Given in, March 1861.

On the arrangement of the Cardiac nerves and their connection with the cerebro-spinal and Sympathetic Systems in Mammalia; accompanied by 50 dissections, and 18 microscopical preparations shewing the Structure of the ganglia.

by

James Pettigrew.

Synopsis.

OVER

page

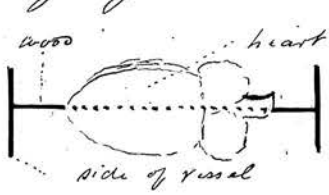
Introduction.

In the present communication I have carefully traced and described those portions of the sympathetic and Vagus furnishing branches to the heart, after which I have endeavoured to explain the nature of the plexuses formed by those branches in and about the Auricles; and the manner in which the plexuses resolve themselves in order to supply the exterior and interior of the Ventricles. In addition I have entered into a microscopic examination of the enlargements or so called ganglia found on the nerves on the surface and in the substance of the organ; and had time permitted it was my original intention to have instituted a series of experiments on the living animal in order if possible to advance the physiology of the question. Such however has been the difficulty in obtaining good dissections that although I

have laboured incessantly for upwards of six months, I have found it impossible to overtake this interesting branch of the enquiry within the period usually allotted to ~~for~~ inaugural dissertations. What I therfore propose in the present paper, is to confine myself more especially to the Anatomical distribution of the nerves as observed by the eye assisted occasionally by the dissecting lens and microscope. Among the difficulties with which I have had to contend might be mentioned the large quantity of Cellular tissue found in the neck and thorax, from amid which the nerve trunks & plexuses were to be wrought; and the perplexing aggregation of fat always met with in the Auricula ventricular grooves, Coronary tracts &c. To remove the adipose tissue while I preserved the plexuses intact was with me a primary object; and having essayed for upwards of a fortnight to effect my purpose according to the old method of nerve dissection, I felt Convinced that some mode other than the Common one must be resorted to before I could proceed with the investigation satisfactorily. Fortunately I lost little time in devising a a method, for having been in the habit of employing warm water in getting rid of fat, Cellular tissue &c in my attempts to unravel the muscular fibres of the heart; it occured to me I might employ it with equal advantage in tracing the alimentary distribution of the Nerves. I made the experiment, and had the gratification of finding that nerve substance stood a heat little short of the boiling point without being

visibly affected; a state of matters which enabled me to remove without difficulty by the aid of a Curved nerve knife, stiff Camels hair brush and sharp pointed forceps, the greater portion of fat Cellular tissue to form the intricate meshes of the most delicate plexus.

To get rid of the remaining fat which was comparatively trivial I had recourse to boiling the hearts in sulphuric ether, a somewhat expensive process, but one which may be economically Conducted by an apparatus so Contrived as at once to Condense and receive the fumes, given off, by the ether during ebullition. This treatment which displayed the nerves on the Surface of the heart absolutely clean had moreover the advantage of securing what I was especially anxious to obtain viz: that the nerves should be taught and precisely in the same position in which they were before the fat was removed, an effect which Could scarcely have been effectually secured by the old method where the forceps would have dragged the fat or nerves or possibly both. In order to secure this advantage the more effectually as well as to permit me to work with greater precision and freedom, I had a dissecting trough made with broad ledges on which to steady the hands and arms, supplied with a longitudinal piece of wood long enough to jam slightly against the edges of the trough, with which I transfixed or centred the heart by entering it at the Aorta and bringing it out at the apex of the left Ventricle so:— a Contrivance which enabled me by simply rotating the



stick or shaft to dissect the entire surface of the heart without once touching it with anything but the dissecting instrument. To perfect still further what I could not help feeling might be considered an improvement in all delicate nerve dissections, it then occured to me to inject the Arteries and Veins; an operation which I conceived would more effectually preserve the relation of the parts, inasmuch as the distended vessels would at once support and relieve the delicate nerve filaments; while the difference in Colour would enable the eye readily to decide betwen nerves and Capillaries. As however an injection to stand warm or even boiling water was a thing unheard of I was for the time at a loss how to proceed. Having explained my difficulty to our sub-Curator Mr Stirling of whose ready ingenuity I have had many convincing proofs, he at once suggested that an injection of paste might answer my purpose. We tried it together and a more admirable injection cannot be imagined. The manner in which it was done was the following. We obtained a quantity of the finest ground German flour and having drenched a little with water precisely as we would have done in making paste, we divided it into two quantities added Different colours and then proceeded to strain each through a thin muslin rag so as to intercept the Coarser particles. This done we injected the arteries & veins (both injection & heart being perfectly Cold) after which we gently stuffed the Auricles and Ventricles with oat meal so as to obtain the fine symmetry

posesed by the organ during the diastole. The rest was done to our hands for having immersed the heart in hot water for ten minutes or so, the paste was made inside the vesels, the vesels distended and everything rendered as natural looking as posible. The principlent feature in this injection is, that when once set it never shrinks and will keep in spirit for any length of time without shadow of Change.

I have ben thus particular in detailing the manner in which my dipections have ben made because when a new method is resorted to I think the Reader should be apprized of the fact; and because it appears to me that where fine moist nerve and vesel Dissections are required this method posesses superior advantages. It may I doubt not be successfuly applied employed in the dissec- of the vessels and nerves of the uterus — the vesels of the placenta, liver, kidneys, spleen, brain & indeed pretty generally in all kinds of dissection human and Comparative. The Care bestowed on my dissec- tions will I trust be found such as fairly to preclude the necesity of fully illustrating my dissertation; & as the Dissections are to be presented to the Anatom- ical Museum, it will be sufficient briefly to enum- erate the facts they are intended to establish, trusting for the rest of my remarks to such deductions as will naturally result from an original Considiration of the subject. The hearts examined in the present investi- gation were particularly as those of man, the horse, ox, Camel, seal, panther, cat, rabbit & calf & especially the latter.

Consideration of such portions of the Sympathetic and Vagus as furnish branches to the heart in the cat, rabbit, calf &c &c

In Preparation 2 which shews the adult male cat the sympathetic and Vagus are displayed so as to exibit the position of the one to the other, and the relation of both to the great vessels. In order moreover to trace the connection existing betwen the vagus and brain on the one hand, and the sympathetic and spinal column on the other, the spinal Canal and Cranial cavity have ben in part exposed on the left side.

Arrangement of the Vagus on the left side of the cat.

On looking at the left side of the neck of the dissection in question, the vagus with its ganglionic enlargement at the base of the Cranium may be readily distingaished. This nurve which lies behind & to the outside of the left carotid artery is incorporated in the upper third of its course * with the sympathetic in the neck. It supplies Comparatively few branches to the heart and these it furnishes in two ways — first or directly by means of branches proceeding at once to the base of the organ; and secondly indirectly by means of branches from the recurrent laryngeal which is itself an offset from the Vagus. The direct branches

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*A similar arrangement is found in the dog, fox, calf-goat and ass (Illustrations of the Comparative Anatomy of the nervous system by Joseph Swan p. 113.)

which are usually three in number are given off on a level with the descending aorta and are for the most part very delicate. They distribute themselves on the pulmonary artery and aorta, and unite with similar branches from the opposite side & with branches from the sympathetic to form the deep cardiac plexus, but supply also a few to the superficial cardiac plexus. The branches from the recurrent laryngeal which are still more delicate than those from the par vagum, are given off as the recurrent curves round the arch of the Aorta and are distributed partially to the superficial cardiac plexus and partly to the deep, but principally the latter.

Arrangement of the Sympathetic on the left side of the cat.

The sympathetic in the neck of the Cat is remarkable as having only one ganglion viz: the superior or first cervical. This ganglion which is situated behind and a little to the inside of the corresponding enlargement on the vagus is somewhat pyriform in shape.* It gives off a double set of branches — the one an upward set communicating with the glosso-pharyngeal, conjoined par vagum, accesory & ninth — the other a downward set communicating with the first cervical nerve, the pharyngeal plexus and the laryngeal nerve; after which it gives off the large cord

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* In the monkey, dog & jaguar the same shape obtains; in the Calf it is thick and oval, in the sheep oval simply — in the Ass longer and thinner than in the calf & much resembling that found in man.

Constituting the Sympathetic in the neck, and one or more filaments to Communicate with branches from the superior or first dorsal ganglion and with the heart. The Sympathetic which as has been already explained is in Contact with the vagus in the upper third of its course separates from that trunk at a point opposite the sixth cervical nerve. When it has reached a point opposite the first dorsal, it divides into two branches; the larger of which proceeds to the first dorsal ganglion situated at the root of the brachial plexus, while the smaller subsequently dividing, unites with the inner division of the phrenic, and a branch from the ganglion proceeding directly to the heart.

Branches from first dorsal ganglion of Sympathetic on left side of cat.

This ganglion which in the Cat is somewhat squareshaped and measures nearly a quarter of an inch in length and about half that in breadth, has in all six branches; three superior and three inferior. Of the three superior branches, one Communicates with the first dorsal nerve and one with the seventh Cervical; while the third which has been already alluded to, Contributes chiefly to the formation of the Sympathetic in the neck. Of the three inferior branches, two proceed directly to the roots of the great vessels to unite with Corresponding branches from the opposite side, and with filaments from the two superior cervical ganglia, to form the superficial Cardiac plexus. They also give branches

to enter into the formation of the deep cardiac plexus composed chiefly of filaments from the vagi and the recurrent laryngeal of the left side. The third of the inferior branches from the first dorsal ganglion is thicker than the others and forms the cord of the Sympathetic in the thorax. ~~From the foregoing description it will appear that on the left side~~, The sympathetic ~~and~~ of the left side it will be observed vagus not only run parallel with each other so far, but are in actual contact – ~~that~~ the upper cervical ganglion in addition to giving off branches of communication to the glossopharyngeal, conjoined par vagum, accesory, first cervical, pharyngeal plexus and laryngeal nerves, sending one or more slender filaments to unite with branches from the superior or first dorsal ganglion, and thereby establishing a direct communication between the heart and the first cervical and first dorsal ganglia. ~~That~~ The branches moreover from the first dorsal ganglion are principally concerned in forming the superficial cardiac plexus, while the branches from the vagus and recurrent laryngeal enter especially into the composition of the deep cardiac plexus.

Arrangement of the Sympathetic & Vagus on the right side of the cat.

The arrangement of the Sympathetic and Vagus on the right side differs little from that on the left, unless that at the point where the vagus gives off the recurrent laryngeal (which in this instance is opposite the second rib) a slight plexus is formed by branches from the sympathetic on the

neck & the first dorsal ganglion and Vagus of the right side. From this plexus a branch of Considerable size proceeds, and disappears behind the Aorta where it gives branches to the Superficial plexus; the branches from the vagus on the right side, proceeding for the most part to the deep plexus.

Perhaps the distinguishing feature in the arrangement of the Cardiac nerves in the cat, Consists in the simplicity & the large size and isolated nature of the first Dorsal ganglion ~~which latter~~ a Circumstance which enablises us to divide any one of its six branches with Comparative facility and precision. As the Sympathetic in the neck, is in Contact with the Vagus in the upper third of its Course, while it is detached in its middle third, the Sympathetic, may readily be divided either in Conjunction or separately. If therefor for physiological purposes, a division of the nerves communicating with the heart is deemed necessary, the Cat of all domestic animals, appears to me the best adapted for the purpose ~~seems to me best calculated to insure fruitful results~~.

Arrangement of the Sympathetic and Vagus on the left side of the Rabbit.

In looking at the left side of preparation 3 which shews the sympathetic vagus and phrenic of a rabbit exposed we are at once struck with the difference in the appearance of the ganglionic arrangement met with at the root of the brachial plexus. Instead of the large solitary square

shaped ganglion found in the Cat, we have a chain of smaller ganglia apparently three in number, although in reality consisting only of two: viz: the last cervical and first dorsal.* (Here then we have an additional ganglion to that found in the Cat.) The first dorsal ganglion which in the Rabbit is in communication with the Cord of the sympathetic in the thorax and the root of the last cervical nerve, sends also a branch to the Vagus. The last cervical ganglion which has six branches and is in this respect precisely analogous to the first thoracic ganglion of the Cat, communicates with the roots of the fifth, sixth and seventh cervical nerves, with the sympathetic of the neck and with the vagus. The sympathetic in the neck of the rabbit like that in the Cat divides into two branches, the one of which communicates with the last cervical ganglion, the other proceeding directly to the roots of the great vessels. As the vagus in the Rabbit ~~differs~~ ~~differs~~ in no essential particular from the corresponding trunk in the Cat unless that it is not united with the Sympathetic in any part of its course, it need not be again described. The points of difference ~~that~~ ~~for~~ between the Cat and Rabbit on the left side of the neck are briefly these. In the Cat there are only two ganglia, the first cervical and first dorsal — in the rabbit there are three, the first last cervical and first dorsal; — in the Cat the sympathetic is incorporated

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*Accor: to Swan the ganglia in the fœc are also two in Number

with the vagus in the upper third of its Course, in the rabbit it is free; — in the cat the first dorsal ganglion communicates with the vagus by one branch, in the rabbit by two; one from the first dorsal ganglion & one from the last cervical; — in the Cat the inner division of the sympathetic communicates with the inner division of the phrenic, in the rabbit no similar Communication existing.

Arrangement of the sympathetic on the Right side of the neck of the Rabbit.

On this side we find the Chain like group of ganglia already described on the left, and in addition a plexus similar to that found in the cat, formed in this instance by three branches from the last cervical ganglion intercommunicating with the divisions of the Sympathetic in the neck and with two branches from the vagus. From this plexus as in that found in the Cat a nerve of Considerable size proceeds to the superficial cardiac plexus.

Arrangement of the Sympathetic and Vagus on the left side of the Calf. Preparation 1.

This Preparation (1) which shews the Sympathetic & vagus exposed as in the Cat and Rabbit differs from these as regards the number of ganglia exhibited by it. Instead of the single ganglion found at the root of the brachial plexus in the cat, and the two ganglia

found in a similar situation in the rabbit; we have a series of ganglia consisting in this instance of three. The superior one which corresponds with and much resembles the first dorsal in the Cat; is situated at the root and rather beneath the brachial plexus. It is somewhat ~~square shaped~~ and has a broad terminal expansion which connects it with the other ganglia of the series viz: the second and third dorsal. Its branches if we exclude the terminal expansion in question are six in number; one to the root of the first dorsal nerve; one to the last cervical; one to the sixth cervical, one forming the sympathetic in the neck & two proceeding directly to the base of the heart. Those branches to the heart which assist in the formation of the superficial cardiac plexus form a network on the aorta and pulmonary artery, after which in conjunction with similar branches from the opposite side they give branches to that surface of the auricles which look towards the great vessels, and to the anterior (apex) of the ventricles especially the right. The remaining ganglia viz: the second and third dorsal are situated opposite corresponding ribs and are somewhat angular shaped; they form an elaborate plexus on the coronary sinus (Sy), in conjunction with slender filaments from the second and third ganglia of the right side; and supply the pericardial surface of the Auricles, and the posterior of the ventricles; especially the left. What is to be more particularly noticed (in the calf is, that) on the left side ~~of the~~

preparation under review is this; that while the superior or first dorsal ganglion gives off branches which supply the Anterior of the heart, whereas the second and third dorsal ganglia (with the exception of a slender filament from the first) furnish similar branches to the posterior.

Arrangement of Sympathetic on the Right side of the Calf.

The Arrangement on the Right side corresponds so closely with that of the left as not to require a separate description. This much however must be mentioned; that whereas on the left side the branches supplying the Coronary Sinus and Posterior of the heart generally proceed from the second and third Dorsal ganglia; while on the right side a large branch for a similar purpose proceeds from the first: (the first dorsal ganglion in this instance giving only small branches to the Anterior of the heart.)

The branches therefore which proceed to the heart of the Calf when those which the Cat & Rabbit possess in Common with it are added, are the following:—

First delicate filaments from the Superior or first Cervical ganglia of the Sympathetic of either side, Communicating with branches from the first Dorsal ganglia of their respective sides and the superficial Cardiac plexus.

Secondly branches from the first Dorsal ganglia of the Sympathetic of either side, which branches are principally

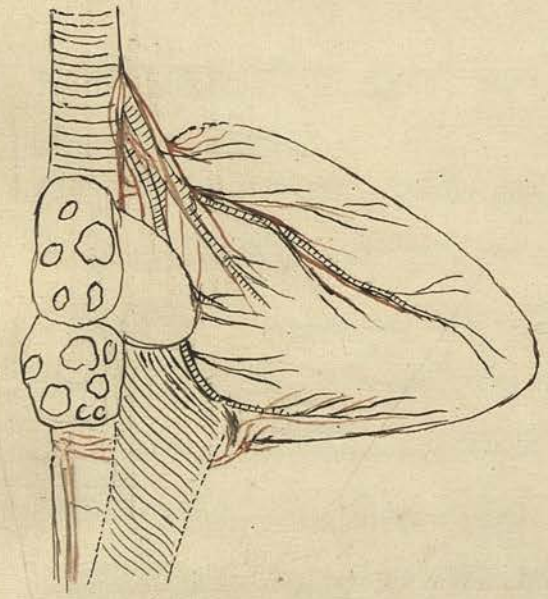
concerned in the formation of the superficial Cardiac plexus, out of which as we shall see presently the anterior and right coronary plexuses are constructed. Thirdly branches from the first second and third dorsal ganglia of the Sympathetic of either side (but especially the left) chiefly concerned in the formation of the deep cardiac plexus, from which the great plexus to the posterior Coronary sinus proceeds: and Lourthly branches from the Vagi of either side, and the recurrent laryngeal of the left side, entering into the composition alike of the superficial & deep plexuses but especially the latter.

As far as the Sympathetic which is the most important is concerned, the nervous supply to the heart of the Calf may be considered as twofold: i.e. there is a supply from the last cervical and first dorsal ganglia of either side to that surface of the auricles which looks towards the pulmonary artery and aorta and the right ventricle more particularly, and another from the third & fourth dorsal ganglia of the left side, sparingly assisted by branches from corresponding ganglia on the right to the pericardial surface of the auricles and the left ventricle almost exclusively.

The distribution of the branches of the vagi in no way interferes with this twofold classification, for a little careful examination will show that while a few of the branches from the vagi of either side (and the recurrent laryngeal of the of the right side) seek that

surface of the Auricles which look towards the pulmonary artery and the right ventricle; the greater portion of the branches from the vagi and those from the recurrent laryngeal of the left side seek the pericardial aspect of the Auricles and the left Ventricle.

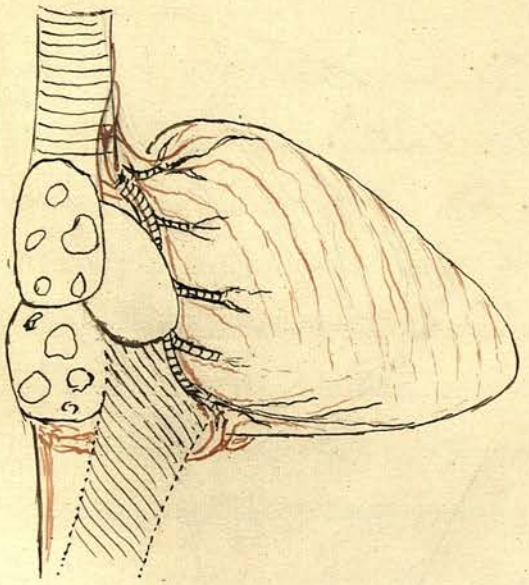
Swan has figured the arrangement of the Sympathetic and Vagus on both sides of the neck of the Calf in his "Illustrations of the Comparative anatomy of the nervous system;" (Plate 26 Fig: 1 & 2) but from what I have seen I am inclined to think he has somewhat exaggerated the number of branches proceeding from the ganglia of the Sympathetic. That the plate in question is to a certain extent apocryphal is evident from the fact, that in Fig: 1 he represents a large branch from the right Coronary artery running down the centre of the right ventricle which the nerves accompany so: —



In this sketch the red lines represent the nerves

Whereas in reality no such branch and no such relation of nerves exist. The right Coronary artery as is

shewn in preparation 35, gives off a series & a basis of (external) branches which run parallel with the muscular fibres and disappear in the substance of the Ventricle, about half an inch from its base; while the nerves cross the vessels and muscular fibres thus: —



The red lines in this as in the previous sketch, represent the nerves. — — — — — — — — —

Arrangement of the Sympathetic & Vagus in Man.

The Sympathetic and Vagus in man have already been so frequently and fully described as to forbid my saying anything concerning them. I dissected two foetuses with extreme care but having failed to detect anything that was not already known I will pass them over by simply recalling to mind that the plexuses formed on the great vessels at the base of the heart by the union of the branches from the first second & third cervical ganglia, pneumogastric & recurrent laryngeal of either side are more intricate & extensive

than is found in any of the lower Animals; a circumstance which contrasts strongly with the fact that as far as the heart itself is concerned the human of all others is the most destitute of nerves.

Recapitulation.

The points which the foregoing dissections of the Cat rabbit and calf seem to establish are these that in Mammals the principal nervous supply to the heart proceeds from the sympathetic — that whereas & in some as in the Cat, a communication exists between the Sympathetic and Phrenic, in others as in the rabbit and calf no such Communication exists; and lastly that while in both species of Mammals the Distribution is as a Rule the same yet in different genera as is more particularly seen in the sympathetic System, the arrangement very materially differs: thus in the Cat we have only four ganglia giving branches to the heart, while in the rabbit we have six; the number in the calf increasing to eight. I have said that in the same species the Distribution is unvarying, but I would have been more Correct in stating that the principle of distribution is the same, for as I shall have occasion to shew presently the arrangement of the nerves on the surface of the heart is in no two instances precisely Similar.

Plexuses formed on the roots of the Pulmonary Artery and Aorta in the calf.

Although strictly speaking the plexuses formed at the base of the heart like the principal nerve supplies are twofold, yet as the superficial cardiac plexus naturally resolves itself into two, in order the more effectually to supply the great vessels (ie the pulmonary artery Aorta) I will speak of them as three: —
First that found on the ascending Aorta, composed of branches from the superior or first dorsal ganglion of either side, and from the pneumogastric of the Right side.
Secondly. That situated on the pulmonary artery (a), and between that vessel and the left auricle, composed of branches from the first dorsal ganglion of the left side, left pneumogastric and left recurrent laryngeal (the Anterior Coronary plexus may be considered as an extension of this plexus;)
And thirdly. That formed on the posterior Coronary sinus, composed almost exclusively of branches from the second third dorsal ganglia of the sympathetic of the left side.

In the first plexus mentioned viz: that found on the Ascending Aorta the nerves as will be observed by a reference to Preparation 5 completely surround the vessel (with coloured threads.) They proceed from the first dorsal ganglion tracked on this occasion to the trachea, & from the pneumogastric of the right side.

This plexus is as a rule difficult to find on account of its being imbedded to a certain extent in the external or cellular coat of the vessel. It supplies branches to that surface of the right Auricle which is in Contact with the Aorta, but its chief function is to supply the right ventricle which it does without almost any assistance from the other plexuses. The fine net work ~~which~~ it ~~furnishes~~ to the right Coronary vessels is especially worthy of observation and is seen to advantage in preparations 7, 18 & 26.

Plexus~~es~~ formed on the Anterior Coronary Vessels of the Calf.

Those branches of the first dorsal ganglion which do not expend themselves on the ascending aorta, descend behind the pulmonary artery to supply branches to that aspect of the left Auricle which looks towards the great vessels, (in this they are assisted by branches from the left pneumogastric and from the Coronary sinus;) reappearing between the left Auricle and pulmonary artery, they form an elaborate plexus on the Anterior Coronary vessels as is shown in preparation 7, to which I now turn.
This plexus viz: that formed on the Anterior Coronary vessels, confines itself in the Calf pretty much to the vessels which it envelopes in all directions; a remark which holds still more true of the plexus as found in the horse (preparation 6) and in man (preparations 9, 12 & 13.) It however

supplies a few branches to the infundibulum and on that part of the left ventricle which is covered by the vessels before they disappear in its substance; nor does there seem occasion for its doing more, when we remember that the right ventricle as a whole, is supplied by the plexus formed on the ascending aorta; while the left ventricle as a whole, is supplied by the plexus formed on the sinus.

What I would more particularly direct attention to when speaking of the plexus formed on the anterior coronary vessels is the manner in which the nerves cross and recross the vessels as seen on the heart of the horse (preparation 6;) the human heart (preparation 9;) and the heart of the calf (Preparation 25.) I would further allude to certain angular enlargements;* one of which is found at the root of the pulmonary artery in preparation 7; (calf) and several of which may be detected in preparations 9, 11 & 13, (human.) These enlargements which have been figured by Scarpa† are found in greatest perfection in the plexus formed on the coronary sinus give one the idea at least in the human heart of the nerves bifurcating or splitting up.

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* Considerable doubt has been hitherto entertained as to the real nature of these enlargements. Behrends e.g. has denied their existence altogether, while others as Scarpa and Lee have described them as ganglia without assigning any reason for so doing. I have examined them microscopically & have ascertained that they contain numerous groups of unipolar nerve cells imbedded in their substance. Vide the 43 page of this dissertation where the cells in question are figured.

† Tabulae neurologicae &c 1794.

The only other thing (and which will be more fully treated further on) is the tendency of the nerves to form ampullae or swellings as they cross the vessels a fact first dwelt upon by Dr Robert Lee of London.* Two of the said swellings are seen on the Anterior Coronary vein of the heart of the horse in preparation 6; and numerous others may be seen on the posterior Coronary vessels of the same preparation.

Plexus formed on the Coronary Sinus of the Calf.

This plexus which is situated on the Coronary Sinus and is more extensive than any of the others† both as regards the number of nerves entering into its Composition & the quantity of enlargements found thereon; is formed almost exclusively from branches of the sympathetic proceeding from the second and third Dorsal ganglia of the left side. It affords the chief supply to the left Ventricle; and is remarkable in this respect, that while it is nominally confined to the sinus and left Coronary vessels (to both of which it gives filaments;) it not unfrequently extends itself so as to embrace the entire left Ventricle in a beautiful net work as shewn in preparation 16. The arrangement of the

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*"On the ganglia & nerves of the heart" Phil: Trans: for 1849.

†This seems necessary because it almost wholly supplies the left ventricle the walls of which are nearly twice as thick as those of the right.

nerves on the Coronary sinus and vessels is of the most intricate description and when carefully traced as in preparations 15, 25 & 26 impress one with the idea of Considerable functional importance. The meshes formed by the tiny nerve filaments as they unite and disunite in the plexus are often so numerous and delicate that it is impossible to preserve them. In one specimen which I shewed Professor Goodsir the sinus was literally covered with them, so that it would have been difficult to have inserted the head of a pin between them. In other specimens as in preparation 15, already alluded to, the meshes or spaces between the nerves are somewhat greater, but even in this, close inspection with the aid of a pocket lens, at once discovers an almost Continuous reticulation or nervous network investing first the sinus, and then the left Coronary vessels. The number of enlargements or nerve expansions found on the sinus of this preparation (15,) between points corresponding with the entrance into it of the posterior and left Coronary veins, is very great and will well repay a careful and protracted examination. These enlargements as seen in different preparations are of divers shapes; they also vary Considerably as regards size. Thus at the confluence of one of the posterior Coronary veins with the sinus in preparation 18, a stellate shaped one with seven branches is seen; another with five branches may be observed on the left Coronary artery posteriorly, in

in preparation 25; a large triangular mass nearly a quarter of an inch in extent & communicating by innumerable filaments is found in preparation 26, at a point corresponding with that where the sinus receives the posterior Coronary vein. In Preparation 26, several irregularly shaped masses are seen on the Sinus; while on the left Coronary artery below the Sinus, a triangularly shaped one is found. Lastly in Preparation 34, a well marked enlargement situated on the Sinus and having five branches may be distinctly seen.

I have been thus particular in describing the foregoing plexuses and more especially that found on the Coronary Sinus; because in no work with which I am acquainted have they at all been adequately represented. Scarpa* and Swan† have figured them only in part, while Lee‡ may be said to have altogether overlooked them. While however I have given to the plexuses that prominence which I considered their due, it will be observed I have not once attempted to specify the number of branches or the arrangement of the branches in each; an attempt which if made must prove abortive from the fact, that although the same principle of arrangement is to be traced in all, a slight diversity in the ultimate distribution is to be found in each.

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* Tabulae Neurologicae 1794.
† Illustrations of the Comparative Anatomy of the nervous system 1835.
‡ On the ganglia and nerves of the heart. Phil. Trans. 1849.

Having now shewn that the heart in the Mammal is chiefly supplied from the sympathetic system of nerves, which system as has been observed varies in the different orders of Mammals as to the number of ganglia Concerned; and having also shewn that the Anterior and posterior Coronary plexuses in the same species differ as to the Number and distribution of their branches: it now remains for me before proceeding to the Microscopic examination of the subject, briefly to consider the Arrangement of the nerves on the Surface and in the substance of the Auricles and Ventricles, which I will do in the hearts of the Calf, Horse, Man &c

Arrangement of the nerves on the Surface & in the Substance of the Auricles.

In speaking of that surface of the Auricles which is turned towards the great vessels it will be remembered I observed that this Aspect was supplied by branches from the first Dorsal ganglia of either side — from the Vagi of either side and from the Coronary Sinus. Bearing this in mind I have only further to remark that the arrangement is plexiform the Nerves from opposite sides uniting to form a plexus as shewn in Preparations 7, 28½ & 53. In the last named preparation (53) in addition to occasional enlargements, a nerve may be distinctly seen entering the substance of the left Auricle. Once in substance the nerves as a rule break up to form minor

plexuses some of the branches proceeding right through the walls to appear on the interior.
The arrangement of the nerves on that aspect of the Auricles which is Covered by the pericardium is in many respects analogous to the Arrangement just described. Thus in preparations 24 & 28, which show the distribution on the right Auricle; we have the nerves forming a reticulation or net work. The nerves which on this aspect of the Auricle in question are very delicate, proceed from the first dorsal ganglion of the right side, right vagus & coronary plexus. On the left Auricle in the foregoing preparations & more particularly in Preparation 28, the arrangement is in all respects similar; the supply in this instance being derived principally from the Coronary plexus*, but also from the first dorsal ganglion of the left side and left vagus.

Arrangement of the nerves on the surface or exterior of the Ventricles in the calf, the horse, man &c. &c. &c.

In taking a comprehensive view of the distribution of the nerves on the surface of the Ventricles, it will be found that notwithstanding the slight variation introduced by occasional interlacings, they follow a common Course; and that

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* In preparation 15, the Coronary plexus extends to the pericardial surface of the left Auricle and on this surface several ganglionic enlargements may be detected.

Course as I have ascertained from numerous dissections is from right to left downwards. On closer inspection it will further be found observed that the direction pursued by the nerves is precisely the opposite of that pursued by the muscular fibres — in other words that while as was shewn in my paper "On the Arrangement of the muscular fibres of the Ventricles"* the fibres form left handed spirals, the nerves on the Contrary form right handed spirals. I mention this because although Lee and others have spoken of the nerves crossing the muscular fibres obliquely from base to apex, no reference is made to the complete Spirals formed thereby. I mention it further because the arrangement besides possessing considerable physiological significance, is curious as shewing that even in the distribution of nerves the spiral may obtain. This general principle (if I may be allowed the expression) in the direction of the nerves, as contrasted with that of the muscular fibres will be readily seen by a reference to preparations H 2 and H 3, where the Ventricles are placed on their bases the better to shew the peculiarity.

Distribution of the nerves on the Right Ventricle of the calf.

As a remarkable illustration of the principle which seems to govern the di

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*Proceedings of the Royal society for april 19th 1860.

direction of the nerves on the ventricles. I would first advert to the arrangement on the right ventricle. This ventricle as has been already explained is supplied by the plexus formed on the aorta and between that vessel and the pulmonary artery. As however the plexus in question is situated posterior to the pulmonary artery and infundibulum, it follows that if the nerves were at once to proceed on their downward course not only would the infundibulum be left destitute of nerves but their direction would nearly correspond with that of the muscular fibres. In order therefore to avoid what would apparently have resulted in defect the nerves at first run forwards so as to cross the infundibulum and supply the vessels thereon; after which — and mark this — they suddenly bend upon themselves at nearly right angles in order fairly to intersect the muscular fibres in the direction from right to left downwards as shown in preparations 16, 26 and 30. That there is a purpose to be served by the direction of the nerves on the Right Ventricle other than supplying the infundibulum, is I think evident from the fact that on the left ventricle where no infundibulum exists the same direction obtains; Again if this had been the object solely in view there could have been no necessity for the bend to which I have alluded, and which has the effect not only of completely altering the direction of the nerves but curiously enough of causing them to cut the spiral formed by the fibres of the right

ventricle in two different places: further the infundibulum might have been wholly as it is partially supplied from the plexus formed on the Anterior coronary vessels; an arrangement which would have precluded the necessity for the nerves diverging from their course originally and the change in direction affected by their bending upon themselves subsequently. As I am at present speaking of the relation of the nerves to the muscular fibres, it might not be out of place to say a word or two with reference to the blood vessels to which I must shortly allude. These as is well known occupy the auriculo ventricular grooves & the Anterior and posterior Coronary tracts; but I am not aware that it is generally understood the chief branches given off by the Coronary arteries on the one hand and received by the Coronary veins on the other, run parallel with the muscular fibre. This arrangement which necessitates the principal branches of the Coronary vessels being likewise crossed by the nerves is worthy of notice; for as Lee has pointed out it is when the nerves are in the act of crossing the vessels that they present those ampullae or swellings which he has figured as ganglia, although on what grounds he does not state. That the nerves are in some way connected with the functional activity of the vessels I have little doubt, for as I shewed on a previous occasion the great plexuses formed at the base of the heart, are so disposed as naturally to resolve themselves on the trunks of the Coronary

vessels which they cross in all directions. By so doing they therefore seem to establish a precedent with which the arrangement in question vis: that by which the nerves are made to cross the vessels is in the strictest conformity. In further corroboration of this opinion I might mention the fact that in many instances as shown more particularly in the right ventricle of preparation 21, the nerves in crossing the vessels give off branches which run parallel with the vessels; while in others as is well seen in preparations 40 & 44, two or more nerves slightly swerve from their course in order to form nervous rings around portions of vessels which imbedded in the substance of the Ventricle accidentally rise to the surface. I need not enter into the ultimate distribution of the blood vessels; suffice it to say, that the main branches from the Coronary vessels gradually imbed themselves in the substance of the ventricles and give off branches which Anastomosing with branches from corresponding and greatly diminished trunks in the interior, have the effect of transpicing as it were the walls of the Ventricles; so that when the Ventricles are dissected by consecutive layers, the ends of the blood vessels protrude like so many pins thrust horizontally through the walls: an arrangement well calculated to restrain the layers within certain limits, while it in no way interfers with the Spiral movements of the whole. Preparations 15, 16, 18, 19 and 29, will

illustrate the relation of the blood vessels & the nerves and muscular fibres in the calf; and preparations 9, 10, 11, 12, 13 & 14, will do the same for the human.

The points to be more especially noticed in the distribution of the nerves on the right ventricle are the following: They are derived from the plexus formed on the Aorta and between that vessel and the pulmonary artery, but derive in addition as was formerly stated a few branches from the plexus on the Anterior Coronary vessels. They run in a spiral direction from before backwards or from right to left Downwards, a course the reverse of that pursued by the fibres and Vessels — as a rule they split up from time to time the branches maintaining a certain parallelism and becoming finer and finer as they proceed or reach the posterior of the Ventricle, as will be seen in preparations 16, 18 and 19. In some instances however as in preparation 26, the arrangement is more plexiform and the peculiarity in this and similar preparations is, that the nerves run together in such a manner as to impress one with the idea of a positive increase of nerve substance at the point of juncture. In the preparation in question and in many others as e.g. preparation 32, the nerves when they have reached the posterior of the Ventricle unite with nerves from the plexus on the Coronary sinus to form little clitate shaped expansions in

the substance of which I have detected numerous groups of true nerve cells. In addition to the plexiform arrangement which the eye at once discovers in preparation 26; a little careful examination with the aid of a lens, will gradually reveal a repitition of a similar arrangement on a minor scale, from which nerve filaments proceed to enter the muscular substance; a fact further illustrated by a reference to preparations 39, 51, 53 &c. In preparation 26, as also in preparation 18; the plexus formed on the right Coronary artery when examined with a lens in a good light, is found to be much more elaborate than is figured by either Scarpa, Swan, or Lee.

When compared with the left ventricle the nerves of the right are found to be on the whole fewer in number. Posteriorly however or where the terminal filaments unite with similar filaments from the plexus on the Coronary Sinus there usually is a part of the right ventricle comparatively unprovided for.

Distribution of the nerves on the left ventricle of the Calf.

This ventricle which is supplied almost exclusively from the plexus on the Coronary sinus, exhibits still more clearly than the right, the spiral course pursued by the nerves. As a rule the nerves on the posterior of the left ventricle proceed in almost parallel

lines subdividing & becoming more & more attenuated as they reach the apex as observed in preparations 16, 19 & 24. On the lateral and anterior aspect of the Ventricle however as is shown in the same preparations the arrangement is more irregular i.e, it assumes to a certain extent the plexiform character. In either of the foregoing preparations indeed and more particularly in preparation or Preparation 16, it may be said to be, altogether plexiform; and the nerves by alternately uniting & disuniting give rise to a curious net work, which envelopes the Ventricle from base to apex. In examining this network it will be found that ~~as many~~ sometimes as many as three branches come together when crossing a vessel, after which they gradually diverge again to unite.

The plexus formed on the left Coronary vessels which may be considered as an extension of that found on the Sinus, is much more intricate than is generally imagined as a reference to preparations 13, 18, 23 & 26, will demonstrate.

When patiently examined with a lens in a good light, the number of branches which it displays is found to be astonishingly large; and on some of the branches (vide preparations 18 & 25,) fusiform enlargements or swellings may be distinctly recognized. The ~~also~~ fusiform enlargements on the nerves of the left Ventricle, are as Lee has correctly pointed out, usually met with when the nerves are crossing the vessels. This number however is by no means

so great as he would lead us to infer*, and I cannot help thinking Lee has committed a grave error in assigning such prominence to them, for it must be remembered that although present in all hearts they are not unfrequently so few and so small as scarcely to be perceptible. I have examined upwards of a hundred hearts and speak guardedly when I express my conviction that he has not only exaggerated the number of these enlargements, but also their size and the number of branches given off by them. That very many of them when crossing the vessels give off branches to run parallel with the vessels, I readily admit; but that they all do so and possess the distinctive ganglionic character which he has attributed to them, is what I must for the present deny. The enlargements, as I have seen them and as a reference to the anterior of the left Ventricle of preparations 20, 21, 22 & 26 will shew, have in many instances rather the appearance of flattenings caused by the bulging of the vessels beneath them; that however they are for the most part something more than mere flattenings is abundantly proved from my having detected in many of them numerous clusters of unipolar nerve cells †; and from the increase of nerve substance frequently observable. Preparation 34, which shows an aggregation of these swellings on the posterior of the left Ventricle displays the increase

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* Lee speaks of ninty eight on the Anterior surface.
† For a description of these unipolar cells see p. 36 of the present dissertation.

referred to. A good example is also seen in a similar situation in preparation 33. On the heart of a Camel which I had the good fortune to obtain through the kindness of Professor Goodsir, the increase was very marked; the enlargements in this instance being of an irregular though somewhat quadrangular shape & communicating with divers nerves.
To say the least of it the enlargements in question are very remarkable; and all the more so as they are not wholly confined to such portions of the nerves as are in contact with the vessels. In preparation 42, within a fourth of an inch from the left apex anteriorly a small ganglionic enlargement giving off a branch to enter a fissure* in the Ventricular wall may be seen without difficulty; and a little careful searching will display not a few others in several of the preparations already adverted to.

Nerves entering the Substance of the Left Ventricle.

The number of branches which dip into the substance of the left ventricle are by no means regular; they vary also as regards their size and mode of disappearance. Generally speaking however they take advantage of a vessel entering the substance and accompany it, or seek an opening between

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*The fissure referred to is that caused by the imperfect apposition of the two parcels of fibres which form the left apex. As a rule nerves are to be observed disappearing at this point to reach the interior.

the muscular fasciculi as shewn in preparations 26, 51 and 55. In preparation 5, which exhibits a horses heart three branches may be seen entering the posterior wall of the left ventricle within a short space of each other. When traced into the substance of the ventricle as far as I have been able to discover the nerves follow the same arrangement as on the surface; i.e. they run slantingly and become in contact with the vessels and muscular substance as they divide and subdivide. The number of branches which seek the substance of the ventricle when contrasted with those found on its surface is insignificant;* and the extreme tenuity of the filaments so distributed renders them somewhat difficult to trace. Preparations 38 & 45, display those filaments in the heart of the horse.

Distribution of the nerves on the surface of the human heart, the heart of the horse &c

The arrangement of the nerves in the human heart much resembles that found in the calf. There is however this difference, the nerves confine themselves more closely to the vessels a peculiarity which also obtains to some extent in the heart of the horse seal &c (preparation 6.) Those branches which do stray across the vessels

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* Lee has expressed a contrary opinion, but a careful examination of the point leads one to the above conclusion.

are much more delicate than is found in similar positions in the calf or any other animal as a reference to preparation G, will shew. The occasion difficulty experienced in obtaining a perfectly healthy human heart is such as to render a satisfactory demonstration next to impossible; but this can be no doubt from what I myself have seen, that the ultimate distribution is in every respect strictly analogous to that described in the calf. I have examined upwards of a dozen human hearts and although I have not succeeded as I could have wished in the dissection of either, I have no hesitation in stating that the difference is less in kind than in degree; the amount of nerves found in the Ventricles of the human heart being somewhat less than in most other animals. The large quantity of fat and the thickness of the pericardium* in the adult human heart, render it somewhat troublesome to display the nerves as fully as could be wished; but in the young heart where the investing membrane is thin & the quantity of adipose matter small, little dissection is required to shew the more salient points. In such a heart it will be found that a leash of nerves issue from between the pulmonary artery and Aorta, to form a plexus on the right coronary vessels; after which they distribute themselves over the right ventricle generally, as imperfectly seen

*Lee very properly divides the pericardium into a serous & fibrous layer and assigns to both the name of Cardiac fascia.

in preparations 9, 11, 12 & 13; while Another and greater leash issues from between the pulmonary artery and left auricle and distributes themselves on the anterior Coronary vessels and left ventricle more especially; (vide same preparations and 9 in particular.) The nervous supply to the posterior of the heart which in the human is derived principally from the Anterior and right Coronary plexuses, is Comparatively speaking very scanty; a deficiency observed in the hearts of many of the lower animals though not to the same extent. As regards the actual number of nerves on the Ventricles of the human heart there is some difference of opinion. According to Scarpa & what I myself have seen, they are as has been already stated fewer in number and more delicate than is found in the lower animals. If however we are to give credence to Dr Robert Lees representations of the nerves on the heart of a Child nine years of age, and a human heart hypertrophied, a position the very reverse of this must be taken up; the fact being that in the figures in question* he has represented the nerves on the human heart as being quite as numerous, as those found on the heart of the young heifer. It is difficult to believe that such is actually the case, and all the more so as Lee is the only observer who has seen them in such profusion. This Author lays particular emphasis

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*Lee on the ganglia & nerves of the heart. plates 1 & 5. (Phil. Trans: 1849.)

on the number of nerves detected by him at the apex of the human heart: that he is quite right in describing and figuring them * as distributing themselves freely over the ~~surface~~ apex and lower thirds of the ventricles there can be no doubt, but that they are to be found in such quantities as he represents is I think a statement to be received with caution.

The enlargements on the nerves of the human heart which have been partially figured by Scarpa † & more fully by Lee ‡ are not so distinct as those found on the nerves of the heart of the calf; neither are they so numerous; nevertheless they are sufficiently well marked to attract attention when looked for. Preparations G, 11 & 13, shew some of these enlargements.

The arrangement of the nerves on the surface of the hearts of the Camel, Alpaca, panther, seal &c is, on the whole so similar to that already described in the Calf, as not to warrant a separate recital.

I will therefore now pass to the Consideration of the

Microscopic structure of the angular enlargements found on the Sinus and large Vessels generally & the fusiform swellings detected on the nerves as they cross the branches of the Vessels before the branches disappear in the

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* Lee "On the ganglia & nerves of the Heart" plates 1 & 5. Philosophical transactions for 1849 &c fol. 1794 Vol. III, IV & VI.

† Tabulae Neurologicae &c fol. 1794 Vol. III, IV & VI.

‡ I can by no means assent to the number and magnitude of these swellings as figured by Lee.

Ventricular substance.

On carefully removing the cellular tissue &c constituting the investing membrane of the heart from one of the enlargements found on the Coronary sinus or large vessels the increase of nerve substance is very apparent. The increase on the nerves as they cross the smaller vessels is not so well marked although when the swelling is detached & examined with a power of 80 diameters or so the point may be readily determined. In order to display the contents of the enlargement some little preparation is necessary: thus the nerves to be examined should be perfectly fresh; secondly the enlargement when removed by the aid of the dissecting lens should be cautiously transferred to a slide after which it should be carefully spread out and examined in glycerine. When the enlargement is treated with an ammoniacal solution of Carmine the same effect is produced as exhibitted on other nerve Centres. Other methods consist in hardening the enlargement in a weak solution of acetic acid & Spirit Chromic acid &c but on the whole I have found the glycerine and Carmine treatment the best.

When an enlargement such as may readily be found on the Coronary sinus of the Calf is examined in glycerine when quite fresh with a power varying from 150 to 300 diameters & upwards large clumps or masses of cells may be found scattered throughout its extent. as shewn in preparation **D**. When such clumps are isolated as has been done in preparations **J K** & **L**

they are observed to consist of large aggregations of cells arranged in the form of a bulb the narrow end of which is usually connected with a single bundle of nerve filaments as seen in drawings 2, 5, 7 & 9. Occasionally however numerous bundles of nerve filaments enter the same clump in which case the clump is irregularly shaped being elongated in the direction of the bundles of nerve filaments entering it as seen in Fig: 6. In close proximity to the bulb like terminal clump described, a smaller clump of an oval form may frequently be detected a drawing of which is given in Fig: 9 (a). This minor clump which is well seen in preparation I closely simulates the original and seems as if it a terminal clump in process of formation. When the terminal clump is treated with Carmine each cell is found to contain a distinct nucleus and one or more nucleoli as is well shewn in preparations O, I, Q & R. The cells for the most part are unipolar; and the arrangement from various observations seems to be the following. The bundle or bundles of nerve filaments on entering the clump resolve themselves into their component nerve fibres and each fibre selects & becomes connected with a nerve cell. This arrangement is more particularly seen at the Margins of the Clumps (Figures 2, 3 & 13) and when a clump is broken up with fine pointed needles as has been done in preparations Q & R & Represented in Figures 10 & 11. On one occasion I found a clump detached from its connections where the ends of the nerve fibres were affixed to the

cells as shewn in Fig: 12. Although in the clumps in question the unipolar cells seem to prevail, bipolar cells are sometimes met with as represented in Fig: 10. When one of the fusiform enlargements found on a nerve as it crosses a vessel is examined an arrangement in all respects similar to that above described is observed — the clump in this instance being for the most part situated in the Centre or on the side of the nerve itself — as figured in drawings 3, 5 & 13. Sometimes a swelling contains numerous Clumps of cells as seen in preparation H. Whether these nerve cells so arranged communicate with each other or send off terminal filaments to the surrounding tissues I have not unfortunately had an opportunity of determining. The preparations illustrating these points have been preserved and accompany this Dissertation.

Conclusion.

In the foregoing investigation I have endeavoured to set forth in a condensed form the facts presented by an extensive and laborious series of dissections. Having no theory to serve and being under no obligation to any one either as regards dissection or description the present research may in the strictest sense of the term be considered original. My mode of procedure was on all occasions the following:— I first carefully dissected each specimen without reference to any authority whatever; after which I as carefully

described it to the exclusion of helps. In order however that I might not be accused of overlooking the labours of others I felt it my duty in the second place to consult the writings of previous investigators in order that in my text the points established by them should be duly acknowledged & Confirmed, while those in which I differed from them should be fairly represented.

The points on which I have endeavoured to throw additional light are these:—

First the manner in which the sympathetic and Vagus give off branches to the heart and the number thereof as determined by dissection of the Cat Calf and Rabbit.

Secondly — the nature of the plexuses formed on the pulmonary artery and aorta.

Thirdly — the Composition of the Anterior & Right Coronary plexuses and those found on the posterior Coronary sinus and left Coronary Vessels. hitherto imperfectly described.

Fourthly — the arrangement of the nerves on the surface and in the substance of the Auricles.

Fifthly — the principle of destribution on the surface and in the substance of the Ventricles as contrasted with that of the blood Vessels and the direction of the Muscular fibres.

Sixthly & Lastly — the enlargements & fusiform swellings found on the nerves on the Coronary sinus & large vessels examined microscopically, the existence of cells therein carefully determined & figured.

See Plates & Descriptions thereof.

Explanation of the Figures.

Figure 1 shews the heart of the calf seen posteriorly — muscular fibres & vessels contrasted with the nerves — Arrangement of nerves on this aspect more or less plexiform — Various ganglionic enlargements containing nerve cells observed on the sinus, coronary vessels, Auricles & Ventricles — Nerves dipping into the substance of the sinus, coronary vessels, auricles & Ventricles &c.

Figure 2 shews a large terminal cluster of nerve cells with a bundle of nerve filaments entering — from the plexus on the Coronary sinus.

Figure 3 shews a cluster of nerve cells situated on one of the enlargements found on the nerves as they cross the vessels of the Ventricles particularly the left — Sometimes the swelling contains several clusters of cells, the cells being more isolated than in this instance.

Figure 4 shews bulbous extremity of a terminal clump of nerve cells — from the plexus on the Coronary sinus.

Figure 5 shews terminal clump of cells found on the course of a nerve with nerve bundle entering — from the surface of the Ventricles.

A V E R.

Figure 6 shows large mass of cells with several nerve bundles entering — from the plexus on the coronary sinus.

Figure 7 shows terminal bulb or cluster of nerve cells with a nerve bundle entering — the cells slightly flattened out.

Figure 8 shows the same — cells partially broken up, nuclei & nucleoli set free.

Figure 9 shows terminal bulb with nerve bundle entering to which is connected a minor bulb of an oval form containing cells of lesser dimension.

Figure 10 shows unipolar and bipolar nerve cells containing nuclei and nucleoli — from one of the terminal clumps above referred to.

Figure 11 shows terminal clumps of nerve cells broken up — & unipolar nerve cells, nuclei & nucleoli set free.

Figure 12 shows clump of cells accidentally detached — unipolar nerve cells seen where the nerve bundle has entered.

Figure 13 shows a cluster of nerve cells situated on the course of a nerve — nerve bundle entering & nerve bundle proceeding from the cluster.

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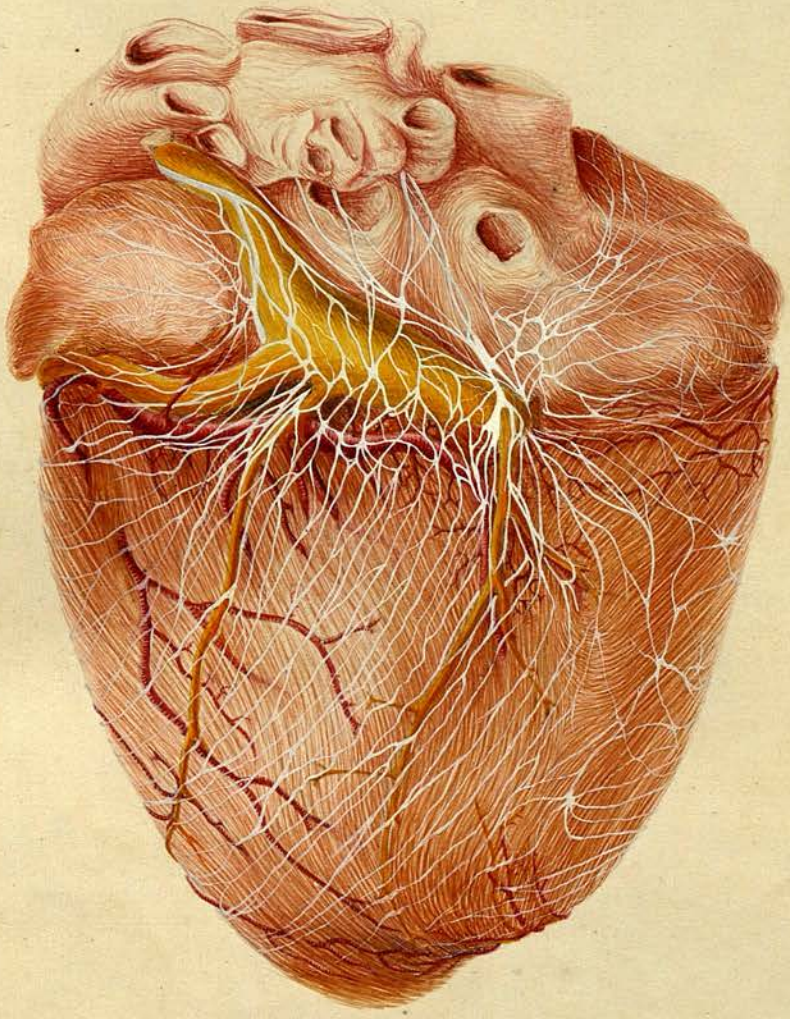

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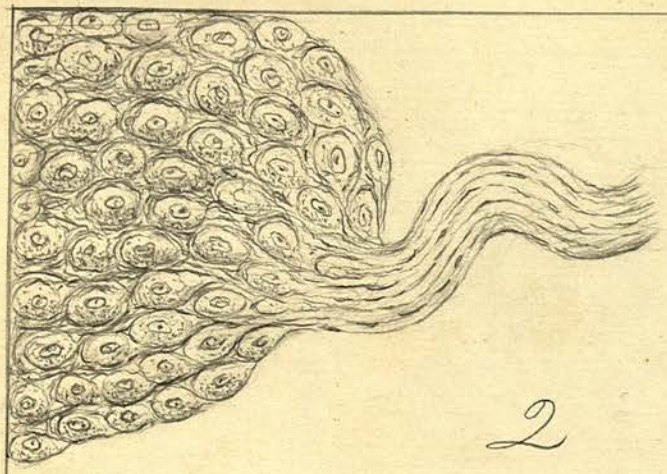

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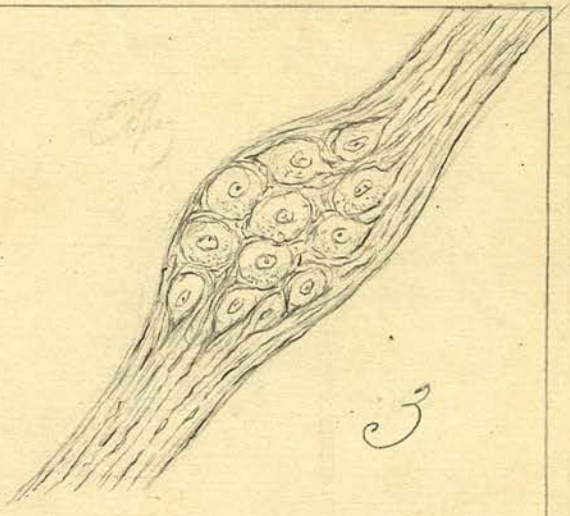

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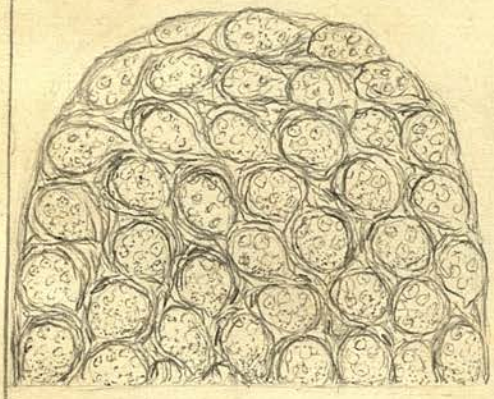

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Fig. 149 C

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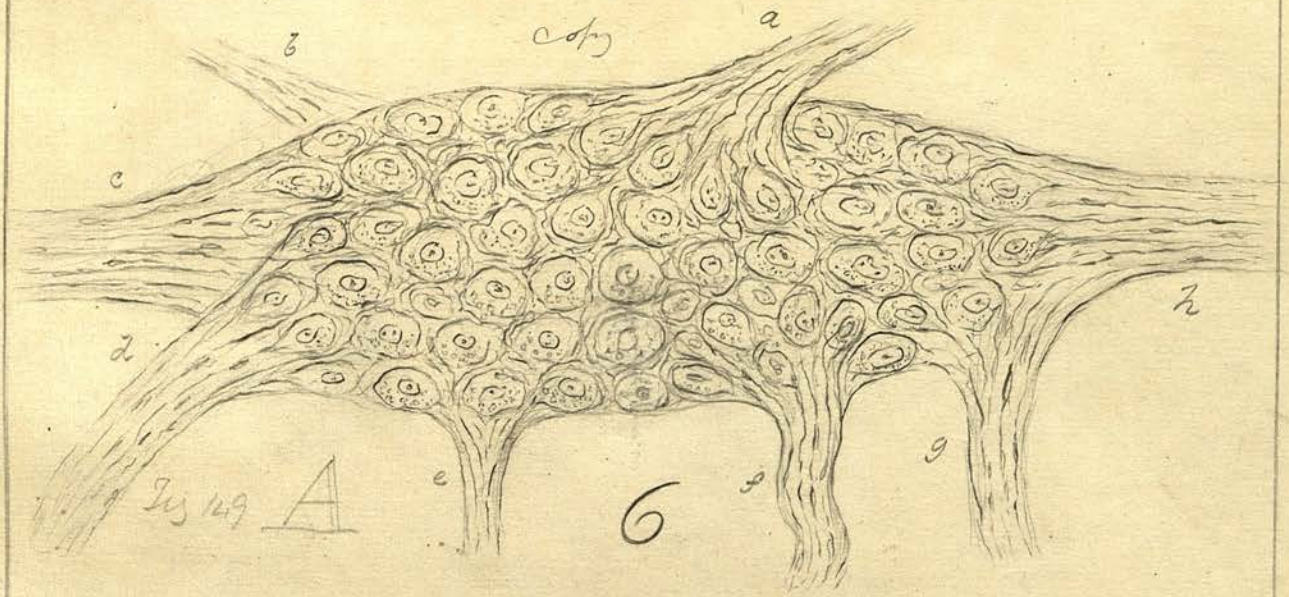

Fig 149 A

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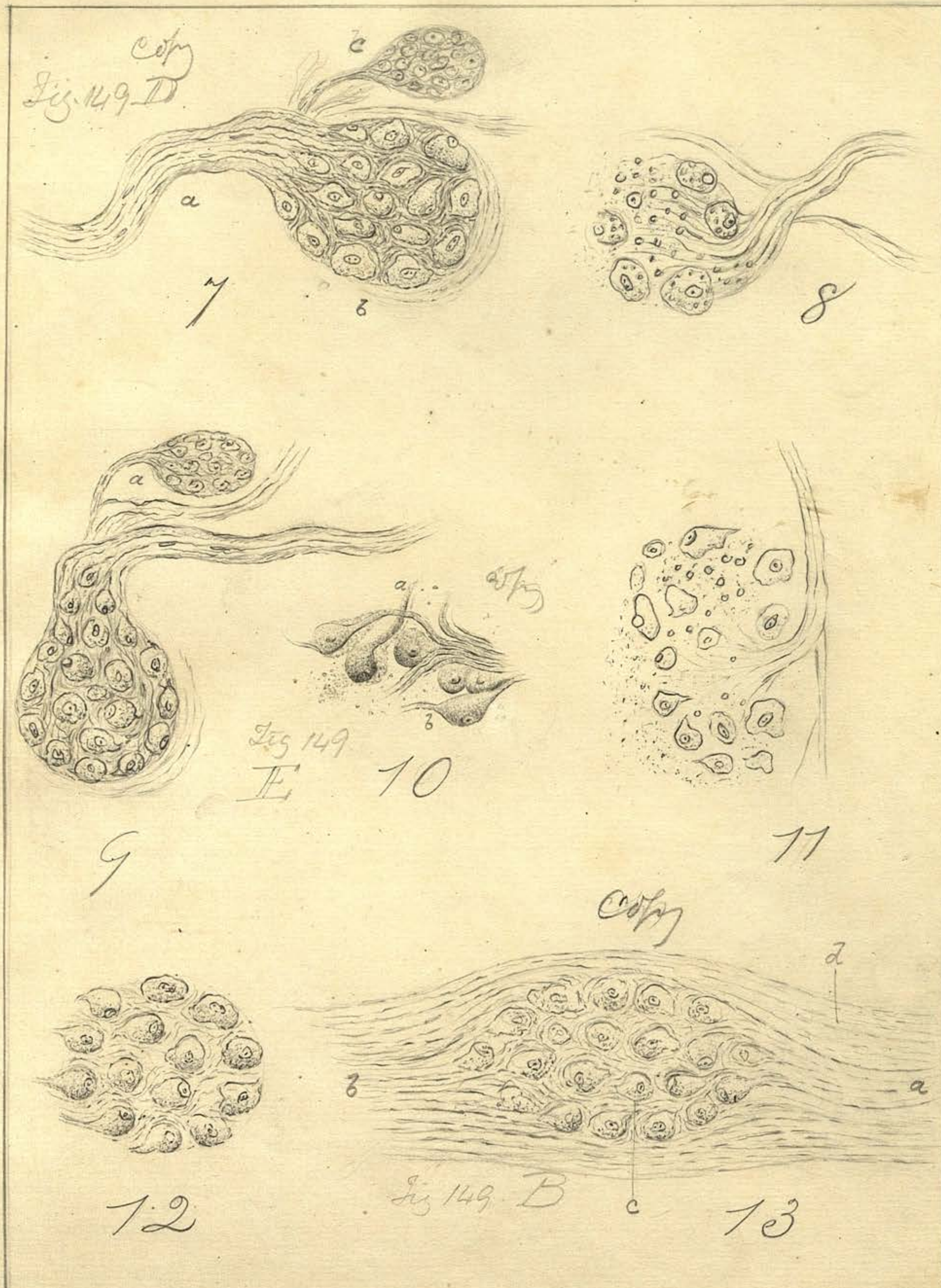

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