accompanied by the great occipital nerve. The lesser occipital nerve winds round the posterior border of the sternomastoid, and supplies the lateral region of the occiput; the suboccipital, being a purely motor nerve, rarely reaches the skin.

Spinal Cord and Vertebral Column.—The accompanying figure (3530) shows well the situation of the spinal cord in the neck vertebræ. It is not so well protected against injury as in other parts, for in the space between the several arches, any sharp instrument piercing the muscular tissue could easily wound the cord. The vertebral artery, as has already been mentioned, is also liable to injury on its way from one vertebra to another. From the great mobility of this part of the spine dislocation occasionally occurs and death is caused by pressure on the cord. In caries of the upper cervical vertebræ, sudden death has taken place from the destruction of the ligaments between the atlas and axis. When this occurs—the head with the atlas inclining forward and leaving the axis in its proper position—the medulla oblongata is crushed against the odontoid process, and so instant death is the result. (Hilton.)

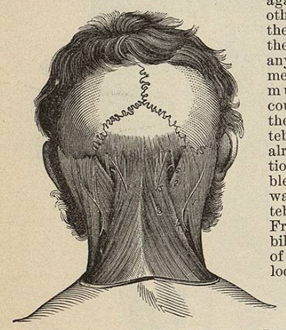

FIG. 3529.—The Skin and Fascia have been Removed, and the Superficial Muscles Exposed. 1, Sternomastoid; 2, splenius capitis; 3, trapezius; 4, small occipital nerve; 5, great occipital nerve; 6, occipital artery. (After Roser.)

Caries of the spine in the cervical region is not uncommon. In its early stages the symptoms are somewhat obscure, the chief complaint being of pain in the course of the great occipital nerve, due to its implication in inflammatory exudation. The peculiar stiff way in which the patient carries his head, and the presence of a slight prominence which is excessively tender, enables the surgeon to recognize the disease. These cases occasionally result in a post-pharyngeal abscess, which has to be opened. This may easily and safely be done by an incision along the posterior border of the sternomastoid. Some advise tapping it with a trocar through the mouth.

BRANCHIAL FISTULÆ AND CYSTS.—In the mammalian embryo, at the fourth week, there are on each side of the head, behind the oral cavity, four fissures which communicate with the anterior part of the alimentary canal. These are the homologues of the clefts found in branchiate vertebrates. The third and fourth fissures in the human embryo disappear about the sixth week, and only the first remains at the end of the ninth week. This persists as the Eustachian tube, tympanic cavity, and external auditory meatus. The structures developed in the folds between the clefts (branchial arches) are as follows:

First Arch (*Mandibular*): Meckel's cartilage, the anterior portion of which is developed into the lower jaw, and the mandibular arch is completed by the malleus bone of the ear.

Second Arch (*Hyoid*): Incus, stapes (Parker), styloid process, stylohyoid ligament, and lesser cornu of the hyoid bone.

Third Arch: Great cornu and body of the hyoid bone.

Fourth Arch: No permanent remains.

Sometimes the clefts between these arches remain more or less open, and this fact explains the occurrence of congenital fistulæ of the neck, as well as that of cysts and diverticula from the œsophagus and larynx.

Paget says (Proc. Royal Med. Soc., 1877): "Cervical branchial fistulas occur as two or three minute orifices on one or both sides of the lower part of the neck, and they lead upward to the œsophagus and pharynx; the lowermost being near the sternal end of the clavicle in front of the sternomastoid muscle, the next opposite the thyroid cartilage, and the highest between the thyroid cartilage and hyoid bone." When two in number, they are often symmetrical; they vary in length from one-half to one and a half inches, and barely admit a probe. They have a smooth lining membrane, which secretes a clear mucous fluid. These fistulæ can be cured by cauterizing them with the galvanocautery. It is probable that many cysts and so-called hydroceles of the neck are due to imperfectly closed embryonal fissures.

Sanguineous cysts of the neck are probably originally branchial cysts, which have communicated with the internal jugular vien. Cases are on record in which, before removal of the cyst, the vein had to be ligatured (Glück: *Deutsche med. Woch.*, No. 5, 1886).

BRANCHIAL DERMOIDS.—These are occasionally seen in the neck, the most common situation being between the geniohyoglossi muscles, where the swelling projects into the submaxillary space and also into the mouth. They can usually be enucleated. A dermoid sometimes is seen under the deep fascia close to the carotid arteries.

THYROLINGUAL FISTULÆ AND CYSTS.—These are met with on the tongue, at the hyoid bone, and lower down over the thyroid cartilage, cricoid, and upper rings of the trachea. They grow slowly with the growth of the individual, and are very difficult to eradicate. The cyst wall is thin and lined with columnar epithelium, perhaps ciliated. Their contents are mucoid. They sometimes burst, leaving fistulous openings which are difficult to close. Unless the cyst be entirely removed, it will recur, for if any part of the epithelial lining be left it will secrete and cause a persistence of the trouble. Thyrolingual cysts and fistulæ are the remains of the thyrolingual duct, which passes up the neck to the tongue behind the hyoid bone. The lower part becomes the isthmus of the thyroid gland, while the upper part persists as the foramen cæcum of the tongue.

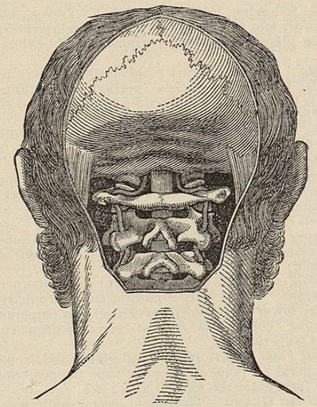

FIG. 3530.—The Superficial Tissues have been Removed to show the Vertebral Artery Passing Through the Transverse Processes of the Vertebræ, and also the Relation of the Cord to the Spinal Canal. (Roser.)

TUMORS OF THE NECK.—The neck is a favorite site for tumors, fibrous, sarcomatous, and others. Sarcomatous tumors in the early stages can be removed, but they nearly always recur. Tumors of the neck, which are apparently so freely movable that their extirpation would seem to be an easy matter, are found, when cut down upon, to be intimately connected with the deep vessels and nerves. In these cases the tumor is freely movable laterally, the vessels going with them, but there is no freedom of movement in the vertical direction. It is remarkable with what impunity large tumors may be removed from the neck, especially if they are benign. It is not uncommon in these cases to ligature both the internal jugular vein and the carotid artery, and to cut through the sternomastoid muscle, and yet have the patient make a rapid recovery from the operation; the tumor, as mentioned above, if sarcomatous, almost invariably returns, for it is impossible in the neck in such cases to remove sufficient of the surrounding healthy structures.

Aneurismal tumors at the root of the neck are comparatively common, and although in many cases these tumors may have the appearance of being connected with the subclavian or innominate arteries, yet they almost invariably proceed from the aortic arch, and push their way upward under the clavicle into the neck. Fusiform aneurisms of the aorta frequently simulate aneurism of one of the great branches.

Tumors in connection with the thyroid gland have been alluded to in the description of that body.

Francis J. Shepherd.

NECROBIOSIS.—The gradual death of tissue due to slowly acting injurious agents is known as *necrobiosis* or *indirect necrosis*, in opposition to *direct necrosis* or *immediate death*. In necrobiosis the death of the cell is preceded by some other retrograde change, such as atrophy, cloudy swelling, mucous, hydropic or fatty degeneration, or by one of the pathological infiltrations. In the case of direct necrosis death of the tissue takes place rapidly without the occurrence of preceding abnormal changes in cellular structure. The preceding retrograde change in necrobiotic processes is by some writers regarded as constituting the necrobiosis; but a distinction should be made between the preceding atrophy, degeneration or infiltration, and the molecular disintegration which constitutes the essential feature of necrobiosis. The retrogressive changes preceding this disintegration usually occur so gradually, and in themselves present such definite characteristics, as to be classed by themselves. The use of the term necrobiosis is more theoretical than practical, inasmuch as a practical distinction between direct necrosis and necrobiosis is at times very difficult or impossible. Necrobiosis is, therefore, best conceived of as a slowly progressive or incomplete necrosis. The gross appearances of necrobiotic tissues vary according to the nature of the preceding retrograde change and the degree of necrosis present. Microscopically, in addition to the characteristic changes presented by the accompanying retrograde change, the nuclei of the affected tissue show karyorrhexis and a greater or less degree of karyolysis. The ultimate picture of necrobiosis is that of necrosis; if the necrobiotic process has been characterized by cloudy swelling, simple necrosis follows; if by fatty degeneration, soft caseation (fatty necrobiosis) occurs; if by hydropic degeneration, liquefaction necrosis results. The sequelæ of necrobiosis are essentially those of necrosis: regeneration, repair, cicatrization, calcification, and cyst formation. Likewise the causes producing necrobiosis are the same as those leading to direct necrosis: mechanical, thermal, chemical, infectious, and nutritional. The injurious agents may act separately or coincidently. As a general rule it may be stated that harmful agents of slight power but of long-continued action are more likely to produce necrobiosis than direct necrosis. Disturbances of blood supply, deficient nutrition and oxygenation, as in the case of chronic anæmia, are among the most important factors leading to necrobiotic processes. Chronic intoxications and infections also play a leading rôle in the production of necrobiosis. Clinically a neuropathic necrobiosis may be distinguished.

Aldred Scott Warthin.

NECROSIS, PATHOLOGY OF.—The condition of local death, the death of individual cells or groups of cells within the living body, is known as *necrosis*. If such local death occurs immediately or very quickly after the action of some injurious agent, it is termed *direct necrosis;* if, on the other hand, the death of tissue is of a slowly progressive nature preceded by other retrograde changes, the process is designated *necrobiosis* or *indirect necrosis*. The use of the word necrosis without modifying designation is usually taken as referring to direct necrosis.

Inasmuch as we have no definite knowledge, either chemical or histological, of the condition of cell life, the essential nature of cell death or necrosis is also unknown to us. The cellular change which marks the exact moment of the passage of life from the cell is at present beyond our knowledge; the slight histological changes taking place in cells at this moment do not permit us to determine with certainty the definite boundary between the states of cell life and cell death. Our conception of necrosis is, therefore, based upon the changes which follow necrosis rather than upon those taking place at the moment of cessation of life. The development of modern microscopical technique has, however, so perfected methods of tissue fixation that it is now possible to fix and preserve definitely the histological characteristics of the cells as they exist at the moment the tissue is placed in the fixing fluid. Our knowledge of the structure of normal living cells has been obtained from the study of cells killed and fixed by such means; and likewise our conceptions of pathological conditions are based upon the relative appearances of cells so treated.

As a result of such study certain pathological criteria have been created. Of these the condition of *necrosis* is that state of the cell which is characterized microscopically by the disappearance of the nucleus and certain molecular changes in the cytoplasm. The disappearance of the nucleus or its failure to respond to nuclear stains is to be taken as the most striking feature of necrosis, inasmuch as the nucleus is to be regarded as the most essential vital element of the cell. Cells may be dead and yet retain their nuclei, but necrosis becomes evident to us microscopically only when certain changes in cell structure have occurred to distinguish the dead cell from living ones. The loss of the nucleus may occur at the moment of death or subsequently; in either case it becomes the criterion of necrosis. To the disappearance of the nucleus and its loss of staining power the terms *karyolysis* and *chromatolysis* have been applied. These changes are very frequently preceded by fragmentation of the nuclear chromatin. This change is known as *karyorrhexis;* it has been shown to consist of regular and definite movements on the part of the chromatin elements. Small masses and granules of chromatin may leave the nucleus and pass into the cell body. With the disappearance of the cell membrane fine chromatin granules may be scattered throughout the cell detritus of the necrotic area. As a result of such diffusion of the chromatin areas of necrosis in the early stage may stain diffusely blue. In other cases the nucleus before its disappearance contracts and becomes smaller, at the same time staining more deeply than normal (*pyknosis*.) Very frequently the nucleus retains its normal form and size, but gradually loses its staining power and fades away, both nucleus and protoplasm being converted into a homogeneous hyaline mass.

Sooner or later, changes take place in the protoplasm of dead or dying cells. The normal granulation of the cytoplasm may disappear and the cell undergo a hyaline change. The cell membrane ultimately disappears and the outline of the cell becomes irregular or lost altogether. Often the cell protoplasm becomes coarsely granular, the cell ultimately breaking up into a granular débris. Vacuolation may take place and the cell become enlarged and swollen from the imbibition of fluid. As the result of such swelling, breaks in the continuity of the protoplasm may occur. On the other hand, the dead cells may under certain conditions become inspissated.

Extrusion and constriction of portions of the protoplasm may occur during the process of dying. Amœboid cells usually assume a globular form. The disintegration of the protoplasm is termed *plasmoschisis*. The ultimate result of the necrotic process is the conversion of both nucleus and cytoplasm into a granular débris; when such appearances are found microscopically, the condition is to be regarded as one of complete necrosis.

Causes of Necrosis.—The causes which may lead to local death of tissue may be classed as follows: nutritional, mechanical, thermal, chemical, toxic, infectious, and neuropathic.

Disturbances of nutrition through interruption of the circulation are among the most frequent causes of necrosis. Local anæmia due to arterial occlusion as a result of thrombosis, embolism, compression, ligature, or arteriosclerosis may be the direct cause of local tissue death (anæmic and hemorrhagic infarction). Likewise stasis due to mechanical, thermal, chemical, or trophic changes in the vessel walls or to weakened heart's action may be a primary or secondary factor of necrosis. Local asphyxia from any cause may result in cell death.

Traumatic violence may through crushing or tearing cause direct death of cells, or through damage to the blood-vessels it may cause necrosis through disturbed nutrition. Cells separated from their normal environment as a rule soon die.

Elevation of temperature from 54° to 68° C. for a short period of time causes the death of tissue; excessive cold produces the same result.

The prolonged action of *x*-rays may lead to necrotic changes. This has been explained as due to the destruction of nerves, but this point has not been definitely settled.

Chemical and toxic substances of various kinds may act directly upon cells and cause their death. The poison may destroy the cells directly or, through chemical union with the cell protoplasm or intercellular substance, render life impossible, or by producing changes in the blood-vessels give rise to necrosis secondarily. Most important of all as agents of necrosis are the bacterial toxins, particularly those of tuberculosis, typhoid, cholera, staphylococcus, and streptococcus infections. Chemical substances, originating within the body, may also give rise to necrosis under certain conditions.

The bile acids, uric acid, metabolic products in diabetes, pancreatic ferments, etc., may under certain pathological conditions give rise to necrotic processes. Fat necrosis is a striking example of necrosis arising from the action of a normal body product under abnormal conditions. The pancreatic juices are absorbed into the lymph and blood streams, the fat-splitting ferment, steapsin, causing necrosis of fat cells in the neighboring fat tissue, or even in such distant regions as the pericardium and fatty marrow.

The direct action of bacteria or other forms of vegetable and animal parasites may also produce necrosis of cells.

Primary lesions of the central nervous system and the peripheral nerves are considered by many writers to give rise to a trophic or neuropathic necrosis. The changes following such lesions are much more to be regarded as dependent upon circulatory disturbances than as trophic manifestations. As a result of lowered nutrition the normal resistance of the affected parts may be diminished and bacterial infection favored.

The causes mentioned above may act separately or coincidently. The degree of necrosis depends not only upon the nature and severity of the exciting cause, but also upon the condition of the tissue at the time of injury. Tissues of lowered vitality, in conditions of general anæmia, marasmus, and cachexia, die more easily than normal tissue; hence long-continued pressure of slight degree, which under normal conditions would produce no effect, may in such conditions as typhoid fever, chronic valvular disease, etc., bring about necrosis (*decubitus, marasmic necrosis*). Necrosis occurs also in the tissues of the aged as a result of slight injuries (*senile necrosis*).

Varieties of Necrosis.—Though the loss of the nucleus and a greater or less disorganization of the cytoplasm form the essential features of necrosis, these changes may be more or less modified, or so associated with other processes as to give rise to different varieties of necrosis, recognizable either by gross or by microscopical appearances. The kind of necrosis depends upon the location and nature of the affected cells, the character and severity of the destructive agent, and the nature of the surrounding tissue, particularly with reference to the absence or presence of fluids. If the dead cells are on a surface exposed to evaporation, inspissation may take place; on the other hand, if there is an abundant supply of fluid, the cells may become hydropic and ultimately liquefy; if the factors necessary for the formation of fibrin are present, coagulation may occur either in the cells or between them. The character of the necrosis may be further modified by infection with putrefactive bacteria. It becomes therefore possible to distinguish the following varieties of necrosis, each form presenting distinct macroscopical and microscopical characteristics when occurring alone. Between these different varieties there is, however, no distinct boundary line. They are very frequently combined or may follow each other in certain cases, so that the practical diagnosis as to the original form may be difficult.

Varieties of necrosis:
1. Simple.
2. Coagulation. { Intercellular. / Intracellular. }
3. Liquefaction.
4. Mummification.
5. Moist gangrene.

} Caseation.

Simple Necrosis.—This form of necrosis is characterized microscopically by the disappearance of the nucleus and a hyaline or granular change in the cytoplasm, the original outlines of the tissue being preserved to a greater or less extent. Usually the dead cells are somewhat larger than normal, the protoplasm being more granular and staining heavily with eosin. Less frequently the cells are hyaline and homogeneous. By some writers this variety of necrosis is regarded as a form of coagulation necrosis, but it seems better to restrict the latter class to those forms

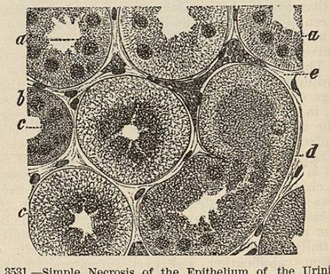

Fig. 3531.—Simple Necrosis of the Epithelium of the Uriniferous Tubes in a Case of Icterus Gravis. (From Ziegler.) *a*, Normal convoluted tubule; *b*, ascending loop tubule; *c*, convoluted tubule with necrotic epithelium; *d*, convoluted tubule with only a part of its epithelium necrotic; *e*, stroma and blood-vessels as yet unaltered. (Preparation hardened in Müller's Fluid, and stained with gentian violet.) Magnified 300 diameters.

of necrosis in which fibrin or fibrinoid substances are formed. Simple necrosis usually follows cloudy swelling; indeed, it may be regarded as a late stage of this degeneration advanced to such a degree that the nucleus has entirely disappeared. Early stages of simple necrosis may often be recognized by the presence of diffuse chromatin. The gross appearances of simple necrosis

are yellowish or grayish discoloration and lessened consistency. Simple necrosis is one of the most common forms of necrosis; it occurs very frequently in the epithelium of the kidneys and liver as the result of intoxica-

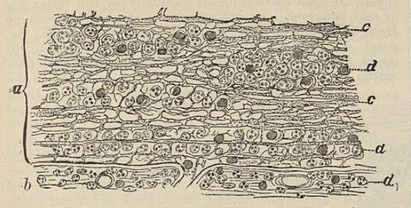

Fig. 3532.—Coagulation Necrosis. Croupous membrane from the trachea. (From Ziegler.) *a*, Transverse section of the membrane; *b*, uppermost layer of the mucous membrane with pus cells, *d*, scattered throughout its substance; *c*, fibrin threads and granules; *d*, pus cells. Magnified 250 diameters.

tions and infections, but may be found in any of the tissues. It is the most common form of necrosis found in anæmic and hemorrhagic infarcts, and in focal necroses due to various forms of intoxication and infection (typhoid, tuberculosis, diphtheria, scarlatina, etc.). A further change in tissues showing simple necrosis, so that all tissue outlines are lost and only a finely granular mass is left, results in the condition known as caseation.

Coagulation Necrosis.—This form of necrosis is characterized by the production, in the necrosed tissue, of fibrin or substances allied to fibrin, the so-called "*fibrinoid degeneration.*" The variety of necrosis described above as simple necrosis is by some writers regarded as a coagulation necrosis, but there is no positive evidence that it represents a coagulation process, and the resulting substance is not allied to fibrin. Coagulation necrosis occurs only in tissues rich in proteids and under conditions favorable for the production of the factors necessary for the formation of fibrin. Two forms are distinguished—*intercellular* and *intracellular*. In the intercellular form fibrin is formed between the dying or dead cells, the granular débris of the latter finally lying in a more or less dense network of fibrin threads. By the use of the Weigert's fibrin method this network of fibrin may be easily demonstrated. The fibrin may exist also in the granular, fibro-granular, or hyaline form. The chief source of the fibrin is most probably an exudate from the blood-vessels, but some of the factors necessary for the formation of fibrin may be supplied by the disintegration of tissue cells or leucocytes. The cells may become hyaline or granular, and ultimately completely disintegrate. This form of necrosis is most frequently seen in the fibrinous inflammations of mucous and serous membranes, and is hence also called *diphtheritic, croupous,* or *membranous* necrosis. The diphtheritic membrane may be taken as the typical example of this variety of necrosis. In all so-called diphtheritic inflammations there is more or less extensive necrosis of the mucosa with the formation of granular or fibro-granular fibrin between the granules of cell detritus. Intercellular coagulation necrosis may also occur in deeper tissues, as in the follicles of the spleen or lymph glands, in the liver, kidney, etc. It is of very common occurrence in the focal necroses of toxic and bacterial origin, and is almost constantly present to some degree in tubercles. It occurs much less frequently in anæmic and hemorrhagic infarction. Many chemicals cause coagulation by direct action. The toxæmia of superficial burns is associated with a form of coagulation necrosis in the splenic follicles and lymph glands similar to that seen in infectious processes. The coagulation of the blood and the process of thrombosis may be regarded as a form of coagulation necrosis. Tissues showing coagulation necrosis are firmer and paler than normal, more opaque, and show slight elevations above the cut surface. The source of the fibrin in the different instances of coagulation necrosis mentioned above is not entirely clear. A portion may result from the coagulation of vascular exudates and from escaped blood cells. In other cases it has been assumed that fibrinogenetic substances are derived from the necrosing cells or from bacterial products. The small quantity of fibrinogen found in the lymph may give rise to a portion of the fibrin produced during the necrotic process.

The intracellular form of coagulation necrosis is characterized by the coagulation of the cell protoplasm into a solid or semi-solid albuminous body more or less resembling fibrin. The most common example of this process is the so-called waxy or hyaline necrosis of striped muscle, commonly known as *Zenker's necrosis*. In this change the muscle loses its striations and becomes converted into a hyaline homogeneous substance which sometimes stains like fibrin, but often does not. To the naked eye such muscle appears pearly white or grayish, semitranslucent, resembling fish flesh. The condition occurs most commonly in cases of long-continued fevers as typhoid, and is found also in anæmic, thermal, and toxic necrosis of muscle. In the fevers the abdominal recti and the adductors of the femurs are most often affected. The exact chemical nature of the coagulated protoplasm is unknown. The simple necrosis which occurs in anæmic infarcts is regarded by some writers as being a similar form of intracellular necrosis (hyaline coagulation), but the process is of a very different nature from the change seen in striped muscle; and, as stated above, there is no definite proof that it is of the nature of a coagulation. Other writers look upon it as an inspissation process. In some instances intracellular coagulation may result from the imbibition of fibrinogen-containing fluids and their subsequent coagulation.

Liquefaction Necrosis.—In this variety of necrosis the dead cells undergo liquefaction; the dissolution may follow a hydropic degeneration or the necrotic cells may be dissolved in the tissue fluids. As a rule liquefaction necrosis occurs primarily in tissues freely bathed in lymph, but containing little of the fibrin-forming substances, as in the brain, cord, and skin. Burns of the second degree (blisters) are very common examples of this form of necrosis. Anæmic infarction of the brain, tissue suppurations, simple softening of thrombi, atheromatous softening in blood-vessel walls, and the digestion of necrotic areas of stomach and duodenum by the gastric juice are all processes characterized by softening and liquefaction. Liquefaction is also of frequent occurrence in certain tumors. In other cases liquefaction is a secondary process following simple or coagulation necrosis. The fibrinous exudates of inflammatory processes become liquefied during the later stages of the inflammation or during the process of healing, as in the case of the resolution of croupous pneumonia. Areas of caseation necrosis and moist gangrene may undergo a secondary liquefaction. On the other hand, coagulation may follow liquefaction, the fibrin-forming substances being produced from leucocytes. In the blebs which

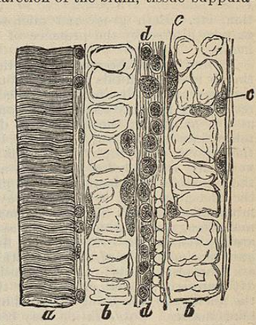

Fig. 3533.—Zenker's Necrosis of Striped Muscle Fibres, from a Case of Typhoid Fever. (From Ziegler.) *a*, Normal muscle fibre; *b*, *d*, degenerated fibres, which have broken down into separate masses; *c*, *c*, cells lying inside of the sarcolemma; *d*, connective tissue infiltrated with cells. Magnified 250 diameters.

appear in gangrenous skin there may occur a coagulation of the fluid, and the coagula may later be dissolved. Macroscopically, liquefaction necrosis is characterized by the formation of blebs on free surfaces, or by cavities filled with softened tissue débris, varying in appearance from a thin watery fluid, as in the case of brain cysts, to thick creamy fluid in abscess cavities. The earlier stages are shown by softening and increase in the amount of tissue juices. Microscopically, the presence of fluid is shown by clear spaces or vacuoles, stringy disintegration, etc. Both gross and microscopical appearances may be altered by the presence of blood or blood pigments.

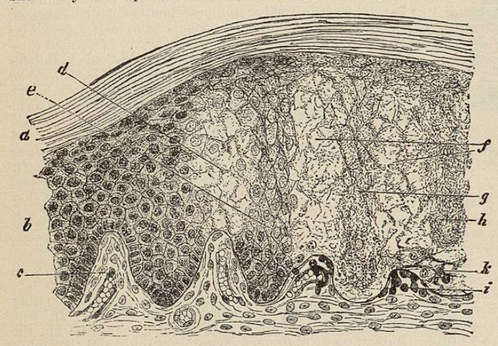

FIG. 3534.—Liquefaction Necrosis. Section through the epidermal and papillary portions of a cat's paw, a short time after it had been burned with fluid sealing-wax (alcohol; carmine). *a*, Horny layer of the epidermis; *b*, rete Malpighii; *c*, normal papilla of the skin; *d*, swollen epithelial cells, the nuclei of which are still visible at a few points, while at others they have entirely disappeared; *e*, epithelial cells lying between the papillæ, the upper ones being swollen and elongated, while the lower still remain in a normal condition; *f*, fibrinous network composed of epithelial cells (broken down so as to be no longer recognizable as such) and exudate; *g*, an interpapillary mass of cells which have become swollen and have lost their nuclei; *h*, a part of a similar mass in which the cells have been entirely destroyed; *i*, a papilla that has been flattened by pressure and that is infiltrated with cells; *k*, solidified subepithelial exudate. Magnified 150 diameters. (Ziegler.)

Mummification Necrosis.—Necrotic tissues exposed to the air lose their fluids quickly through evaporation, and become leathery, dry, hard, shrivelled, brownish, or black, resembling mummy tissue. The condition is also known as dry gangrene; the amount of decomposition which takes place is, however, very slight, the dryness rendering the growth of saprophytic bacteria impossible. In the very early stages before the fluids are entirely removed there is some putrefaction usually present, as shown by the fact that there is almost always some odor about mummified tissue. The process may be regarded as a moist gangrene in which the processes of decomposition are cut short by the evaporation of fluid. Senile diabetic gangrene, gangrene of the extremities following freezing are examples of this form of necrosis. Microscopically, dry gangrene is characterized by the disappearance of the nuclei, the cells being flattened or contracted into hyaline masses. Cornification may be taken as a physiological example of this form of necrosis.

Moist Gangrene.—If necrotic tissues containing fluids become infected with saprophytic organisms with resulting decomposition, the condition is known as moist gangrene (*sphacelus, gangræna humida, gangræna putrida*). The formation of gas bubbles due to the presence of gas-forming bacteria gives rise to emphysematous gangrene (*gangræna emphysematosa*). The different forms of moist gangrene, though distinguished by various names, are in their essence identical, since bacteria develop only in moist tissues. As mentioned above, moist gangrene may be changed to the dry form through evaporation. Gangrenous tissues are black, greenish, or brownish in color, according to the amount of blood pigment present. If there was much blood in the tissue before death the gangrene may be *black;* if the tissues were anæmic the condition is sometimes designated *white gangrene.* Such forms are also distinguished clinically by the terms *hot* or *cold gangrene.* In hot gangrene the heat may come from an abundant blood supply in the neighboring tissues. The odor of putrefaction is always present in moist gangrene, and various gases may be formed. Ptomaïns and other poisonous substances are formed in the gangrenous area, and the absorption of these may lead to sapræmia. Softening and liquefaction are always present to a greater or less degree. Microscopically, moist gangrene, in addition to the essential features of necrosis, is characterized by the presence of products of decomposition in the form of fatty acid crystals, tyrosin, leucin, triple phosphate, blood pigment, etc. The general picture may be that of a simple coagulation or liquefaction necrosis, or a combination of these forms may be present. Liquefaction is always present in a greater or less degree according to the stage of the process; all elements of the tissues, even bone and fascia, ultimately becoming dissolved. Moist gangrene may be caused by external injuries, chemical action, freezing, burns, *x*-rays, pressure, disturbances of circulation with impaired nutrition, intoxications, and infections. Lesions of the central nervous system and peripheral nerves are also regarded as direct or indirect causes of gangrene (*neuropathic gangrene*). The tissues usually affected are those most likely to be infected with saprophytic organisms, viz., the extremities, skin, lungs, external genitals, uterus, and intestines. (See also *Gangrene.*)

Caseation Necrosis.—The term caseous is used as a gross descriptive designation for necrotic processes in which the dead areas bear more or less resemblance to cheese in color and consistency. Two forms may be distinguished, the *hard* or *firm* and *soft caseation.* Either simple or coagulation necrosis or moist gangrene may be followed by caseation; the latter condition is to be regarded as a post-necrotic change representing a more advanced stage of cellular disintegration. If coagulation necrosis is present, the caseation is usually of the firm variety; if there is much fluid in the part or if the necrosis had been preceded by fatty degeneration, soft caseation will result. Caseous areas are yellowish or grayish-white, more or less firm, dry, or viscid, and on section resemble cheese in consistency. Microscopically, the outlines of tissue elements are entirely lost, nuclei are absent, and the cells broken into fine granules. Fibrin threads may be shown by proper staining; fat droplets and vacuoles may be present. Early stages of caseation may stain diffusely blue from diffused chromatin; old caseation stains red with eosin, but shows no trace of chromatin. The chemical nature of caseous material is unknown; it probably includes many different substances derived from the breaking down of proteids. Caseation is a constant change in tubercles and gummata, and is of frequent occurrence in old infarcts, focal necroses, rapidly growing tumors, etc. Caseous areas not infrequently become liquefied. It is probable that diffusion processes take place between the area of caseation and the surrounding tissue; in this way the former may become infiltrated with fluid.

According to clinical or macroscopical characteristics the various forms of necrosis are also described as *focal, diffuse, spreading, central, circumscribed,* etc. Of these varieties *focal necrosis* deserves special mention. The term is applied to small necrotic foci, occurring very frequently in the course of various intoxications and infections, such as typhoid, diphtheria, scarlatina, smallpox, puerperal eclampsia, tuberculosis, toxæmia of burns, etc. The foci are found chiefly in the liver, spleen, lymph glands, and kidneys. The form of the necrosis is usually simple, but fibrin is often present in the necrotic material. The later stages present the appearance of caseation. Focal necroses may not be visible to the naked eye, or they may resemble miliary tubercles or abscesses, for which they may be mistaken. At other times they may appear as small pale yellow or grayish spots barely distinguishable from the surrounding normal tissue. Microscopically, small islands of simple coagulation or caseation necrosis are found. When the necrosis has been recent, diffuse or fragmented chromatin may be present and the areas may stain deep blue. About the necrotic areas there is often a leucocyte infiltration. Many of the leucocytes become involved in the necrotic process; their chromatin becomes diffuse, giving rise to a deeply staining periphery. In the liver focal necroses are often limited to the central zone of the lobule about the central vein; hence the designation *central necrosis.* The same term is also applied to central necroses of bone. Focal necroses are due to the direct action of bacilli or to poisons acting directly upon the cells or to local asphyxia. The changes in the small capillaries of the affected tissue play a very important part. Fibrin may be first formed in the capillaries and lymph vessels, and thus shutting off the supply of nutrition cause cell death. In other cases changes in the capillary walls may be first produced by the injurious agent; capillary thrombosis follows, and to this the cellular necrosis may be secondary. Transudation of serum through the injured capillary walls may also lead to necrosis of the surrounding cells. The sequelæ of focal necrosis are the same as those of necrosis in general.

Fat Necrosis.—The necrosis of the fat-containing cells of adipose tissue forms a condition so striking in its clinical and pathological aspects as to warrant special mention. The condition occurs most frequently in the abdominal fat in connection with pancreatitis. The necrotic areas appear in the fat as grayish or yellowish, or in some cases black, opaque areas, soft or gritty, slightly elevated and usually circular in outline. The appearance sometimes is such as to suggest that the fat had been seared by a hot iron. Microscopically, the fat cells are enlarged, the nuclei absent, the contents granular or presenting the appearance of fine needles radiating from the centre of the cell. Osmic acid has no effect upon the altered fat cells. With ordinary stains the necrotic fat cells react in a variety of ways. The granular detritus in the fat cells consists of a combination of lime salts and fatty acids. If the process is old, the amount of lime salts may be great. It has been definitely shown that fat necrosis is due to the fat-splitting ferment of the pancreas, which under certain inflammatory conditions of that organ gains access to the tissues through the blood or lymph. Experimentally, fat necrosis may be produced by injection of pancreatic extract, by ligature of the pancreatic vessels, by introduction of pieces of pancreas into adipose tissue or into the peritoneal cavity, and by the direct action of steapsin in fat tissue. Not only may the abdominal fat be affected in cases of pancreatitis associated with fat necrosis, but also the fat of the pericardium, liver cells, retroperitoneal region, and bone marrow. In the majority of cases the condition is fatal, but recovery has been noted, the dead fat cells becoming calcified.

Hæmolysis, the destruction of the red blood cells, and *leucolysis,* the disintegration of leucocytes, are discussed by some writers under the head of necrosis. The exact nature of these processes is not at present definitely determined. Bacterial products, various poisons, the blood sera of animals of different species, or of the same species under certain conditions, are the chief factors in the production of these conditions. Normal hæmolysis occurs in the spleen, lymph glands, hæmolymph glands, and bone marrow. In pernicious anæmia, sepsis, and many of the acute infections and intoxications hæmolysis occurs in these organs to a greatly increased extent. Pathological destruction of the red cells in the circulating blood occurs also in a variety of infections and intoxications. The term *hæmocytolysis* is more properly applied to this condition, but has been largely superseded by the word hæmolysis.

Sequelæ of Necrosis.—The course of the necrotic process depends upon the anatomical nature and location of the affected tissue, the course and manner of the injurious influence causing the necrosis, the condition and environment of the affected part, the amount of blood and lymph, the nature of preceding changes, the opportunity for the access of air and putrefactive agents to the part, etc. About the necrotic area there is always a more or less marked inflammatory reaction in the surrounding living tissue. As a result of such inflammation the necrotic area becomes isolated and sequestered. The process is called *sequestration,* and the area of necrotic tissue so shut off a *sequestrum.* The ultimate sequelæ will be: (1) *Regeneration* following the absorption or casting off of the dead tissue, new tissue resembling the normal being formed; (2) *cicatrization;* (3) *calcification;* (4) *cyst formation,* the dead tissue being liquefied and encapsulated; (5) *chronic abscess* or *ulcer.*

Aldred Scott Warthin.

NECROSIS OF BONE. See *Bone, Pathology of.*

NEMATODA.*—The class of the Nematoda or round worms constitutes a large, rather uniform, and clearly demarcated group, which by many recent authors has been regarded as of the rank even of a phylum, in which case the name Nemathelminthes has been applied. The group is characterized by a cylindrical body, often filiform even in its attenuation, and by the heavy cuticular investment which carries in some cases small bristles, hooks, or spines, but which is consistently without appendages and manifests at most surface striation, but never true segmentation. The body cavity is extensive, but unprovided with a peritoneal epithelium, and the sexual and excretory systems do not stand in any connection with it. Another striking feature is the entire absence of cilia in all stages of development.

An alimentary canal is present, at least in some stage of the life history of all forms. It is with rare exceptions a permanent structure in the members of the sub-class of true round worms, or Eunematoda; but in the sub-class of the hairsnakes or Gordiacea, the alimentary canal is greatly reduced in the adult, in that the mouth is closed and a delicate solid string of tissue is the only vestige of the anterior portion of the canal. The posterior region still retains its cavity and functions in connection with the reproductive organs of both sexes, which have with it a common outlet. In the Eunematoda, on the other hand, the male organs join the alimentary canal to form a common cloaca, but the female system is entirely unconnected with the alimentary system, and the vulva occupies a variable position in the midventral line. The sexes are separate, though in rare instances parthenogenesis or hermaphroditism modifies the usual balance.

By far the largest number of forms belongs to the Eunematoda, which will be considered first, while the Gordiacea and, as an appendix, the Acanthocephala will be discussed subsequently. Among the Eunematoda the better known forms are parasitic, though some are free living and an occasional species is capable of making use of both types of environment. The free living species are uniformly insignificant, but among parasitic forms one finds the microscopic blood parasites and the meter long guinea worm. In respect to location also there obtains great variety; and one finds these parasites in all regions of the alimentary, respiratory, circulatory, excretory, and muscular systems, and in connective tissue and serous cavities.

The greatly elongated cylindrical form tapers as a rule more or less toward both ends, though generally speak-

* A general discussion of parasitism and its effects will be found under the heading *Parasites.*