

THE EXTENT OF CARDIAC MUSCLE IN THE
GREAT VESSELS OF THE DOG

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THE EXTENT OF CARDIAC MUSCLE
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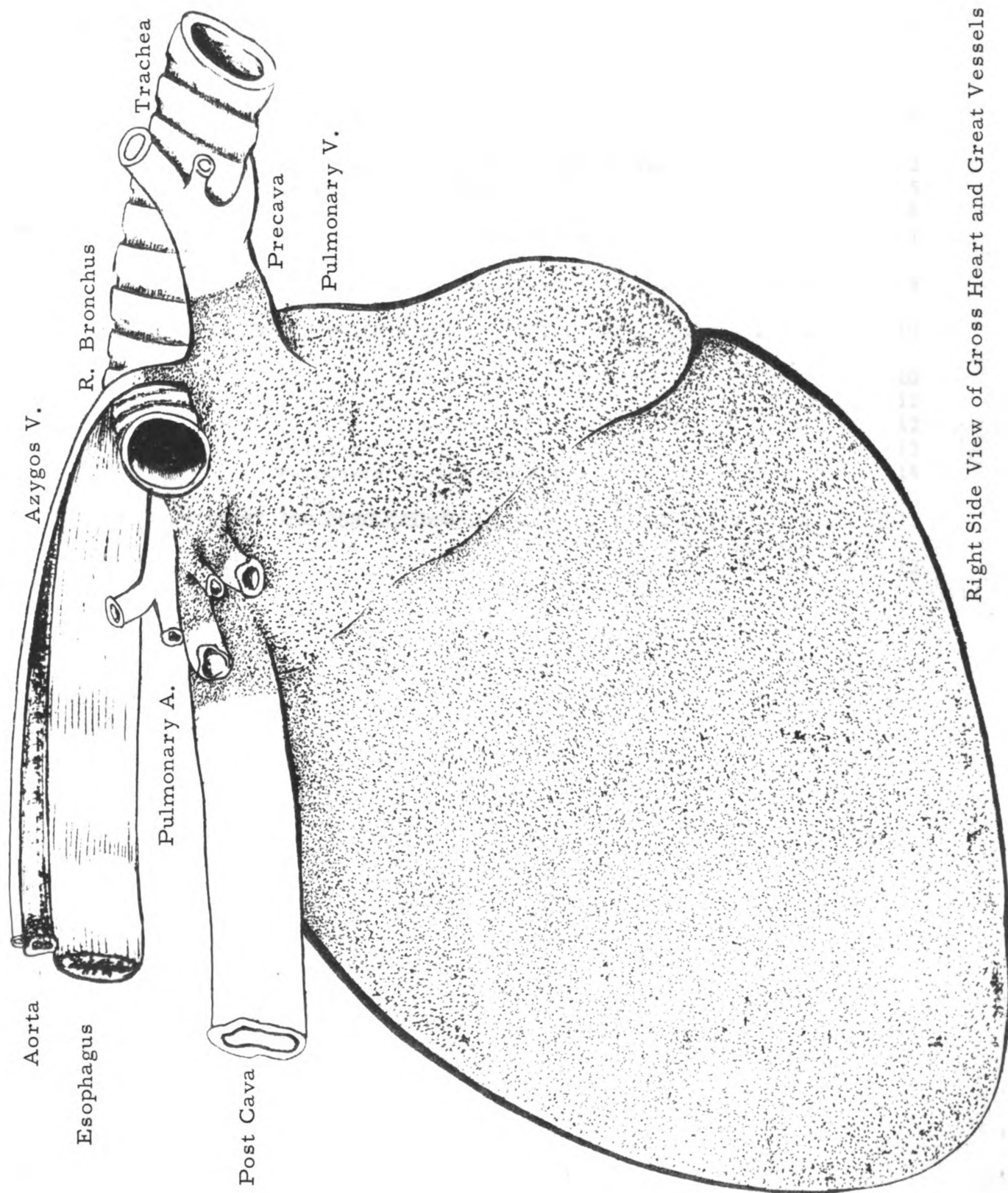
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Frontispiece

The gross structure of a canine heart showing the extent of
cardiac muscle in the great vessels.



Right Side View of Gross Heart and Great Vessels

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Chapter	
I. REVIEW OF LITERATURE	2
Superior Vena Cava and Azygos Vein	2
Inferior Vena Cava	5
Pulmonary Veins	6
Pulmonary Artery and Aorta	7
II. MATERIALS AND METHODS	9
III. RESULTS AND DISCUSSION	10
Superior Vena Cava	10
Azygos Vein	11
Inferior Vena Cava	12
Pulmonary Veins	13
Pulmonary Artery and Aorta	14
IV. SUMMARY AND CONCLUSIONS	15
LITERATURE CITED	17

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LIST OF TABLES

Table		Page
I	Cardiac muscle measurements in the great veins.	16

LIST OF PLATES

Plate		Page
I.	Superior vena cava near heart showing cardiac muscle	20
II.	Arrangement of cardiac muscle in superior vena cava	20
III.	Termination of cardiac muscle in superior vena cava	22
IV.	Fibrous attachment to cardiac muscle in superior vena cava	22
V.	Junction of azygos vein and superior vena cava	24
VI.	Arrangement of cardiac fibers in azygos vein	24
VII.	Termination of cardiac muscle in azygos vein	26
VIII.	Termination of cardiac muscle in inferior vena cava	26
IX.	Inferior vena cava near heart showing cardiac muscle	28
X.	Inferior vena cava showing one of the vasa vasorum	28
XI.	Fibrous attachment to cardiac muscle in the inferior vena cava	30
XII.	Cardiac muscle in the pulmonary vein	30
XIII.	Pulmonary vein near heart showing arrangement of cardiac muscle	32
XIV.	Arrangement of cardiac muscle fibers of pulmonary vein in cross section	32
XV.	Fibrous attachment to cardiac muscle in pulmonary vein	34
XVI.	Junction of pulmonary artery and heart	34
XVII.	Junction of aorta and heart	36

INTRODUCTION

Although scientific literature contains innumerable reports of investigations on various parts of the circulatory system, none has been found which gives a histological picture of the extent of cardiac tissue in the great vessels of the heart. There are many references to the muscular content of the superior vena cava and a few gross studies which describe the muscle arrangement in the inferior vena cava and pulmonary vein.

This investigation is an attempt to correlate the data already written on the muscular content of the vessels surrounding the heart and to determine how far cardiac muscle extends into the superior and inferior vena cava, pulmonary vessels, and aorta from the musculature of the heart. This study is confined to the dog.

REVIEW OF LITERATURE

Superior Vena Cava and Azygos Vein

A great many investigators have mentioned that cardiac muscle exists for some distance in the great vessels around the heart. Often these reports have been made in connection with work on the sino-atrial node. Muir (1955), remarked that nodal fibers in the rat are continuous with the inner circular and outer longitudinal cardiac muscle fibers of the vena cava. Shaner (1929), contended that the S-A node anlage is in the muscular wall of the superior vena cava in cattle, but failed to mention the type of muscle. Meyling and ter Borg (1957), and Truex and Copenhaver (1947), reported that fibers of the conduction system are connected with the ordinary heart muscle of the sinus venosus, and that the transition from nodal to cardiac type fibers is gradual. Flack (1910), not only found this to be true but added that in the mammalian heart there are possibly other fascicles of cardiac muscle around the orifices of the pulmonary veins.

A histological study of the S-A region by Davies and Blair (1935), confirmed the continuity of muscle fibers in the sino-auricular region with those of the coronary sinus and atrium in bovine and man. The extent and type of muscle fibers found were not determined. According to Davies and Blair, three investigators in the mid-twenties, Brune, Pace, and Segre, working with ruminants and man, found that there is no connection between fibers of the S-A node and the muscle of adjacent vessels. The type and extent of the muscle in these vessels were not mentioned.

Keith and Flack (1907), issued a comprehensive report on the muscular connections between the divisions of the heart in mammals, using sixteen different vertebrate animals from several classes of the phylogenetic series. The authors reported that the higher an animal is in the vertebrate scale, the less the amount of sinus muscle present. Unlike many references on studies of this nature, Keith and Flack stated that there is a layer of longitudinal heart muscle fibers which passes uninterrupted from the auricular septum into the superior vena cava. In the porpoise, the musculature of the pre-cava is largely of the primitive type, while in the dolphin and ram there is no difference between the musculature of the superior vena cava and auricle. Nomura (1952), working only with the mouse, remarked that the muscular components of the nodal system rarely exhibit direct continuity with ordinary heart muscle.

The anatomy of the valvular mechanisms around the venous orifices of the heart has been investigated frequently. Keith (1903), analyzed these structures in mammalian and reptilian embryos and found that "loop-shaped cardiac muscle fibers" surround the terminal one-half inch of the superior vena cava. This is the earliest report which includes measurements of the extent of cardiac muscle in any vessels.

Several gross studies on the heart, and structures adjacent to it, have been reported and these supply us with some useful and interesting information. Papez (1920), described the musculature of the atria in man, cattle and dog. He observed that the main bundles of muscles of the atria spread in all directions from their origins around the opening of the superior vena cava. Many of the superficial bundles begin in the region of the S-A node. These extend in a circular pattern up the caval wall. Glomset and Glomset (1940), confirmed these results, but Muir (1955),

noted that the superficial layers of cardiac muscle in the wall of the superior vena cava of the rat are not circular but longitudinal. Papez (1920), reported that in man, beef and dog all muscle above the S-A node is in the superior vena cava and in dog the cardiac muscle is as far as and surrounds the beginning of the azygos vein. The muscle in the caval wall extends away from the heart for two or more centimeters. Glomset and Glomset (1940), found this distance to be from one-half to two inches depending on the species of domestic animal. Luschka (1863), and Robb (1934), recognized that cardiac tissue continues for a brief distance from the atria onto the wall of the great veins. Thomas (1959), completed a study on the pig and dog with results comparable to those of Papez (1920). Both investigators found two definite layers of cardiac muscle at the terminations of the venae cavae. They found that cardiac muscle extends along the pre-cava onto the last tributary of that vessel, the azygos vein, but neither investigator made any measurements. It was also found that heart muscle ends by dwindling out in the venae cavae and azygos vein. Thomas added that there are no major differences in the muscular arrangements of the venae cavae in the pig and dog. However, he mentioned that in the dog cardiac muscle extends from the superior vena cava into the azygos vein while in the hog this never occurs. Arey (1957), Krolling and Grau (1960), stated that cardiac muscle extends into the adventitia of the vena cava, but the exact distance was not given.

Anatomists and physiologists have written much concerning the structure of the heart. Numerous articles have been written on the origin and conduction of the motor impulses of the heart. Maximow and Bloom (1957), reported that the impulse arises in the sinus venosus. Since most investigators are in agreement that it is cardiac muscle which transmits the impulse,

it is obvious that heart tissue must be present in the sinus. In a comprehensive physiological study, Lewis, et al. (1914), working entirely with dogs, found that conducting impulses are conveyed by cardiac muscle. These impulses cease at the termination of heart muscle in the venae cavae. Using electrical probes placed at various points on the walls of the superior and inferior vena cava they discovered that the excitatory process spreads cranially in the cardiac muscle of the vena cava. Some research workers have said that the conduction time in the superior vena cava is slow. However, Lewis, et al. reported just the opposite and attributed the difference in the rate of conduction to the spiral or circular arrangement of the muscle fibers. They further concluded that the conduction rates of the musculature of the postcava are different from those in the precava, because of the longer "cuff" of fibers upon the inferior vena cava.

Inferior Vena Cava

Investigators who have continued to investigate the excitatory processes of the heart have reported cardiac muscle in the inferior vena cava.

Keith (1903), in a comparison of the mammalian and reptilian embryos related that the right sinus venosus receives both the superior and inferior venae cavae. They are both surrounded by "loop-shaped" cardiac muscular fibers which stem from the heart. The extent of these cardiac fibers on the vessels was not determined. Robb (1934), and Papaz (1920), reported that the distance to which cardiac muscle-bundles of the atria continue onto the inferior vena cava varies in hearts from different species. These fascicles of heart muscle usually end in fibrous bundles. It was also shown that the cardiac muscle bundles continuing downward over the inferior

vena cava are not arranged in a circular pattern, as observed by most investigators in the precava. Thomas (1959), noted that cardiac muscle fibers continue onto the inferior vena cava of the hog and dog for approximately one centimeter and in no case beyond two centimeters. These cardiac fibers constitute the entire thickness of the caval wall. An investigation by Franklin (1932), on the thoracic inferior vena cava in rabbits and cats revealed that only connective tissue is present. There was no mention of the level at which the sections were taken but it is reasonable to assume that they were not close to the heart since other investigators, Keith (1903), Lewis et al. (1914), Papez (1920), Robb (1934), and Thomas (1959), reported cardiac muscle continuing for some distance down the postcava in animals of different species.

Trautmann and Fiebiger (1957), Krolling and Grau (1960), Copenhaver and Johnson (1958), and Maximow and Bloom (1957), stated that near the heart, the walls of large veins contain varying amounts of cardiac muscle fibers.

Pulmonary Veins

Flack (1910), completed a study on the S-A node. He found remnants of heart muscle extending from the sinus and continuing around the orifices of the pulmonary vein of the left auricle. In a report by Keith and Flack (1907), it was related that in the heart of the frog embryo the cardiac musculature of the sinus at the S-A junction, includes the orifices of the pulmonary veins. It is possible, therefore, that the cardiac muscle of the sinus remains around the opening of the pulmonary veins in the adult stage. Keith (1903), working with the human species, had already established that contractions of the auricles cannot spread backward into the pulmonary

veins because of the presence of "loop-shaped" cardiac muscle fibers at the openings of the pulmonary vessels. In addition, Keith found that the pulmonary veins lacked striated muscle fibers until they perforated the pericardium. Glomset and Glomset (1940), in a gross study noticed that the cardiac muscle fascicles of the pulmonary vessels have about the same arrangement as those of the superior vena cava. Papez (1920), was in complete agreement with this. He stated that some of the cardiac muscle bundles that extend onto the left pulmonary vein encircle the vessel in a radiate and somewhat circular manner. In addition, it was noted that all veins are covered by fascicles of heart muscle originating in the atria. Robb (1934), and Thomas (1959), agreed with their colleagues and reported that in the dog there are three pulmonary vessels and all contain cardiac muscle. Smith and Calhoun (1960), found cardiac muscle in the wall of the pulmonary veins extending into the lung of the albino rat. Arey (1954), Copenhaver and Johnson (1958), and Maximow and Bloom (1957), reported cardiac muscle extending for a distance into the pulmonary veins in man.

Pulmonary Artery and Aorta

Bremer and Weatherford (1946), described short, broad, flat muscle cells "somewhat resembling cardiac muscle" in the aorta. Arey (1957), and many other investigators have noted heart muscle in the roots of the aorta and pulmonary artery. This is to be expected since the roots of these vessels have been incorporated in the heart during the developmental period. No other reference to cardiac muscle in either the pulmonary artery or aorta has been found.

Although this study has not taken into consideration the coronary arteries it has recently been shown by Polacek (1959), that the coronary arteries are "over-bridged" by muscle bundles of ventricular or atrial myocardium.

MATERIALS AND METHODS

For this study the heart and surrounding blood vessels of twelve dogs were used. Included in this group were six female and four male mongrel type dogs and one male purebred poodle. These animals were obtained from the departments of Anatomy, and Surgery and Medicine at Michigan State University.

The hearts from five freshly killed animals were fixed in mercury-formol-saline solution (Dawson and Friedgood, 1938), or formalin-alcohol-acetic acid (Lavdowsky's) mixture (Guyer 1949). The other seven were embalmed specimens injected with latex. Longitudinal sections were taken from the superior and inferior vena cava, pulmonary vein, azygos vein, pulmonary artery and aorta. The sections were dehydrated in dioxane, embedded in paraffin and sectioned at 8 microns. The extension of cardiac muscle into the veins and arteries was measured with a calibrated ocular micrometer. Statistical analysis of the measurements in Table I were outlined by using the "t" test.

Three different staining techniques were used. Hematoxylin and eosin were used to facilitate the study of muscle, Weigert's and VanGieson's and Crossman's modification of Mallory's connective tissue stain aided the study of the connective tissues.

RESULTS AND DISCUSSION

Superior Vena Cava

Extent. In medium sized mongrel-type dogs cardiac muscle extended for distances ranging from 1.58 to 2.38 centimeters in both sexes. The average distances were 1.85 and 1.90 centimeters for males and females respectively. In a small dog (poodle), cardiac muscle extended for only 1.35 centimeters while in a larger animal (shepherd-type) cardiac muscle fibers extended for 3.05 centimeters. The average extension of cardiac muscle in all dogs, regardless of type or sex was 2.04 centimeters. Papez (1920), and Keith (1903), reported similar findings on dog and man.

The widths of cardiac muscle was measured as close to the heart as possible and at intervals of 4.2 mm thereafter to its terminal point. As can be seen in Table I, the cardiac muscle band tapered to an average width of .14 mm at its termination. The widths at corresponding points were somewhat greater in the females than in the males. The average width at the point nearest the heart being .09 mm in the females compared to .71 mm in the males. In the poodle the width nearest the heart was .49 mm while in the large shepherd type it was 1.27 mm.

Arrangement. In the dog cardiac muscle was continuous from the wall of the atrium into the wall of the superior vena cava. Near the heart cardiac muscle is arranged in an inner and outer circular manner with a layer of longitudinal fibers between (PLATE I). A few muscle bundles were spiral and therefore appeared oblique in sections. The longitudinal bundles dwindled out in the first centimeter or so from the

heart, while the mixed circular and spiral bundles remained to the termination (PLATE III, IV).

Termination. The cardiac muscle fibers in the superior vena cava ended in fibrous tissue. Elastic and white fibrous connective tissue extended between the muscle bundles and appeared to invest the tapered muscle fiber in some places (PLATE III).

Azygos Vein

Extent. Measurements of the extension of cardiac muscle along the wall of the azygos vein were taken from a point as near as possible to its junction with the superior vena cava.

Cardiac muscle extended for distances ranging from 4.07 mm to 7.64 mm in medium sized mongrel-type dogs. The average measurement for the males was 6.65 mm while the females averaged 6.12 mm. In the poodle cardiac fibers extended 6.90 mm and in the shepherd type 9.26 mm. The average extent for all dogs was 7.23 mm.

The width of the cardiac muscle at the junction of the azygos vein and the superior vena cava averaged .19 mm in males and .16 mm in the females of mongrel type. In the poodle the range was from .13 mm to .32 mm in the shepherd type. The average distance that cardiac muscle extended along the azygos vein in all the dogs in this study was .19 mm.

Arrangement. Cardiac muscle continued from the superior vena cava onto the wall of the azygos vein (PLATE V). In some places the muscle appeared to extend only in a circular direction (PLATE VI).. The cardiac muscle in the vena azygos terminated by dwindling out (PLATE VII).

Termination. While many elastic fibers were present and extended along the cardiac muscle fibers, the fibrillae themselves seemed to attach to prominent collagenous bundles (PLATE VII).

Inferior Vena Cava

Extent. Cardiac muscle extended for distances ranging from 7.35 mm to 9.71 mm in dogs of the same type with the average distance for both sexes being 8.59 mm. In a poodle the extent was 7.05 mm and in the shepherd type it was 13.67 mm. The average extent for all dogs used was 9.48 mm.

The width of the cardiac muscle mass in the mongrel-type dog at the point nearest the heart averaged .67 mm in the males and .65 mm in the females. The same point measured .61 mm in the poodle and .98 in the larger type dog. The average width of cardiac muscle in the inferior vena cava was .72 mm.

Arrangement. The inferior vena cava was characterized by a cardiac muscle sheath (PLATE VIII). Near the heart the bundles were arranged both circularly and spirally (PLATE IX). PLATE X shows the junction of the inferior vena cava with a vasa vasorum.

Termination. Elastic and white fibrous connective tissue fibers were present at the termination of cardiac muscle in the inferior vena cava. Elastic fibers were more concentrated around the ends of the cardiac muscle than at other places in the wall of the cava. In many places there was a connection between the elastic fibers and the investing coat of the cardiac muscle. At several places elastic fibers coursed between the bundles of muscle (PLATE XI).

Pulmonary Veins

Extent. Fascicles of cardiac muscle were present in the pulmonary veins but did not extend as far as the lung in any of the dogs observed in this study (PLATE XII).

Cardiac muscle was present for distances ranging from 1.10 mm to 8.08 mm in mongrel-type dogs. The extent in the poodle was 7.64 mm and in the shepherd type 12.20 mm. The average distance which cardiac muscle extended in all animals used regardless of type or sex was 7.58 mm.

The widths of the cardiac muscle nearest the heart were .57 mm and .44 mm in the male and female mongrels respectively. The widths in the poodle and larger shepherd type were .47 mm and 1.49 mm with an over-all average of .74 mm for all animals.

Arrangement. Cardiac muscle did not end abruptly at the openings of the pulmonary veins into the heart. Atrial heart muscle was continuous onto the walls of the pulmonary veins. Near the entrance to the heart the cardiac muscle was arranged in an outer and inner circular pattern with a few middle longitudinal bundles (PLATE XIII). The muscle arrangement here is similar to that of the superior vena cava. This agrees with the work of Glomset and Glomset (1940). Distal to this point and extending to its termination the outer circular muscle was absent, leaving outer longitudinal and inner circular layers (PLATE XIV).

Termination. Elastic and collagenous fibers were present at the terminal point of the cardiac muscle in the pulmonary vein (PLATE XV). The elastic fibers closely invested the tips of the muscle fascicles but did not penetrate the muscle mass as it did in the venae cavae. White fibrous

tissue was in greater proportion to elastic fibers than in the other vessels.

Pulmonary Artery and Aorta

Cardiac muscle did not extend onto the pulmonary artery or aorta (PLATES XVI, XVII). A fibrous connective tissue band was present in the wall of the pulmonary artery at its exit from the heart (PLATE XVI). Malewitz and Calhoun (1958), investigated this region in the turkey and reported white fibrous cartilage at the junctions of the pulmonary artery and aorta with the heart. The elastic and smooth muscle fibers in the wall of the aorta end in white fibrous tissue. There is no apparent continuity of these fibers with the cardiac muscle of the heart (PLATE XVII).

SUMMARY AND CONCLUSIONS

A histological study was undertaken to determine the presence, extent and arrangement of cardiac muscle in the venae cavae, azygos vein, pulmonary veins, pulmonary artery and aorta in the dog.

Cardiac muscle was found in the venae cavae, pulmonary veins and azygos vein, but was absent from the pulmonary artery and aorta. Statistically there were no significant sex or breed differences in the extent of cardiac muscle in any of these vessels. The average distances to which cardiac muscle coursed in the superior vena cava, inferior vena cava, pulmonary vein and azygos vein of all the animals used were 2.04 cm, .948 cm, .758 cm, and .723 cm respectively. Measurements indicated that the cardiac muscle mass gradually narrowed between the heart and the terminal point.

The cardiac muscle pattern in the superior vena cava and pulmonary veins was very similar. Both vessels contained muscle bundles which were circular, spiral and longitudinal. The inferior vena cava lacked longitudinal cardiac muscle bundles. Cardiac muscle was continuous from the superior vena cava onto the wall of the azygos vein.

In all veins observed, the cardiac muscle ended in fibrous tissue. At the point of termination the elastic fibers were more prominent than the collagenous tissues.

TABLE I.

CARDIAC MUSCLE MEASUREMENTS IN THE GREAT VEINS

	Superior Vena Cava						Inferior Vena Cava						Pulmonary Vein						Azygos** Vein					
	Width (mm)						Width						Width						Width					
	Length (mm)	0.0*	4.2	8.4	12.6	16.8	21.0	25.2	Length	0.0*	4.2	8.4	12.6	Length	0.0*	4.2	8.4	Length	0.0**	4.2	8.4			
M 1 C-1	23.81	.88	.58	.47	.44	.41	.12	---	8.70	1.03	.47	.10	---	4.23	.51	.23	---	7.64	.26	.22	---			
M 2 C-4	18.52	.50	.45	.32	.13	.11	---	---	7.68	.26	.19	.11	---	3.41	.35	.09	---	6.17	.17	.11	---			
M 3 C-9	15.87	.55	.41	.26	.16	.08	---	---	8.23	.63	.52	.27	---	6.23	.61	.49	.29	6.46	.16	.13	---			
M 4 C-11	16.02	.92	.50	.41	.38	.32	---	---	8.54	.76	.60	.26	---	8.08	.80	.32	.23	6.32	.17	.13	---			
Average	18.55	.71	.48	.36	.28	.23			8.29	.67	.44	.18		5.48	.57	.28	.26	6.65	.19	.15				
F 5 C-2	16.46	.70	.61	.41	.17	---	---	---	9.55	.77	.51	.17	---	1.10	.63	.29	---	5.63	.14	.08	---			
F 6 C-3	16.90	.78	.60	.33	.22	---	---	---	8.65	.16	.13	.05	---	3.82	.44	.14	---	6.05	.17	.13	---			
F 7 C-5	17.93	.44	.23	.16	.11	.04	---	---	9.71	.70	.45	.24	---	6.17	.23	.13	.11	4.70	.13	.04	---			
F 8 C-6	21.16	.76	.45	.32	.26	.08	---	---	7.35	.77	.55	.20	---	6.32	.60	.52	.32	6.76	.19	.05	---			
F 9 C-10	22.93	.92	.89	.55	.30	.24	.16	---	9.26	.83	.61	.20	---	7.64	.32	.14	.11	7.49	.20	.19	---			
Average	19.08	.90	.69	.44	.27	.14			8.90	.65	.45	.17		5.01	.44	.24	.18	6.12	.16	.09				
M 10 C-7	13.52	.49	.47	.24	.05	---	---	---	7.05	.61	.36	.20	---	7.64	.47	.23	.16	6.90	.11	.05	---			
F 11 C-8	30.57	1.27	1.01	.54	.52	.29	.22	.16	13.67	.98	.85	.47	.27	12.20	1.49	1.08	.55	9.26	.32	.29	.11			
Tot. Av.	20.43	.84						9.48	.72					7.58	.74			7.23	.19					

1. All animals were medium sized, mongrel type dogs except C-8 which was larger (shepherd type) and C-7 which was a purebred poodle.

*Distance (mm) from the heart at which measurements were taken.

**Distance (mm) from the superior vena cava at which measurements were taken.

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PLATE I

Longitudinal section of superior vena cava showing the arrangement of cardiac muscle near the heart. H & E; x 110.

1. Circular cardiac muscle
2. Spiral cardiac muscle
3. Longitudinal cardiac muscle

PLATE II

Cross section of superior vena cava showing the arrangement of cardiac muscle. H & E; x 130.

1. Outer circular
2. Inner circular
3. Endothelium
4. Adventitia

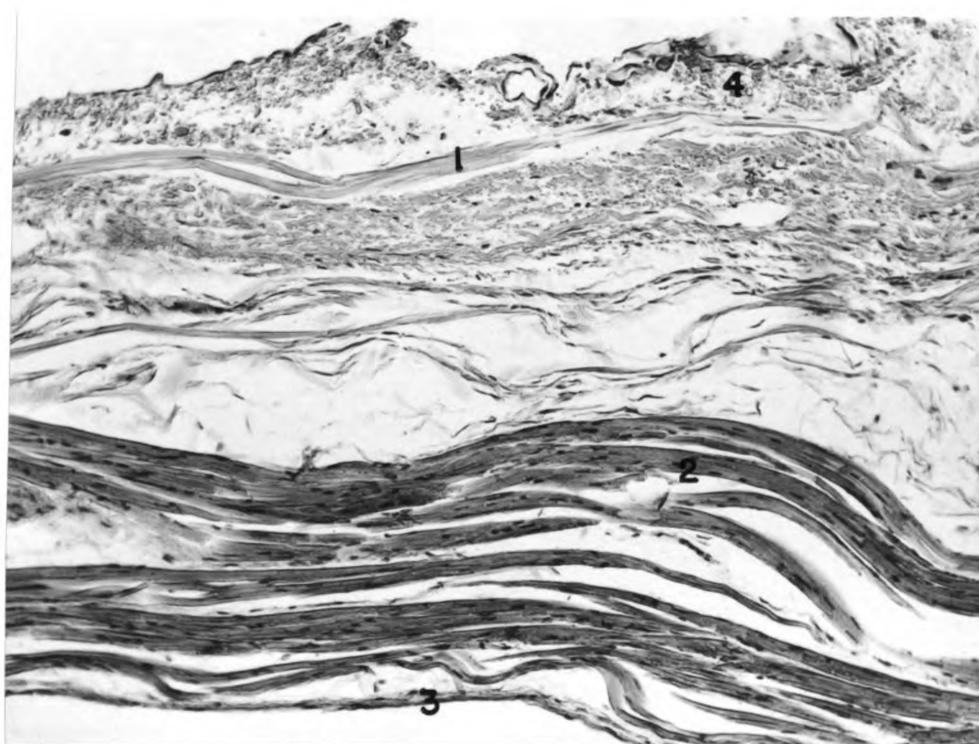
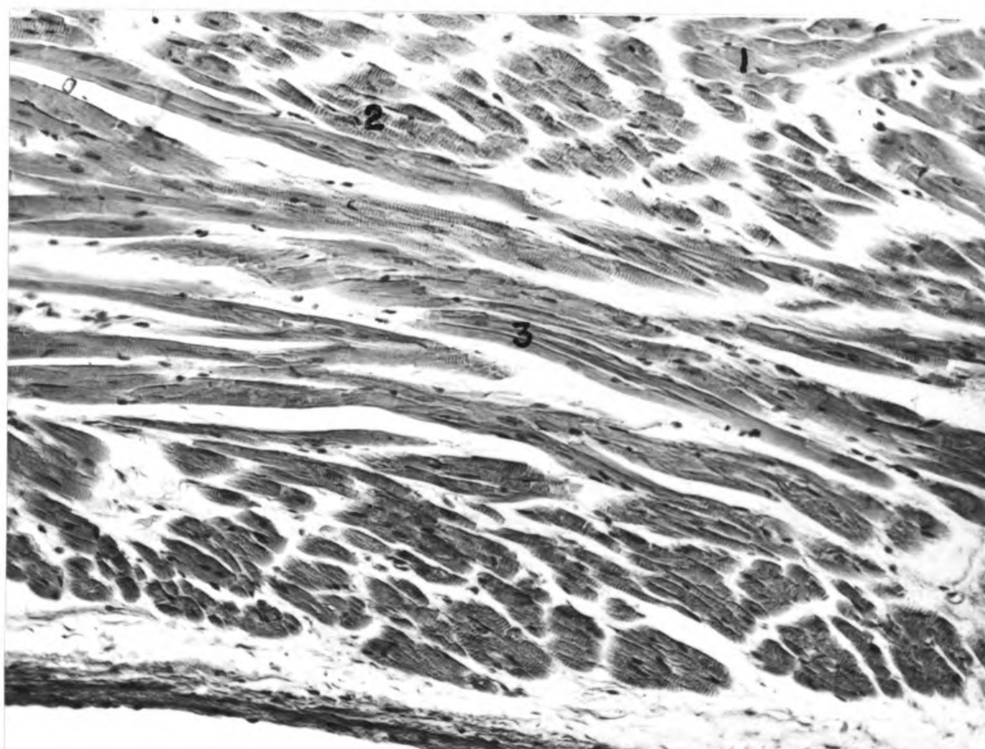


PLATE III.

Longitudinal section of superior vena cava showing the termination of cardiac muscle. H & E; x 130.

PLATE IV.

Longitudinal section of superior vena cava showing the association between fibrous tissue and cardiac muscle. H & E; x 250.

1. Elastic tissue
2. White fibrous tissue
3. Cardiac muscle

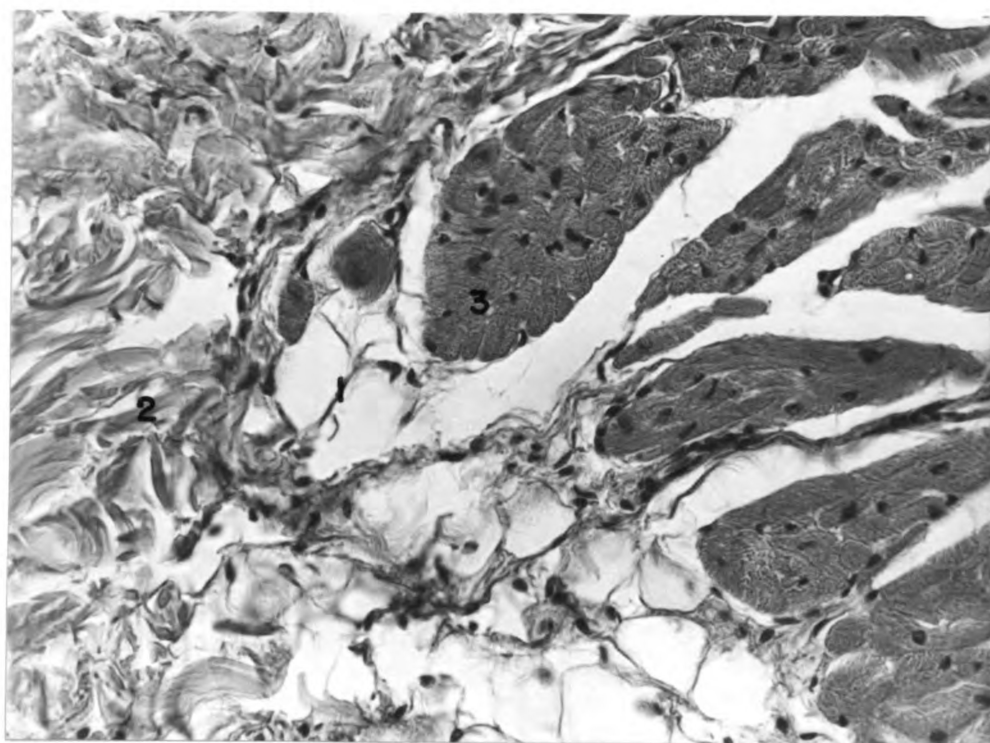
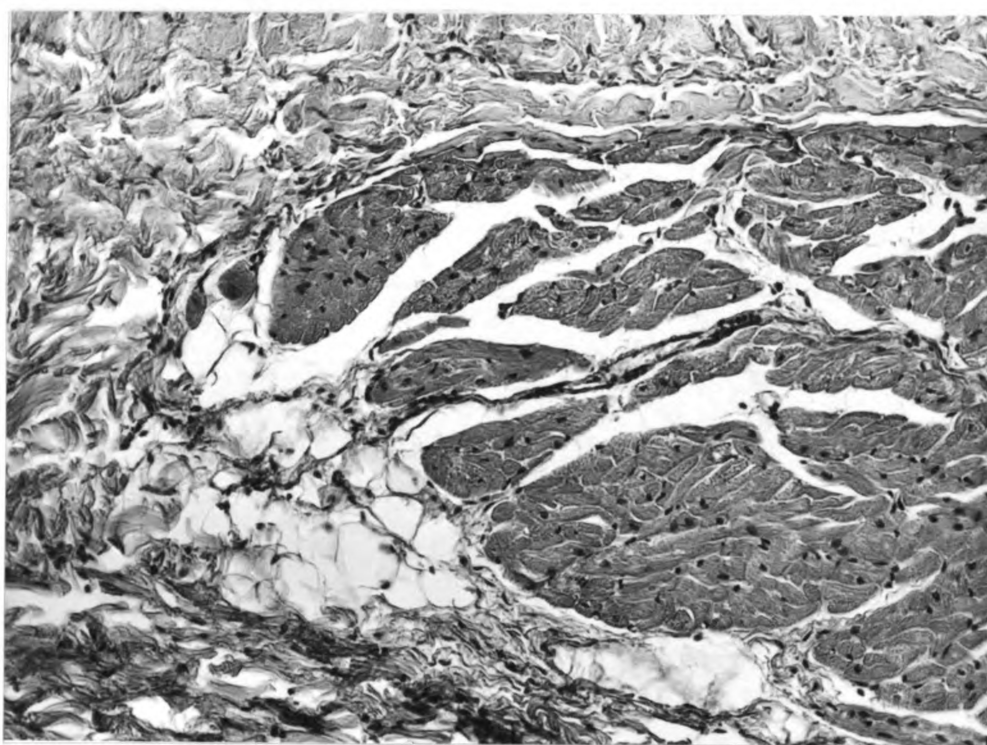


PLATE V.

Section taken at junction of azygos vein and superior vena cava.
Note the continuation of cardiac muscle along the azygos
vein from the vena cava. H & E; x 100.

1. Cardiac muscle in vena cava
2. Cardiac muscle in azygos vein

PLATE VI.

Cross section of azygos vein showing the arrangement of cardiac
fibers. H & E; x 190.

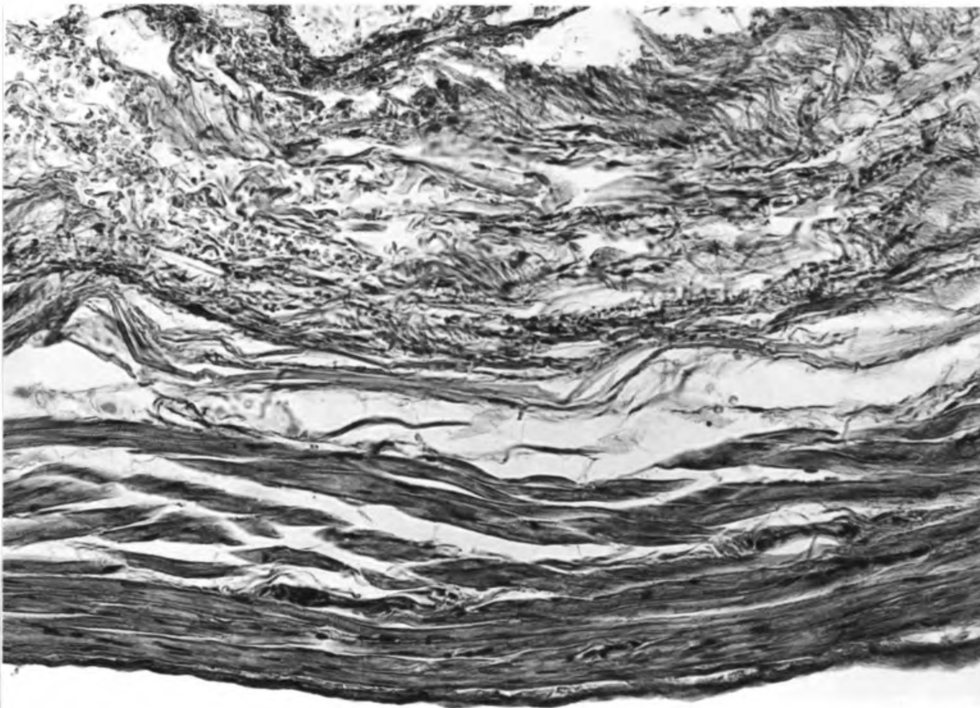
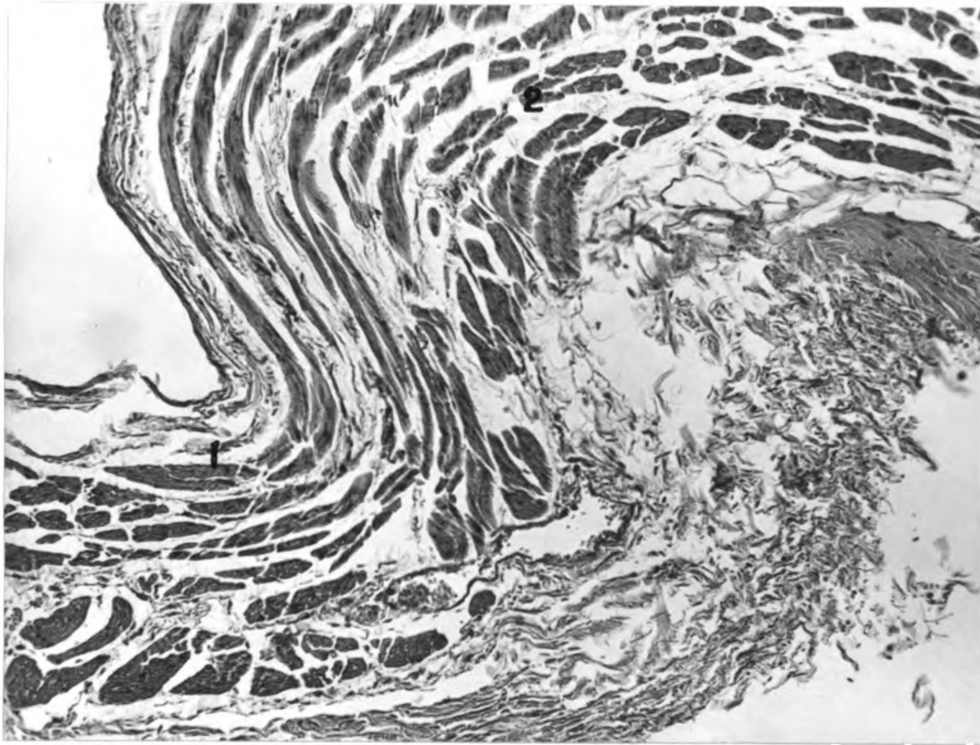


PLATE VII.

Longitudinal section of azygos vein showing the termination of cardiac muscle. H & E; x 300.

1. Collagenous fiber
2. Cardiac muscle
3. Elastic fiber

PLATE VIII.

Longitudinal section showing the termination of cardiac muscle in the inferior vena cava. H & E; x 105.

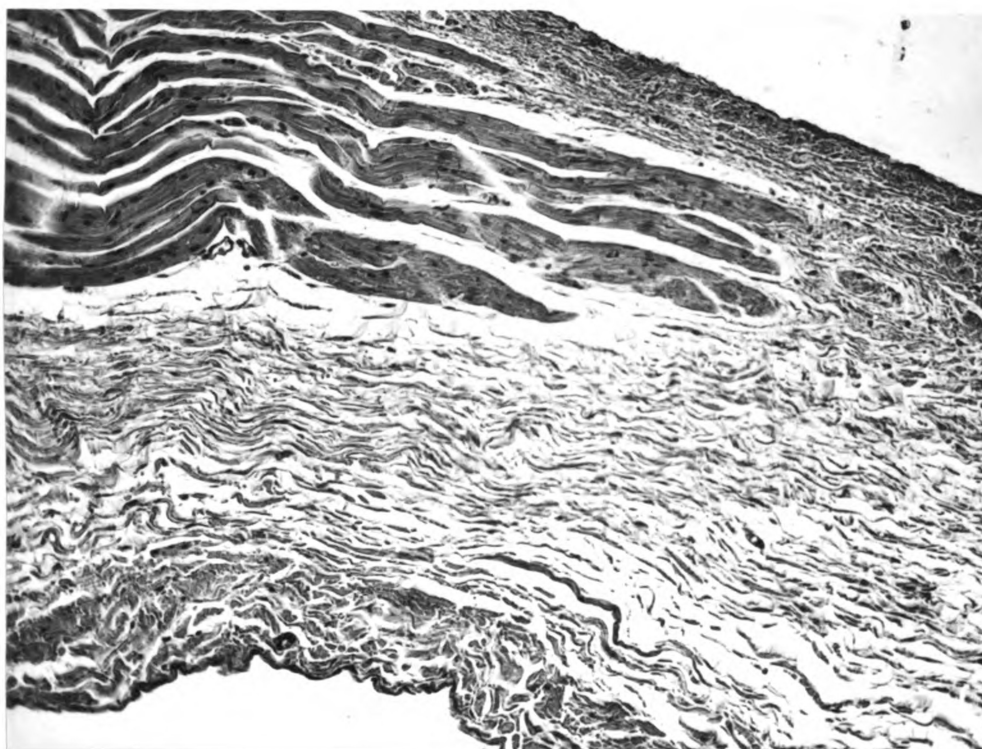
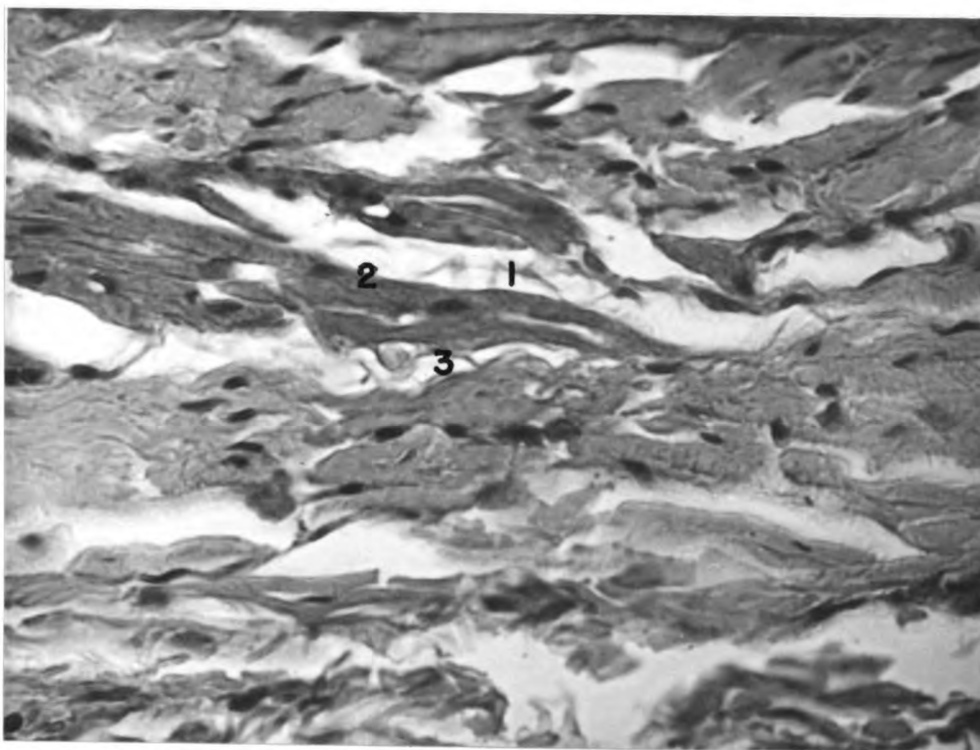


PLATE IX.

Longitudinal section of the inferior vena cava showing the arrangement of cardiac muscle fibers near the heart. H & E; x 105.

1. Cardiac muscle in the heart
2. Cardiac muscle in the vena cava

PLATE X.

Longitudinal section of inferior vena cava showing one of the vasa vasorum. H & E; x 100.

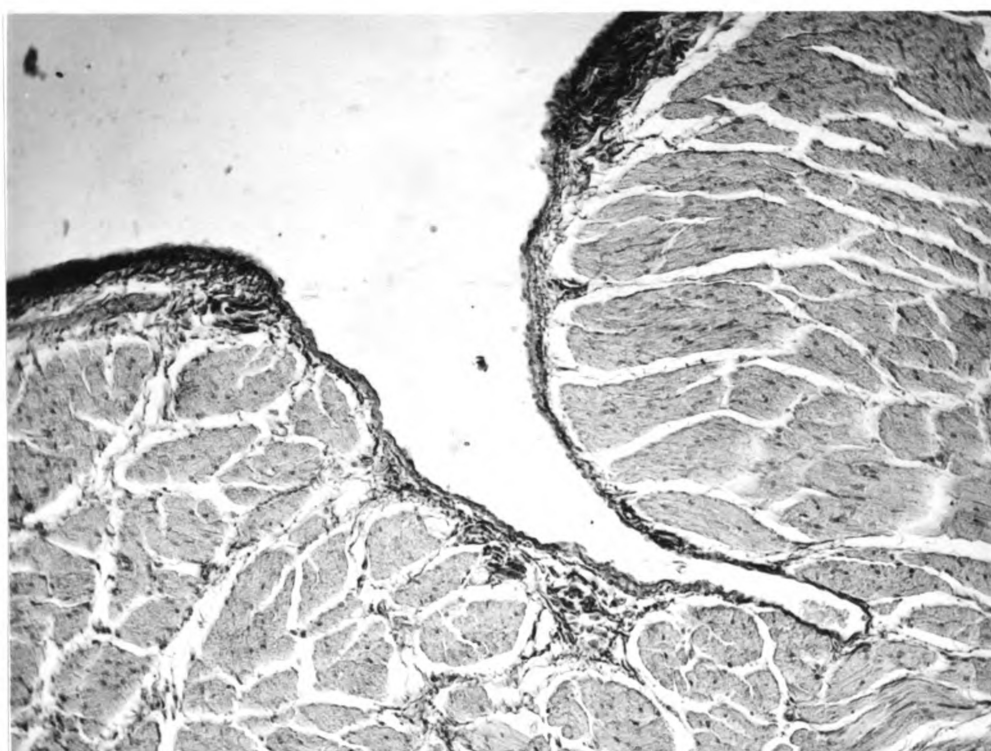
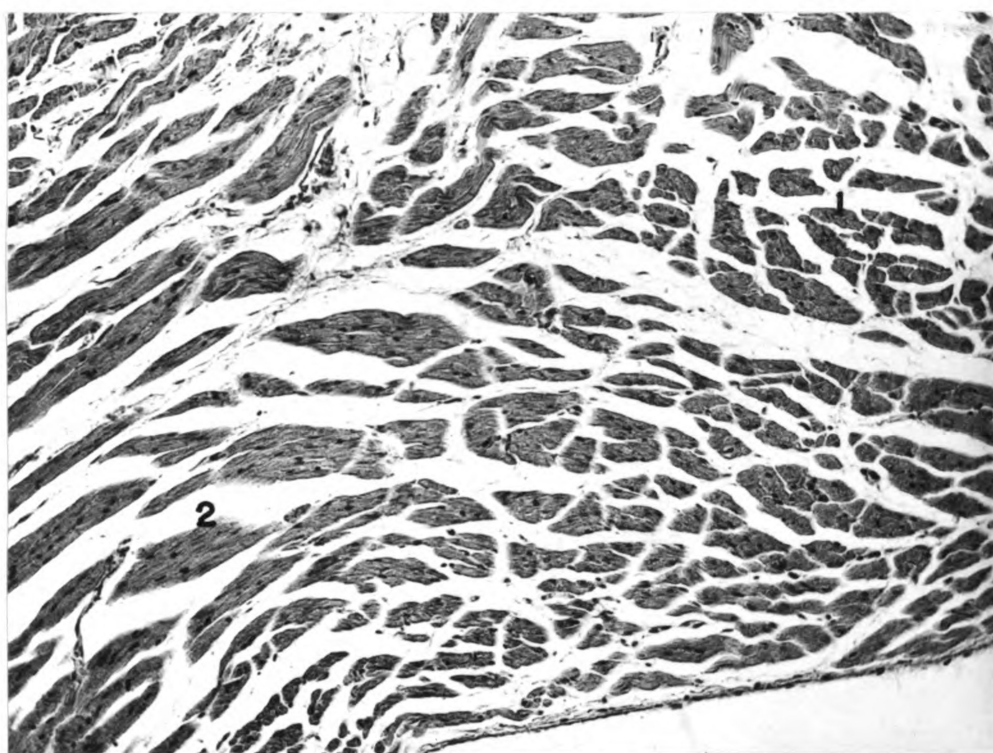


PLATE XI.

Longitudinal section of the inferior vena cava showing the attachment of connective tissue fibers to the terminal bundles of cardiac muscle. H & E; x 580.

1. Elastic fiber
2. Collagenous fiber
3. Cardiac muscle

PLATE XII.

Longitudinal section of the pulmonary vein. Note that the cardiac muscle in the pulmonary vein does not extend into the lung.
Weigert and VanGiesen; x 32.

1. Lung
2. Cardiac muscle
3. Branch of pulmonary vein

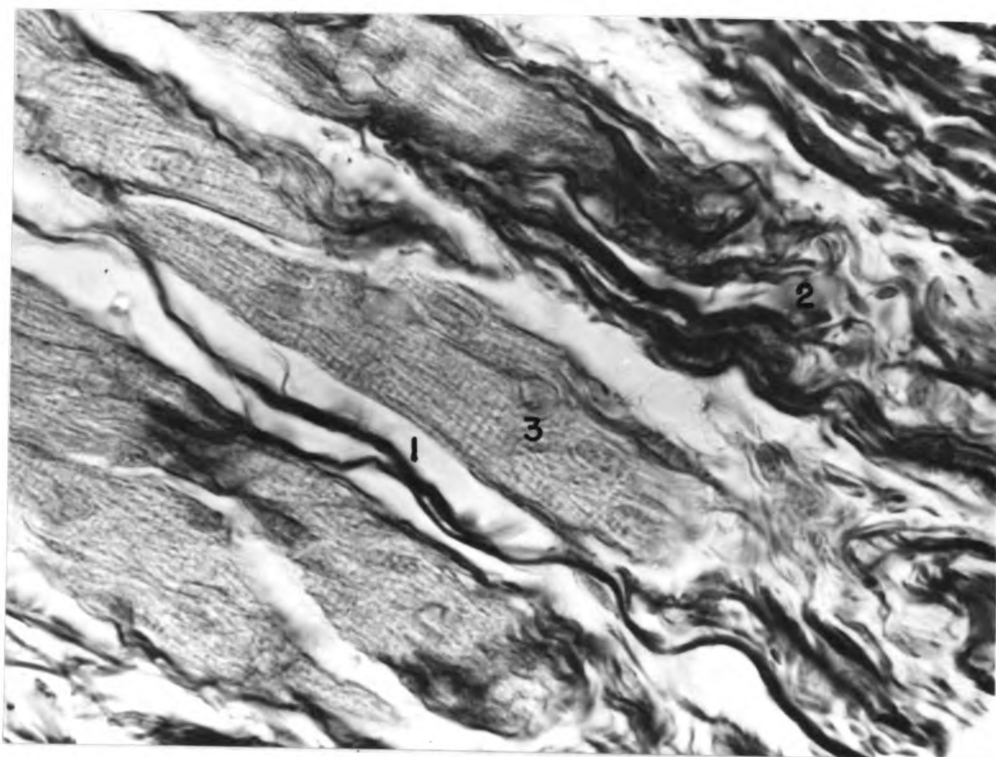


PLATE XIII.

Longitudinal section of the pulmonary vein showing the arrangement of cardiac muscle fibers near the heart. H & E; x 95.

1. Inner circular
2. Middle longitudinal
3. Outer circular

PLATE XIV.

Cross section of pulmonary vein showing the arrangement of cardiac muscle fibers. H & E; x 180.

1. Inner circular
2. Outer longitudinal

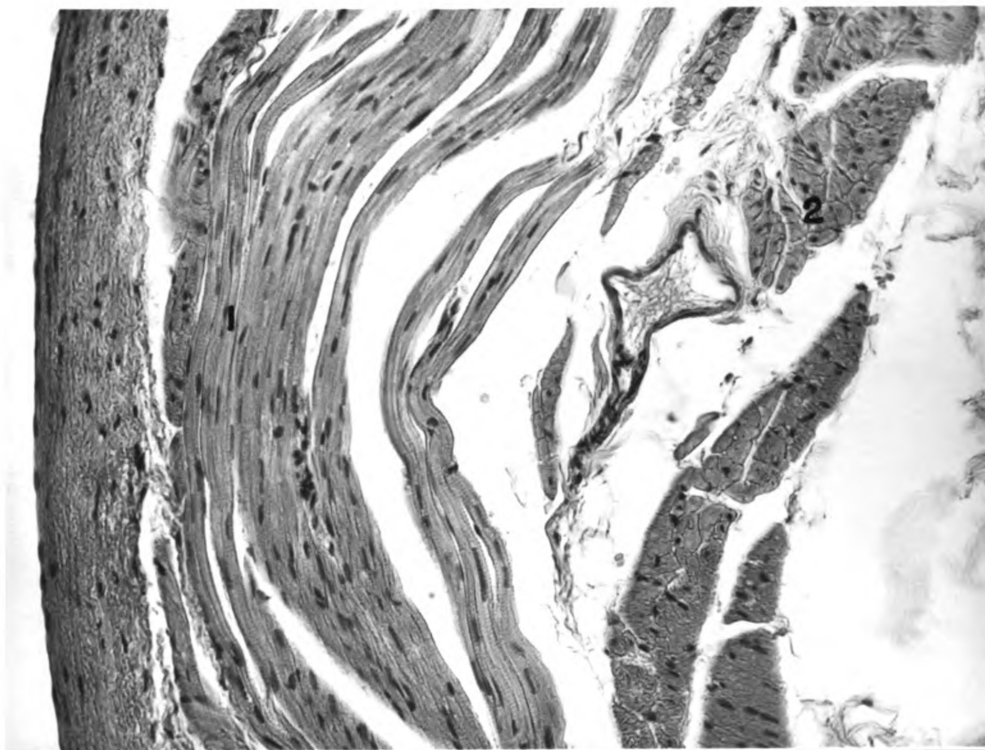
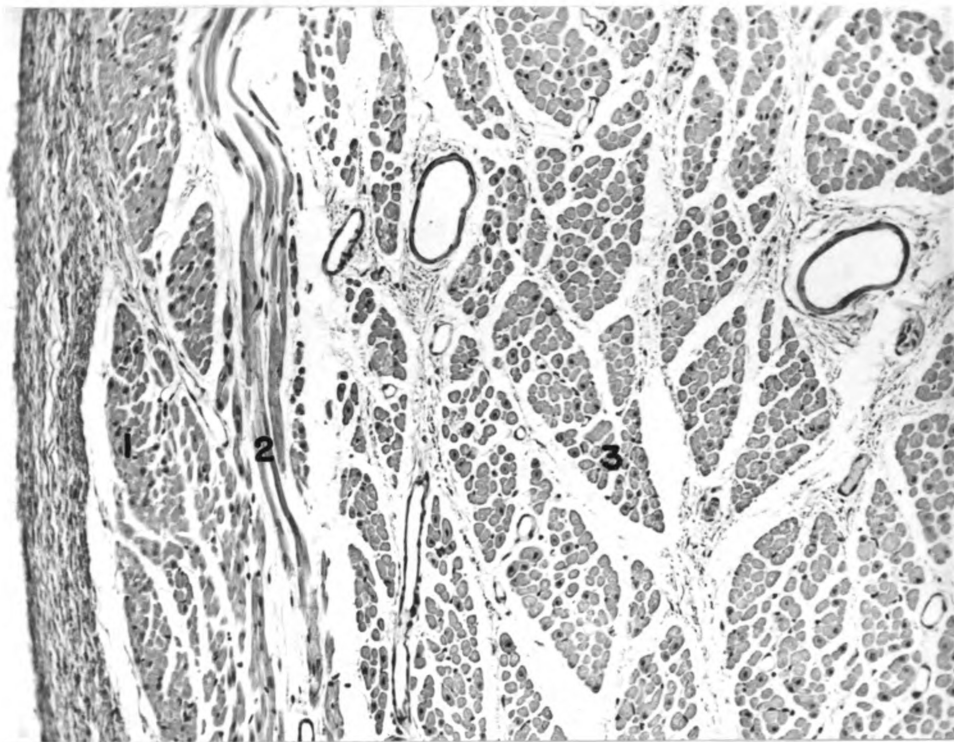


PLATE XV.

Longitudinal section of the pulmonary vein showing the attachment of connective tissue fibers to the terminal bundles of cardiac muscle. H & E; x 600.

1. Elastic fiber
2. Collagenous fiber
3. Cardiac muscle

PLATE XVI.

Longitudinal section showing the junction of the pulmonary artery and heart. H & E; x 70.

1. Cardiac muscle in heart
2. Fibrous tissue in wall of pulmonary artery

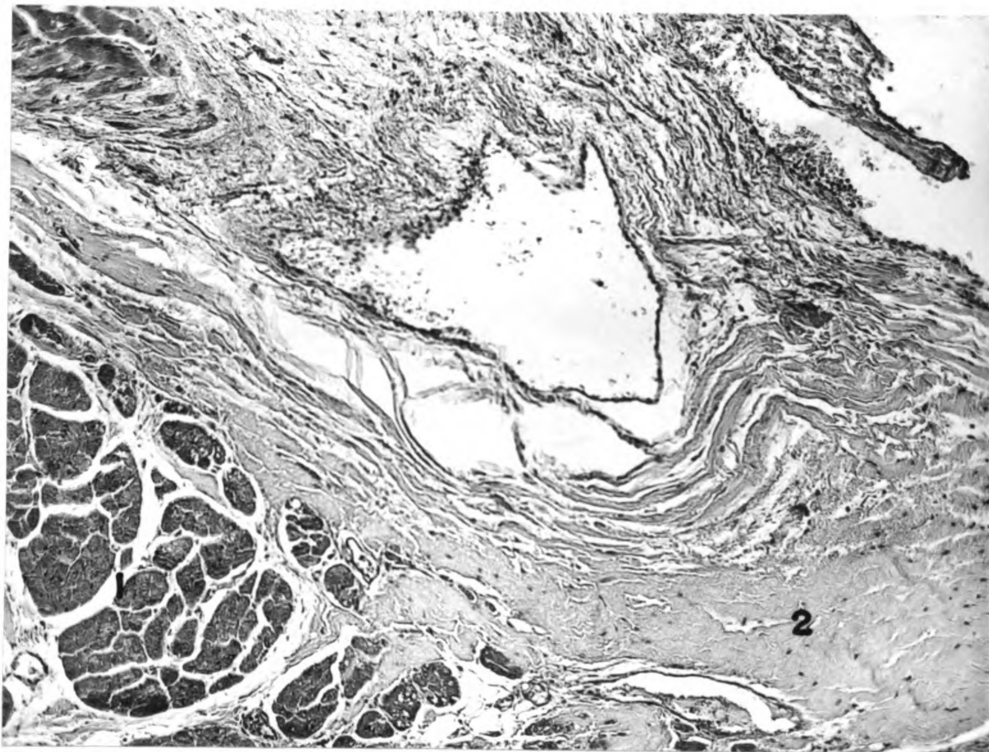
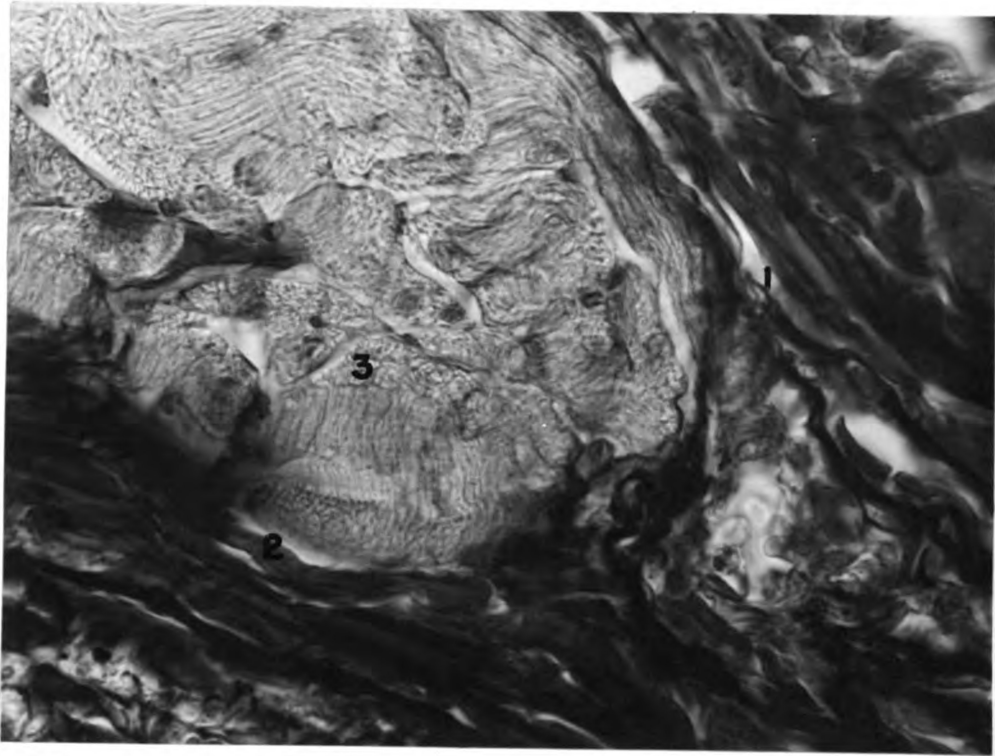
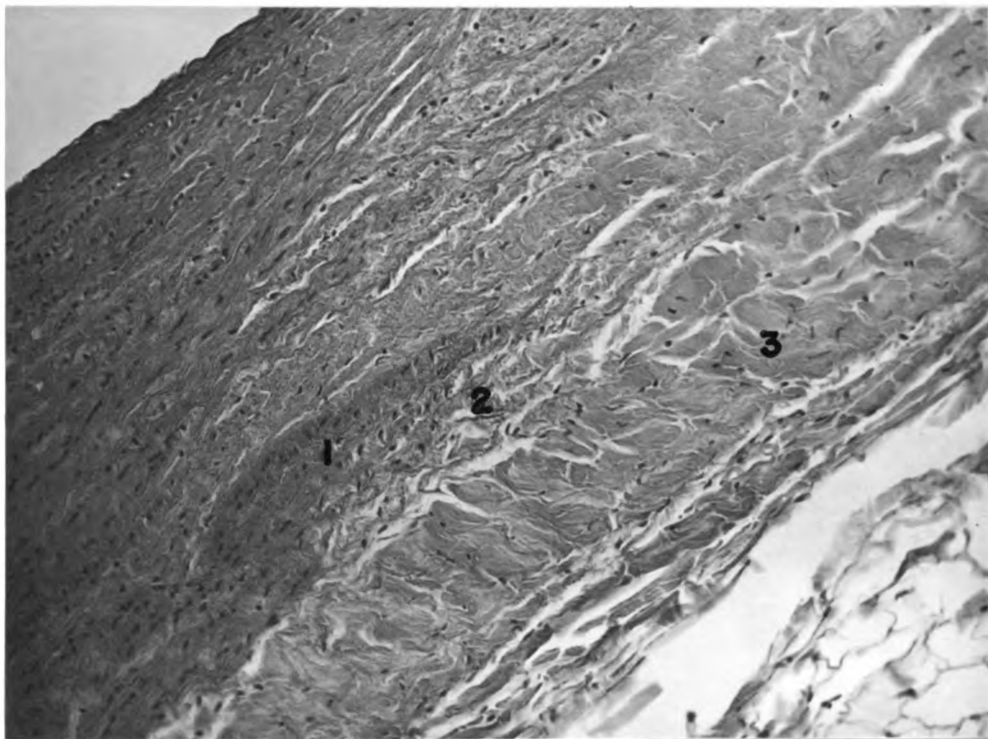


PLATE XVII.

Longitudinal section showing the junction of the aorta and the heart. H & E; x 85.

1. Cardiac tissue in heart
2. Elastic fiber
3. White fibrous tissue



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