventricle, FR) fibrous ring, RA) right atrium and AM) attachment of muscular valve

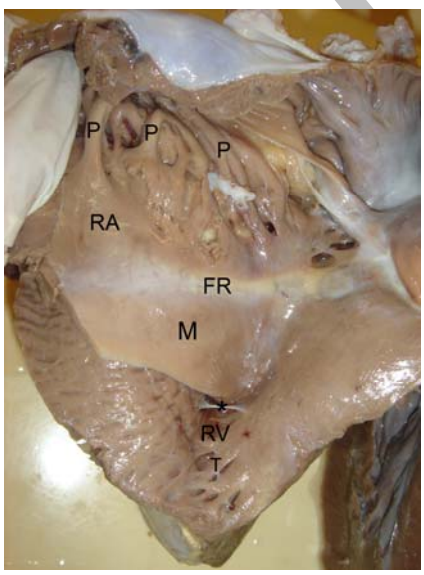

Fig. 8: Right side of heart of ostrich, opened by removal of greater part of right wall. *) moderator band, M) muscular valve, FR) fibrous ring, P) pectinate muscle, RA) right atrium, RV) right ventricle and T) trabeculae carneae

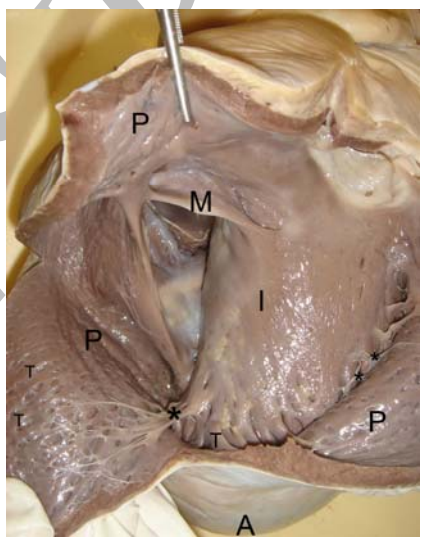

Fig. 9: Interior features of right ventricle. A) apex, I) interventricular septum, P) parietal wall of right ventricle, *) moderator band, M) muscular valve and T) trabeculae carneae

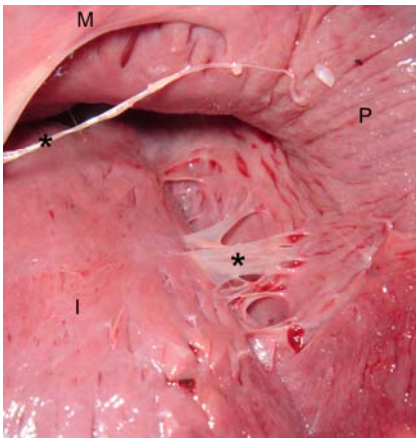

Fig. 10: Showing location of moderator bands in right ventricle. M) muscular valve, *) moderator band, P) parietal wall of right ventricle and I) interventricular septum

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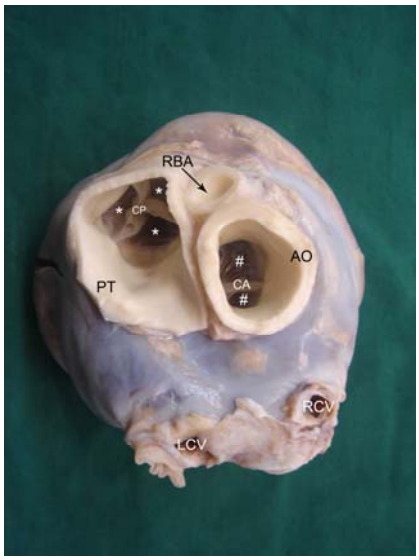

Fig. 11: Heart of ostrich, transverse section just cranial to aortic and pulmonary valve. AO) aorta, PT) pulmonary trunk, *) pulmonary sinus, CP) cusp of pulmonary valve, CA) cusp of aortic valve, #) aortic sinus, RBA) right brachiocephalic artery, RCV) right cranial vena cava and LCV) left cranial vena cava

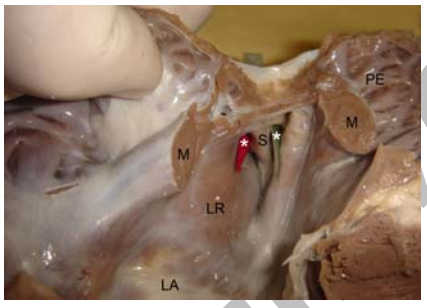

Fig. 12: Interior of the left atrium in the heart of ostrich. PE) pectinate muscle, S) septum, *) opening of pulmonary veins, LA) left atrium, LAO) left atrioventricular orifice, M) muscular ridge

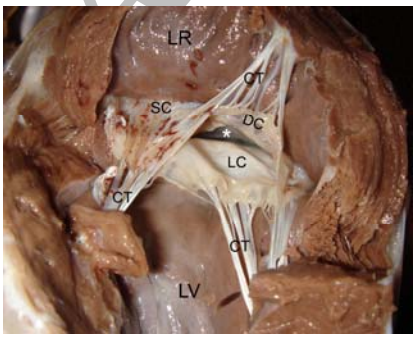

Fig. 13: Left side of heart of ostrich, opened by removal of the part of left wall. LA) left atrium, LV) left ventricle, *) left atrioventricular orifice, CT) chordae tendinae, DC) dorsal cusp, LC) left cusp and SC) septal cusp

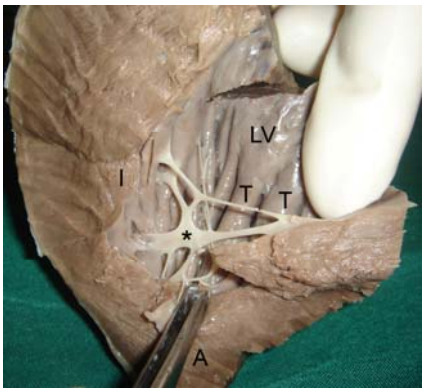

Fig. 14: Interior feature of left ventricle in ostrich heart. *) moderator band, LV) left ventricle, T) trabeculae carneae, I) interventricular septum and A) apex

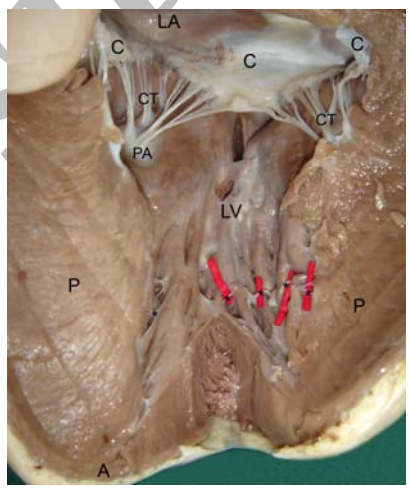

Fig. 15: Interior features of left ventricle in ostrich heart. P) parietal wall of left ventricle, LV) left ventricle, *) moderator band, CT) chordae tendinae, PA) papillary muscle, A) apex, C) cusps of left atrioventricular valve and LA) left atrium

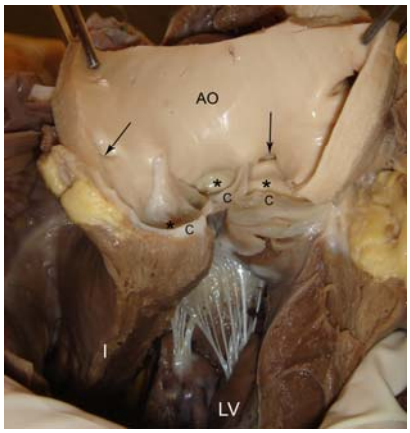

Fig. 16: Interior of the vestibule of aorta in the ostrich heart. AO) aorta, C) cusps of aortic valve, *) aortic sinuses, arrow) opening of coronary arteries

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wall thicker than the right ventricle.

Details of the interior of the right and left atria and ventricles in ostrich heart resemble those of typical birds except for three special features. The first feature of specific interest in the ostrich heart is the right atrioventricular valve. This stout muscular valve is not only fixed to interventricular septum, but also gives attachment to rough parietal wall of ventricle by a thick muscular stalk that prevents collapse of the valve and backflow of blood into the atrium during ventricular systole; while the muscular valve only connect to septum by a short left septal attachment in the fowl (Getty, 1975) and by a sail-like membrane in the turkey (Nickel *et al*., 1977).

The second feature of specific interest in the ostrich heart is that the left and right pulmonary veins enter the dorsal wall of left atrium independently and their openings in the atrium are completely separated from each other by a septum. While in the fowl two pulmonary veins usually enter the dorsal wall of the left atrium, separately but occasionally, they form a common pulmonary vein (Getty, 1975). Also in the turkey they form a common system (Nickel *et al*., 1977).

The third feature of specific interest in the ostrich heart is presence of moderator bands in both the right and left ventricles and in different locations. The right ventricle has one tendinous moderator band about the base of the ventricle that extends from the septum to the muscular valve. Also the moderator bands are usually about apex of the right ventricle that extend from septum to parietal wall. In the left ventricle there were some tendinous moderator bands close to the apex that extend from septum to parietal wall and between trabeculae carneae of parietal wall. The moderator bands tend to prevent overdistention and serves as the pathway for the passing of purkinje fibers across the lumen of the cavity forming a part of the conducting system.

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