liest cases of myositis ossificans progressiva were reported in the Philosophical Transactions of 1740. In the same journal in 1741, Copping gives the following graphic description of a case: "Das ganze Rückgrat war ein zusammenhängender Knochen, von dem sich ein scharfer Rand erhob, der wie eine Handhabe aussah, woran man das Skelet halten konnte. Es waren ihm jedes Jahr aus den Fersen Hörner gewachsen, wie die Sporen bei den Hähnen und die Ueberwüchse von Knochen waren in so grosser Menge da, dass es eben so schwer sein würde sie zu zählen als die Stalactiten in der Grotto der Calypso." In 1869, Münchmeyer, giving to the disease the name suggested by von Dusch, myositis ossificans progressiva, described the disease so accurately that little has been added to his description by later writers.

He declares the disease to be a constitutional affection of slow course with periodical exacerbations followed by periods of apparent repose. The first disturbance of the muscle tissue begins with a marked infiltration of the intermuscular connective tissue, so that the name myositis ossificans interstitialis which has been suggested is not inappropriate; the second stage, that of connective-tissue induration, consists of an excessive growth of intermuscular connective tissue with destruction of the striated muscle as a result of pressure atrophy or fatty degeneration. The third stage is that of ossification, which begins in the centre of the affected muscle in the connective-tissue ground substance. The disease begins in youth with local swelling and later loss of function and ossification. Sometimes local and radiating pain is associated with it and also slight febrile reaction. The skin may be of higher temperature than normal and the connective tissue may be œdematous. The swelling may disappear after from two to four weeks, leaving the muscle hard and ossified, a condition which is sometimes temporary, but generally spreads to the origin and insertion of the muscle and remains permanent. With very few exceptions, the disease makes its appearance in the muscles of the back, especially in those of the upper portion of the back or of the neck. In connection with the neck muscles, the ligamentum nuchæ becomes ossified and the long muscles of the back generally form one mass of bone; later, the muscles of the scapulæ and the latissimus dorsi are involved; afterward the anterior muscles of the neck are attacked and then the deltoid and the muscles of the axial space. The final result is usually complete fixation of the head, immobility of the entire spinal column and ankylosis of the joints of both shoulders in the position of adduction, with fixation of the scapulæ. Still later, the muscles of the arm and forearm may become inflamed and the elbow-joint ankylosed; the muscles of the hand, however, possess almost complete immunity. In the further course of the disease the muscles of the pelvic girdle, the glutei, and then those of the lower limbs become involved; only at the last and in very severe cases does the disease extend to the muscles of the jaw and of the palate, while the face muscles usually remain intact. Münchmeyer notes the complete immunity of all muscles which are not attached to bone at both extremities, hence of heart muscle, of the diaphragm and sphincters, the muscles of the eye, of the tongue, the facial muscles, the muscles of the genital regions, and the muscles of the abdomen. This immunity is not, however, absolute, since Münchmeyer notes the occurrence of bony tumors in one case on either side of the chin, the location of which coincided with that of the triangularis menti. The disease rarely advances steadily; it is quite characteristic that there should be pauses which may last for years, the renewal of the process being either spontaneous or the result of some injurious influence. Deformities of a more or less severe degree, involving the position of the head, of the spine, and of the extremities result from the fixation of the joints, from the degeneration and loss of function of the muscles, and from the increase and subsequent contraction of the connective tissue. Münchmeyer closes his detailed description of this rare and terrible disease with the following vivid picture: "At first deprived of only a few not very necessary motions, the patient after a time can no longer carry food to his mouth, the hip and knee on one side become immovable, and finally walking becomes impossible. And during this whole long time, there is a constant alternation of hope, as each tumor disappears and as each pause occurs, and the sad feeling of bitterest disappointment as each new symptom appears, until finally all hope is gone, the mouth can no longer be opened, the food can be introduced only through an opening artificially made between the teeth; even swallowing and speaking become at times extremely difficult. The mental condition in a few cases indicates perfect resignation, but generally deep psychic depression prevails."

Although the disease is a comparatively rare one, a careful study of the literature has resulted in finding seventy-eight cases, most of which have followed the typical course which has been described. Exhaustive study of the literature of this disease has been made by Münchmeyer, Pinter, Pincus, Roth, and others, the results having been carefully tabulated by Pincus.

Little is known regarding the etiology of the affection. It occurs very generally in youth, with very few exceptions under fifteen, often in infancy, but Kronecker reports a case beginning at fifty-four. Males seem to exhibit a certain predisposition to the disease, nine of Münchmeyer's twelve cases being males and thirty of Roth's thirty-nine. Many factors are mentioned as predisposing to the disease, such as cold, damp, poor hygienic surroundings, insufficient nutrition, rheumatism, and other constitutional affections. A congenital predisposition is naturally suggested by the fact that it so universally occurs in early childhood, that it is so generally symmetrical in its development, and also by the fact that it is often accompanied by a curious congenital malformation. This is microdactylie, an ankylosis of the phalanges of the thumb, and a lack of one phalanx of the great toe on both sides. This malformation was first noted by Florschütz in 1873, since which time it has been observed in about seventy-five per cent. of all cases reported. While this is the most common abnormality noted in connection with this affection, other anomalies are mentioned, such as hallux valgus and other malpositions and incomplete development of the testis and other organs. Lexer has described quite minutely the microscopical appearance of sections taken from several tumors removed from two cases of myositis ossificans progressiva. Near the periphery of his preparations he finds quite normal muscle fibres. Nearer the centre, the muscle fibres are more or less degenerated, the cross striations lost, the muscle nuclei increased, so that the fibres in many cases resemble giant cells; the fibre is broken up, while the intermuscular connective tissue is increased and infiltrated with leucocytes, especially in the neighborhood of the capillaries. The connective tissue contains many cells of different forms, arising from division of the connective-tissue cells, which may be regarded as fibroblasts, while in some places may be seen cartilage cells with formation of hyaline cartilage. Nearer the centre the ground substance becomes denser, the former connective-tissue cells lie in small angular spaces, and the formative cells lie in rather regular rows on the dense tissue which comprises the osteoid trabeculæ. Later these become calcified and thus bone is formed. The fact that these tumors consist of true bone, often with all the structure of compact bone, is noted by many authors, who have not given so detailed a description of their findings as has Lexer. The degeneration of the muscle fibres, the increase of the connective tissue, and its infiltration with leucocytes are noted by all who have examined these tumors microscopically. Kissel, however, reports a case in which no osseous tissue was found, although the clinical picture was typical of the disease. The tumors showed only young connective tissue with remains of altered muscle. In his case some of the tumors disappeared, leaving no trace, while others broke down and a puriform liquid was discharged. This case improved somewhat under treatment and was regarded by Kissel as an incipient stage of the disease.

The *prognosis* in this disease is undeniably very bad. The course is, however, very slow, interrupted by many pauses of longer or shorter duration, and death directly assignable to the disease is very rare. As a usual thing, the disease drags its slow course along, the patient becoming more and more helpless, all vital functions unimpaired, until some pulmonary complication or some other intercurrent affection closes the scene.

Treatment seems practically useless; yet, as in all hopeless diseases, many remedies are tried, partly in hope of relieving the most painful symptoms, and perhaps partly in the hope that the diagnosis may be wrong. Among the remedies suggested are thyroid extract, phosphoric acid, sodium salicylate. In a few cases, extirpation of the tumor was attempted in the earlier stages. So unanimous is the opinion regarding the bad prognosis in this disease that we may well be doubtful of the correctness of the diagnosis in those cases in which cure or permanent improvement is noted.

The disease has something in common with muscular rheumatism, with the muscular dystrophies, with polymyositis acuta, and with the multiple osteomata, but the history of the case, the order of advance of the disease from one series of muscles to another, the symmetrical nature of the affection, with the characteristic deformities resulting from the progress of the disease, make the diagnosis easy, especially in the later stages.

Cases of myositis ossificans confined to single muscles or groups of muscles are less frequently noted in the literature, either because the disease is less easily recognized or because it seems less striking and worthy of note. A careful study of the literature has resulted in finding thirty-five cases. Some of these cases followed a single severe injury, as in the four cases reported by Cahen, in which the growth resulted from the kick of a horse. Other cases resulted from repeated injury or strain, under which heading we may include the ossification of the deltoid and arm muscles in soldiers and of the thigh muscles in riders. This perhaps includes far the largest number of this class of cases. Then we have ossification of muscles occurring in the course of a chronic inflammatory process, which may be rheumatic, syphilitic, or tuberculous.

Cahen describes a case in which, six weeks after a kick had been received, a bony tumor was found about 12 cm. long on the left thigh, corresponding to the position of the biceps. After the failure of other modes of treatment, the tumor was excised; after a short time the tumor returned and was again removed, this time with the periosteum, to which it had become adherent. The sections from these two growths present somewhat different appearances. At the periphery of the section of the first tumor and crowded by connective tissue containing many blood-vessels and large spindle cells, he finds muscle fibres which have undergone many degenerative changes—hyaline degeneration, increase of nuclei of sarcolemma, loss of striation, etc. Near the centre of the tumor, he finds irregularly arranged trabeculæ of bone, with an epithelium-like lining of osteoblasts, with many lacunæ and giant cells, and the spaces filled with a marrow extraordinarily rich in blood-vessels and connective-tissue cells. All through the preparation are scattered bits of muscle, the relation being so intimate that single muscle fibres are completely embedded in bone. In the sections from the second tumor, no muscle fibres are seen. There are three distinct zones: a zone of greatly increased connective-tissue cells, then a zone of small-celled hyaline cartilage, which, by ingrowth of blood-vessels and giant cells, is changed into bone. There is no distinct boundary between the cartilage and bone, the cells becoming smaller and losing their capsules while the intercellular substance becomes denser, more opaque, and stains bluish-red in the hæmatoxylin-eosin double stain. The development of bone in all cases investigated stood in direct relation with an increase of the intermuscular connective tissue.

Lehman describes the case of a woman of thirty-six years, who presented herself with a tumor in the thigh which had been developing at irregular intervals since her seventeenth year. The tumor was extirpated and with it the greater part of the biceps, which was involved in the tumor mass. Microscopical examination showed

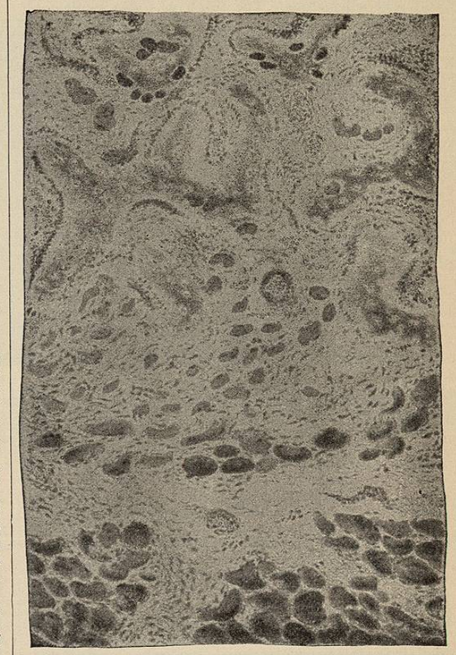

FIG. 3424.—Microscopic Appearance of Muscular and Osseous Tissue, Removed from one of the Tumors in a Case of Myositis Ossificans. (Cahen.)

a large amount of adipose tissue, permeated by bands of altered muscle. The changes in the muscle were as follows: 1. Indistinctness or entire loss of cross striation; this condition is called "streifige Degeneration des Muskels." 2. Loss of longitudinal striation—homogeneous appearance of muscle. No true fatty degeneration was however noted. 3. Increase of muscle nuclei, as is seen in atrophied muscle. These changes are accompanied by proliferation of connective-tissue cells. The young connective tissue, in the course of its maturing, undergoes manifold changes until from it peculiar fibrous or osseous tissue is developed. The osseous tissue is typical compact bone except that the lamellar systems are irregularly arranged and differ materially in the size and age of the systems. In some portions of the tumor bone was found, in others musculo-connective tissue, and in others a tissue which forms a transition between bone and connective tissue and might be called osteoid, since the structure of bone is distinct, but calcification is incomplete. This case is interesting on account of the large amount of fat tissue developed among the degenerated muscle fibres, so that Lehman has named this a case of myositis ossificans lipomatosa.

The author has recently reported two cases of myositis ossificans limitata, the autopsies on which were performed by Dr. Warthin. One of these cases was that of a young farmer, aged twenty-three years, the cause of whose

death was pulmonary and laryngeal tuberculosis. He died April 11th, 1897. His clinical history presents nothing of interest in this connection until March 1st, 1897, when he complained of pain in the left leg. On examination the left leg and foot were found swollen, soft, and œdematous. The thigh was also swollen, although less than the leg. On March 28th, 1897, examination showed the left leg only slightly œdematous and it was no longer painful. No tumor was detected, however, and a marasmic thrombus was believed to have caused the œdema. The autopsy showed a very general tuberculous process. Both lungs were infiltrated with tubercles and contained large cavities. Small tubercles were found in the spleen, liver, adrenals, and kidneys, and a tuberculous ulcer in the lower portion of the ileum. The bronchial glands contained many areas of caseation, the mesenteric glands were enlarged, many of them caseated, and all the lymph glands of the body were enlarged. In the left saphenous vein was found an old obturating thrombus, which extended through the femoral, the left external iliac, and into the left common iliac and the abdominal vena cava. Around the wall of the femoral vein there was an area of hyperæmia and infiltration, originating apparently from an enlarged lymph gland near by. This gland on section showed infiltration and caseation. The microscopical appearance was as follows: Both femoral vessels were nearly or quite filled by thrombi in various stages of organization. The entire section showed marked hyperæmia, all the smaller vessels and even the capillaries being distended and packed full of blood corpuscles. The connective tissue surrounding the large blood-vessels, as well as that around the smaller ones, was infiltrated with leucocytes, which were especially numerous in the tissue around the capillaries. This leucocytic infiltration was especially marked in the intermuscular connective tissue and around the capillaries of the endomysium. Many of the leucocytes showed degeneration and in some portions of the sections larger or smaller necrotic, abscess-like areas were found. Surrounding these necrotic areas, and indeed in many portions of all the sections, attempts at repair were noticeable. The inflammatory tissue had been replaced by a new granulation tissue, rich in small, thin-walled blood-vessels and in large plate-like cells with little fibrous tissue. The most marked changes, however, were in the muscular tissue. In addition to the alterations in the intermuscular connective tissue already noted, various degenerative changes in the muscle were observed.

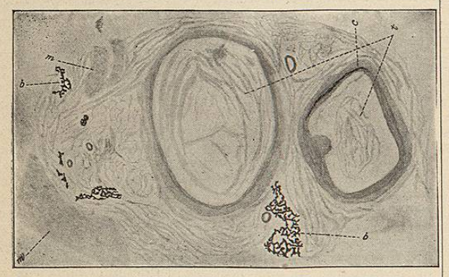

FIG. 3425. — Section Through Both Thrombosed Femoral Vessels, Muscles, Fat, Connective Tissue, and Granulation Tissue Containing Plates of Bone. *m*, Muscle; *b*, bone; *c*, calcification; *t*, thrombus. Drawn under the dissecting microscope, with aid of camera lucida. Magnified about eight times. Reduced to one-half size of drawing. (DeWitt.)

In some portions of the sections, especially at a distance from the centre of the inflammatory area, the muscle appeared fairly normal, both in size and in the finer structure. Near the centre of the inflammatory area, however, the muscle fibres were much smaller, of very irregular contour, and either tapered to a point or divided into numerous bundles of finely fibrillar tissue resembling fibrous connective tissue. The cross striation was lost and in some even the longitudinal striation seemed lost or very indistinct, so that the fibre appeared finely granular or entirely homogeneous. In some places a muscle nucleus, with a fusiform fragment of sarcoplasm, was separated off from the rest of the cell. The nuclei may be absent from a considerable portion of the fibre and crowded together at one end or at one side, and often a small fragment of muscle containing many nuclei, or even a mass of nuclear substance in which the nuclear outlines were very indistinct was seen. Small, isolated, fragments of muscle could be seen in the granulation tissue and even in and near the inflammatory, necrotic areas, containing numerous nuclei embedded in homogeneous-appearing protoplasm, producing the appearance of giant cells. These may be interpreted as attempts at regeneration of the degenerated muscle fibre, although probably many of the forms, especially those in the necrotic areas, were degenerating sarcolytes. In addition to the simple atrophy, fatty degeneration and Zenker's waxy necrosis were noted.

In the granulation tissue, which seemed to have replaced the larger inflammatory areas, were irregularly branching and anastomosing trabeculæ of osteoid tissue consisting of a dense matrix, enclosing rather large cells usually not surrounded by a capsule. The spaces between the trabeculæ were filled with very vascular granulation tissue, somewhat resembling bone marrow. Many of the large cells of these areas were arranged on the trabeculæ, like the layer of osteoblasts on the trabeculæ of developing bone. Most of the osteoid tissue had undergone calcification, at least in the central portion, so that, according to Ziegler's definition, it represented a true ossification process. It may be added that some of the sections were stained by Schmorl's bone stain, and, while, as might be expected from the short duration of the process and the thinness of the trabeculæ, no structure of compact bone was to be seen and the cells did not show the processes so characteristic for adult bone cells, yet in each case a layer of greater or less width surrounding the trabeculæ gave the typical color reaction given by bone to that stain. In some of the sections these plates of bone formed a nearly continuous ring around the large blood-vessels. In others they were scattered throughout the section in smaller masses, always found in the granulation tissue, never in the old connective tissue, nor in the inflammatory tissue which was still undergoing retrograde changes. These ossified masses were found, not only immediately around the femoral vessels, but also extending out in all directions between the degenerating and regenerating muscle fibres, wherever a sufficiently large area of granulation tissue was found. The relation of the plates of bone to the other tissues in the section is represented in Fig. 3425. In the marrow spaces were often seen bits of degenerated muscle, atrophied, non-nucleated, and appearing homogeneous.

By Unna's orcein differential stain and also by Weigert's stain for elastic tissue it was shown that a regeneration of the yellow elastic-tissue fibres was taking place in the granulation tissue. Although the patient was tuberculous, no tubercle bacilli were found in the enlarged lymph glands in the neighborhood of this inflammatory process, nor was the structure that of a tubercle, but rather that of a simple, necrotic abscess. The changes in the tissue indicate that the intermuscular inflammation, the changes in the muscle, and the bone formation antedated by a considerable period the thrombosis, which was probably secondary to the other changes.

In the second case, the clinical history presented nothing of interest except the fact that the femur was broken about five weeks before the death of the patient, but the fracture was not in the immediate neighborhood of the point of ossification of the muscle. The microscopical appearance of the two cases was identical and an obturating thrombus was found in the femoral vein in both. The fact that in these two cases the ossification was not discovered until the autopsy had been made and the

tissues examined microscopically is of interest as suggesting the possibility that pathological ossification of muscle after injury or inflammation may occur much more frequently than is generally supposed or than can be gathered from the literature, since such an ossification, if limited in extent, may not excite any symptoms that would lead to the diagnosis of myositis ossificans. When the diagnosis is made and the disturbance is sufficient to warrant it, operation seems to offer great hope of recovery. In the cases reported by Cahen, Lehmann, Munro, and others, entire extirpation of the tumor, with the periosteum in cases in which the bone had become adherent to the periosteum, resulted in perfect recovery. Much difference of opinion has arisen as to the true character of the bone formation. Virchow places the disease on the border line between inflammation and new growth and is supported by Lexer, Bollinger, and many others. Mays asserts that it is a true tumor and is supported by Kümmel, Pinter, Helferich, Pincus, Partsch, Cahen, and others. Cahen bases his assumption on the microscopical appearance, especially on the fact that new connective tissue, cartilage, osteoid tissue, and bone are found in the same section, thus showing the characteristics of an atypical growth. They consider the inflammatory phenomena and muscle degeneration to be secondary to the tumor formation. Pincus, after a most exhaustive study of the literature and of his own cases, arrives at the conclusion that myositis ossificans progressiva is not a disease, but undoubtedly a tumor belonging to the multiple osteomata and exostoses of Virchow. He states that the process begins in the periosteum, the muscle degenerating secondarily, and that an inborn, not hereditary, constitutional anomaly lies at the foundation, the constitutional anomaly consisting of an excessive productivity of the periosteum and connective tissue of the locomotor apparatus. The disease needs for its development an external cause, which may be trauma or rheumatism. The apparently spontaneous cases arising in early life are really of traumatic origin and due to intrapartum injuries. Nicoladoni advances the hypothesis that it is a trophoneurosis, comparable to progressive muscular atrophy and pseudohypertrophy of muscle. Electrical tests, however, indicate the absence of any neuropathic factor and the disease is probably myopathic, and either primarily inflammatory in character or having the primary characteristics of a neoplasm. In the progressive form of the disease many of the tumors are probably neoplasms, while others, as would seem to be indicated by Lexer's description, are developed on an inflammatory basis. In consequence of the diffuse interstitial myositis, an indifferent granulation tissue arises, which may change either into scar tissue or into cartilage and bone. In the myositis ossificans limited to single muscles or groups of muscles, the primary condition is an inflammatory process in the intermuscular connective tissue resulting in the degeneration of the muscle fibres, either from simple pressure atrophy or from fatty degeneration, so that the name myositis interstitialis ossificans seems not inappropriate. Processes of repair are then established, granulation tissue rich in fibroblasts and small blood-vessels, in which white fibrous and yellow elastic fibres are sparingly developed, is formed. Instead of changing to mature connective tissue, however, a portion of this granulation tissue changes to trabeculæ of osteoid tissue, and the rest into bone marrow which fills the spaces between the trabeculæ. This is not unusual since, as is well known, the different members of the connective-tissue group change with great readiness to other forms of connective tissue. Cold, unsanitary surroundings, trauma, either single or repeated, irritation, as in the exercise bones, or chronic pathological processes may act as the direct causes of the development of the disease. This might be satisfactory on the etiology of the affection, were it not that the exciting cause is often so slight and trivial that we cannot believe it sufficient to produce the disease in a normal individual.

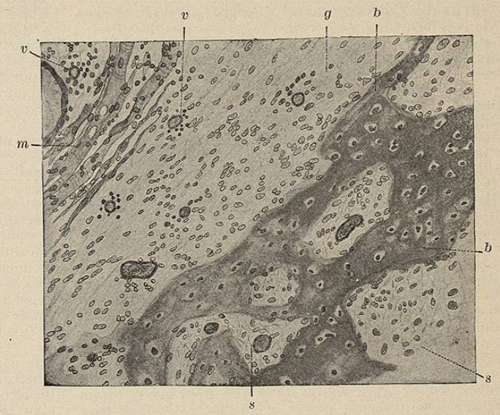

FIG. 3426.—Section Through a Few Trabeculæ of Pathological Bone Formation, with Marrow Spaces, Surrounding Granulation Tissue, and, at the Periphery, Degenerating Muscle Fibres. *b*, Bone; *m*, degenerating muscle; *g*, granulation tissue; *s*, marrow spaces; *v*, capillaries surrounded by connective tissue infiltrated with leucocytes. Drawn with the aid of the camera lucida. No. 2 eyepiece; one-sixth inch objective. Reduced to one-fourth. (DeWitt.)

This is especially true of the progressive type, while in the stationary form of the disease the irritant cause which has operated on hundreds of cases has produced ossification in very few. The explanation of these facts has opened a large field for conjecture and speculation. Virchow believes that in these individuals there is an ossifying predisposition, either hereditary or congenital, which he calls diathesis ossificata sive ossea. Maunz suggests as a predisposing causative factor a disturbance of embryonic development. He says: "In the 'Anlagen' of musculature, where in later life pathological bone formations occur, osteoblastic nuclei enter. These nuclei remain dormant so long as they are held in check by the physiological resistance of the neighboring tissues. If, however, this be weakened, the bone Anlagen develop into the pathological bone formation." He explains in a similar way the occurrence of exostoses and osteophytes which are so frequently found in conjunction with the muscular ossification. Those who favor the view of embryonic disturbance cite the frequent occurrence of microdactylie in this disease as an evidence in favor of their hypothesis. Atavistic influence, misplaced periosteal buds and osteoblasts, etc., have been suggested. Direct heredity, however, seems from the history of the cases reported to have very little influence. Atavistic influence seems to be contraindicated by the fact that in the hand and foot, where splint bones are most common in the lower animals, these osseous growths rarely occur. In the progressive myositis ossificans, beginning in early life, it may be necessary to admit the hypothesis of a congenital condition consisting of an abnormal activity of the osteoblastic, or, if we accept the Weismann theory of embryonic development, the persistence of indifferent, undifferentiated mesenchymal cells, which, under the requisite conditions of nutrition, develop abnormally into nodules of fibrous connective tissue, cartilage and bone, sometimes in connection with the skeletal bones, sometimes in fascia, tendons, ligaments, or intermuscular connective tissue. In the localized form of the disease, however, no such hypothesis seems to be necessary. In these cases granulation tissue is formed, a new connec-

tive tissue, whose cells may therefore revert to the undifferentiated, indifferent, embryonal cell type, mesenchymal cells, which may develop into fibrous tissue, cartilage, or bone according to the prevalent nutritive conditions.

Wounds and Injuries of Muscles.—Injuries of muscle may be of the most varied degree of severity, from a slight strain or sprain, twisting, or laceration of a few fibres of the muscle, which results in the so-called myalgia, to complete severance of all the fibres of the muscle.

Myalgia is a temporary condition of pain in the muscle, which is usually neuralgic, and which is caused by a slight traumatism, with possibly an inflammation of the muscle, or may arise from an acute infectious disease, from syphilis, or from some toxic agent, as mercury, alcohol, or lead. The affection is usually but trivial, and is cured spontaneously, especially if the affected part is put at rest by the use of splints or strapping. Local applications of heat and anodyne solutions are useful, and the pain may at times be so severe that hypodermic injections of morphine may be necessary. If the muscle fibres are weakened by disease or degeneration, or if the strain upon the muscle is too great, either from an external force or from too violent and sudden contraction, the muscle may be fractured, either completely or partially. Fractures and lacerations of healthy muscle are rare except in cases of sudden, unexpected, or unusual contractions. Such accidents are more common among soldiers. Certain diseases, however, such as typhoid fever, yellow fever, scarlet fever, and other severe fevers weaken the resistant power of the muscle, which may undergo various degenerative changes which make it more brittle. The rectus abdominis, the rectus femoris, the adductors of the thigh, the calf muscles, the psoas, and the flexors of the forearm are the muscles most frequently fractured. The symptoms of fracture of muscle are quite characteristic, consisting of sudden sharp pain, with a sensation of giving way and powerlessness of the muscle. In case of complete rupture, a gap is immediately formed between the broken ends of the muscle by the contraction of the parts, and this gap, which can easily be palpated, is a characteristic feature of the affection. It is soon filled, however, by an extravasation of blood, which may form a hæmatoma of greater or less extent and hence a prominence in place of the depression. The skin becomes discolored usually from the extravasation of blood. Wherever muscle is lacerated, whether the tear is large or small, blood extravasates into the tissues, except in those cases in which the injury is very near the tendinous extremity of the muscle, where the vascular supply is poor. The interference with the function of the muscle depends upon the extent of the laceration, the use of the muscle being lost in cases of complete rupture. If only a few fibres of the muscle are broken, recovery is usually rapid and complete and the function of the muscle may be quite well restored even when the injury is quite extensive. In these milder cases the only treatment usually necessary is perfect rest of the affected part. If, however, the muscles are completely torn across, it is usually necessary to suture their ends; and where there is a considerable gap between the ends, it may be well to fill in the interval with the muscle from an animal (muscle grafting), or with sutures of chromicized catgut or kangaroo tendon to act as a framework for the reparative material. The interval is at first filled with granulation tissue, even the engrafted muscle undergoing degenerative changes; later a scar tissue is formed, penetrated in places by the regenerated muscle fibres. In spite of the experimental work on muscle grafting previously mentioned, the consensus of opinion among surgeons and pathologists seems to show that, while the function of the muscle may be fairly well restored, muscle fibres are not regenerated in sufficient numbers to fill the intervening space. At times the injury results in the formation of bone in the granulation tissue, following the law of the metaplastic tendencies of the connective tissues. In some cases the muscle remains intact, while the overlying fascia is torn, generally as the result of the imperfect healing of some former wound. In these cases the muscle may protrude through the opening in the fascia, forming a muscle hernia. Féré collected thirty-one cases of muscle hernia in epileptics, fifteen of which were symmetrical, a finding which would seem to indicate a certain nervous influence as a possible etiological factor in these cases. The hernia is distinguished from a neoplasm in the muscle, from an aneurism, etc., by the fact that it disappears entirely or diminishes in size when the muscle is at rest, becoming prominent during the contraction of the muscle. Generally the opening in the fascia can be felt through the skin. The condition may often be attended by considerable inconvenience, pain and loss of function of the affected muscle. Rest and bandaging are usually sufficient to effect a cure in recent cases. In cases of long standing it may be necessary to freshen the edges of the rent and unite them by stitches. It is distinguished from fracture of muscle by the fact that the symptoms usually develop more gradually than those of fracture. It affects the adductor muscles by preference. Muscle may also be more or less completely crushed by external violence. The results of this as well as of other injuries of muscle depend upon several factors. Apparently identical injuries may in one case cause only temporary disturbance of function, in another ossification, and in another paralysis. Young tissues tend to heal more readily than old. The condition of the muscle at the time of the injury, whether at rest or contracted, has a marked influence on the effect of any traumatism. The nerve fibres which may be cut, injured, or compressed may have a vital bearing on the permanency and severity of the functional disturbance. Single or repeated injuries of muscle may have a real or fancied relation to the development of malignant tumors, a fact which may be explained by the assumption that embryonic tumor-tissue germs are latent in the muscle, which are either excited to activity by the irritation produced by the traumatism or permitted to grow because the normal resistance of the tissues is removed or diminished as an effect of the injury.

II. Involuntary Muscle.

Involuntary muscle has a wide distribution, occurring in the walls of the digestive tract, blood-vessels, skin, in the capsules of many organs, and making up the greater part of the structure of the uterus, bladder, and other organs. Its structure is far simpler than that of voluntary, striated muscle, and its pathological changes are therefore less complicated and have received less attention and research. It consists of mononuclear, fusiform cells, cemented together to form bundles or membranes, which are separated by a larger or smaller amount of connective tissue. The pathological processes in non-striated, as in striated muscle, consist of inflammations, degenerations, and tumors. Certain abnormalities may be noted occasionally, such as the presence of striated muscle fibres among the involuntary muscle fibres of the uterus. These may be due to the metaplasia of non-striated into striated muscle or to the misplacement of embryonal cells.

The pathological processes occurring in involuntary muscle have not attracted the attention of investigators as have those of voluntary muscle. This may be explained, in part at least, by the fact that any disturbance in the function of voluntary muscle causes unmistakable symptoms, while in most cases the symptoms of change in involuntary muscle are masked and indefinite and the pathological processes in it are often not recognized until after the death of the patient. In most cases of muscular atrophy, whether neuropathic or myopathic, and in other muscular degenerations the statement is made either that the involuntary muscle was normal or that it was not examined. Certain regressive changes, analogous to those which occur in striated muscle, are, however, observed, having been described especially in connection with inflammations and tumors of the myomatous type. Œdema of non-striped muscle is frequently

noted. Kenntmann described a case of myometritis œdematosa, in which the muscle fibres of the uterus became so soft and œdematous that the uterine wall was perforated by a sound. Microscopical examination of the myometrium in this case showed the muscle bundles separated by large clear spaces, equal in size to the muscle bundles themselves. This condition was especially marked in the vascular middle layer, in which the blood-vessels presented thickened walls, the connective tissue of the intima being especially thickened. The muscle cells appeared cloudy and in places atrophied. Near the vessels the muscle fibres appeared especially narrowed, even the nuclei being atrophied. Large areas were found in which the muscle had undergone pathological degeneration. No solid strands or bundles were found, and the single fibres were so small that they gave the impression of being reduced to fine fibrils, whose single thicker part, we might almost say whose single dimensional part, consisted of the degenerated and poorly stained nucleus. The connective tissue was probably somewhat increased, but not markedly so; still in places where the muscle was most degenerated, some increase of connective tissue could be observed. Similar degenerative changes are frequently observed and described in myomata of the uterus, which have undergone myxomatous or œdematous degenerative changes.

Atrophy of involuntary muscle occurs under conditions similar to those of atrophy of voluntary muscle. A neuropathic form of atrophy of involuntary muscle—although a form which may be considered neuropathic has been mentioned in connection with vitiligo and other skin diseases—has not so far as I have been able to find, been described. The atrophies are largely due to circulatory disturbances, as in the case above described, or to pressure of a fluid or cellular exudate, as in inflammations. No better picture of atrophy of involuntary muscle has been given than that by Kenntmann. Similar atrophy of the involuntary muscles of the skin in skin diseases has been described by Unna, Pospelow, and Lelois and Vidal.

Hypertrophy of non-striated muscle frequently occurs and may be physiological or pathological. The best example of the physiological hypertrophy is that found in the pregnant uterus. Pathological hypertrophy occurs as a result of stenosis or obstruction of the intestinal canal and other ducts. This is regarded by Herczel as a true hypertrophy, without increase of the number of cells, although many authors regard it rather as a hyperplasia accompanying the hypertrophy. Hypertrophy of the skin muscles was also described by Unna in keratosis suprafollicularis and in pityriasis rubra and other skin diseases. In elephantiasis streptogenes he found the non-striated muscles enlarged, but not increased in number. Calcification of involuntary muscle was noted by Meslay and Hyeme and others, and Brunings reports a case of fatty degeneration of a myoma, the process corresponding to that in progressive muscular atrophy. True ossification of uterine myomata has also been noted. Liquefaction necrosis of the dermal muscles was noted by Unna in abscesses and a collaginous degeneration of these muscles in erysipelas. Gangrene and other forms of necrosis have also been observed in myomatous tumors, as well as cystic degeneration. Nuclear degenerative changes have also been noted, such as atrophy, vacuolation, granulation, and karyolytic changes. The question of the *regeneration* of involuntary muscle is one which has been considerably discussed, and upon which authors are still at variance. Vignolo-Lutati, in his experimental study of the pathological conditions in the skin muscles, was never able to find karyokinetic division figures, but frequently, especially after the less severe injuries, he found appearances which he interpreted as direct nuclear division. Ziegler states that "there is a new formation of smooth muscle fibres and also a regeneration after traumatic, toxic and chemic injuries, as well as in the hypertrophic new formations of muscle, as in tumors; that this process begins with the karyokinetic division of the nucleus of the muscle cell. However, it is shown by experiment as well as by observation of men that there is very little reproduction of the non-striated muscle fibres, as in the healing of wounds and areas of degeneration, the regeneration soon ceases and the loss of substance in the muscular coats of stomach, intestine and bladder is replaced mostly by connective tissue. The new muscle tissue is formed probably entirely from pre-existing muscle tissue." Moleschott and Piso Borne and Busachi support these conclusions, while Arnold, Aeby, Frey, Neumann, and Virchow favor the view that it may originate from connective-tissue cells, and Kölliker and Förster believe that it develops from embryonal germ cells or formative cells. Tizzoni also found a zone of proliferation near the diseased area in typhoid ulcer of the small intestine; and Baumgartner in cases of tuberculosis found mitoses in the muscle tissue of the arteries, veins, and bronchi near the affected area. Herczel and Baumgartner were unable to find signs of proliferation after their experiments, while Vignolo-Lutati found only direct nuclear division in the skin muscles in his experiments. From all this work we may conclude that regenerative changes occur in non-striped muscle as in striated muscle, both by mitotic and by amitotic nuclear division; but that the result is only a partial replacement of the destroyed muscle tissue, the main portion being replaced by scar tissue.

Inflammatory processes in smooth muscle are exceedingly common, although generally secondary to similar processes in the neighboring tissues. Vignolo-Lutati reports the development of inflammatory changes in the involuntary muscle of the skin as the result of the injection of bacria and also of chemical, thermic, and mechanical irritants. With some variations in degree, the pathological picture in all these experiments was essentially the same. The intermuscular connective tissue was infiltrated with leucocytes, which were either diffusely scattered through the tissue or formed small nodes. The blood-vessels were distended and filled with blood, while the whole tissue appeared œdematous. The muscle fibres were swollen, vacuolated and hydropic, and crowded apart by the exudate. The muscle nuclei were either granular or vacuolated and karyolytic figures were noted in some of the experiments. After the simpler mechanical injuries the nuclei showed direct division, which the authors regarded as preliminary to regeneration of the muscle fibres. Purulent inflammation of the non-striated muscle of the uterus is a very frequent occurrence, while Aristoff notes a case of syphilitic inflammation of the muscle coats of the stomach, extending from the mucosa. Tuberculous nodes have been noted in the non-striped muscle of myomas of the uterus, as well as in involuntary muscle in other localities.

Muscle Tumors.—Certain tumors composed largely of muscle are known as myomas, one class of which consists of striated muscle and are called rhabdomyomas, while the other and more common class of myomas consist of non-striated muscle and are called leiomyomas. The rhabdomyomas have a stroma of connective tissue in which cells and fibres are found which resemble striated muscle cells in various stages of development, degeneration, and regeneration. None of the cells appear as normal, mature striated muscle cells. Many of the cells are small, spindle-shaped cells with a single nucleus or with a few nuclei and with a very faint striation or even showing no transverse striation at all. Others are larger and the striation more distinct, but irregularly arranged, while the nuclei appear at the periphery of the fibre. Some appear granular, with undifferentiated hyperchromatic nuclear substance collected in the centre or near the periphery. Drops of glycogen may be seen in the protoplasm. Sarcomatous, myxomatous, fatty, cartilaginous, or osseous tissue may be mixed with the muscle tissue of these tumors, giving rise to the rhabdomyosarcomas, rhabdomyomyxomas, rhabdomyochondromas, etc. The teratomas also consist in part of muscle tissue closely resembling the atypical striated muscle tissue of the rhabdomyomas. The rhabdomyomas may occur in regions in which striated muscle is normally present, but