FURTHER STUDIES OF THE CONDUCTING SYSTEM OF THE BIRD'S HEART

By FRANCIS DAVIES, M.D. (London)
Anatomy Department, University College, London

INTRODUCTION

The histological investigation of the conducting system of the hearts of a number of the smaller birds, undertaken by the present writer (*J. Anat.* Jan. 1930), revealed that the specialised elements of this system comprise the following:

(*a*) *Sinu-auricular node*, situated beneath the epicardium at the base of the right venous valve, its specialised fibres being continuous with the neighbouring auricular myocardium and with the subendocardial Purkinje fibres in the vicinity.

(*b*) *Sub-endocardial Purkinje network* of both auricles, from which Purkinje fibres penetrate into the depth of the auricular myocardium around the branches of the coronary arteries, reaching in some places to the sub-epicardial connective tissue, and establishing continuity with the auricular myocardium. Neither the sub-endocardial nor the periarterial Purkinje fibres of the auricles form any specialised connections with the ventricular muscle (ordinary or specialised).

(*c*) *Auriculo-ventricular node*, situated in the lower and posterior part of the auricular septum, immediately to the left of the opening of the left superior vena cava, its specialised fibres being continuous below with the auriculo-ventricular bundle and with the right auriculo-ventricular Purkinje ring, and above with the ordinary auricular myocardium but not with the auricular Purkinje fibres.

(*d*) *The auriculo-ventricular bundle* passes from the lower end of the auriculo-ventricular node through the posterior part of the right auriculo-ventricular fibrous ring (near the posterior septal attachment of the muscular right auriculo-ventricular valve), where it lies just beneath the endocardium. Thence it is prolonged forwards, downwards and to the left into the depth of the ventricular septum, in which, midway between its right and left surfaces and about one-quarter of the distance from the base to the apex of the septum, the bundle divides into its right and left limbs. This site of the bifurcation of the bundle is just below and to the right of the anterior septal attachment of the muscular valve. The rounded right limb and the broad flattened left limb approach the endocardium on the corresponding sides of the ventricular septum, where they spread out to become continuous with the sub-endocardial

Purkinje network on either side of the septum. The right limb, as it approaches the endocardium, gives off a small branch which runs upwards and to the left, immediately beneath the endocardium, to enter the muscular valve at its anterior septal attachment. The main auriculo-ventricular bundle and its right and left limbs are not enveloped by a well-defined fibrous sheath, the specialised fibres being in direct apposition to and establishing continuity with the neighbouring septal myocardium.

(*e*) *Sub-endocardial Purkinje network* of both ventricles, from which Purkinje fibres penetrate through the thickness of the septal and free walls of the ventricles around branches of the coronary arteries, following in their course the "pattern" of the myocardial branches of the coronary arteries, reaching in some places to the sub-epicardial connective tissue, and establishing continuity with the ventricular myocardium. The ventricular sub-endocardial and periarterial Purkinje networks form no direct connections with the auricular muscle (ordinary or specialised).

(*f*) *Recurrent branch* of the auriculo-ventricular bundle, given off at the bifurcation of the main bundle, running upwards and to the left in the depth of the ventricular septum, in front of the mitral orifice, and finally in the connective tissue on the left side of the root of the aorta, where it inclines backwards to join the aortic end of the right auriculo-ventricular Purkinje ring behind the root of the aorta.

(*g*) *Right auriculo-ventricular Purkinje ring*, commencing from the lower and posterior part of the auriculo-ventricular node and running round the right auriculo-ventricular orifice in the connective tissue between the auricular and ventricular myocardial components of the muscular valve, finally joining the recurrent branch of the main auriculo-ventricular bundle behind the root of the aorta. On its way round it establishes continuity with the auricular and ventricular myocardial components of the muscular valve.

PRESENT WORK

In the present work an attempt has been made to display some of these elements of the specialised avian conducting system by dissection in the heart of a large bird, namely the ostrich. Three ostrich hearts were available for study, all previously fixed in formalin. The first heart was cut into a series of transverse horizontal slabs, each rather less than half an inch in thickness. The cut surfaces of the ventricular septum were examined, but the main auriculo-ventricular bundle could not be identified with any degree of certainty by the naked eye. By a careful examination with the dissecting microscope of the precise localities in which the auriculo-ventricular bundle had been found in the previous histological study, it was just possible to distinguish the slightly paler bundle from the neighbouring septal myocardium. The bundle was separated by blunt dissection from the cardiac muscle in each slab of the upper part of the ventricular septum and thus traced through the successive slabs upwards to the posterior part of the junction of the right auricle and

ventricle, where it lay just beneath the endocardium, and downwards to its bifurcation in the depth of the septum, whence the rounded right limb and the broad flat left limb were traced to the endocardium on the corresponding sides of the septum. The bifurcation of the bundle was situated about one-quarter of the way down the ventricular septum, and it lay midway between the right and left surfaces of the septum. In the microscopic study of the conducting system of the hearts of smaller birds, it was noted that the main bundle and its divisions were not enveloped by a well-defined fibrous sheath, actual continuity being established between the peripheral specialised fibres of the bundle and the neighbouring cardiac muscle. In separating the bundle and its limbs from the septal myocardium in the slabs of the ostrich heart, it was found that the connection between the bundle and the neighbouring septal muscle was so intimate that fine strands of the bundle became torn out as the cardiac muscle was separated. Slab 6 contained the lower part of the auriculo-ventricular bundle, the bifurcation of the bundle and the commencement of the right and left limbs of the bundle. The upper surface of the slab (fig. 1) showed the bundle which has broadened out just above its bifurcation, and the lower surface (fig. 2) showed the bifurcation of the bundle and the commencement of the rounded right and flattened left limbs. Fig. 3 shows the right and left limbs of the bundle in slab 7, passing to the endocardium on the corresponding sides of the septum. Slabs 6 and 7 together comprise about the lower inch of the upper quarter of the ventricular septum. The broad flattened bundle just above its bifurcation (fig. 1) lies midway between the right and left surfaces of the septum, and its surfaces are parallel with those of the septum.

In the second and third hearts an attempt was made to dissect the auriculo-ventricular bundle and its two limbs *in situ*. By superimposing the slabs of the first heart, in which the bundle and its divisions had been defined, a good guide to the topography of the bundle was obtained for the dissection of the other hearts. Dissection of the bundle *in situ* proved to be a long and careful task, the dissecting microscope being almost constantly employed, owing to the fact that the septal myocardium had to be removed piecemeal to approach the bundle in the depth of the ventricular septum, and also because, as was the case in the separation of the bundle from the myocardium in the heart slabs, when removing the cardiac muscle immediately adjacent to the bundle, the delicate bundle was easily damaged and fine strands of the bundle became torn out with the separated myocardium.

In the second heart the following parts of the avian-conducting system were defined: lower part of the auriculo-ventricular node, the main auriculo-ventricular bundle and its right and left limbs, and the commencement of the recurrent branch of the main bundle (fig. 4). In the third heart, in addition to the above elements, the commencement of the right auriculo-ventricular Purkinje ring from the lower and posterior aspect of the auriculo-ventricular node was also defined (fig. 5). The auriculo-ventricular bundle, when dissected out, takes the form of a delicate, pale, ragged, semi-translucent band, its ragged

appearance being due to unavoidable tearing in the process of dissection owing to the intimate connection of the bundle and the septal myocardium. The upper part of the bundle is rounded, but near its bifurcation it broadens out into a flattened band (the surfaces of which are parallel to the surfaces of the ventricular septum). It commences from the lower end of the auriculo-ventricular node in the connective tissue of the posterior part of the right auriculo-ventricular fibrous ring, close to the posterior septal attachment of the muscular right auriculo-ventricular valve. Here it lies just beneath the endocardium. Thence it passes forwards, downwards and to the left into the depth of the ventricular septum, until it attains a position about one-quarter of the way down the septum, a little below and to the right of the anterior septal attachment of the muscular valve. Here it lies midway between the right and left surfaces of the ventricular septum and divides into its right and left divisions. The right limb is small and rounded and passes to the right side of the septum, where it broadens out beneath the endocardium. The left limb is broad and flat and passes to the endocardium on the left side of the septum. From the left side of the bifurcation of the main auriculo-ventricular bundle a small round recurrent branch is given off, which passes upwards and to the left in the depth of the ventricular septum. It is the commencement of the recurrent branch of the main bundle which was traced in the previous microscopic study to the root of the aorta. From the posterior aspect of the lower end of the auriculo-ventricular node a small round bundle is given off, which runs into the connective tissue between the auricular and ventricular myocardial parts of the muscular valve at its posterior septal attachment. It is the commencement of the right auriculo-ventricular Purkinje ring.

These macroscopic dissections of parts of the avian-conducting system form an interesting corroboration of the reconstruction of these parts of the system in the previous histological study. Microscopic sections were made of many parts of the dissected system and showed the typical Purkinje structure. Fig. 6 is a micro-photograph of a piece of the dissected bundle. It shows that, although in this large heart there is some connective tissue about the Purkinje elements, there is not the same well-defined fibrous sheath such as is found in the large mammalian heart. The intimate relation of the Purkinje to the ordinary cardiac muscle is also seen.

It is well known that the sub-endocardial Purkinje network is visible to the naked eye through the ventricular endocardium in the larger mammalian hearts. In the ostrich heart the network can also quite readily be recognised through the ventricular endocardium, as a fine pale network beneath the endocardium. A strip of endocardium from the free wall of the right ventricle of the ostrich heart was dissected off and on staining showed that the visible network consisted of Purkinje fibres.

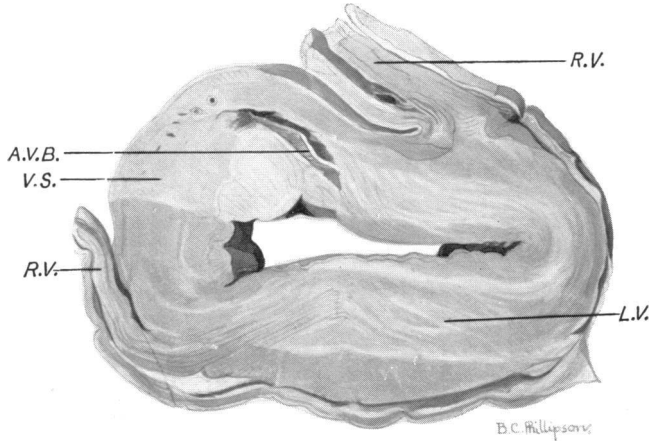

Fig. 1

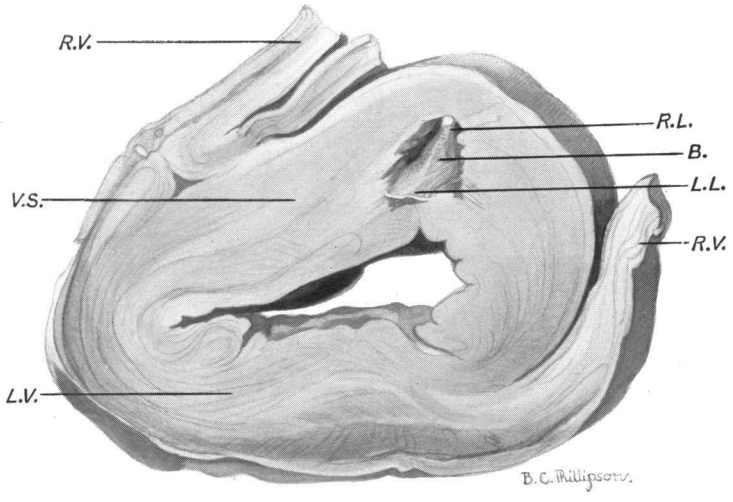

Fig. 2

Fig. 3

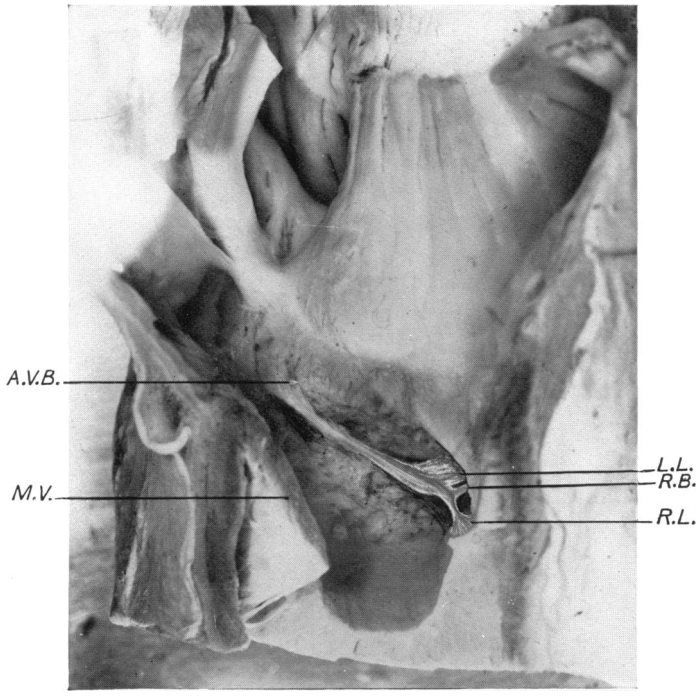

Fig. 4

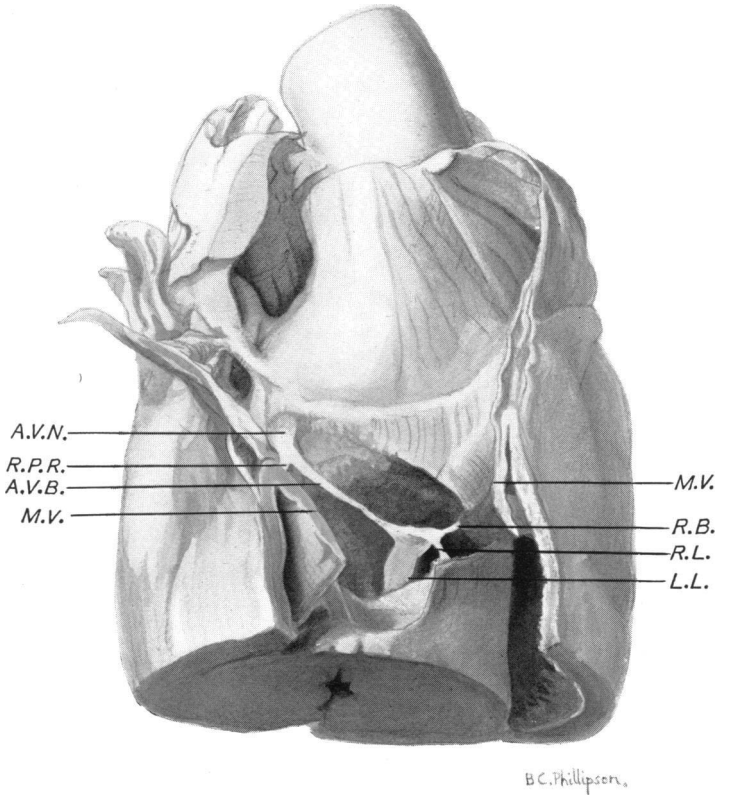

Fig. 5

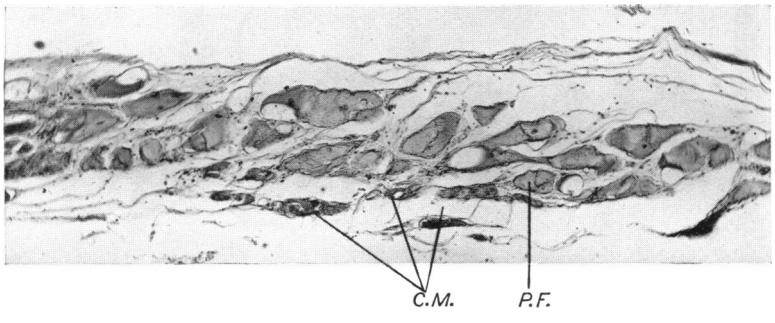

Fig. 6

SUMMARY AND CONCLUSIONS

The gross dissection of certain parts of the specialised avian-conducting system corroborates the topographical reconstruction of these parts of the system, and the intimate connection of the specialised elements of the main parts of the system with the neighbouring myocardium, as determined in a previous microscopic study. Attention is also drawn to the visible sub-endocardial ventricular Purkinje network.

I wish to express my gratitude to Sir Thomas Lewis for his interest and suggestions for future work. My anatomical and histological researches afford significant corroboration of the results obtained in his electrical studies of the bird's heart. (*Phil. Trans. Roy. Soc.* 1916, vol. CCVII, B.)

DESCRIPTIONS OF PLATES I–III

PLATE I

Fig. 1. Upper surface of slab 6.
Fig. 2. Lower surface of slab 6.

PLATE II

Fig. 3. Upper surface of slab 7.
Fig. 4. Dissection of auriculo-ventricular bundle *in situ*.

PLATE III

Fig. 5. Dissection of auriculo-ventricular bundle *in situ*.
Fig. 6. Micro-photograph of section of auriculo-ventricular bundle.

ABBREVIATIONS USED IN FIGURES

A.V.B. Auriculo-ventricular bundle.
A.V.N. Auriculo-ventricular node.
B. Bifurcation of auriculo-ventricular bundle.
C.M. Cardiac muscle.
L.L. Left limb of auriculo-ventricular bundle.
L.V. Left ventricle.
M.V. Muscular valve.
P.F. Purkinje fibres.
R.B. Recurrent branch of auriculo-ventricular bundle.
R.L. Right limb of auriculo-ventricular bundle.
R.P.R. Right Purkinje ring.
R.V. Right ventricle.
V.S. Ventricular septum.