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# The coronary circulation of the heart of the ostrich (*Struthio camelus*)

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## INTRODUCTION

The cardiovascular circulation of domestic and wild birds has been investigated by various authors, with the domestic fowl receiving the most attention. Petrén (1926) and Myczkowski (1960) studied the coronary arteries of the domestic fowl and various wild birds, while Adams (1937) investigated the heart of the kiwi and yellow crested penguin. Macalister (1864) dissected one ostrich and mentioned a right and left coronary artery. Most of these studies have concentrated on the arterial supply, while the venous drainage has received very little attention. Furthermore, most descriptions are based on observations made on only one or two specimens and in general are lacking in detail. Of all birds, the least information appears to be available for the ratites, an avian group of considerable interest because of their terrestrial mode of life. In the present study, therefore, the arterial supply and venous drainage of the heart of the ostrich (*Struthio camelus*) has been investigated. The nomenclature used is that of the *Nomina Anatomica Avium* (Baumel *et al.* 1979).

## MATERIALS AND METHODS

Thirty seven fresh adult or subadult ostrich hearts were injected with coloured Revultex (Midas Chemicals) as follows: (i) Twenty via the coronary arteries; (ii) Four via the left cranial vena cava; (iii) Two via the right cranial vena cava; (iv) Six directly into the intra-atrial openings of the cardiac veins; (v) Two via the intra-atrial openings of the veins as well as the coronary arteries; (vi) Two via the intra-atrial openings of the veins using 2 parts Revultex and 1 part barium sulphate; (vii) One via the left cranial vena cava using the Revultex/barium sulphate mixture.

The hearts were then fixed in 10 % formalin for one day (when the epicardium was removed) and left in formalin until they were dissected.

Three fresh adult hearts were injected with vinyl resin solution (Turdoc), two via the coronary arteries and one via the aorta. They were stored for two days at room temperature and then digested with sodium hydroxide to produce corrosion preparations of the arteries.

Three hearts were injected via the left cranial vena cava with polyester resin (General Industries Ltd) after the method of Nerantzis, Antonakis & Avgoustakis (1978). The initial injection pressure of 100 mmHg was increased to 150 mmHg during the last two minutes of the working life of the resin. After 2 hours the hearts were digested with concentrated hydrochloric acid to obtain corrosion preparations of the cardiac veins.

The hearts injected with the Revultex/barium sulphate mixture were opened after

the method of Lindsay & Smith (1965), X-rayed and photographed. The technique was slightly modified by extending the ventricular incisions into the atria to include them in the X-ray photograph.

The Revultex-injected hearts were dissected macroscopically and photographed to illustrate the course of the vessels.

The intra-atrial openings of the four main veins were measured in nine hearts, while the external diameter of the Revultex-filled veins were measured in all the hearts, using Vernier callipers.

## RESULTS

### *Topographical observations*

The sternum of the ostrich is an oval, dish-like structure, lying perpendicular to the ventral body wall, with its concave surface facing caudally. The heart lay within the hollow of the sternum with its long axis perpendicular to the ventral body wall (or ground surface in the standing bird) and its apex in the deepest part of the hollow (Fig. 8). A general examination of the heart surface revealed that the coronary groove resembled that of the mammal, while the interventricular grooves were shallow furrows, marking the septal and outer ventricular walls. Both the coronary groove and the interventricular grooves contained blood vessels. *In situ*, the paraconal interventricular groove crossed the ventrocranial surface from left to right above the apex, to become continuous with the subsinuosal interventricular groove on the right caudal aspect of the heart.

### *Arterial supply*

#### *Arteria coronaria dextra*

The right coronary artery originated from the right ventral aortic sinus ±10 mm dorsal to the right ventral semilunar valvule (Fig. 6). Initially it ran cranially and slightly to the right, where it was related, dorsally and to the right, to the cranial

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KEY TO LABELLING IN FIGURES

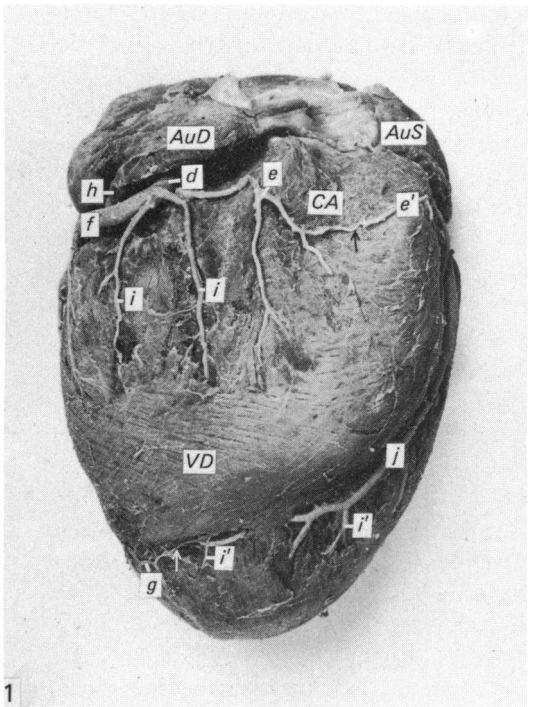
*A*, aorta; *AD*, atrium dextrum; *AS*, atrium sinistrum; *AuD*, auricula dextra; *Aus*, auricula sinistra; *CA*, conus arteriosus; *H*, heart; *L*, liver; *S*, septum interventriculare; *St*, sternum; *TP*, truncus pulmonalis; *VAD*, valva atrioventriculare dextra; *VCC*, vena cava caudalis; *VD*, ventriculus dexter; *VP*, venae pulmonales; *VS*, ventriculus sinister; *a*, valvula semilunaris dextra ventralis; *a'*. valvula semilunaris sinistra; *b*, arteria coronaria dextra with its ramus profundus (*c*), the branch to the valva atrioventricularis dextra (*c'*), ramus superficialis (*d*), rami conales (*e*), ramus circumflexus (*f*), ramus interventricularis subsinuosus (*g*), rami atriales (*h*), rami ventricularis (*i*), and the branch to the right trigonum fibrosum (*l*). *b'*, arteria coronaria sinistra with its ramus profundus (*c'*), ramus superficialis (*d'*), ramus conalis (*e'*), ramus circumflexus (f'), rami atriales (*h'*), rami ventricularis (*i'*), with its septal branch (*i''*), ramus interventricularis paraconalis (*j*) and rami interatrialis (*k*). *m*, vena cardiaca sinistra: pars interventricularis; *n*, vena cardiaca sinistra: pars basilaris; *o*, venae ventriculares; *p*, venae conales; *q*, vena ventricularis of *n*; *r*, vena cardiaca circumflexa sinistra; *r'*, medial branch of *r*; *s*, vena atrialis; *t*, vena cardiaca dorsalis; *u*, vena apicis; *v*, venae cardiacae ventrales; *w*, vena cardiaca circumflexa dextra; *x*, venae septales; *y*, venae cardiacae minimae. Arrows indicate anastomoses.

Fig. 1. Cranial view of the adult heart showing the paraconal interventricular and right circumflex arteries.

Fig. 2. Right view of the adult heart showing the right circumflex and subsinuosal interventricular arteries.

Fig. 3. Caudal view of the adult heart showing the left circumflex and subsinuosal interventricular arteries.

Fig. 4. Left view of the adult heart showing the left coronary artery with its circumflex and paraconal interventricular branches.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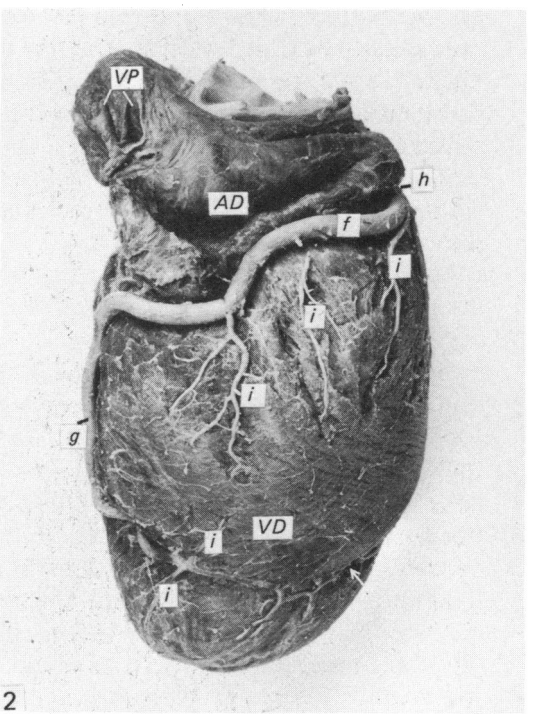
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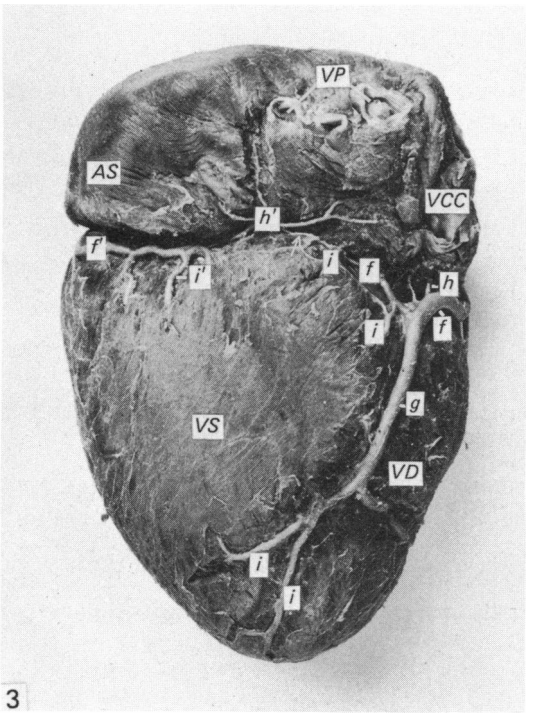
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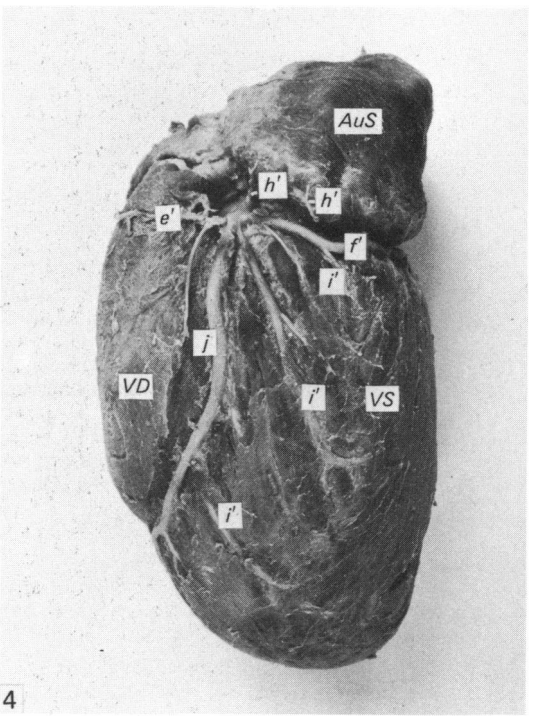
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part of the right auricle, and, to the left, to the base of the pulmonary trunk and conus arteriosus.

Close to its origin it gave off a ventrocaudally directed *Ramus profundus* and continued as the *Ramus superficialis* (Fig. 5). The deep branch entered the interventricular septum and gave off numerous branches to supply the caudal part of the septum. Distally, it gave off a small branch (Fig. 5) which entered the distal (caudoventral) part of the right atrioventricular valve to turn dorsocranially in the valve and supply its distal part.

Macroscopically the deep branch could not be traced beyond the distal border of the right ventricle, i.e. it did not reach the walls of the right or left ventricles or the apex of the heart.

At the point where the superficial branch of the right coronary artery appeared in the coronary groove on the surface of the heart, it gave off one or two branches to the left, the *Rami conales* (Figs. 1, 6). The conal branches supplied the base of the pulmonary trunk and the right side of the conus arteriosus. They anastomosed with corresponding branches from the left coronary artery. The superficial branch now turned to the right and caudally to continue in the coronary groove as the *Ramus circumflexus* (Figs. 1–3, 5–7). Along its course, it gave off lateroventrally (apically) and medioventrally directed *Rami ventriculares* (Figs. 1, 2, 5, 6). The lateral branches ran distally for 5–40 mm on the surface of the right ventricle, entered the wall and divided to supply the greater part of the wall of the right ventricle. The medial branches entered and supplied the proximomedial part of the wall of the right ventricle as well as the cranioproximal part of the right atrioventricular valve.

In addition to the ventricular branches, three to four dorsomedially directed *Rami atriales* (Figs. 1–3) were given off. On reaching the atrial wall, they usually divided into ascending branches to the pectinate muscles and descending branches to the more ventrally situated basi-annular muscle.

On reaching the subsinuosal interventricular groove, the circumflex branch gave off a large ventrally directed *Ramus interventricularis subsinuosus* (Figs. 2, 3, 6, 7). The continuation of the circumflex branch in the coronary groove gave off one or two ventrally directed ventricular branches and a medially directed vessel that supplied the right fibrous trigone, the caudal part of the aortic bulb and the ventral part of the left recess of the right atrium (Fig. 6). This vessel commonly anastomosed with the interatrial branch of the left coronary artery. In most of the hearts, an atrial branch was given off from the right circumflex branch which supplied the right atrium, ventrally and to the left of the caudal vena cava (Fig. 7). If this vessel were weakly developed or absent, its function was taken over by the last atrial branch of the left circumflex branch (Fig. 3). The circumflex branch of the right coronary artery ended by anastomosing with the circumflex branch of the left coronary artery.

After a course of 10–50 mm in the subsinuosal interventricular groove the sub-

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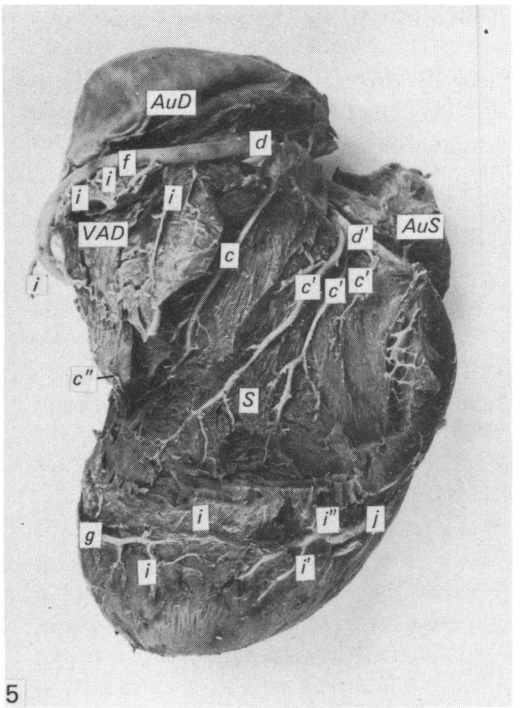
Fig. 5. Right view of the adult heart with the right ventricular wall removed to show the interventricular septum with the left and right coronary arteries and their deep and superficial branches.

Fig. 6. Basal view of the adult heart showing the origin of the left and right coronary arteries with their various branches.

Fig. 7. Caudal view of the adult heart showing the anastomoses between the left and right circumflex arteries and the caudal atrial blood supply.

Fig. 8. Left view of a 4 months old ostrich showing the orientation of the heart *in situ*.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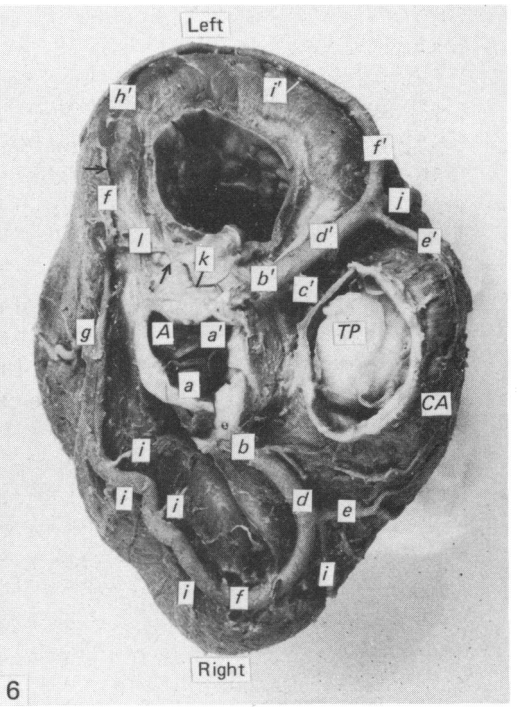
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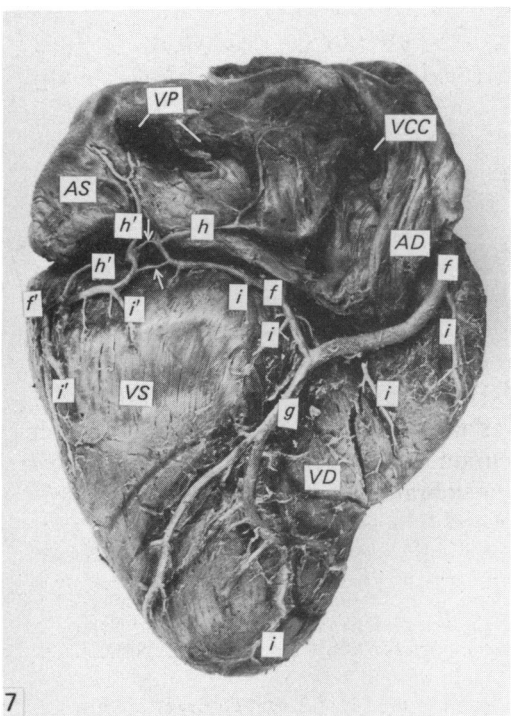
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sinuosal interventricular branch bifurcated (Figs. 3, 7). One branch continued along the caudal aspect of the heart to the apex, giving off numerous ventricular branches which supplied the wall of the left ventricle and the apex. The other branch turned cranioventrally into the paraconal interventricular groove. Along its course it gave off ventrally directed ventricular branches which supplied the right part of the left ventricle and apex, as well as dorsally directed ventricular branches which supplied the caudoventral part of the right ventricle along the paraconal interventricular groove. Some of the vessels penetrating the ventricular wall along the interventricular grooves were also distributed to the interventricular septum. Over the apex and in the paraconal interventricular groove numerous small homo- and intercoronary anastomoses were present.

*Arteria coronaria sinistra*

The left coronary artery originated from the left aortic sinus ±6 mm dorsal to the left semilunar valvule (Fig. 6).

Initially it ran craniolaterally to the left where it was related, to the right, cranially and dorsally, to the pulmonary trunk and, caudally, to the left and dorsally, to the left auricle.

The first branch given off by the left coronary artery was a small, caudally directed vessel, the *Ramus interatrialis* (Fig. 6), running between the aorta and left auricle. Here it supplied the aortic bulb and the left auricle. It then entered the floor of the left recess of the right atrium where it supplied the latter as well as the interatrial septum. In most hearts it ended by anastomosing with a branch of the right circumflex artery.

Fairly close to the origin of the left coronary artery it gave off one to four ventrally directed *Rami profundi* and continued as the *Ramus superficialis* (Figs. 5, 6). The deep branches entered the interventricular septum cranial to the aorta and to the deep branch of the right coronary artery, where they divided into numerous small branches which supplied the cranial part of the interventricular septum. The finer branches of the arteries could be traced macroscopically only as far as the paraconal interventricular groove. They did not reach the left or right ventricular walls.

One of the hearts dissected showed intercoronary anastomoses between the left and right septal branches, while homocoronary anastomoses between the left septal branches were common.

At the point where the superficial branch of the left coronary artery appeared on the surface of the heart, a laterally directed *Ramus conalis* (Figs. 1, 4, 6) was given off to the right. This branch supplied the left part of the conus arteriosus and anastomosed with the corresponding branch of the right coronary artery. The superficial branch now divided into a smaller, caudally directed *Ramus circumflexus* and a larger, ventrally directed *Ramus interventricularis paraconalis* (Figs. 4, 6).

The paraconal interventricular branch ran in the paraconal interventricular groove

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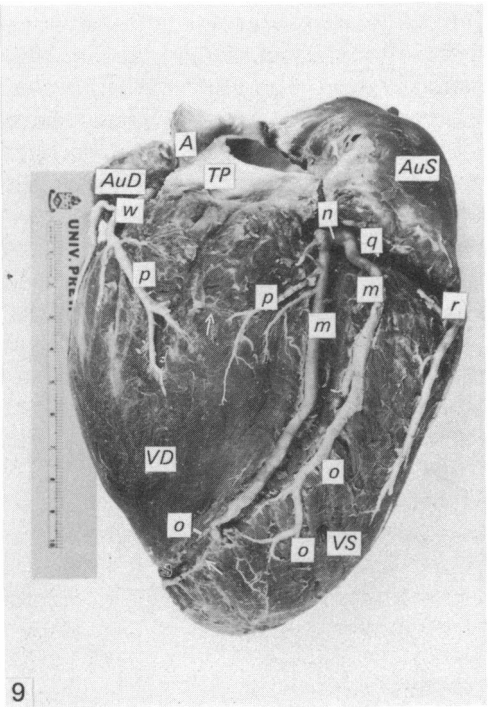
Fig. 9. Cranial view of the adult heart showing the double nature of the interventricular part of the left cardiac vein.

Fig. 10. Left view of the adult heart showing the left cardiac, left cardiac circumflex and dorsal cardiac veins.

Fig. 11. Caudal view of the adult heart showing the double nature of the dorsal cardiac vein.

Fig. 12. Right view of the adult heart showing the ventral cardiac veins which unite to form the right cardiac circumflex vein.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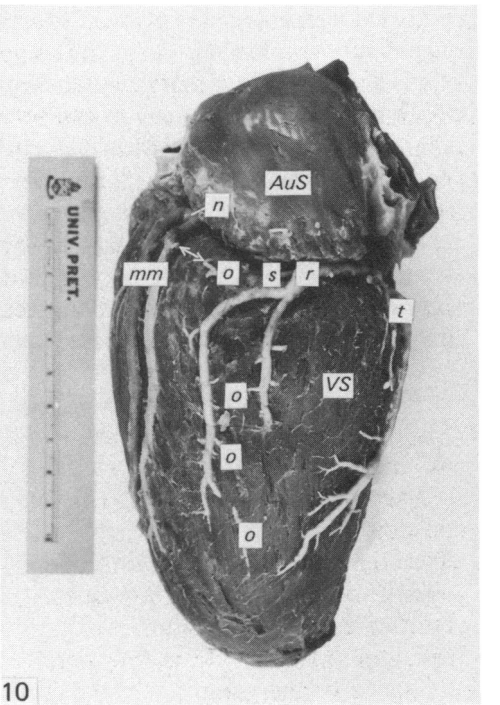
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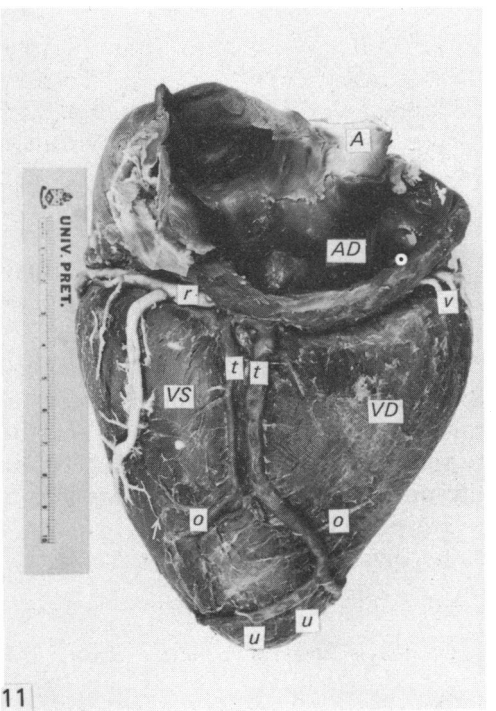
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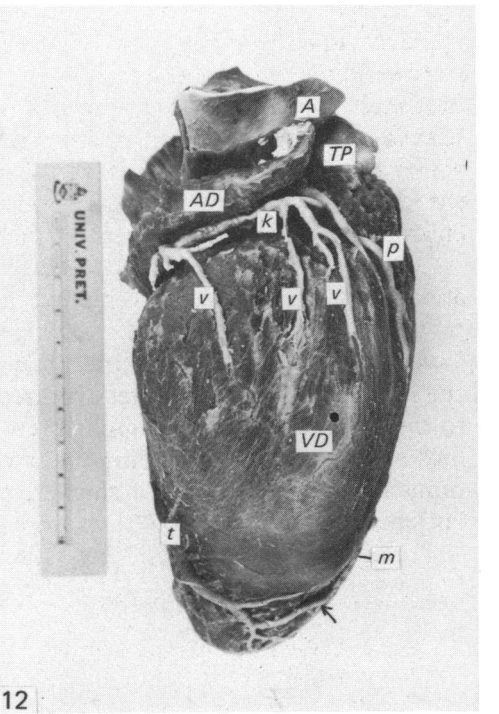
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and gave off dorsally and ventrally directed *Rami ventriculares* (Figs. 1, 4, 5) supplying the left and right ventricular walls. The vessels penetrating the ventricular walls also supplied the interventricular septum (Fig. 5).

The circumflex branch turned to the left and caudally to follow the coronary groove along the left and caudal aspect of the heart. Along its course, it gave off several ventrolaterally directed ventricular branches (Figs. 3, 4, 7). They ran parallel to the long axis of the heart to supply the wall of the left ventricle. A few medially directed ventricular branches (Fig. 6) supplied the proximomedial part of the wall of the left ventricle. In addition to the ventricular branches, three or four *Rami atriales* (Fig. 7) were given off dorsally. When they reached the wall of the left atrium they divided into ascending branches supplying the pectinate muscles of the left atrium and descending branches into the basi-annular muscle of the left atrium. The last of the atrial branches was a fairly large vessel (Figs. 3, 7) ascending on the caudal surface of the left atrium immediately to the left of the two pulmonary veins, to supply the caudal part of the left atrium as well as the dorsal part of the left recess of the right atrium. In some hearts it also supplied the right atrium ventrally to the caudal vena cava (Fig. 3). This vessel was sometimes reinforced by an anastomosing branch from the circumflex branch of the right coronary artery.

The left circumflex branch terminated by anastomosing with the right circumflex branch in the coronary groove (Figs. 3, 7).

### *Venous drainage*

The ostrich heart, like the heart of the fowl, was drained by four main cardiac veins, as well as numerous luminal veins.

#### *Vena cardiaca sinistra*

The left cardiac vein was a large vein, measuring 3·4–4·5 mm at its intra-atrial opening. It consisted of two main parts, the *Pars interventricularis* and *Pars basilaris* (Figs. 9, 10, 15).

The interventricular part ran in the paraconal interventricular groove to the level of the distal quarter of the heart. In seven hearts it was seen as a double vein, one branch lying in the groove, the other caudally to it on the wall of the left ventricle (Fig. 9). Along its course it received ventrally and dorsally directed *Vv. ventriculares* (Fig. 9), draining the walls of the left and right ventricles. In addition, a few *Vv. septales* (Figs. 13, 14), draining the interventricular septum, joined it. Proximally it received *Vv. conales* (Fig. 9) draining the left part of the conus arteriosus. At the distal part of the groove, the interventricular segments of the left and dorsal cardiac veins anastomosed (Fig. 9). Small anastomoses also existed between the left and right conal veins (Fig. 9). The septal veins anastomosed with the luminal veins (Figs. 13, 14). In the hearts where the interventricular segment was double, the two parts joined before or at the coronary groove. On reaching the coronary groove, the interventricular segment turned caudally to become the basilar segment (Fig. 15).

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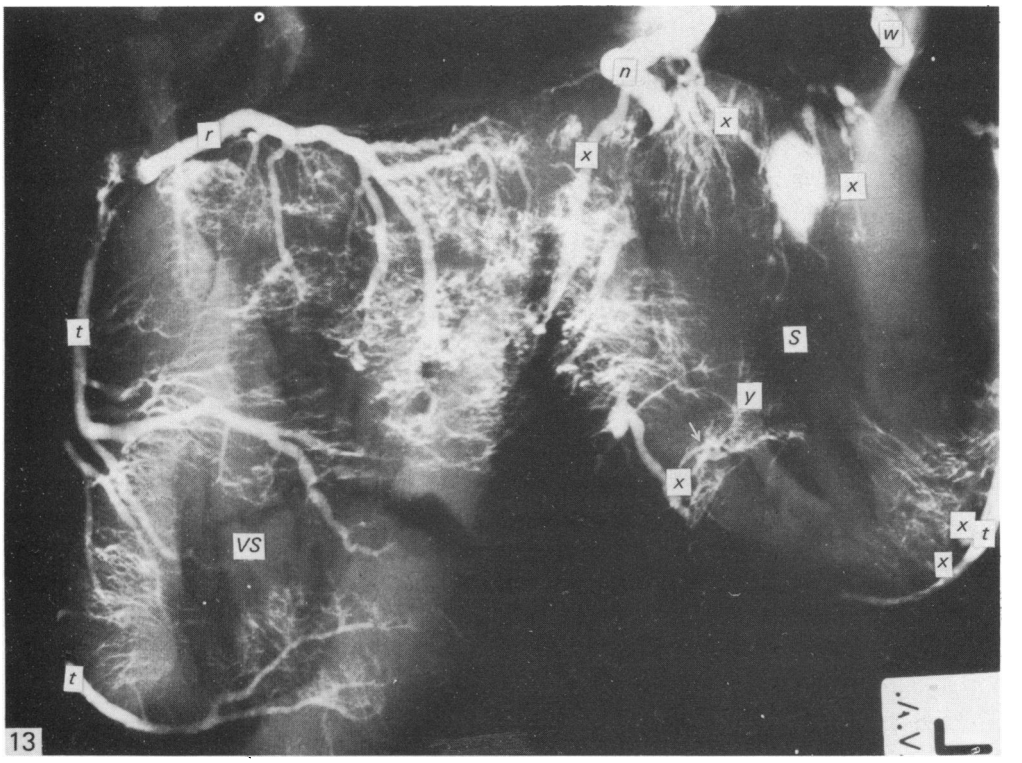
Fig. 13. X-Ray photograph of an opened adult heart showing the left ventricle and interventricular septum with the cardiac veins.

Fig. 14. Right view of the adult heart with the right ventricular wall removed to show the venous drainage of the interventricular septum.

Fig. 15. Basal view of the adult heart showing the openings of the left cardiac, left cardiac circumflex and dorsal cardiac veins into the right atrium.

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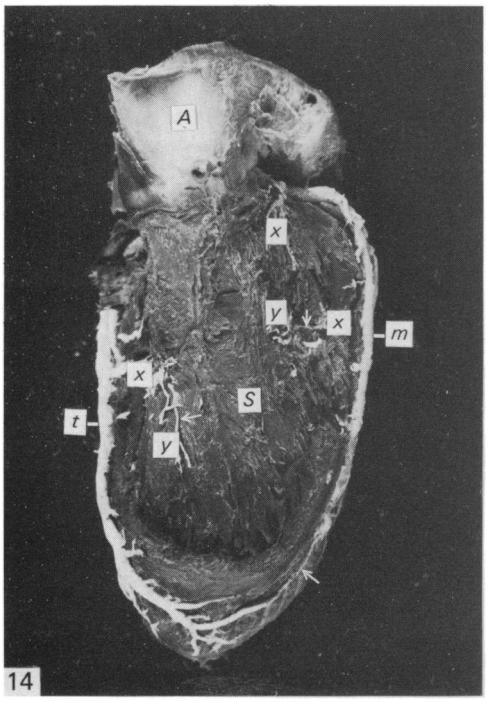


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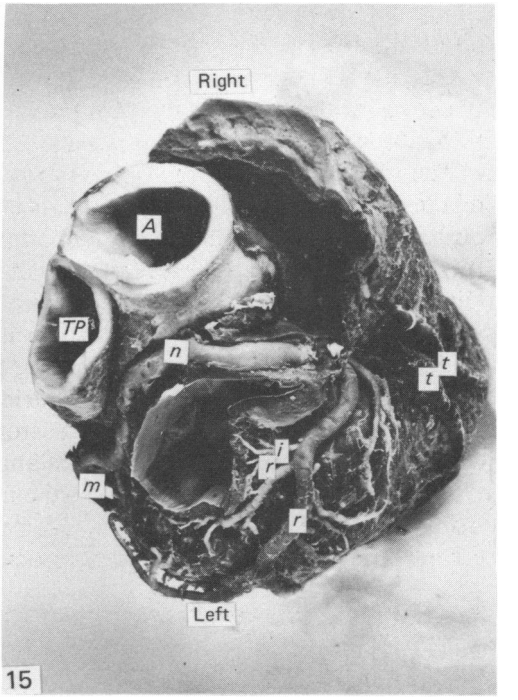


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The basilar segment passed deep (ventral) to the left circumflex artery in most of the hearts. It ran caudally in the fat-filled space between the left auricle (to the left) and pulmonary trunk and aorta (to the right) (Fig. 15). At the caudal level of the aorta, the vein penetrated the floor of the left recess of the right atrium to open in a common sinus for the left cardiac vein, left cardiac circumflex vein, and dorsal cardiac vein, immediately ventral to the intra-atrial opening of the left cranial vena cava. Along its course the basilar part received ventricular veins (Fig. 9) draining the cranial left part of the wall of the left ventricle. These veins varied in size, depending on the development of the left cardiac circumflex vein. Small anastomoses were present between the latter and the ventricular veins.

A major contribution to the basilar segment came from two to four *Vv. septales* (Figs. 13, 14) draining the proximal half to third of the interventricular septum. In all the hearts dissected, anastomoses were found between the septal veins of the left and ventral cardiac veins in the space between the pulmonary trunk cranially and aortic bulb caudally. In one specimen, the most caudal of the septal veins did not drain into the basilar part, but into the left cardiac circumflex vein, close to its intra-atrial opening. One or two small *Vv. atriales*, draining the medial (right) part of the left auricle and the left recess of the right atrium, joined the basilar part before it entered the right atrium.

*Vena cardiaca circumflexa sinistra*

The left cardiac circumflex vein (Figs. 9, 10, 11) accompanied the left circumflex artery superficially in the coronary groove. It measured 2·4–3·2 mm in diameter at its intra-atrial opening, which was located in a sinus ventral to the opening of the left cranial vena cava. Along its course, it received ventricular veins (Fig. 10) draining the left and caudal part of the wall of the left ventricle, except the apex and the area to the left of the subsinuosal interventricular groove. In addition, it also received dorsally directed atrial veins from the left and caudal parts of the left auricle.

A very constant, but variably developed vein lay medial to the left cardiac circumflex vein in the coronary groove (Fig. 15). This vein drained the medioproximal part of the wall of the left ventricle and the basi-annular muscle of the left atrium. It joined the left cardiac circumflex vein before the latter opened into the right atrium. In one heart, the most caudal of the septal veins did not open into the basilar part of the left cardiac vein but into the left cardiac circumflex vein close to its intra-atrial opening. In four hearts, the left cardiac circumflex vein joined the dorsal cardiac vein to form a common opening into the right atrium.

Small anastomoses existed between ventricular veins of the left cardiac circumflex and basilar part of the left cardiac veins in the coronary groove (Fig. 10), as well as with the dorsal cardiac vein along the subsinuosal interventricular groove (Fig. 11).

*Vena cardiaca dorsalis*

The dorsal cardiac vein was the largest of the cardiac veins, measuring 4·4–5·5 mm at its intra-atrial opening. In most hearts the vein was double (Fig. 11). The bigger of the two veins lay in the subsinuosal interventricular groove and bifurcated at its distal end (Fig. 11). The one branch curved to the right, ventrally and cranially to enter the paraconal interventricular groove, while the other continued on the caudal aspect of the heart to turn anti-clockwise around the apex. In five hearts, the two veins were of the same size; in these cases, the left one continued on the dorsal aspect of the heart, while the right one followed the paraconal interventricular groove.

Along its course, the dorsal cardiac vein received ventricular veins (Fig. 11) from the left and right ventricles, *Vv. apicis* from the apex (Fig. 11), septal veins (Figs 13, 14) from the interventricular septum and right atrioventricular valve, and, in some hearts, atrial veins (Fig. 11) from the right atrium.

Numerous anastomoses between the dorsal cardiac vein and left cardiac, ventral and luminal veins could be seen in common areas of drainage.

The two parts of the dorsal cardiac vein generally united near or at the coronary groove to open with a common opening into a sinus in the right atrium, immediately to the right of the intra-atrial opening of the left cardiac circumflex vein. In five hearts the two vessels did not unite. In these cases the right branch of the vein opened more dorsally, directly into the right atrium, while the left branch opened into the sinus.

*Venae cardiacae ventrales*

The branches of the ventral cardiac veins did not unite to form a single trunk, but remained mostly as separate veins which crossed the coronary groove superficially to open separately between the pectinate muscles of the right auricle. They consisted of ventricular veins (Fig. 12) from the proximal wall of the right ventricle and the right atrioventricular valve. One or two of the ventricular veins received atrial veins from the right atrium. The veins from the cranial part of the right ventricle mostly united to form a right cardiac circumflex vein (Fig. 12). The latter ran in the coronary groove, received the right conal vein (Fig. 12), crossed the circumflex branch of the right coronary artery superficially, received a septal vein and opened into the craniomedial part of the right auricle. The right and left septal veins anastomosed behind the pulmonary trunk.

On opening the right auricle, an additional vein could be seen subendocardially, draining the proximal part of the right atrioventricular valve. It drained either directly into the right auricle, or joined one of the ventricular veins close to its intra-atrial opening.

*Venae cardiacae minimae*

On examination of the inner surface of the heart, numerous small openings of luminal veins (Fig. 13, 14) could be seen in the right atrium and ventricle. No veins could be seen in the left side of the heart. Some of these short veins anastomosed freely with the dorsal and left cardiac veins along the subsinuosal and paraconal interventricular grooves. They seemed to play a role in the venous drainage of the interventricular septum and right atrioventricular valve.

## DISCUSSION

The coronary circulation of the ostrich heart differs fundamentally from that of the domestic fowl (*Gallus domesticus*) and some other avian species.

In all the ostrich hearts examined, only two arteries come from the aorta. This is in contrast to the findings of Lindsay & Smith (1965) and of Petrén (1926) who reported that more than two arteries come from the aorta in a significant number of hearts studied (20 % and 40·3 % respectively). Rigdon & Frölich (1970) found that there are usually two coronary arteries in white Pekin (*Anas platyrhynchos* and Muscovy (*Cairina moschata*) ducks. Lindsay & Smith (1965) found that the vessels simulate coronary arteries, while Petrén (1926) concluded that more than two (generally three) coronary arteries are common in birds capable of powerful flight.

Therefore it can be expected that flightless birds like the ostrich will seldom have more than two coronary arteries.

The main blood supply to the heart of the ostrich comes from the superficial branches of the coronary arteries. The large superficial branches pass along the coronary groove as the circumflex branches, which then continue in the interventricular grooves as the interventricular branches to the apex of the heart. The arterial and ventricular walls, and part of the interventricular septum, are supplied by these vessels. The deep branches of the coronary arteries are small. They supply only the interventricular and part of the right atrioventricular valve. This is in contrast to the situation in the dometic fowl as described by Lindsay & Smith (1965), Petrén (1926) and Myczkowski (1960), where the deep branches give off septal branches which supply the interventricular septum, and ventricular branches which emerge at the interventricular grooves to form the main supply to the ventricular walls. The deep arterial branches in the ostrich heart are the septal branches only, since the ventricular branches are absent. Adams (1937) found that the superficial branches of the kiwi (*Apteryx australis*) and yellow eyed penguin (*Megadyptes antipodes*, formerly yellow crested penguin, *Megadyptes antipodum*) are the larger vessels. Petrén (1926) concluded that the main blood supply to the avian heart comes from the deep branches of the coronary arteries, except in birds that swim, where the superficial branches are larger. On the other hand, Myczkowski (1960) found that the superficial branches are the larger vessels in the hearts of the avian species that he studied. These two authors mostly studied different species.

In contrast to the domestic fowl, the interatrial artery of the ostrich heart is very small. It supplies part of the left auricle and interatrial septum only.

The left and right coronary arteries of the ostrich heart are equally well developed. They form a balanced circulation with numerous homocoronary and intercoronary anastomoses (Baroldi, Mantero & Scomazzoni, 1956).

The venous drainage of the ostrich heart corresponds basically to that of the domestic fowl as described by Lindsay (1967). Because of the different arterial supply, the left cardiac, left cardiac circumflex, dorsal cardiac and sometimes the ventral cardiac veins are concomitant veins of the arteries. The venous drainage of the right atrioventricular valve is mainly through a subendocardial vein which usually opens directly into the right atrium.

## SUMMARY

The distribution of the coronary arteries of the ostrich is described and compared with existing accounts of other species of birds. The blood supply to the ventricular walls, part of the interventricular septum and atria comes from the superficial branches of the left and right coronary arteries. The deep branches are small, supplying most of the interventricular septum and part of the right atrioventricular valve. The left and right coronary arteries are of equal size, forming a balanced circulation. Numerous homocoronary and intercoronary anastomoses are present.

The venous drainage of the ostrich heart corresponds in the main to that of the fowl. Four major systems of veins are seen with multiple anastomoses between them. The major trunks are located underneath the epicardium and apart from some of the ventral cardiac veins, are concomitant veins of the arteries. The intra-atrial openings of the left cardiac, left cardiac circumflex and dorsal cardiac veins lie near to but separate from each other in a sinus below the intra-atrial opening of the left cranial

vena cava. The dorsal cardiac vein consists of two branches. In some hearts the two branches do not unite, in which case the right branch opens separately into the right atrium, dorsal to the sinus, while the left branch opens into the sinus.

Many luminal cardiac veins are seen, draining the interventricular septum, right atrioventricular valve and to a lesser extent the right atrium.

The right atrioventricular valve is drained mainly by a subendocardial vein, opening directly into the right atrium or into a ventral cardiac vein.

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## REFERENCES

ADAMS, W. E. (1937). A contribution to the anatomy of the avian heart as seen in the Kiwi (*Apteryx australis*) and the Yellow crested penguin (*Megadyptes antipodum*). *Proceedings of the Zoological Society of London, B* **107**, 417–441.

BAROLDI G., MANTERO, O. & SCOMAZZONI, C. (1956). The collaterals of the coronary arteries in normal and pathologic hearts. *Circulation Research* IV, 223–229.

BAUMEL, J. J., KING, A. S., LUCAS, A. M., BREAZILE, J. E. & EVANS, H. E. (ed.) (1979). *Nomina Anatomica Avium*. London: Academic Press.

LINDSAY, F. E. F. & SMITH, H. J. (1965). Coronary arteries of *Gallus domesticus*. *American Journal of Anatomy* **116**, 301–314.

LINDSAY, F. E. F. (1967). The cardiac veins of *Gallus domesticus*. *Journal of Anatomy* **101**, 555–568.

MACALISTER, A. (1864). On the anatomy of the ostrich (*Struthio camelus*). *Proceedings of the Royal Irish Academy* IX, 1–25.

MYCZKOWSKI, K. (1960). Morphology of the coronary arteries of fowl and some wild birds. *Folio morphologica* XI (1), 21–30.

NERANTZIS, C., ANTONAKIS, E. & AVGOUSTAKIS, D. (1978). A new corrision casting technique. *Anatomical Record* **191**, 321–326.

PETRÉN, T. (1926). Die Coronärarterien des Vogelherzens. *Morphologisches Jahrbuch* **56**, 239–249.

RIGDON, R. H. & FRÖLICH, J. (1970). The heart of the duck. *Zentralblatt für Veterinärmedizin, A* **17**, 85–94.