is more often torn than the sarcolemma, which remains intact and connects the severed ends of the sarcous substance (Fig. 3391). The sarcolemma, under favorable circumstances of light and preparation, does not appear homogeneous, but fibrillated and punctated, and in some cases there seems to be a connection between the sarcolemma and the endomysium. Occasionally, when the sarcous substance is torn and retracted, a thin layer remains adherent to the sarcolemma around part or the whole of the circumference. In such a case the sarcolemma appears striated, but much less opaque than the whole fibre (Fig. 3391). When the entire sarcous substance retracts, the sarcolemma appears like a hollow transparent sac, and is often folded (Figs. 3386, 3391). If the fibres are considerably stretched in preparation, the sarcolemma joining the broken ends of the sarcous substance may become very slender and appear like a tendinous termination. In most cases, however, the sarcolemma may be traced between the retracted ends of the sarcous substance, although both ends may not be visible in the same field of the microscope. Whether the sarcolemma simply encloses the sarcous substance as the finger of a glove covers the finger, or whether it has a structural connection with the sarcous substance, is not yet determined. According to the views of Krause, delicate partitions arise from the sarcolemma and pass entirely through the muscular fibre, dividing it into compartments. When the sarcolemma of insects is slightly raised from the surface of the fibre, it is wavy, and at the part of the wave nearest the sarcous substance a delicate process is seen to extend to the muscular substance. This appearance was pointed out and figured by Bowman, and may be seen with the greatest clearness in the muscular fibres of the larva of *corydalis*. The common appearance in vertebrate muscle is that shown in Figs. 3386, 3391, where the sarcolemma seems to be simply an enclosing sac.

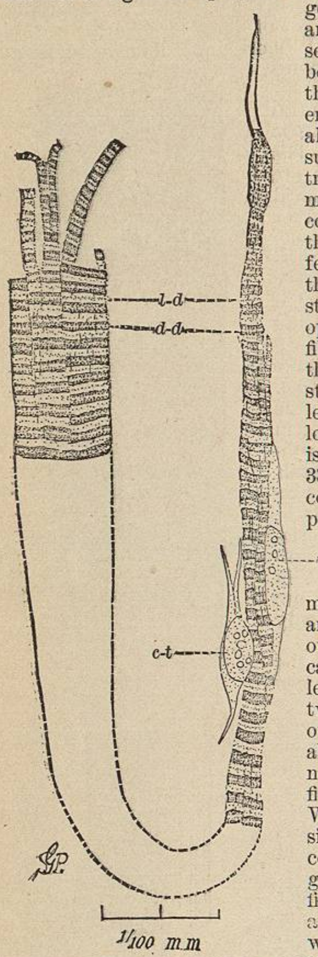

FIG. 3392.—The Terminal Part of a Muscular Fibre ending within a Muscle, to show the End of the Fibre, Isolated Fibrils, and the Various Discs which are sometimes seen in Mammalian Muscle. From the latissimus of a kitten five weeks old. The fibre is not striated beyond the swelling near the terminal end, and a striated branch is present on the right side just beyond the large muscle corpuscle. At the larger end the discs are displaced so that part of a dark disc is opposite a light disc. The entire length of fibre here shown is 0.95 mm. The intermediate part, indicated by dotted lines, is greatly abbreviated. Drawn with a camera lucida at a magnification of 800 diameters. All the details of structure were determined with a $\frac{1}{18}$ homogeneous immersion objective. (Drawn by Mrs. Gage.) *c-t*, Connective-tissue corpuscle partly covering the fibre; *d-d*, dark disc. This is very distinctly divided into two equal parts by a narrow light band (middle or Hensen's disc, compare Fig. 3393); *l-d*, light disc. This is divided into two equal parts by a narrow dark band (membrane of Krause, intermediate disc, compare Fig. 3393); *m-c*, muscle corpuscle. The cell body, nucleus, and nucleoli are all very distinct.

Sarcous Substance (*Muscular or Contractile Substance*).—The substance proper of the striated muscular fibres is divided into two constituents: (1) the more or less homogeneous, semiliquid intermediate substance or *sarcoplasm*, corresponding to the hyaloplasm of undifferentiated cells; and (2) the *fibrils* or sarcostyles, corresponding to the spongioplasm or network of many cells. The fibrils are arranged longitudinally, and are believed to be composed of thicker and thinner segments. The space unoccupied by the fibrils is filled by the sarcoplasm. As the thicker segments of the fibrils are opposite one another throughout the entire fibre, there is given the appearance of a dark segment or disc followed by a light segment when the muscle is studied under the microscope with transmitted light. The dark disc corresponds to the thicker part of the fibrils, and the light disc to the thinner part where the sarcoplasm is in greatest abundance. The longitudinal arrangement of the fibrils gives also the appearance of longitudinal striation; but this is usually less marked than the transverse striation. While the appearance of a striated muscular fibre is so evident and characteristic, the finer structure has proved one of the most difficult problems in histology.*

The difficulty of the investigation is greatly increased because it is so hard to distinguish between appearances which may be purely optical and those which are due to structural differentiation. The case is well stated by Bowman (1840): "The improvements which have taken place in the construction of microscopes appear, indeed, to have only afforded grounds for new differences of opinion"; and by Leydig (1885): "The complexity of structure of muscular tissue, and the fineness of its component parts give rise to so many doubts that one is often led to wish that it were possible to go beyond the present attainable enlargement and perfection of the microscopic image." The most varied animals are selected from which to obtain muscular tissue for this most difficult investigation; insects and crustacea are favorite objects, from the distinctness of the structural details in

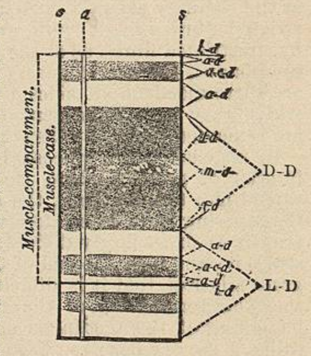

FIG. 3393.—Diagram to Show a Muscle Compartment, a Muscle Case, and the Discs into which a Muscle Compartment is divided, according to some Histologists. Modified from Engelmann. (Drawn by Mrs. Gage.) *Muscle compartment:* This one of the series of segments of which a striated muscular fibre is supposed to be composed. It includes one entire dark disc (*D-D*) and half a light disc at each end of the dark disc. It therefore corresponds in extent to a Bowman's disc. For those who accept the existence of Krause's membrane, it is the part of a muscular fibre between two such successive membranes. *Muscle case:* This, according to Krause, comprehends a sarcous element (muscle prism), with a limited amount of intermediate substance at the sides and ends. The whole case is enclosed by Krause's membrane at the ends, and a special membrane at the sides. In the figure, the muscle case is the part of the muscle compartment between s and *a*; *D-D*, *dark-disc*, composed of two dark bands (*t-d*) separated by a lighter disc (*m-d*), *middle disc of Engelmann*, or Hensen's disc. *L-D*, *light disc*. This is composed of two symmetrical halves, each half forming the end of a muscle compartment. Each half is composed of two light discs (*a-d*), and a granular disc (*ac-d*), the so-called *granular* or *accessory disc*, and the disc *i-d* (*intermediate disc*), the latter forming the boundary between two successive muscle compartments. Krause's membrane is usually said to consist of the intermediate disc and the two adjacent accessory discs, with the light discs between them.

their muscular fibres. No matter what animal is chosen, it is too often assumed that the structure of all striated muscle is identical with that under consideration—an assumption which often requires the imagination to fill out details not visible when muscle, other than that taken as the standard, is examined. From his own study, the writer believes that all the appearances described by original observers may be demonstrated, if muscles from a sufficiently great number of animals are studied both before and after the application of a sufficiently large variety of chemical agents, and if a microscope having sufficient range of magnification and excellence of image is employed.

* In the epidermis of *lampreys*, and perhaps also in some other fishes, there are large clavate cells which resemble very strikingly short pieces of striated muscular fibres. Not only is the agreement very marked, both in ordinary and polarized light, but the resistance of these cells to the action of caustic potash is like that of muscular tissue (Max Schultze, Arch. f. Anat. u. Phys., 1861, p. 281).

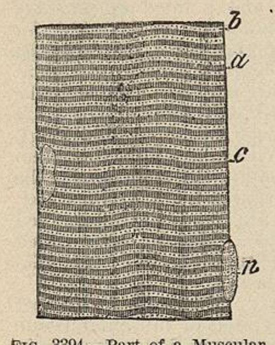

FIG. 3394.—Part of a Muscular Fibre from the Adductor Magnus of a Rabbit, to show the Appearance to an Extended Mammalian Muscular Fibre. Magnified 700 diameters. (Ranvier.) *a*, Dark disc; b, Krause's membrane or intermediate disc; *c*, light disc; *n*, muscle corpuscle seen in profile.

It was shown by Bowman,[4] whose paper in the "Philosophical Transactions," 1840, is the most prominent landmark for the histology of striated muscular tissue, that the fibres have a tendency to break up into fine fibrils (*primitive fibrillæ*), which extend parallel with the long axis of the muscle, and appear in structural details like the entire fibre, and that they may also break up into discs which are at right angles to the long axis of the fibre. In breaking into discs (*Bowman's discs*), the plane of cleavage is through the middle of the light disc (Figs. 3392, 3393;) each disc of Bowman is therefore composed of an entire dark disc, with half a light disc at each end. These appearances were considered by Bowman to indicate, not the existence of fibrils and discs in the living muscle, but of minute rounded or angular particles (*Bowman's sarcous elements*), which form the true contractile part of the fibre; and that these are connected together on all sides by a more fluid and non-contractile substance, sarcoplasm—that connecting the sarcous element end to end into fibrils—differing somewhat from that connecting them side by side into discs, as is shown from the fact that the reagents causing the muscle to divide into fibrils do not cause it to break readily into discs, and those causing the fibre to divide into discs do not cause it to break readily into fibrils. When, however, the cementing materials at both the sides and ends give way, the sarcous or ultimate elements of the fibre are, according to Bowman, isolated. Bowman's views were so simple, and so in accordance with observed facts, that they were almost universally accepted. There is, however, great difficulty in deciding what should be considered a primitive fibril composed of a single row of sarcous elements placed end to end, as it is possible to separate a fibre into fibrils so small that the structural characters are difficult of determination. The term *sarcous element*, to indicate the ultimate structural and contractile part of a muscular fibre, has been retained by most histologists, although the interpretation of what constitutes a sarcous element varies with almost every original investigator.

The following are a few of the more important modifications or enlargements of the views of Bowman upon the intimate structure of striated muscular tissue:

(A) *Action of Polarized Light.*—It was shown by Bruecke (1857) that the sarcous elements of striated muscular tissue are *anisotropic* (doubly refractive), and act like positive uniaxial crystals, while the intermediate substance is *isotropic* (singly refractive). As the sarcous elements retain their anisotropic character apparently unchanged during the shortening and broadening of contraction, Bruecke supposed that they were not simple but compound bodies, and he applied the term *disdiaclasts* to what he considered the elementary particles composing the sarcous elements, thus borrowing the terminology of Bertholin, who used this term to designate the hypothetical crystals of calc spar. On the whole, it cannot be said, however, that polarized light has been of material aid in comprehending the structure and action of muscular tissue.

(B) *Muscle Compartments, Additional Discs.*—It was shown by Bowman that, in addition to the broad light and broad dark discs, there sometimes appeared a narrow, dark line in the light disc and a narrow light band in the dark disc (Fig. 3392). The dark line in the light disc was also figured and described by Busk and Huxley, who considered it a disc composed of a row of minute sarcous elements. It has also been insisted on by Sharpey and Martyn, and later by Krause. Krause interpreted it as a continuous membrane (*Krause's membrane*, intermediate disc), extending from the sarcolemma and dividing the muscular substance into compartments (*muscle compartments*) which apparently correspond exactly in extent to the discs of Bowman (Fig. 3392). The view that Krause's membrane is a real structure, which extends from the sarcolemma through the fibre, thus making a complete partition, is supported by the fact that when the sarcolemma of insect muscle is partly torn from the fibre, delicate processes are often seen to extend to or toward the sarcous substance from the sarcolemma opposite the middle of the light disc. This appearance has not been observed and figured for mammalian muscle. The view of a continuous membrane making a partition in the fibre at regular intervals is opposed by the fact that a worm has been seen to move along within the sarcous substance from end to end of the fibre. Furthermore, the sarcous substance of the fibre closed up behind the worm, and the fibre appeared as before and still showed unmistakable contractions. Also, that in living and contractile muscular fibres of insects, which are apparently uninjured, the discs sometimes become displaced for a short distance along a sharp line, so that a dark disc is opposite a light disc. The displacement of the discs is shown in Fig. 3392, but here it might have been due to the traction exerted in preparation, and hence does not bear upon this question as does the displacement of the discs in the living and uninjured fibre.

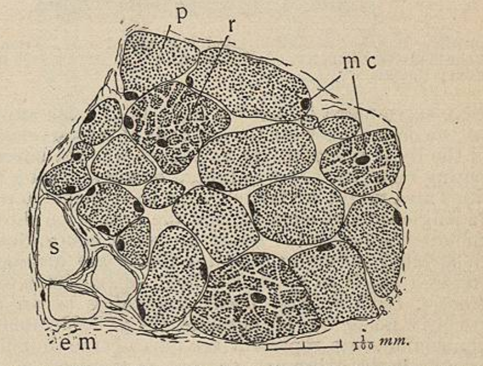

FIG. 3395.—Fascicle of Human Striated Muscle to show the Diversity in Size of Fibres, the Muscle Columns, and the Position of the Nuclei. (Drawn by Mrs. Gage.) Magnified about 350 diameters. *em*, Endomysium or connective tissue between the individual muscular fibres. In the lower left-hand corner some of the fibres are absent, the endomysium alone showing. *mc*, Muscle corpuscles. In muscular fibres with much sarcoplasm and evident muscle columns, some of the nuclei are in the middle of the fibre instead of at the surface; *p*, pale fibre with evenly distributed fibrils, and little sarcoplasm, and the nuclei all at the surface; *r*, red fibres showing abundant sarcoplasm and evident muscle columns. Some of the nuclei are in the middle of the red fibres; *s*, spaces from which the muscle fibres have been removed to show clearly the surrounding endomysium.

Besides the discs just considered, German investigators have described others which are shown in the diagram (Fig. 3393).

(C) *Muscle Cases.*—Besides the muscle compartments Krause considers that each sarcous element (muscle prism) is entirely enclosed by a membrane (Krause's membrane) forming the end, and a special membrane forming the sides (Fig. 3393).

(D) *Cohnheim's Areas, Muscle Columns.*—Cohnheim, in 1863, showed that in transections of frozen muscular fibres, there appeared dark polygonal areas (Cohnheim's

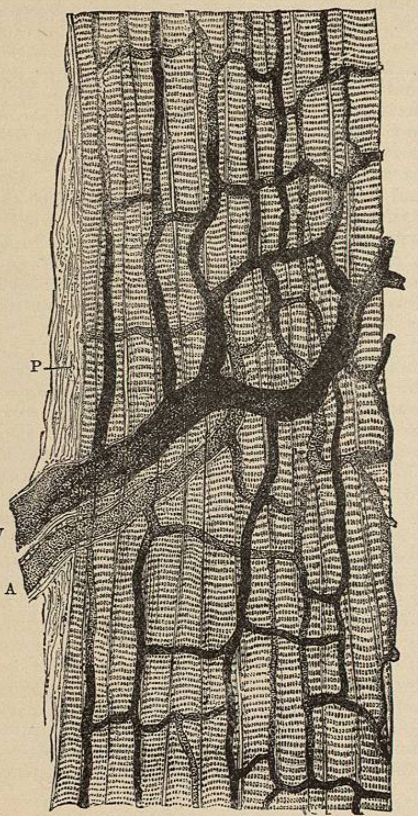

FIG. 3396.—Blood-Vessels of Striated Muscular Tissue. From a cat. Magnified 300 diameters. (Heitzmann.) *A*, Artery; *P*, perimysium; *V*, vein.

areas), surrounded by narrow light lines. He supposed that the dark areas were the cut ends of sarcous elements, and the light intermediate substance was the lateral cementing material. It was found, however, that a Cohnheim's area might be far too large to represent a section of a single sarcous element, and the area often showed a punctated appearance; hence arose the conception that in a striated muscular fibre the fibrils are arranged in bundles (*muscle columns*, Kölliker; *primitive muscular cylinders*, Leydig, Fig. 3386), something as an entire muscle is made up of fascicles (Fig. 3382), and that Cohnheim's areas represent sections of the bundles of fibrils (muscle columns), so that a transection of an entire muscular fibre has the same general appearance as the transection of an entire muscle. This is most striking in fibres with a large amount of sarcoplasm (Fig. 3395).

(E) *The Reticulated Arrangement of Contractile Substance.*—Heitzmann[9] (1873) introduced a new idea as to the structure of striated muscular tissue—viz., that, like simple protoplasm, the sarcous substance is made up of a reticulum of the true contractile matter, the meshes of this reticulum being filled by a more fluid intermediate substance. According to this view, the reticulum is so arranged that the nodal or crossing points (sarcous elements) are at regular intervals both transversely and longitudinally, the transverse row giving the appearance of a continuous dark disc, and the longitudinal row of a fibril. The light disc is traversed by the filaments of the reticulum, which pass between the nodal points. This hypothesis, with unimportant modifications, is now adopted by many histologists, and appears to be most in harmony with the latest views concerning histological structure.

(F) *Red and Pale Muscle.*—It has been known for a long time that some muscles, independent of their contained blood, are red and others pale. Ranvier[14] drew especial attention to this fact and pointed out an easy object for study in the semitendinosus of the rabbit for red muscle and the semimembranosus for pale muscle. Structurally the red muscle is characterized by abundant sarcoplasm, so that the fibrils are not very compact; the nuclei are not all at the surface, but some of them are between the well-marked muscle columns. The longitudinal striation is evident. With pale muscle the sarcoplasm is relatively small in amount, the nuclei are at the surface and the longitudinal striation is not well marked. In man the red and pale fibres are frequently intermixed in the same muscle (Fig. 3395). Muscle tissue called upon for almost constant contraction, like the diaphragm, has also much sarcoplasm.

VASCULAR SUPPLY OF STRIATED MUSCLE.—As in other tissues, the blood- and lymph vessels of muscular tissue do not enter the structural elements or fibres, but are in the connective tissue surrounding them.

(A) *Blood-vessels.*—The blood-vessels of this tissue are very numerous, and are estimated to contain one-fourth of the blood in the entire body. As a rule, each muscle receives two or more arteries, and gives off a corresponding number of veins. The larger vessels run in the perimysium, and send small branches into the fascicles, where they break up into a characteristic, parallelogrammic network of fine capillaries, the longer part of the mesh extending parallel with the fibres. The capillaries are the smallest in the body, many of them being smaller than the blood corpuscles of the animal to which they belong. In man the size varies from 3.5 μ to 6.5 μ (Kölliker, 1867) (Figs. 3382, 3396). It was shown by Ranvier that in red muscle the transverse branches of the capillary network and the smallest veins often possess saccular dilatations which are supposed to serve as reservoirs of oxygenated blood to supply the muscles during a long-continued contraction, or to act as receptacles during a maximal contraction.

(B) *Lymphatic Vessels.*—The lymphatic vessels of striated muscular tissue are supposed to be numerous. They lie between the fibres in the perimysium and endomysium, and are said by Klein "to have the shape of continuous long clefts or channels."

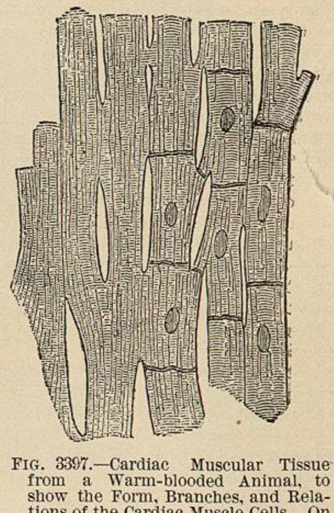

FIG. 3397.—Cardiac Muscular Tissue from a Warm-blooded Animal, to show the Form, Branches, and Relations of the Cardiac Muscle Cells. On the right the limits of the separate cells with their nuclei are exhibited somewhat diagrammatically. Magnified. (Schweiger-Seidel.)

Nerves of Striated Muscle.—The nervous supply of striated muscle is exceedingly abundant, and consists of both motor and sensory fibres. The special terminations of the nerves in the tissue will be considered under Nerves (*q.v.*).

MUSCLE SPINDLES.—Bodies of fusiform shape discovered by Kölliker[11] (1862) in the breast muscle of frogs. About the same time Kühne found similar bodies in mammalian muscles. It was discovered also that these spindle-shaped bodies contained one or more striated muscle fibres. The muscle fibres within the spindle were named by Kölliker, Weismann's fibres, in honor of their discoverer. The more common designation, however, is *intrafusal fibres.*

A muscle spindle consists of a thick, fusiform envelope of laminated fibrous tissue, somewhat comparable with the capsule of the Pacinian bodies. In the long axis of this fusiform envelope, and frequently passing through its entire extent, is a bundle of small muscle fibres. Entering at one of the poles and near the middle two or more nerve fibres join the spindle. The sheath of Henle of the nerve fuses with the wall of the spindle. Blood-vessels and lymphatics are also present (Fig. 3400).

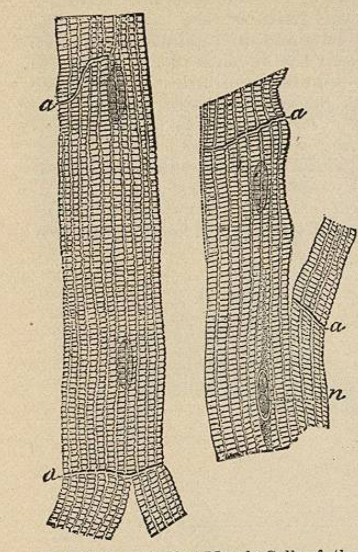

FIG. 3398.—Cardiac Muscle Cells of the Left Ventricle of a Dog, showing the Form, Branches, Nuclei, and Striæ of the Cells. The longitudinal, transversely striated bands in each cell represent muscle columns. Magnified 600 diameters. (Ranvier.) *a*, Intercellular cement at the junction of the cells; *n*, nucleus. The one opposite the *n* shows a conical mass of unstriated protoplasm at each end.

These muscle spindles are most frequently found near a nerve and a blood-vessel (Fig. 3411, *D*). In mammals they vary from 1.5 to 10 mm. in length, and from 0.15 to 0.4 mm. in diameter. Sometimes the spindles are compound, two or three being placed side by side, or end to end.

The muscular fibres (intrafusal fibres) in a spindle vary in number from one to twenty; but a number varying from three to ten is most common in mammalian muscle. In size they are usually much smaller than the ordinary fibres of the muscle in which they are situated. This is more marked in adult than in new-born animals. The size of the intrafusal fibres varies from about 5 μ to 20 μ in diameter. They are characterized by coarser striation and the nuclei are in many cases in the middle of the fibre instead of at the circumference. Frequently also in the middle of the spindle the nuclei are so numerous that the striation is lost or obscured (Fig. 3400, *A*).

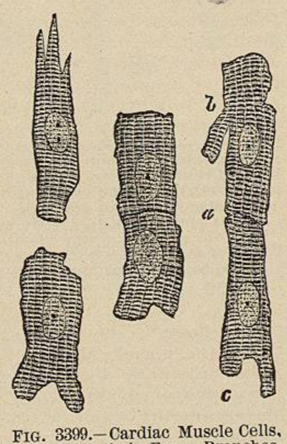

FIG. 3399.—Cardiac Muscle Cells, showing their Form, Branches, Nuclei, and Striæ. From the heart of a young rabbit.* Magnified 425 diameters. (Schaefer.) *a*, Line of junction between the cells (intercellular cement); *b*, *c*, branches of the cells.

The significance of these bodies has been much discussed, and various conclusions have been reached. Experiments by Sherrington and others make it almost certain that the bodies are innervated by both motor and sensory nerves, and the belief is becoming general that they are in some way connected with the muscular sense (Batten[2]) (Huber and DeWitt[20]).

CARDIAC MUSCULAR TISSUE.—*Distribution.*—Cardiac muscular tissue is present in the heart of all vertebrates, and, so far as has been investigated, in all those parts of the blood-vascular system exhibiting rhythmical pulsations, as the *conus arteriosus* of amphibia and many fishes, and the great veins next the heart in mammals.*

In the cold-blooded animals, fishes, amphibia, and reptiles, cardiac muscular tissue is composed of striated cells which are much longer than broad, and which as a rule are considerably branched and contain a single nucleus (Figs. 3401–3404).

In warm-blooded animals—birds and mammals—cardiac muscular tissue is in the form of anastomosing segments or fibres with nuclei at more or less regular intervals along the fibres.

By caustic potash and other dissociating agents it is easy, in the new-born and young, to separate the cardiac meshwork into segments which are usually branched and with a single or double nucleus in each segment (Figs. 3399, 3413–3415). These segments with their branches have the appearance of cells, and are so considered by

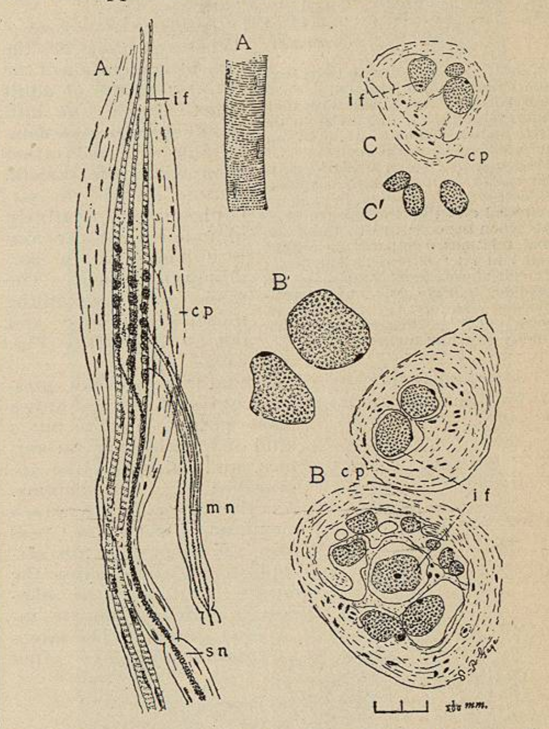

FIG. 3400.—Muscle Spindles. (Drawn by Mrs. Gage.) *A*, Longitudinal view of a muscle spindle from the striated muscle of the rabbit (modified from Kölliker); *cp*, connective-tissue capsule with nuclei; *if*, intrafusal striated muscular fibres in the long axis of the spindle—near the middle they are thickly nucleated; *mn*, motor nerve distributed to the spindle; *sn*, sensory nerve entering near the pole of the spindle. The sensory nerve is usually very large. *A'*, An ordinary muscular fibre of the rabbit drawn at the same scale as the spindle to show the comparative size and fineness of striation. *B*, Transection of a compound muscle spindle from the human sartorius magnified 350 diameters (*cf.* Fig. 3410, *D*); *if*, intrafusal muscular fibres. Two were present in the upper and nine in the lower spindle; the diversity in size is well shown in the lower spindle; *cp*, connective-tissue capsule of the spindle, this appears to be composed of nucleated laminæ something as in the Pacinian bodies. *B'*, Two ordinary striated fibres near the spindle and drawn at the same scale for comparison. *C*, Transection of a muscle spindle from the sartorius of a child at birth. Magnified 350 diameters (*cf.* Fig. 3410, *C*); *if*, intrafusal fibres; *cp*, connective-tissue envelope or capsule. *C'*, Three ordinary muscular fibres near the spindle and drawn at the same scale for comparison. They are no larger than the intrafusal fibres.

most anatomists. In the adult it is much less easy to separate the heart muscle into these cell-like masses. In sections parallel with the so-called fibres, appearances

* This figure appeared in Quain's "Anatomy," eighth edition, p. 119, but the source was not given. On inquiry, Dr. Schaefer informed the writer that the cells are from the heart of a young rabbit.

* According to the investigations of Ranvier, the muscular tissue of the rhythmically pulsating *lymph hearts of amphibia* is in structure like the ordinary skeletal muscles, except for a greater tendency to branch; also, like the skeletal muscles, its motor nerves are paralyzed by curare.

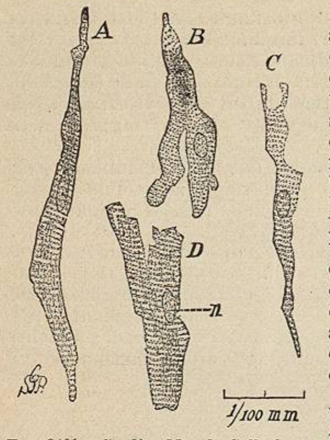

FIG. 3401.—Cardiac Muscle Cells from the Ventricle of a Minnow, to show the Forms of the Cells with their Branches, Nuclei, and Striæ in the *Teleostean Fishes*. *A*, Cell approximately fusiform in outline; *B*, branched cell, which appears granular rather than regularly striated; *C*, cell with depression, in which a rounded end like the branch of *B* fits when the cells are in their normal relations (compare the middle cell and its relations in Fig. 3415); *D*, cell approximating in shape the cardiac muscle cells of warm-blooded animals; *n*, nucleus. In cells *A*, *C*, the transverse striæ distinctly cross the nucleus.

like those in Fig. 3397 are readily obtained if one omits the apparent division into cells. In the adult, the heart seems to be made up of a sponge-work of muscle substance. It is believed by some of the later investigators (v. Ebner and Heidenhain) that in the course of development the muscle cells form a kind of syncytium, and that in the adult at least no true cell boundaries are present.

Intimate Structure.—Whatever may be the true interpretation of the cellular nature of adult heart muscle, the intimate structure is comparable with red rather than with pale skeletal muscle, that is, the sarcoplasm is relatively abundant, and the longitudinal striation usually quite evident. The nuclei are always in the muscle substance and not at the surface (Fig. 3405).

A sarcolemma like that of skeletal muscle is not present, but the large amount of sarcoplasm forms not only a mass within the fibre but a kind of mantle over the surface, and this gives the appearance of a sarcolemma. As the so-called Krause's membrane seems to pass from the surface of this sarcoplasmic mantle across the muscle substance, the likeness is quite striking to insect muscle. The sarcoplasmic mantle is often

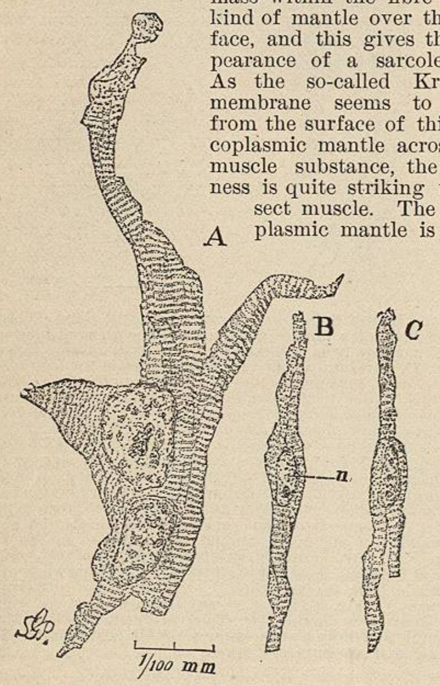

FIG. 3402.—Cardiac Muscle Cells from the Ventricle of *Necturus lateralis*, to show the Various Forms of Cells and their Structural Details in a *Perennibranchiate Amphibian*. *A*, Large-branched cell with two nuclei which contain numerous nucleoli. Near the end of the longest branch the regular transverse striation is replaced by irregularly arranged granules. Large cells like this are common in the heart of *Necturus*; they are plate-like, as was determined by a profile view; *B*, *C*, cells of approximately the same thickness as breadth; they form the great bulk of the heart, and usually are branched; *n*, nucleus with nucleoli.

wavy also, and the Krause's or intermediate membrane seems to be attached to the hollow of the wave.

Blood- and Lymph Vessels of Cardiac Muscular Tissue.—The vascular supply of this tissue is very copious. The cardiac muscle cells are enclosed in a parallelogrammic network of capillaries, and the rootlets of its veins are formed by the union of several capillaries at the same point. The larger veins possess valves in man and the higher mammals at least. The lymphatics are numerous and consist of passages and spaces in the intermuscular connective tissue (perimysium) which communicate with the subpericardial lymph vessels.

Nerves of Cardiac Muscular Tissue.—Myelinic and amyelinic nerve fibres and small ganglia are very numerous

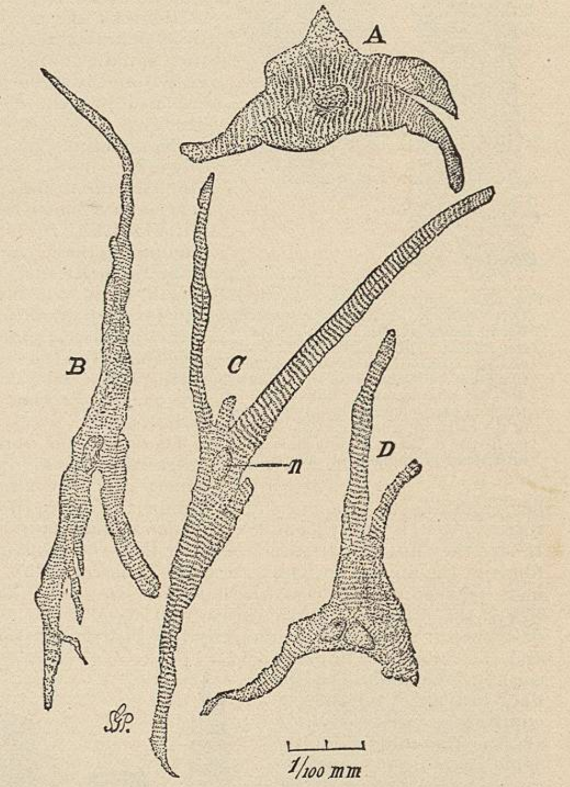

FIG. 3403.—Cardiac Muscle Cells from the Ventricle of a Toad (*Bufo lentiginosus*), to show the Various Forms of Cells and their Structural Details in an *Anourous Amphibian*. The striation is rather fine throughout, and toward the ends is, in many cases, replaced by irregularly arranged granules. *A*, *D*, Broad-branched cells. Cells of this kind are plate-like, as was determined by causing them to roll over so that a profile view could be obtained; *B*, *C*, branched cells of approximately the same thickness as width. Both these cells would be nearly fusiform if the lateral branches were removed; *n*, nucleus. In *D*, two nuclei are present.

in the heart. The fibres extend in every direction between the muscle fibres. The special mode of their termination will be discussed under *Nerves* (*q. v.*).

SMOOTH OR UNSTRIATED MUSCULAR TISSUE.—This is the contractile tissue in the animal body, composed of elongated, mostly uninucleated, fusiform cells or fibres, which are arranged in membranes, sheets, plexuses, or scattered bundles, in the various organs.

Distribution.—This tissue is present in many invertebrates and in all the classes of vertebrates. In man and most mammals it is found in the following situations: (A) *Throughout the alimentary canal:* (1) muscularis mucosæ; (2) muscular coats of the stomach and intestines, part of the œsophagus, and in the œsophageal accessory muscles; (3) as membranes or scattered bundles in the ducts of the salivary glands, in those of the pancreas and of the liver, in the intestinal villi, and in the gall-bladder.

(B) *Respiratory organs:* in the trachea, bronchi, infundibula, and, according to some authors, in the alveoli of the lungs. (C) *Urinary organs:* in the medullary portion of the kidney (Jardet[10]), in the calyces and pelvis of the kidney, in the ureter, urinary bladder, and urethra. (D) *The generative apparatus:* (1) *male*, in the dartos of the scrotum, epididymis, vas deferens, vesiculæ seminales and musculi ejaculatorii, prostate, Cowper's glands, and the corpora cavernosa; (2) *female*, in the ovary, Fallopian tubes (oviducts), in the uterus and all its ligaments, in the vagina, corpora cavernosa; in the nipples, and the surrounding areolæ. (E) *Vascular system:* in the endocardium, semilunar valves, middle coat of almost all the blood-vessels and larger lymphatics, in the adventitia of some arteries and veins, and in some of the lymphatic glands. (F) In the capsule, and in many mammals also in the trabeculæ of the spleen. (G) *In the skin* in connection with the sweat and ceruminous glands, and forming the arrector pili. (H) *In the eye and its vicinity*, the *musculus orbitalis et palpebralis* of H. Mueller, in the orbital fissure and forming the ciliary muscle (tensor choroidæ or muscle of accommodation), the sphincter and dilator of the pupil.

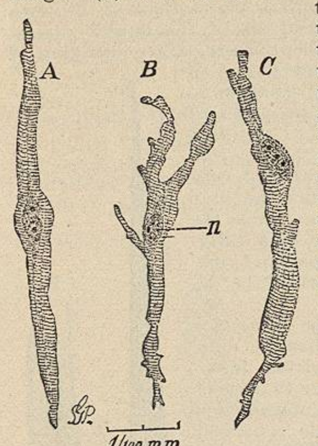

FIG. 3404.—Cardiac Muscle Cells from the Ventricle of a Young Alligator, to show the Various Forms of Cardiac Muscle cells and their Structural Details in the Heart of a Reptile. *A*, Fusiform cell; *B*, *C*, branched cells. These make up nearly the entire mass of the heart, very few being simple spindles like *A*; *n*, nucleus in which the nucleoli are very distinct.

Figs. 3401 to 3404 are at a uniform magnification of 500 diameters. The drawings were made with a camera lucida, and the finer details of structure were determined with a $\frac{1}{18}$ homogeneous immersion objective, and added free-hand. (Drawn by Mrs. Gage.)

Constituents of Unstriated Muscular Tissue.—These are: (A) The contractile or muscular fibre cells or fibres forming the essential elements. (B) Connective tissue forming a kind of perimysium which surrounds the muscular tissue and, penetrating between the fibres, combines them into bundles. (C) Blood- and lymph vessels and nerves.

Relations of the Fibres.—The fibres forming a bundle or fascicle are cemented to one another throughout their entire extent, lapping and interlacing so that apparently solid bundles or membranes without fissures are formed (Fig. 3406). As a rule, there are no distinct tendons for unstriated muscular tissue, since in muscular membranes which entirely surround an organ, tendons would be unnecessary; and in other cases the close relations of the fibres to the surrounding fibrous tissue, and the commingling of its perimysium with the surrounding fibrous tissue, serves to connect the muscles to the part to be acted upon. In special and rare cases, tendons appear to be formed by the insertion of single unstriated fibres into the fork of an elastic tissue fibre.

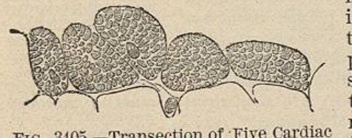

FIG. 3405.—Transection of Five Cardiac Muscle Cells, to show the Form and Relations of the Cells in Section, and the Central Position of the Nucleus in Three of Them. In the other two the section was not at the level of the nucleus. The minute dark areas in the cells represent sections of muscle columns (Cohnheim's areas). Magnified 550 diameters. (Ranvier.)

Intimate Structure of Smooth or Unstriated Muscular Fibres (muscular or contractile fibre cells, smooth or plain muscular fibres or muscle cells, non-striped or non-striated muscular fibres, unstriped or unstriated muscular fibres or muscle cells, involuntary muscular fibres, fibre cells, or muscle cells). As stated above, smooth or unstriated muscular tissue is composed of special fibres or cells which form the essential and contractile part of the tissue. They are also its anatomical or structural elements, and are in general fusiform, sometimes branched, and usually contain but a single nucleus (Figs. 3406, 3409). The fibres vary greatly in size, ranging from 30 μ long and 4 μ wide to 230 μ long and 15 μ wide. In the gravid uterus they may attain a length of 500 μ. Those of the vascular system are usually smaller than those in other situations, and they are almost invariably of very irregular outline (Fig. 3408).

Nucleus.—The nucleus is usually oval in outline (rod-shaped in those of the vascular system), and averages about 15 μ to 20 μ long and 4 μ to 10 μ wide. It extends lengthwise of the cell, and often contains one or more

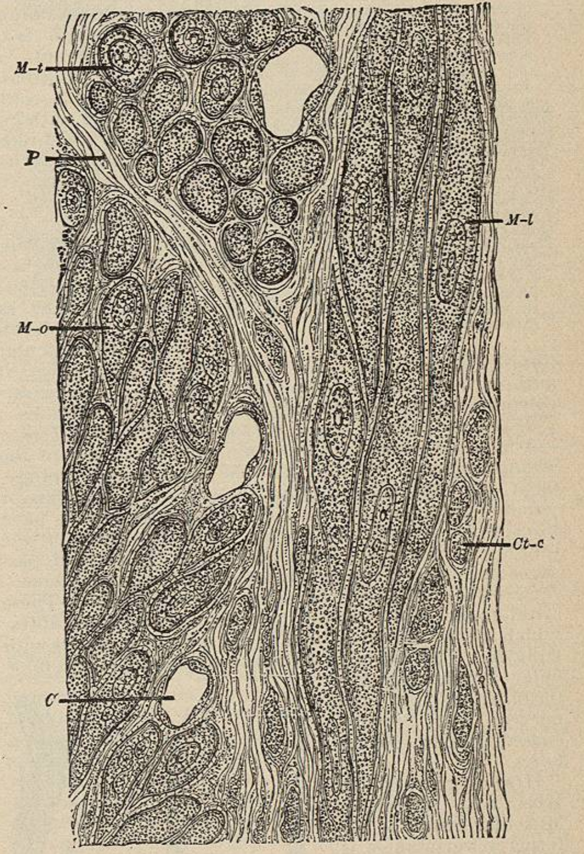

FIG. 3406.—To show the Form and Relations of Smooth Muscular Fibres in their Length and in Direct and Oblique Sections. From the human uterus shortly after delivery. Magnified 500 diameters. (Heitzmann.) *C*, Capillary (the cut ends of two other vessels are shown in the figure; *Ct-c*, connective-tissue corpuscle, or plastid in the perimysium; *M-l*, smooth or unstriated muscular fibres shown lengthwise and in their normal relations to one another; *M-o*, ends of smooth muscular fibres cut obliquely; *M-t*, ends of smooth muscular fibres cut transversely; *P*, perimysium, or interstitial connective tissue.

nucleoli (Figs. 3406, 3408, and 3409). A complex intranuclear network has been described by recent authors. At each end of the nucleus there is in many cases a conical mass of granular matter; this is supposed to be protoplasm not yet differentiated into contractile substance.

Contractile Substance of the Smooth or Unstriated Muscular Fibres.—In the fresh condition, and after many methods of preparation, the smooth muscular fibres appear homogeneous, except for a few scattered granules, the nucleus, and the slight amount of granular matter at