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.

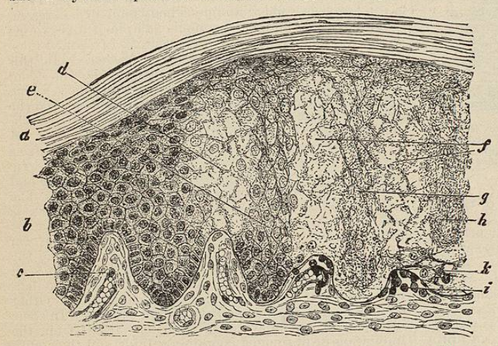

FIG. 3534.—Liquefaction Necrosis. Section through the epidermal and papillary portions of a cat's paw, a short time after it had been burned with fluid sealing-wax (alcohol; carmine). *a*, Horny layer of the epidermis; *b*, rete Malpighii; *c*, normal papilla of the skin; *d*, swollen epithelial cells, 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.*

ing the head is truncated and the tail acute. The chitinous cuticula invests the entire body, and is introverted a short distance at all orifices. It bears rarely unjointed spines and bristles and is marked often by delicate surface striations. In cross section (Fig. 3537) the body appears circular, and shows beneath the cuticula a thin hypoderma layer, which is prominently thickened at four points. Of these the lateral lines, fields, or areas, as they are called, are largest, and are visible in surface view as delicate longitudinal stripes (*c*, Fig. 3535). The dorsal and ventral median lines are much less prominent and are distinguishable ordinarily only in sectional views.

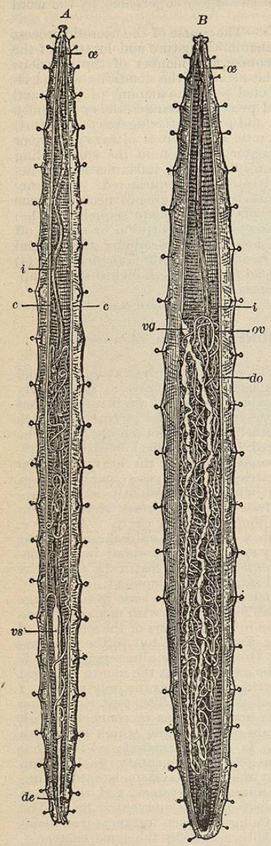

FIG. 3535.—Internal Anatomy of *Ascaris lumbricoides*, opened along dorsal line. *A*, Male; *B*, female; *c*, lateral line; *de*, ductus ejaculatorius; *do*, uterus; *i*, intestine; *œ*, œsophagus; *ov*, coiled ovary; *vg*, vagina; *vs*, seminal vesicle. (After Delafond.)

Directly below the hypodermis is the muscular layer which is interrupted by the lines already noted, and hence appears as four muscular fields. The muscle cells (*m*, Fig. 3536) are of a peculiar type in that a protoplasmic body is distinct from the contractile fibrillar portion. The main trunks of the nervous system occupy the dorsal and ventral areas, while the lateral areas contain each a delicate canal, which has been interpreted as part of the otherwise unexplained excretory system; with the latter are associated, however, certain stellate cells of peculiar character, which project from the lateral fields into the body cavity and are known as phagocytic organs.

The alimentary canal (*i*, Fig. 3535) is a straight simple tube extending from the mouth, which is always terminal, to the anus, which varies in location from the posterior end to a position on the ventral surface, some little distance removed from it. Various features connected with the canal are of great systematic importance. About the mouth are found a number of lips and papillæ characteristic of the genus or family. The buccal or pharyngeal cavity, an enlargement at the outset, the muscular œsophagus with a triangular lumen (Fig. 3537) and a terminal enlargement which may be indistinctly marked, or may partake of the form of a distinct bulb, or even two such, with a valvular apparatus, the intestine proper followed by the rectum and cloaca in the male—these constitute the distinct parts of the alimentary system.

FIG. 3536.—Section of Body Wall. Highly magnified. *n*, Nucleus and *p*, protoplasmic body of muscle cell, *m*.

The sexual organs have the form of a long coiled tube, in the attenuated distal end of which the sexual cells are produced, while the proximal portions afford storage for the perfected germ cells before they are discharged from the body. In the female the system is regularly bifid, although one horn of the uterus may be undeveloped to a greater or less extent, while in the male only a single tube is present. The varied debouchment of the system in the two sexes has already been noted. About the vulva chitinous lips often of notable thickness are developed, and on the external surface near the male orifice numerous papillæ characteristic of the genus or species, and at times a sucker also are to be found; these function as accessory copulatory apparatus, while in the same category are included expanding folds of the body wall known as the bursa and awl-shaped chitinous structures called spicules. The bursa varies from a pair of simple folds lateral to the cloaca to a cup or bell surrounding it and the posterior end of the body. The spicules, either one or two in number, with an accessory guiding piece in some instances, are developed in a dorsal evagination from the cloacal wall and provided with special musculature for extrusion and retraction. Their form varies greatly in different species, and with the bursa and circumanal papillæ constitutes the means for determination of the species.

The Eunematoda are oviparous, but in some cases the eggs are retained long enough in the uterus to contain when laid a partly or fully developed embryo; and in a few species the embryo deserts the shell before it is extruded from the body. All stages in the development of this ovoviviparous habit may be observed.

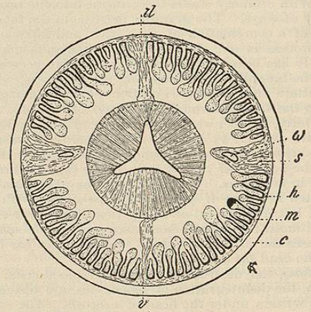

FIG. 3537.—Transsection of *Ascaris lumbricoides* at level of œsophagus. *c*, Cuticula; *h*, hypoderm; *i*, intestine; *m*, muscle layer; *d*, dorsal, *s*, lateral, *v*, ventral lines; *w*, excretory canal. (After Hertwig.)

Ordinarily the eggs which undergo development external to the body of the host are provided with a heavy shell to resist the action of an unfavorable environment. In case the eggs undergo development while still in the uterus, the shell is thin. Some species develop directly, *i.e.*, without a change of host, though a certain stage in the life history at least is passed in the outer world; in other cases the immature worm lives in another animal, known as the intermediate host, than that which harbors the adult, or rarely in a different part of the body of the one host. In a few species a parasitic generation alternates with a free living generation of such different form as to have been regarded as another species; and the alternating generations differ radically in method of reproduction. In one case at least (*Trichinella*) the entire life history is passed within the host and transportation to a new host depends upon the carnivorous habit. In other cases also (blood filariæ) the life history is passed within two hosts and no part takes place externally; but in most instances there is a free living stage and infection is brought about primarily through the drinking-water. Some prominent exceptions to this general statement are noted later.

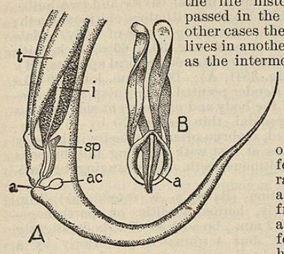

FIG. 3538.—*Anguillula aceti*. *A*, Tail of male; *ac*, accessory piece; *sp*, spicules; *B*, spicules partially protruded from anus. Magnified. (After Stiles.)

The family of the Anguillulidæ, which is difficult to characterize, contains mostly free nematodes of small size, transparent, filiform, and tapering to both ends. The œsophagus is inflated or has one or two bulbs at the posterior end. The female possesses double symmetrical uteri and short reflexed tubular ovaries, with vulva at or behind the centre of the body, with few, large ova, and with development rapid, often ovoviviparous. The male has two equal chitinous spicules, with or without one or more accessory pieces. The type genus is

Anguillula Ehrenberg 1826.—Buccal cavity very minute; œsophagus cylindrical with two bulbs, the posterior having a valve apparatus; vulva behind centre of body; male without bursa; accessory piece single, fan-shaped. The best-known species is the vinegar eel, which has recently been found as a parasite of man.

Anguillula aceti Müller (Fig. 3538).—Cuticula unstriated, body tapering slightly anteriad; tail greatly attenuated. Male 1.35 to 1.45 mm. long by 24–28 μ wide. Spicules 38 μ long, similar, twisted; accessory piece slightly caudad; no bursa; papillæ at least two preanal and one postanal. Female, 1 to 2.4 mm. long, by 40–72 μ in diameter, contains embryos 0.22 mm. long by 12 μ in diameter.

This worm, which is everywhere common in vinegar, has been recently studied by Stiles and Frankland in the rôle of a human parasite. The specimens were taken in great numbers from the urine of a female patient, and were present during a period of thirty-three days. The urine was always very acid and once had a marked odor of vinegar. In this sample the worms lived two months, and individuals then removed to vinegar became vigorous and bred rapidly.

Pathology.—The patient had chronic parenchymatous nephritis of a degenerative type, and the urine frequently contained albumin, but not while the parasites were present. No symptoms traceable to them were observed, and their presence in the bladder remained unexplained. The suspected use of vaginal douches acidulated with vinegar was denied by the patient, and no grounds existed for questioning the truth of the statement. Evidently this parasite might be present in the vagina if such a practice were followed. Billings and Miller have reported two other cases from the United States in which, however, the source of the parasite was not demonstrated beyond question.

Leptodera A. Schneider 1866.—Œsophagus with two bulbs, the posterior with or without valves. Male with or without bursa, often six to ten papillæ on the bursa or on the median line; two short spicules and a single accessory piece. Some species are hermaphroditic. A somewhat indistinct genus, difficult to separate from that last described, and perhaps identical with it.

Leptodera Niellyi R. Blanchard 1885.—(Syn.: *Anguillula leptodera* Nielly; *Rhabditis Niellyi* R. Bl. 1888.)

This species is known only in the larval form, in which it measures 333 μ in length and 13 μ in breadth. The alimentary canal was the only internal organ described; it displayed two enlargements in the pharynx, the second pharyngeal bulb having a dentate armature.

The worms were discovered by Nielly in 1882 in a young man, fourteen years of age, who was born near Brest, and had never been out of that region. A dermal eruption, much like craw-craw, of about five or six weeks' standing, affected chiefly the patient's limbs. In the fluid of each papule were found several worms, and the blood showed on microscopical examination at the outset of the malady many small nematoda, which, however, could not be found later; at no time were they found in fæces or urine.

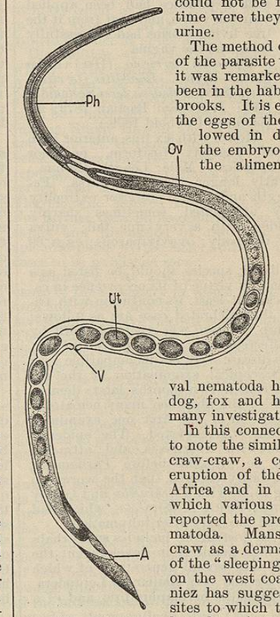

FIG. 3539.—*Strongyloides stercoralis* from Human Intestine. × 80. (After Braun.)

The method of the introduction of the parasite was unknown; but it was remarked that the lad had been in the habit of drinking from brooks. It is easily surmised that the eggs of the worm were swallowed in drinking, and that the embryos, hatching out in the alimentary canal, bored their way into the circulation and thus reached the skin. Their presence both in the blood and in the papules is thus easily explained. They may have been, however, larvæ of some imported filaria, though dermatosis caused by larval nematoda has been observed in dog, fox and horse in Europe by many investigators.

In this connection it is important to note the similarity of this case to craw-craw, a contagious vesicular eruption of the skin, observed in Africa and in South America, in which various investigators have reported the presence of larval nematoda. Manson regards craw-craw as a dermatosis characteristic of the "sleeping sickness," endemic on the west coast of Africa. Moniez has suggested that the parasites to which this case is due may have been imported by some sailor from Africa, and associates with it the case of elephantiasis, also observed in Brittany.

Leptodera pellio (A. Schneider 1866).—(Syn.: *Rhabditis pellio* A. Schneider 1866; *R. pellio* Bütschli 1873; *R. genitalis* Scheiber 1880.)

Male: Length, 0.8–1.5 mm.; bursa with seven to ten ribs on each side; spicules 27–33 μ in length, nearly alike. Female: Length, 0.9–1.3 mm., posterior extremity long

and pointed, vulva a little in front of the middle; ovary not paired; eggs oval, 60 by 35 μ.

Scheiber found this species at Stuhlweissenburg, Hungary, in the urine of a native woman suffering from pyelonephritis, pneumonia, and acute intestinal catarrh. During the entire illness the worms were found in the vagina in all stages of development. Several other authors have found what is closely related, if not the same form, in the urine in cases of hæmaturia; but the parasitism is probably accidental, since Oerley has shown that *R. genitalis* Scheiber must be referred to *R. pellio*, a common free living form found in moist earth and putrefying substances, and also that worms of this species will multiply in the vagina of white rats. There is further to be noted both the habit of Hungarian peasants in employing moist earth for poultices and the record of Scheiber, that patient and clothing were earth-stained, rendering it altogether likely that such a poultice had been applied near the vulva, and that from it the free living worms had successfully colonized the vagina.

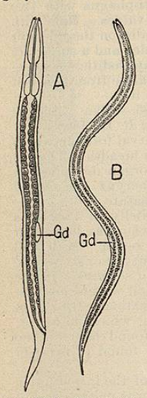

FIG. 3540.—*Strongyloides stercoralis*. *A*, Rhabditiform larva from fresh fæces. ×145: *B*, filariform larva from culture; *Gd*, genital cell. ×135. (After Braun.)

Leptodera terricola (Dujardin 1845.)—(Syn.: *Rhabditis terricola* Duj. 1845; *Pelodera teres* Schneider 1866; *P. setigera* Bastian 1879; *R. Cornwalli* Cobbold 1879.)

Mouth with six lips, anterior bulb of pharynx fusiform, posterior spherical. Male: Length, 1.3 mm.; tail attenuated, slightly longer than the bursa. Female: 2 mm. in length and over; posterior extremity sometimes regularly attenuated, sometimes sharply rounded and provided with a very fine tail; vulva about the middle of the body; ovoviviparous; eggs 60 by 40 μ.

This typical free living species should be listed as a pseudo-parasite of man by virtue of its occurrence in cadavers, and, in one case at least, its confusion with trichina. The facts in this celebrated case are as follows: The English schoolship *Cornwall* was visited in 1879 by an epidemic which affected many cadets and killed one. The symptoms of the disease were not incompatible with trichinosis, and microscopical examination of the exhumed cadaver, undertaken two months later, demonstrated in the muscles of the abdomen many nematoda, which, with the exception of the first one examined, were dead, but not one was encysted. The epidemic was pronounced therewith trichinosis, and attracted enough attention to be brought before Parliament. Cobbold and Bastian easily showed that the worms in question had nothing to do with *Trichinella*, and Oerley established their identity with *L. terricola*, which had undoubtedly penetrated the body after inhumation.

The family of the Angiostomidæ includes small rhabditis-like nematoda which manifest in development the alternation of two types of sexual generations of which the first is dicœcious, free and very similar to Leptodera, while the second is parasitic, hermaphroditic, and of a different structure.

Strongyloides Grassi 1879.—Parasitic generation with simple mouth in which no armature is present; cylindrical pharynx very long. Free generation with small oral cavity; pharynx with two bulbs, the anterior fusiform, the posterior spherical and armed; male with two small spicules similar.

Strongyloides stercoralis Stiles and Hassall 1902.—(Syn.: *Anguillula intestinalis* and *A. stercoralis* Bavay 1877; *Leptodera intestinalis* and *L. stercoralis* Cobbold 1879; *Pseudorhabditis stercoralis* Perroncito 1881; *Rhabdonema strongyloides* Leuckart 1883; *Strongyloides intestinalis* Grassi 1883; *R. intestinale* Blanchard 1885.)

Free generation (Bavay's *A. stercoralis*) both sexes occur; body slender, tapering toward the ends; mouth with three or four indistinct papillæ; œsophagus 0.16 mm. long, with well-developed buccal cavity and two bulbs, the posterior of which is armed with three chitinous teeth; anus with protruding lips on right side of body. Male (Fig. 3541, B): 0.75–1 mm. long, 35 to 66 μ thick, with short recurved tail and two curved, conical spicules, 38 μ long. Female (Fig. 3541, A): 1–1.4 mm. long, 50–75 μ broad, with long slender pointed tail; vulva a little behind the middle of the body and on the right side; uterus double; eggs ellipsoidal, thin-shelled, 70 by 45 μ, segmentation advanced, embryo often hatched within body of mother; embryos at first with tapering tail, bulbous œsophagus, and chitinous teeth, soon changing to filariform stage.

Parasitic generation (Bavay's *A. intestinalis*) (Fig. 3539). Female only, hermaphroditic or parthenogenetic; length 2.1–2.2 mm., breadth 30–39 μ, body slightly tapering anteriorly, but terminated posteriorly by a short bluntly conical tail, with rounded and slightly dilated tip; mouth with three poorly developed lips (or none? Strong); œsophagus cylindrical, with no swellings, one-fourth the length of the body or more, distinguishable readily only in color from the intestine; vulva transverse in posterior third of the body; uterus with five to six (nine to twenty?) ellipsoidal eggs, 50–59, or 65–70 μ by 30–34, or 39 μ, and often joined in strings of two or three. The eggs are segmenting when laid, they develop rapidly and hatch before being ejected with the excrement. Embryos rhabditiform, 0.3–0.6 mm. long by 16–22 μ wide; first molt within twenty hours if in incubator.

Dr. Normaud discovered the species in 1876, when examining microscopically the stools of soldiers returned from Cochin China, who were suffering from acute dysentery. Somewhat later he found at the necropsy of a soldier who had died from Cochin China diarrhœa, the other form of the species. Both of these forms were originally studied and described by Bavay. It was in 1883, before the connection of the two was established by Leuckart, who showed them to be phases in the life history of the same species. In life man harbors in the canal the one* form (*A. intestinalis* Bavay) and its young which, reaching the exterior with the fæces, may be transformed then into the other adult (*A. stercoralis* Bavay); the latter transformation may also take place in the intestine after death, as in cultures made in confirming these discoveries. Later authors have added many details, which may be summarized as follows:

The parasitic generation, which recalls a strongylid or a filaria in general appearance, produces eggs so abundantly that from an ordinary infection more than a million embryos may be evacuated in a single stool. The embryos (Fig. 3540, A) measure at hatching 0.2–0.24 mm. long by 12 μ broad, but develop so rapidly that those in the stools have attained a length of 0.30–0.60 mm. by a width of 16–23 μ. The embryos are characterized by a rhabditiform œsophagus, and under normal temperature they soon moult; and then, protected as if by a cyst in the larval skin, await more favorable conditions for further development. If kept, however, at a temperature of 25–35° C. they develop to sexual maturity in fifteen to eighteen hours; they copulate in thirty hours, and the females begin to lay at fifty to fifty-five hours.

After the first moult the structure of the embryos becomes more distinct, and one can see three or four oral papillæ and a buccal cavity, together with an anterior enlarged and median constricted region of the œsophagus, which is terminated by the œsophageal bulb, containing an apparatus for trituration composed of three chitinous teeth. The intestine which follows ends in a slightly protruding anus located on the right side. Also

* It is disputed whether the other form may very rarely be found under the same circumstances.

on the right, about one-third the distance from the bulb to the tail, is the whitish lenticular proton of the sexual system.

In most cases studied in temperate regions after a few days in culture, these embryos die or change form, becoming elongate and with more tapering tails, the œsophagus loses its teeth and enlargements and becomes a uniform cylinder; the embryos resemble young filariæ and have taken on the strongyloid form (Fig. 3540, B).

Only thirty to forty eggs are deposited by each female of the free generation (Bavay's *A. stercoralis*), which develop so rapidly as to approach the ovoviviparous condition; they hatch out young worms about 0.32 mm. long, in which the œsophagus manifests a distinct rhabditiform character. After the first moult, which occurs when they are about 0.35 mm. long, they acquire in from thirty to thirty-six hours the strongyloid appearance, in that the mouth shows four lips, the œsophagus is cylindrical and has lost its dental armature, the tail is shortened, and bears near its end two small lateral wings. At the end of eight days the free form can no longer be found in the cultures, and all the young have become strongyloid larvæ. If introduced into the intestine, these larvæ develop into the parasitic female, with which the cycle begins anew.

A remarkable modification of this, the normal life cycle of the species, was discovered by Grassi, who found that the development might be abridged since the rhabditiform embryos may transform directly into the strongyloid larvæ without the intervention of any free sexual generation. This direct development has been confirmed by Leichtenstern, who has observed it for weeks in succession, while at other times alternation with the free rhabditiform generation comes in. The causes of this transformation are unknown as yet; it must, however, be regarded as an important etiological factor, since the infection of man may be due to the accidental introduction of either sort of larvæ, or of the adult parasitic form. Stiles has suggested that this abbreviation is a step toward perfect parasitism.

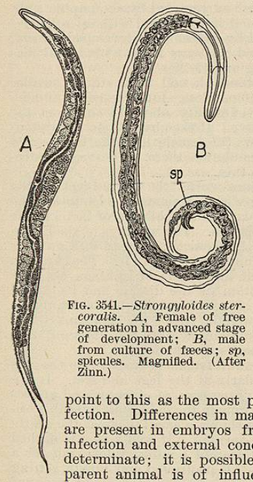

FIG. 3541.—*Strongyloides stercoralis*. *A*, Female of free generation in advanced stage of development; *B*, male from culture of fæces; *sp*, spicules. Magnified. (After Zinn.)

The method of introduction can only be inferred to be impure water or vegetables, salads, etc., which have been contaminated by human excrement. Although Normaud acquired the disease in Cochin China, while having refrained absolutely from drinking any but imported water, and was accordingly inclined to question the part played by water in its dispersal, yet in the absence of further evidence general considerations must point to this as the most probable source of infection. Differences in manner of development are present in embryos from a single original infection and external conditions seem to be indeterminate; it is possible that the age of the parent animal is of influence. Embryos with direct development are at least more resistant, and alone survive under unfavorable environment.

It has been claimed after culture experiments by Wilms that there are not two varieties of the parasite, one developing by the direct, the other by the indirect method, but that embryos from the same lot of eggs may develop in either fashion. Though the number of cases observed is probably too small for definite conclusions, it is striking that cases infected with the tropical strongyloids develop usually with the interpolation of the free sexual generation, while cases infected in temperate regions, both of Europe and America, manifest almost exclusively direct development. It should not be forgotten that there may be concerned here more than one species of closely related and heretofore confused forms, which would account for some of the apparently conflicting statements. Certain it is that the figures of the larvæ, given by various authors, do not agree in the form and proportions of the different regions in the œsophagus, which for individuals in the same moult are ordinarily regarded as constant, and an examination of the adult parasites, as figured by two most recent observers, Strong and Braun, shows numerous differences in detail, which can hardly be errors in observation.

The observations of Grassi, that the alternation of generations described above is not a necessary feature in the life cycle of this species, is still further of importance as explaining the enormous number of worms found in the intestine in some cases. Leuckart records an instance in which prodigious quantities of the worms were evacuated even a year and a half after leaving the locality of infection. Such evidence leaves little reasonable doubt of the multiplication of the parasite in the human alimentary canal, as in fact related species do so reproduce in other animals and as *Anguillula aceti* multiplies in the human bladder as noted above.

Distribution.—*Strongyloides stercoralis* occurs very widely. The entire tropical and subtropical zone of Africa, Asia, the Philippines, and the East Indies form apparently its original home, within which its occurrence is all but universal. It has also been recorded from Martinique, Brazil, Hawaii, and in Europe from Sicily, Italy, and Mount St. Gothard tunnel, Spain, Russia, and among brickworkers along the Rhine and in East Prussia. First reported in the United States by Strong, it has been observed and studied since then twice in Baltimore by Thayer, who showed its probable endemic character. For further data on its occurrence as well as for bibliography and discussion of previous cases consult the splendid paper by the latter author. Stiles has 5 further cases to be published soon.

Pathology.—At first the worm was regarded as the cause of the dysentery in which it was originally discovered and with which it is usually associated; more recent investigations have thrown some doubts upon this view. The rarity of the worm in the intestine at the outset of the disease, its abundance in stools of convalescents, its absence in cases which have freely bilious diarrhœa, and often in severe attacks of Cochin China diarrhœa, and finally its frequent presence in individuals enjoying normal health, all militate against the supposed pathogenic rôle of the species; and both Grassi and Leichtenstern go so far as to proclaim the species entirely innocuous, "innocent commensals of man."

On the other hand, its presence is not regarded by all authors as harmless, even though they do not regard it as the cause of the disease. Sonsino has found that in Italy excessive multiplication of the species may give rise to acute enteritis followed by dangerous anæmia. Golgi and others have observed epithelial lesions which they have attributed probably with justice to the action of this parasite. Its extraordinary multiplication in the human alimentary canal must contribute to the irritation of the mucosa and to the development of the lesions produced by the so-called Cochin China dysentery. Recent observations of Askanazy serve to demonstrate the pathological character of these worms, which he finds to be actual parasites of the intestinal wall in the duodenum and jejunum. Here they penetrate chiefly the mucosa, being often found in the epithelium of Lieberkühn's glands. They may penetrate to the muscular layer or rarely deeper than this. These migrations are in search of food, as the chyle-filled body of the worm shows; but no evidence was found to show that they ever suck the blood of their host.