N E R V E   E N D I N G S

I N   T H E

R E P T I L I A N   L U N G

By

ARTHUR CARHART JONES

A THESIS

Presented to the Faculty of the Graduate School of
the University of Oregon
in partial fulfillment of the requirements
for the degree of
Master of Arts.

June, 1925.

C O N T E N T S

Bibliography.

Beale, L.P. 1860 On the distribution of nerves to the elementary fibers of striped muscle. Phil. Trans. Roy Soc. London, 1860, 611.

Berkeley, H.J. 1893 The intrinsic pulmonary nerve in mammals. Jour. Comp. Neur., vol. 3, pp. 107-111.

Carlson, A.J. and Luckhardt, A.B. 1920 Studies on the visceral sensory nervous system. I Lung automatisms and lung reflexes in the frog (R. pipiens and R. catesbiana). Amer. Jour. Physiol., vol 54, pp.55-75.

Carpenter, F. W. 1924 Intramuscular nerve endings of sensory type in the small intestine, with a consideration of their probable function. Jour. Comp. Neur., vol. 37, pp 439-454.

Eugling, M. 1908 Untersuchungen uber den peripheren Tonus der Blutgefasse. Pfl. Arch. 121, 275.

Gegenbauer, C. 1901 Vergleichende Anatomie der Wirbelthiere. vol. 2, pp. 300-324.

Glaser, W. 1920 Innervation der Blutgefasse in L. R. Muller: Das vegetative Nervensystem. Berlin, Springer.

Karsner, H. T. 1911 Nerve fibrillae in the pulmonary artery of the dog. Jour. exper. med., vol. 14, No. 3, pp. 322-325.

Kingsley, J.S. 1917 Outlines of comparative Anatomy of vertebrates. Blakiston, Philadelphia.

Krimke, A. 1884 Die Nerven der Kapillaren. Dissertation. Munchen.

Krogh, A. 1922 The anatomy and physiology of capillaries. Yale Univ. Press.

Larsell, O. 1921 Nerve terminations in the lung of the rabbit. Jour. Comp. Neur., vol 33, No. 2, pp. 105-131.

Larsell, O. 1922 The ganglia, plexuses and nerve terminations of the mammalian lung and pleura pulmonalis. Jour. Comp Neur. vol. 35, pp. 97-132.

Miller, W. S. 1893 Structure of the lung. Jour. Morph. vol. 8, pp. 165-188.

Miller, W. S. 1916 Anatomy of the lungs. Reference Handbook of the Medical Sciences, 3rd Ed., Wm. Wood and Company.

Ploschko, A. 1897 Nervenendigurgen und den Ganglien der Respirationsorgane. Anat. Anz., Bd. 13, S. 12-22.

Rouget, Ch. 1879 Sur la contractilite des capillaires sanguins. C.R.88, 916

Wiedersheim, R. Comparative anatomy of vertebrates. Translation by Parker, N. pp. 280-298.

Wolff, Max 1902 Ueber Ehrlich'sche Methylenblau-farbung und uber Lage und Bau einiger peripherer Nervenendigungen. Arch fur anat. u. Entwick., S. 155-183.

NERVE ENDINGS IN THE REPTILIAN LUNG

Introduction

Detailed anatomical knowledge is lacking of the nerve supply of most of the visceral organs. This is true of man and the mammals, in which forms such studies as have been made have for the most part been conducted. In sub-mammalian vertebrates there is an almost total lack of literature on the subject. The value of comparative studies, both anatomical and physiological, is gaining increasing recognition, and it is with a view to filling some of the gaps in our knowledge of the innervation of one of these organs, namely the lung, that the present investigation was undertaken. The scope of the present account will be confined to an anatomical description of the nerve trunks and nerve terminations in the lungs of reptiles, as represented by the turtle and the snake.

Review of Literature

The literature of comparative anatomy is silent concerning the innervation of the reptilian lung. The morphology of this organ has been well described by Gegenbauer ('01), Wiedersheim ('07), Miller ('93), Kingsley, ('17), and others. Miller describes the snake's lung as a long, simple sac, smooth in its caudal two thirds, coarsely alveolated in the cranial third. The alveoli are not alveoli in the true sense of the term, but are out-pocketings from the central open cavity of the lung. They are bounded by bands or fasciculi of smooth muscle which vary in elevation, being quite low in the distal portions and progressively higher cephalad. These alveoli are quite shallow in the distal portions of the lung, mere depressions in the walls; they become smaller, deeper and have a more truly sac-like form in the regions nearer the main bronchus, the muscular walls are thicker about them, and they may even have quite a constricted, rounded opening or mouth. Secondary air sacs extend laterally from these deeper alveoli, marked off in turn by subdivisions from the smooth muscel trabeculae. The bronchus opens into the cranial end of the central lung cavity at the medial side but is not continuous. Its opening is held patent by irregular placques of cartilage within the wall. These represent the irregular cartilage rings of the smaller bronchi in higher forms, but they do not extend more than a millimeter or less beyond the aditus of the single bronchus.

The snake has only one functional lung as a rule, the other being so small as to be vestigial or entirely lacking. The trachea is thus directly continuous with the bronchus as a single tube, lined by annular cartilaginous plates which are open dorsally, as in the mammal. These rings are often fused together, or may be quite irregular in shape and position, and become more so as the hilum of the lung is approached. The open portion of the cartilaginous tube posteriorly is closed by a network of smooth muscle fasciculi which corresponds in position and general arrangement to the muscle of Reisseissen in the mammal. It is, however, a more open mesh and the fibers lie more obliquely to the transverse axis of the trachea, some even being at right angles to it, paralleling the lumen. The muscle fasciculi of this network merge insensibly with those of the lung itself at the hilum, the transition in the mucosa from low columnar to flat epithelium being the only suggestion of a change at this point.

The lung of the turtle is much more complex in structure than that of the snake. The trachea and bronchi are essentially the same, though the former is much longer and tends to be convoluted or curved. The main stem bronchus enters the lung at the upper ventral portion of the apex, and subdivides into several tubes. These lead to chambers or atria, separated from each other by septa; the points of entrance are termed by Kingsley ('17), "infundibula." The septa and walls of the atria are alike lined by air sacs or alveoli which are smilar to those described in the cranial portion of the snake's lung. They are deeper, however, with secondary sacculi in their walls, and their mouths may be small and circular or wide and oval. They are also of a more uniform size than in the snake. The atria are smaller and more numerous at the cephalic end or apex of the turtle's lung, larger and simpler toward the base. The bronchi do not extend so far caudally, and air reaches these distal portions by way of large, rounded openings in the medial portions of the septa, which here fail to fuse with the medial wall of the lung. The structures which make up the turtle's lung are built upon a heavier pattern than those of the snake's lung, the muscle bands are thick, wide and coarse and the alveoli are much larger.

Material and Methods

The common garter snake, Eutaenia, was used for the greater part of this investigation. Several species of this genus are found in northwestern Oregon; the prevailing ones being E.vagrans, E.leptocephala, and

E. sirtalis (B. and G.). Some experiments were also carried out on the turtle, Chrysemys marginata. The best results with the snake material were obtained by the use of 0.1% methylene blue in Ringer's solution or 0.75% NaCl solution. Methylene blue ~~in~~ of 0.5% gave the best stain with the turtle lung.

The usual technic of injection in the snake consisted of cannulizing the trachea and heart under ether anaesthesia. Saline 0.75% was then first injected through the cannula in the heart, the blood being drained away by severing the jugular and portal veins. The injection pressure must not be high because of the danger of rupturing the cardiac walls. As soon as the washings became clear the stain was immediately introduced through the same cannula and the lung allowed to remain undisturbed for five to ten minutes. Less satisfactory results were obtained by filling the lung with the stain through the tracheal cannula, draining after five minutes. The addition of one or two drops of 1% osmic acid to 100cc of the stain was effective in preventing sloughing of the bronchial and alveolar epithelium.

Following either method, aeration of the lung was carried out by means of a rubber hand bulb, inflating and deflating rapidly for fifteen minutes or longer, until the proper blue color of the tissue indicated sufficient oxidation of the stain. Extirpation of the lung in the snake is difficult on account of the danger of rupturing the thin distal portion when removing the liver from its attachment, so this was usually begun before the oxidation was completed. The lung was at once filled with ice-cold 8% ammonicum molybdate and placed in an excess of the same solution, kept at refrigerator temperature twelve hours or over night.

(Note. The molybdate must be dissolved in cold water to avoid formation of free molybdic acid which destains the tissues.) The ammonium molybdate was washed out by rinsing the lung several times with cold water, allowing it then to remain in a stream of running water for an hour. The lung was next filled with cold 95% alcohol, in which it was allowed to remain an hour, during which time the alcohol was changed several times. This was followed by absolute alcohol, also cold, in which the tissue was allowed to remain four or five hours or overnight. The lungs were last placed in xylol, and either embedded in soft paraffin or opened and laid flat on large slides as spread preparations. Sections were cut from the paraffin blocks at 50 and 100 micra and mounted serially.

Several preparations were also made with the use of the osmic acid technic to show the myelinated nerve fibers. The lung was filled with 0.25% osmic acid after the usual washings of saline, then dissected out and left in an excess of the same solution for thirty-six hours or longer. Numerous washings in running water were followed by immersion in 95% alcohol for one week, after which the tissue was dehydrated in changes of 95% and absolute alcohol, cleared in xylol and mounted flat or embedded and sectioned serially as stated above.

Observations.

1. Snake

Both vagi give fibers to the single lung of the snake, and sympathetic connections are also present, but their exact location and extent within the lung has not been certainly ascertained in this investigation. These components form a rather coarse-meshed, simple plexus about the trachea, main bronchus and pulmonary vessels, composed for the most part of large trunks which are made up of many myelinated fibers. These lie entirely outside the cartilaginous rings of the trachea and bronchus and correspond to the extrachondrial plexus of the mammalian lung. Groups of ganglion cells are encountered in the loose areolar tissue about the trachea and bronchus. The connective tissue about these ganglia is thickened, forming thin capsules, with which the large nerve trunks are in close connection, even forming part of the wall. From these trunks myelinated nerve fibers penetrate the ganglia and are seen to terminate about the nerve cells in simple basket-like networks, to be further described below. Unmyelinated nerve fibers are found within the nerve trunks, many of which are seen to originate from the ganglion cells. Isolated nerve cells also are found near the main nerve trunks of the extra-chondrial plexus along the bronchi and within the loose tissues just inside the hilum. These are of the same cell type and have connections similar to those in the larger ganglia.

Within the trachea between the cartilage plates and the muscle bundles lies a much finer plexus of nerves, many of which are myelinated though the majority are devoid of a sheath. These fibers form a finer network than that outside the trachea, the meshes lying for the most part transversely to the long axis of the air tube; only a few of the larger myelinated fibers parallel the lumen. This may be called the subchondrial plexus; it is derived from branches of the outer plexus which penetrate the wall. The finer fibers are for the most part post-ganglionic; many of them are seen to send out fine collaterals to the smooth muscle beneath which the plexus lies.

As the single main bronchus approaches the lung sac the cartilage plates become more irregular, anastomosing with each other and forming unevenly-shaped plates which become more sparse caudally and are lost entirely at or near the point where the air tube enters the atrium. This disappearance of the cartilage at this level ~~thus high~~ in the lung leads to a fusion of the two formerly separate plexuses, and from this point distally their fibers proceed as a single network. I have not encountered terminal ganglia beyond this point. The nerve strands and blood vessels take their course within the larger smooth muscle trabeculae which form the boundaries of the so-called alveoli, or chambers, which line the cephalic one-third of the snake's lung. As the trabeculae become thinner and more sparse in the more caudal portions of the lung the nerve fibers can often be seen crossing the open floors of the atria just beneath the epithelium, and in those regions where the lung wall contains no muscle at all, only a few myelinated trunks can be discerned, here usually paralleling the larger blood vessels, though sometimes isolated. They ramify through the submucous connective tissue and send fine rami up into the basement membrane.

SENSORY TERMINATIONS (Snake)

A few sensory nerve endings have been seen in the epithelium of the trachea and main-stem bronchus. These are of a rather simple type, showing less arborization than those described in the mammalian lung (Larsell, '21), but they appear to be of the same general construction. Three or four principal branches proceed from the medullated nerve fiber, and from these secondary and tertiary divisions extend into the epithelium. The main nerve fiber and all the branches are studded with varicosities which vary in size and shape; and upon all the fine terminal endings are small, rounded knobs. (Fig. 1.) In the bronchial epithelium these terminal knobs lie at varying depths between the epithelial cells, some of the finer arborizations crossing others above and below.

A similar type of ending has been observed in both snake and turtle preparations lying within the respiratory epithelium of the alveoli; resembling in both form and position the endings described by Wolff ('02) in the interalveolar septa of the frog's lung. Rather large, varicosed, medullated fibers follow the muscle bands and branch upon entering the alveoli; and from these primary rami secondary branches may be given off. At the ends of the latter rami lie the terminations, which are composed of principal branches, from which secondary and tertiary arborizations extend, all ending in fine, rounded knobs. (Figs. 1 and 2.) Fine rugosities are seen upon all the terminal fibers of the nerve endings, often more marked and larger at points of branching, thus appearing as nodal points. Cross sections through these endings and oblique views of the same make it quite certain that they lie within the respiratory epithelium. The manner of branching of the main nerve fiber gives rise to groups of sensory terminations, scattered over the floor of an alveolus, most of them entirely isolated from the smooth muscle fasciculi which form the walls, others in close contact with them.

Like endings have been noted in the caudal portion of the snake's lung, well beyond the limit of smooth muscle, though here they are much less frequently encountered and are apparently of simpler construction. Some myelinated fibers do not branch to form a group as is the usual condition, but terminate in single endings of the type described. The larger groups of sensory endings of this type were most numerous in the upper, alveolated portion of the snake's lung.

A second type of sensory termination (Figs. 3 and 4) appears in the snake's lung, differing quite markedly from the first described. These are found in the walls of the alveoli, but are distinctly seen to lie deep to the epithelium within the connective tissue. Usually they are situated at the ends of very short side branches of a main trunk. However, some of the large trunks terminate in endings of this type. (Fig. 5). They are peculiar in the fact that they are surrounded by a capsule, quite distinctly seen even in preparations in which no counter-stain has been used. As figures 3 and 4 show, the capsule appears as a series of concentric lamellae about the rather complex ending, which is composed of two to four primary branchings from which finer secondary and tertiary fibers arise, all terminating in rounded knobs. The latter usually are quite short and often bent as though confined within the limits of the capsule. The larger of these encapsulated sensory nerve endings are quite complex, with numerous tertiary branchings, and such large endings are as a rule the terminations of myelinated fibers. Those which lie along the course of the fibers are smaller, exhibit less arborization, and have fewer tertiary rami. The medullary substance of the main nerve fiber terminates just proximal to the capsule.

The position of these endings is of interest, for they always are found near a point of junction of two or more smooth muscle trabeculae and where the nerve trunk leaves its usual course within a trabecula to traverse the floor of an alveolus. I have failed to find them in the epithelium of the main bronchus. This encapsulated ending is not found in large groups, as is the simpler type first described, though two are often found together.

A third and entirely different type of ending is that found within the smooth muscle bundles ehtmselves. (Fig. 6). This differs widely from those previously described. The nerve fibers leading to such endings are large and medullated, their trunks studded with heavy varicosities. As they near their terminations they branch after much the same fashion as those which terminate in the alveolar epithelium. The nerve trunks always lie within the smooth muscle bundles. Their branches follow the smaller subdivisions of the trabeculae, in the substance of which the endings are found, lying among the smooth muscle cells. Each secondary branch terminates in a single nerve ending. Careful focussing reveals a series of fine fibrils which proceed usually from nodal varicosities of the primary branches of the ending. These fibrils penetrate between the smooth muscle cells or embrace the muscle bundle. Cross sections show definitely that the fibrils of this ending lie <u>between</u> the smooth muscle cells, their rounded terminations are not in direct relation to the cells as are the simple motor knobs. Some of the terminal twigs cross each other or may anastomose, and in larger endings of this type the primary and secondary branches cross and wind about the muscle band in an intricate manner. In the proximal portion of the snake's lung groups of these endings are quite frequently encountered, as many as eight or ten having been counted arising from the branchings of a single large, myelinated fiber. (Fig. 7). As the smooth muscle bands become more sparse in proceeding caudad, these endings are less often seen, and are not so frequently grouped, but more usually lie singly as terminal endings. A striking fact is that these endings also are almost invariably found near points of bifurcation of the smooth muscle bands which line the alveoli.

The name of "smooth muscle nerve spindles" has been applied to similar endings by Larsell, ('21) who described them first in the mammalian lung. The structure in the snake, while simpler, is so nearly identical as to justify a similar interpretation and nomenclature. The position and structure of these spindles would indicate that they are stimulated by contraction and relaxation or stretching of the smooth muscle bands in which they lie. The ~~analogy with~~ similarity to the neuro-muscular spindles of skeletal muscle and the sensory spindles in tendon is quite striking.

Carpenter ('24) has found tufted or arborescent endings in the longitudinal smooth muscle coat of the dog's small intestine, to which he ascribes a sensory function. These lie free between the muscle cells, and do not embrace the muscle strands as do those just described, but are made up of exceedingly delicate, heavily varicosed fibrils, compactly arranged. These fibrils are more numerous and are set more closely together than are those of the smooth muscle nerve spindles, hence the latter are probably distinct forms, though possibly analogous.

MOTOR TERMINATIONS (Snake)

Motor endings of simple type are found in the snake's lung, in the musculature of trachea and bronchus, and also in the tunica media of the pulmonary arteries and veins.

Several writers have described motor endings in the smooth muscle of the trachea in the mammal, and Ploschko ('97) described small ganglion cells with fine processes which pass to the smooth muscle bundles, where they divide and terminate in small rounded knobs upon the individual muscle cells. Larsell ('21) also has described these ganglion cells, which he found both singly and in groups. These cells are surrounded by networks of finely varicosed fibers which seem to originate from the vagus, splitting to form basket-like pericellular synapses about the small ganglion cells. This arrangement provides the typical pre-and post-ganglionic mechanism which is found throughout the visceral efferent system.

The reptilian lung forms no exception to this rule. Ganglion cells are found along the trachea and bronchus, and within the cellular tissue of the hilum of the lung. They appear in small groups or singly in the snake's lung, the larger ganglia being surrounded by capsules of connective tissue. The nerve trunks lie in relation to the capsules or may traverse their substance. (Fig. 8). From the cells bare axone fibers are sometimes distributed directly to the smooth muscle bundles, where their collateral branchings may be traced to fine, knob-like terminations upon the smooth mus - cle cells. (Fig. 9). In other instances the axone fibers join the larger trunks and become lost, as it is impossible to trace individual fibers of so small a size. It is apparent, however, that similar small, unmyelinated fibers are given off from these nerve trunks within the lung parenchyma. Their branches can be seen everywhere in favorable preparations as numerous filaments lying parallel between the smaller smooth muscle bundles of the trabeculae, these in turn giving off collateral twigs at right angles which end in the familiar knob-like motor endings described.

Motor fibers in the smooth muscle of the trachea and bronchi are much more numerous than are those in the alveolated portion of the lung itself, where they become proportionately less in number as the smooth muscle fasciculi become fewer and father apart.

INNERVATION OF THE PULMONARY VESSELS. (Snake.)

Sections of the snake's lung stained with the methylene blue technic are very faborable for observations on the innervation of the pulmonary blood vessels. There appears to be a much richer nerve supply than experimental evidence would infer, and in the larger branches of the pulmonary artery a very thickly-set fibrillar network is seen. The nerve bundles lie in the adventitia, winding about the lumen in an irregular manner, roughly parallel to the lumen, anastomosing with or crossing other bundles at frequent intervals. They give off secondary collateral fibers to the smooth muscle of the tunica media, in much the same manner as do the motor fibers in the smooth muscle of the lung. (Fig. 10). These secondary branches usually run in the same direction as the trunks in the adventitia, and from them proceed extremely fine, beaded fibrils which parallel the circumferance of the blood vessel, between the muscle cells; their terminal twigs bear motor knobs similar to those described in the lung itself.

The origin of these fibers to the blood vessels is in doubt. Karsner, ('11) demonstrated a fine network of nerve fibers with small end knobs in the tunica media of the pulmonary artery of the dog, but merely suggested an origin from the anterior and posterior pulmonary plexuses. Berkeley ('93) and Larsell ('21) have observed that the smaller branches of the pulmonary artery in the dog and rabbit derive nerve fibers from trunks which lie in the bronchial extrachondrial plexus. I have noted like connections both in the hilum of the snake's lung, where the large nerve trunks lie close to the main pulmonary artery, and in more distal, smaller divisions of the artery. Carlson and Luckhardt ('20) have obtained results experimentally which indicate that these motor nerve are derived chiefly from the vagus in the reptile and amphibian.

Fine nerve fibers to the capillary walls have been demonstrated in several of my preparations. These have been repeatedly seen and described in mammal, reptilian and amphibian. They were first noted by Beale ('60), confirmed by Krimke ('85), and developed by Glaser ('20) and by Krogh and his assistants ('20-'22). The nerves show fine varicosities at irregular intervals, and appear to anastomose with fibers paralleling other capillaries. (Fig. 11). I have seen no ganglion cells in connection with these networks. The fibers usually lie upon or at the sides of the capillaries, each of which has at least one, sometimes two, accompanying fibers; in some cases the nerve fibers run in a close spiral along a portion of the capillary, instead of paralleling it. Eugling ('08) did degeneration experiments which seem to prove that these fibers are derived from the dorsal sympathetic as post-ganglionic trunks. Anatomical evidence, according to Krogh ('22) seems to point to an anastomosing network as the true condition. The physiological application of the anatomical condition here found opens a wide field for investigation, since motor effectors in the form of the cells of Rouget ('79) have been proven to exist.

Observations (continued.)

2. Turtle.

The arrangement of nerve fibers about the trachea and bronchi of the turtle is almost identical with that in the snake. The trunks of the extrachondrial plexus are large and heavy, while those of the subchondrial plexus are fewer in number, small and fine, with a larger number of unmyelinated fibers. Ganglia of a much greater size than those of the snake are connected with the nerve trunks which parallel the trachea and main-stem bronchi.

The main bronchi in the turtle lung subdivide at the hilum, and cartilage plates of irregular shape are found well down within the upper portion of the lung, as far as the infundibula which empty into the upper atria. The arrangement of the plates is quite loose in this region, so there is not a definite point of fusion of the extra- and sub-chondrial plexuses, but they gradually merge together and are continued into the substance of the lung as one plexus. Ganglia do not appear beyond the first branching of the main-stem bronchus.

The larger nerve trunks lie within the smooth muscle bands. Frequently smaller branches depart from the main trabeculae and traverse the alveoli for long distances, passing over the intervening muscle bands beneath the basement membrane in a direct course, only to become lost again within the substance of another muscle fasciculus.

SENSORY TERMINATIONS. (Turtle)

The sensory nerve terminations of the turtle's lung include the same three types which were found in the snake material, namely, (1) a simple type of ending lying within the epithelium upon the floors of the alveoli and in the mucosa of the bronchi; (2) a more complex structure placed beneath the basement membrane and surrounded by a capsule, and (3) the smooth muscle nerve spindle, almost identical in form and distribution with that found in the lung of the snake.

The first type of ending is so nearly identical with the one described in the snake that further description is unnecessary.

Encapsulated sensory terminations in the turtle lung are larger and more complex than those seen in the snake's lung. They lie near the muscle bundles in such relation to points of bifurcation as to suggest that they are stimulated by the collapse of the alveoli or by their excessive distension. The secondary and tertiary branches of this ending are characteristically short, and the entire ending is quite rounded, giving the impression of a flat disc. They less frequently lie at the ends of short laterals from the medullated trunks, but usually are placed singly at their terminations. I have never found these endings in groups.

The muscel spindles are large in the turtle's lung. They are usually embedded among the smooth muscle cells of a trabecula, but may lie superficially, their rami surrounding the muscle bundle. Numerous anastomoses between the secondary and tertiary branches are the rule, the varicosities are heavy, often appearing as plate-like widenings rather than as small knobs. The latter are numerous, however, and all terminals lie between the muscle cells.

MOTOR TERMINATIONS. (Turtle)

Efferent visceral fibers are seen in all the turtle preparations as fine, non-medullated filaments dotted with minute enlargements, lying between the smooth muscle cells, upon which they terminate. The source of these fibers in the mammal has been found by Larsell ('22) to be the vagus nerve, through which preganglionic fibers pass to the terminal ganglia. These lie on the main-stem bronchi or within the hilum of the lung. (Fig. 12). The ganglia of the turtle lung are larger, and include a greater number of nerve cells than do those in the snake. The pericellular networks (Fig. 13).

about the cells are also somewhat more complex, but the essential arrangement of afferent and efferent nerve fibers, nerve trunks and capsule are identical in these two reptiles.

INNERVATION OF THE PULMONARY VESSELS. (Turtle)

The networks of minute, unmyelinated fibers in the walls of the pulmonary vessels are exceedingly rich in the turtle. They appear to be more numerous than those seen in the arteries of the snake's lung; the arrangement, however, is almost identical, so does not necessitate a second detailed description.

I have failed to find in the turtle lung the capillary nerve network which appeared in some of the snake material, partly, perhaps, because of the variation in staining technic.

Summary.

1. Sensory terminations are present in the epithelium of the mainstem bronchi and the alveoli of the snake's lung. Two structural types are present, the first being non-encapsulated, finely branched, with endings lying between the epithelial cells. The second type is encapsulated, and is located in the connective tissue just beneath the epithelium, usually near the wall of an alveolus or at a bifurcation of smooth muscle bands.

2. A specialized intramuscular nerve ending is found in the lungs of both snake and turtle, the fibers of which lie between the smooth muscle cells or twine about the muscle fasciculi; the fibers with which they are connected are myelinated and are derived from the trunks of the plexuses about the bronchi.

3. Nerve endings of motor type are present in the smooth muscle trabeculae of the trachea, bronchi and lung parenchyma of both forms investigated.

4. Intrapulmonary ganglia of varying size are located in the hila of the lungs near the bronchi in these reptiles. The ganglion cells are surrounded by basket-like, pericellular networks, which probably represent the terminations of preganglionic myelinated nerve fibers from the pulmonary plexuses. Postganglionic axones are distributed to the smooth musculature of the bronchi and lungs.

5. The pulmonary vessels are supplied by a rich plexus of very fine nerve fibrils, which terminate in relation to the smooth muscle cells of the tunica media.

The capillaries are seen to be supplied by fine network of nerve fibers which parallel them or wind spirally about the lumina.

DESCRIPTION OF FIGURES

Fig. 1 Sensory nerve terminations in epithelium of an alveolus in the cephalic third of a snake's lung. Snake 10 (a). Methylene blue stain. Spread preparation. Camera Lucida.

Fig. 2 Group of sensory nerve terminations in epithelium of alveolar floor. Snake 10 (a). Methylene blue stain. Spread preparation. Camera lucida.

Fig. 3. Encapsulated sensory nerve endings situated in sub-epithelial connective tissue near a muscle bundle. Snake 13 (a) ii. Methylene blue stain. Spread preparation. Camera lucida.

Fig. 4 Sensory nerve terminations of encapsulated type located near a bifurcation of two smooth muscle trabeculae. Snake 13 (a) i. Methylene blue stain. Spread preparation. Camera lucida.

Fig. 5 Terminal encapsulated ending of sensory type overlying a junction of smooth muscle bands. Snake 13 (a) iv. Methylene blue stain. Spread preparation. Camera lucida.

Fig. 6 Smooth muscle nerve spindle embracing a small muscle bundle. Snake 10 (2). Methylene blue. Spread preparation. Camera lucida.

Fig. 7 Aggregation of smooth muscle nerve spindles about end of an alveolus in cephalic portion of snake's lung. Snake 10 (2). 50 micra. Methylene blue stain. Camera lucida.

Fig. 8 Large, fusiform ganglion near main stem bronchus of snake, showing portions of peri-cellular, basket-like networks and the relation of nerve trunks to capsule. Snake 24 (2). Methylene blue stain. 100 micra. Camera lucida.

Fig. 9 Motor nerve terminations in smooth muscle of small trabecula of snake's lung. Snake 7 (a). Methylene blue stain. Spread preparation. Camera lucida.

Fig.10 Distribution of unmyelinated nerve fibers in tunica media of a small pulmonary artery. Snake 7 (a). Methylene blue stain. 50 micra. Camera lucida.

Fig.11 Network of capillaries with accompanying plexus of fine nerve fibers, seen in wall of an alveolus. Snake 25 (a). Methylene blue stain. Spread preparation. Camera lucida.

Fig.12 Ganglion in hilum of turtle lung, showing portion of nerve trunk in relation to capsule. Turtle 15-R (17). Methylene blue stain. 100 micra. Camera lucida.

Fig.13 Cluster of ganglion cells near bronchus of turtle lung, showing typical basket-like, pericellular networks about the sympathetic ganglion cells. Turtle 15-R (17). Methylene blue stain. 100 micra. Camera lucida.

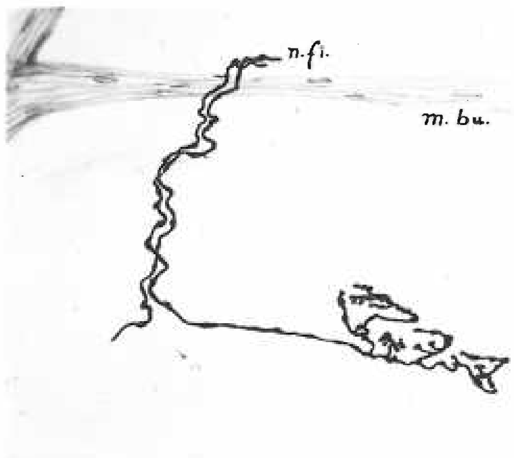


Fig 1.

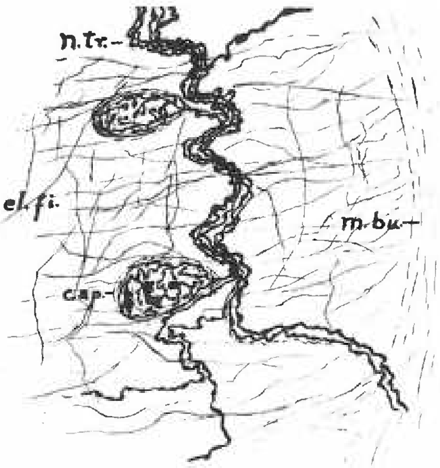


Fig. 3

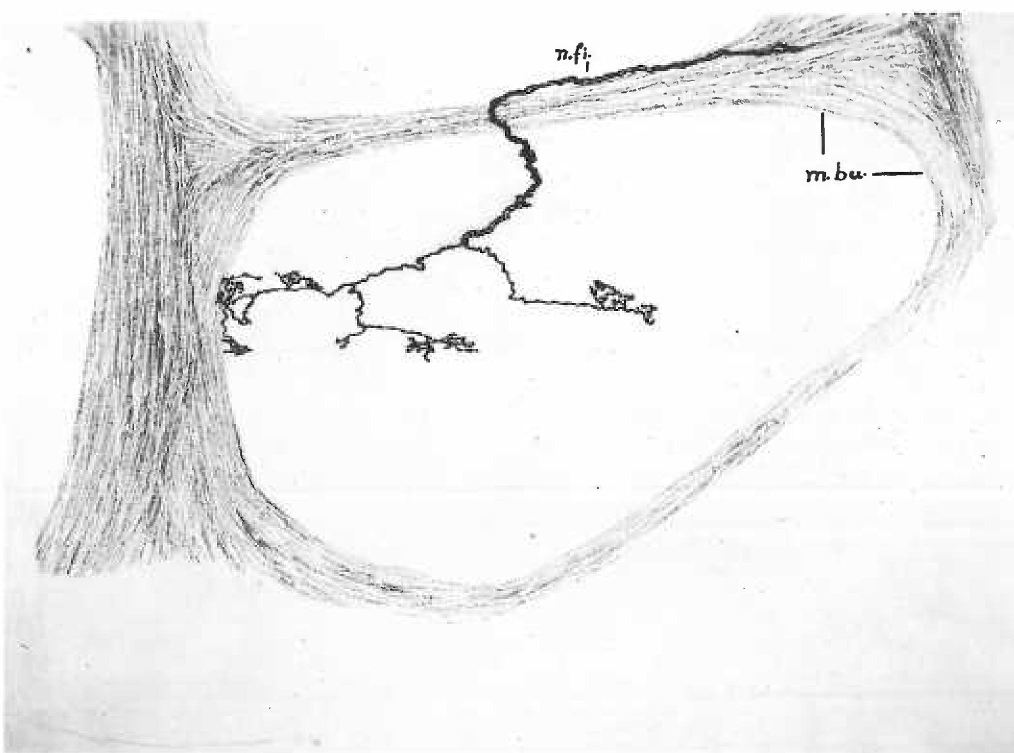


Fig. 2

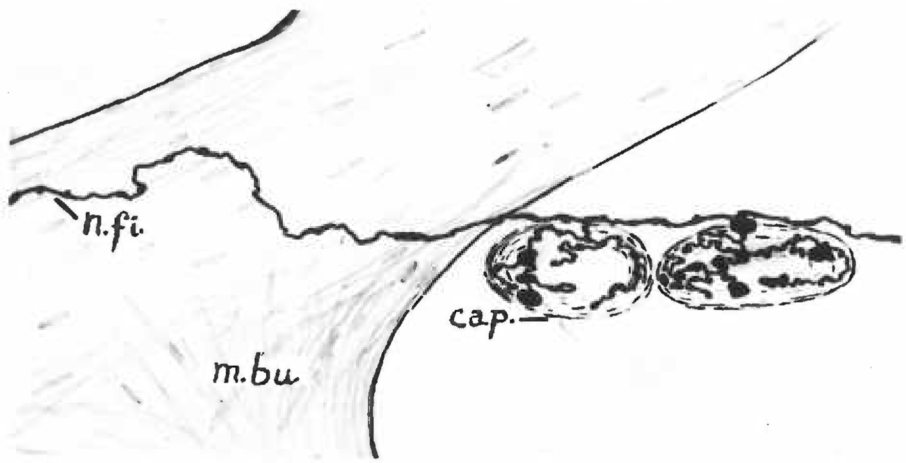


Fig. 4.

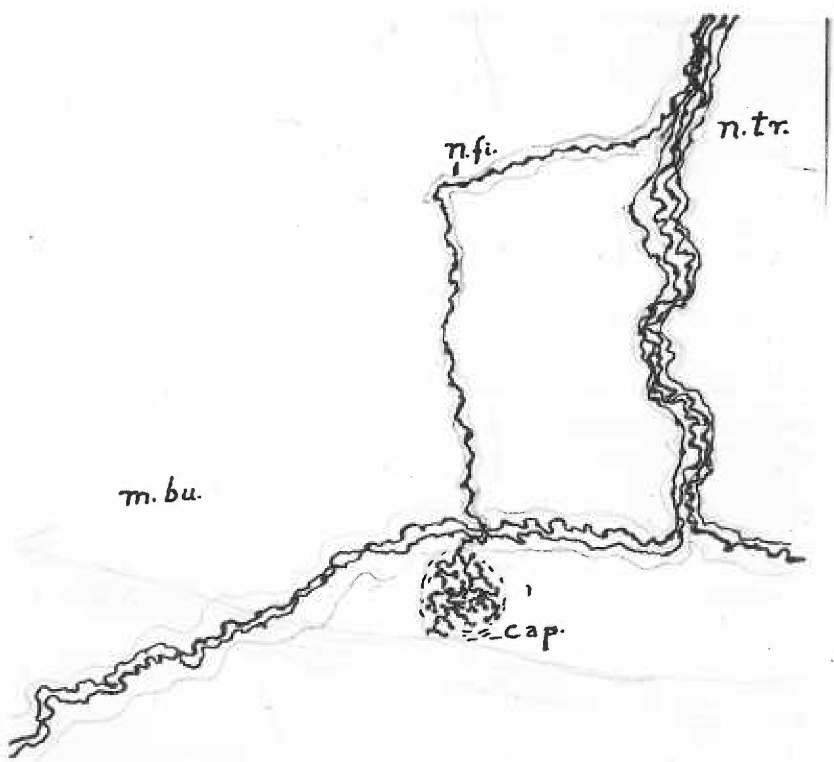
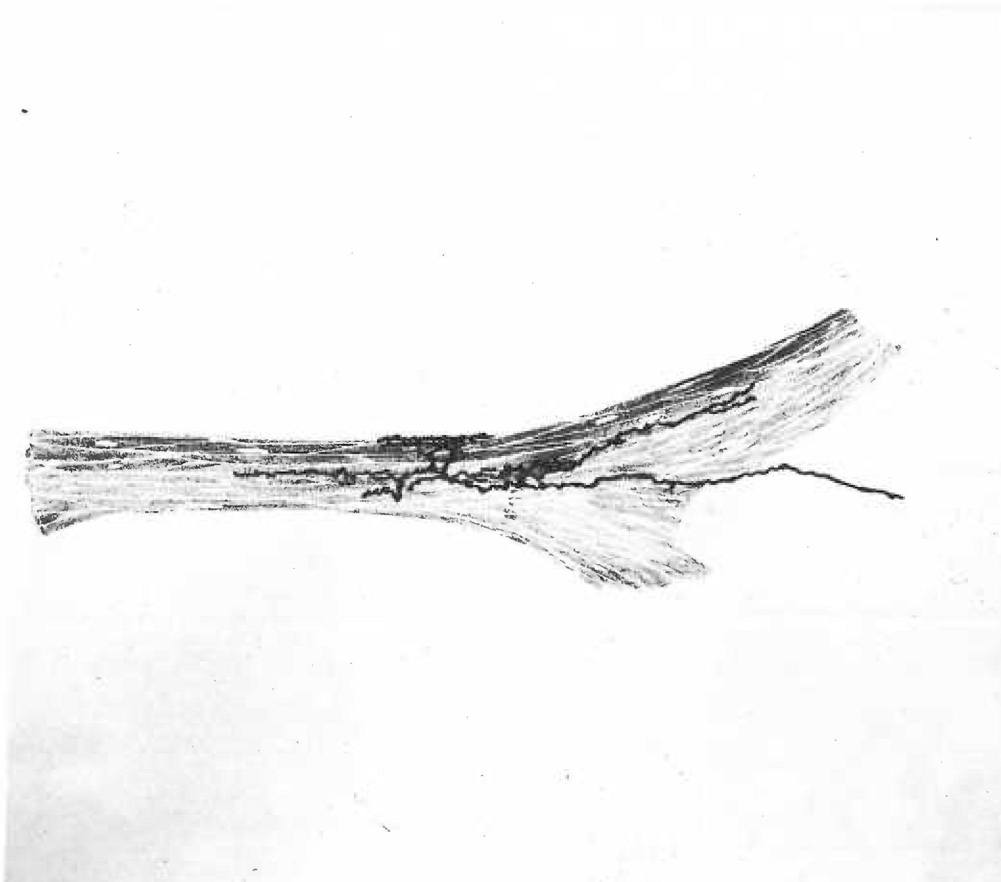


Fig. 5



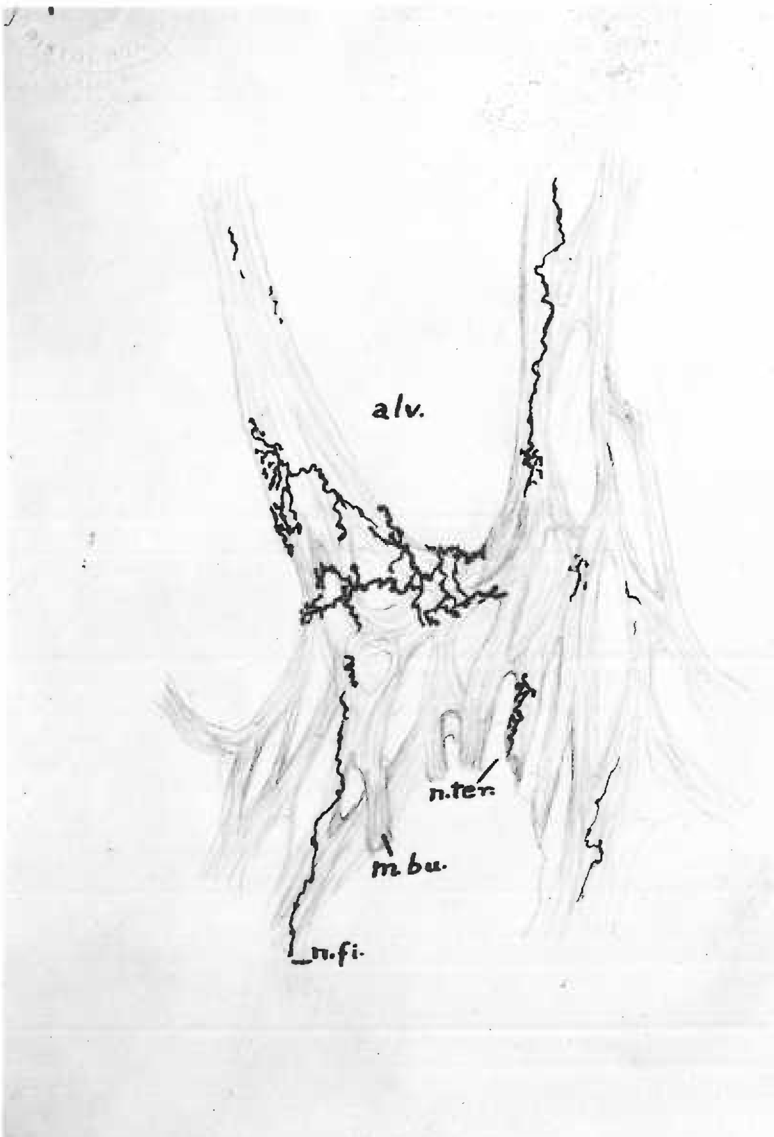


Fig. 7.

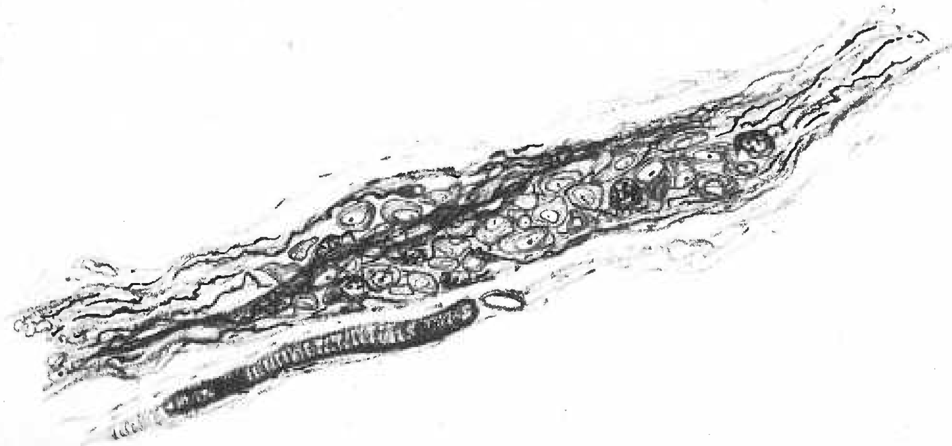


Fig. 8.

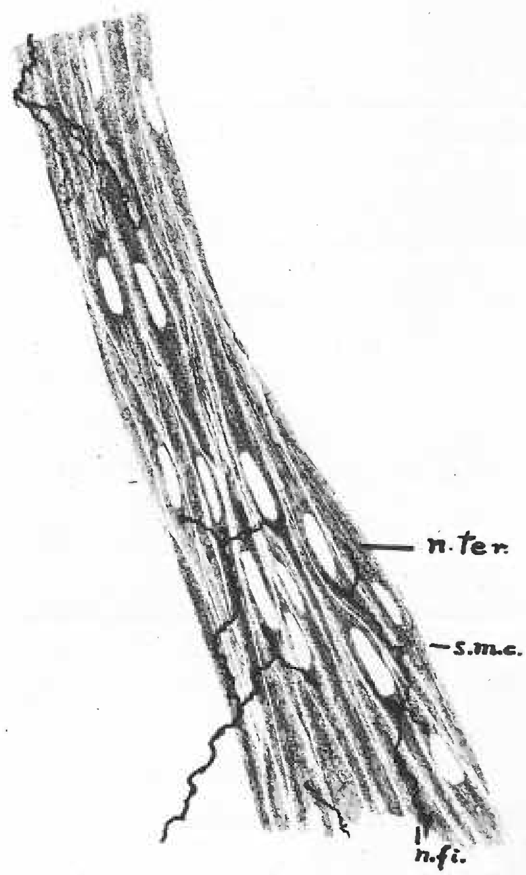


Fig. 9.

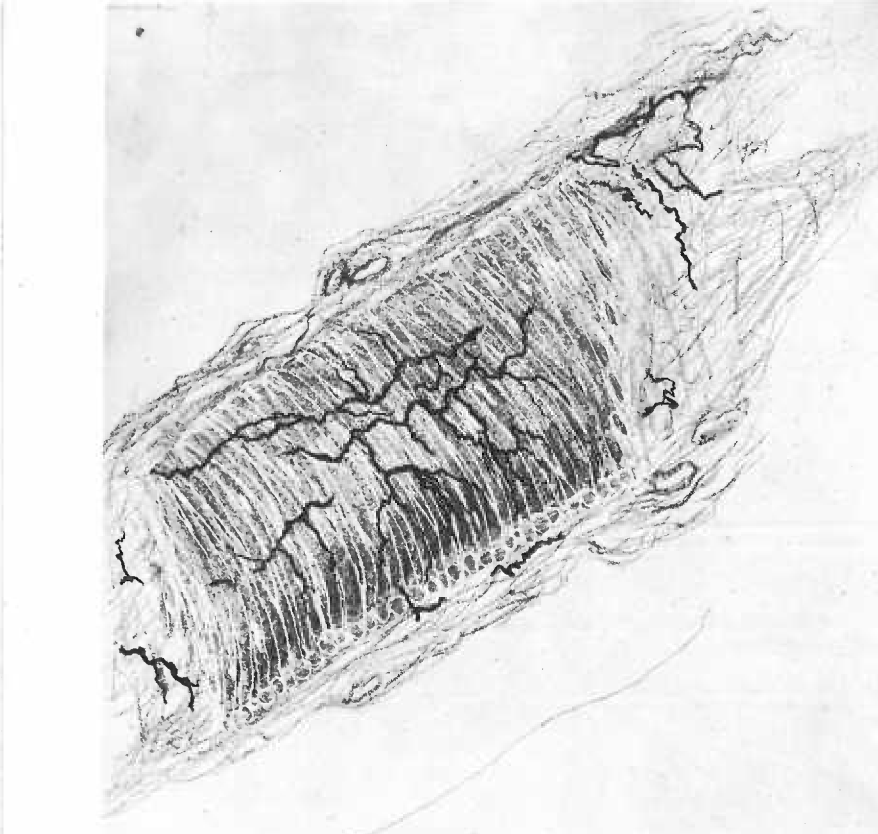


Fig. 10.

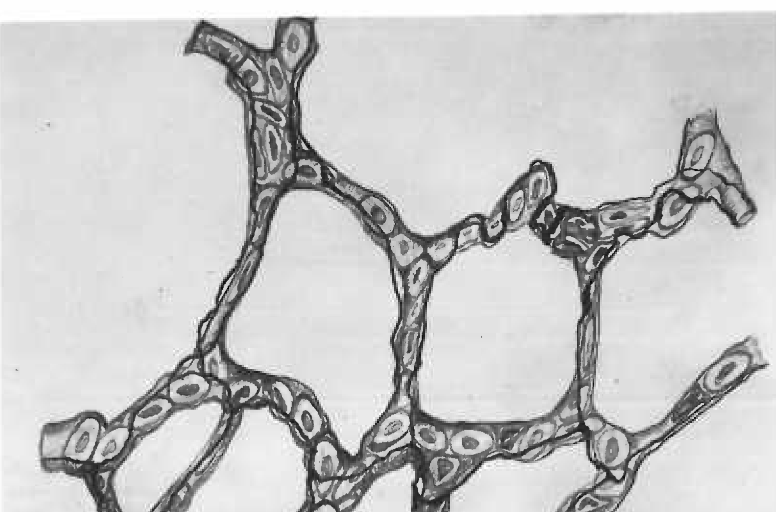


Fig. 11.

Fig. 12.

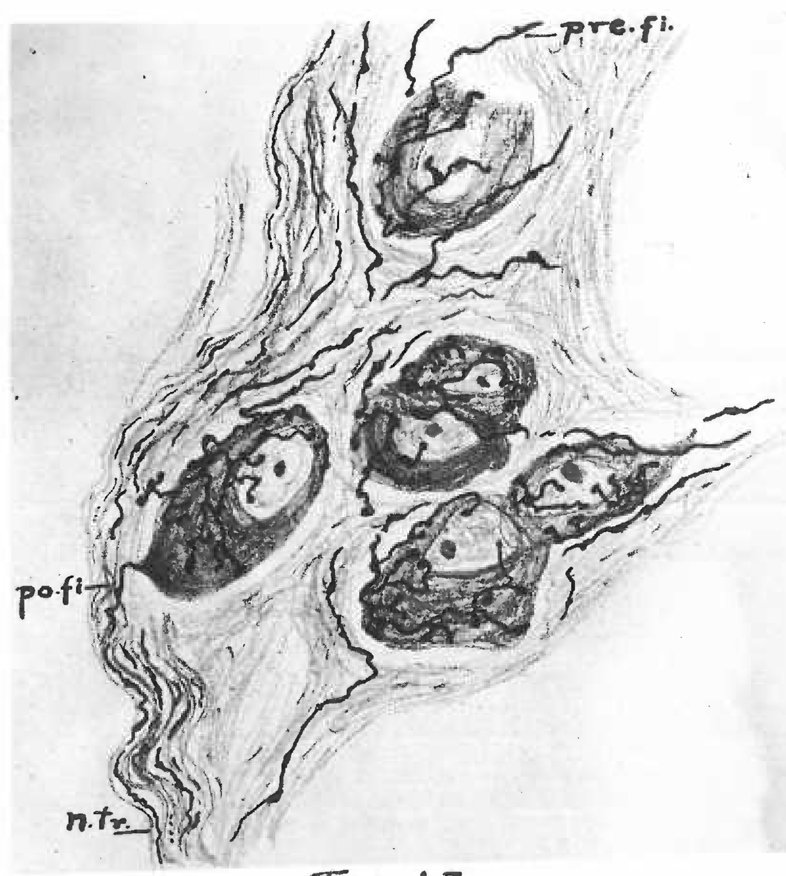


Fig. 13.