and due to occlusion of the ducts, leading to bile intoxication or purulent inflammation.

VII. Congenital Defects of the Gall Bladder and Gall Ducts.—The gall bladder may be absent entirely, without serious inconvenience; a shrivelled pouch or a contracted tube takes its place. In atresia of the ducts, jaundice, umbilical hemorrhage, and marasmus are present during life. The jaundice is present at birth, or makes its appearance a few days afterward, persists, and deepens. The stools show an absence of bile; the urine is bile-tinged. There is from the first a tendency to hemorrhages, and this increases ecchymosis under the skin; bleedings from the mouth, nose, or bowels take place.

Umbilical hemorrhage, occurring after the separation of the cord, is especially marked. As the child grows older it loses in flesh, becomes extremely weakened, and dies of cholæmia or exhaustion, in spite of an ability to take much nourishment. At first the liver is normal, but if the child lives it becomes very large, and the spleen is likewise increased in size. Ascites may develop. If hemorrhages do not occur, the child lives many months. In a case reported by Lotze, the child lived seven months.

R. Lomer[15] reports a curious case. It was one of congenital obliteration of the right hepatic and the cystic ducts. The whole right lobe had undergone cystic degeneration and was shrunken, the gall bladder was obliterated, but the left lobe remained normal. He analyzes a series of cases, and, from the fact that usually the parents are syphilitic and several of their children are similarly diseased, he holds that an intra-uterine hepatitis of syphilitic origin is the cause of the disease. This is the usually accepted explanation of the pathology of congenital disease of the ducts. The obstruction, which is fibrous, may be in a main duct or in one of its branches. The gall bladder may be normal, but contains a serous fluid. It may be obliterated or remain as a fibrous cord. The ducts in the liver may be dilated, or some may appear like fibrous cords. Sometimes the portal fissure is the seat of local perihepatitis, and usually the surface of the liver is involved. The liver is icteric, the seat of connective-tissue overgrowth, or atrophied. Some parts become cystic. Rolleston and Hayne[16] describe a congenital obliteration of the bile ducts giving rise to an advanced hepatic cirrhosis; Thompson (Allbutt's "System of Medicine" and Thesis, Edinburgh, "Congenital Obliteration of Bile Ducts") has collected fifty such cases. Ford[17] gives cases of congenital obstruction producing the so called biliary cirrhosis.

The jaundice due to congenital defects of the ducts is to be distinguished from that jaundice-like discoloration of the integuments, conjunctiva, etc., that is physiological. In this condition, which is common in new-born infants, bile is present in the stools. Jaundice of the simple catarrhal variety also occurs in infants. It usually responds promptly to treatment, and has not the malignant aspect of disease dependent upon deficiency of the ducts. Then, again, a pylephlebitis occurs sometimes in infants. In this case fever and the usual evidences of pyæmia are present.

VIII. Parasites.—They may develop within the biliary passages (distoma), they may emigrate from the intestines (round worm), or they may find their way into the ducts by ulcerative action (echinococcus). Rarely, the latter develop within the ducts.

1. *Distoma hepaticum (large liver fluke) and Distoma lanceolatum (small liver fluke).*—Common in sheep and cows, rare in man. The large fluke is found in the gall bladder or large bile ducts; the small one generally in the finer ducts. Both species may occur in the same subject. The latter variety produces the most notable changes in the liver.

The presence of these parasites sets up a chronic catarrhal and suppurative inflammation of the ducts. Enlargement of the gall bladder and ducts occurs secondarily. A fibrous inflammation of the walls takes place, with secondary calcareous degeneration of the products of inflammation; the ducts become much enlarged and thickened, and the lumen is dilated. Occlusion of the ducts results on account of the inflammatory disease and the presence of the parasites in the canal. By necessity, therefore, we have the symptoms, previously noted in this section, of the above anatomical changes, and of obstructive jaundice. In addition, nervous symptoms of a reflex nature—as syncope, convulsions, or aphonia—may be present. A positive diagnosis can be made only by finding the parasites in the vomited matter, or in the fæces. Death occurs sometimes on account of the inflammatory complications, or from exhaustion.

2. *Round Worms (Ascaris lumbricoides).*—They usually wander from the intestines, and are found with their head toward the liver. Rarely, after adhesive inflammation and fistulous communication between the gall bladder or ducts and the intestine, worms are found in the biliary passages. The number of them varies—from one to three or four, usually. They are often found alive on making an autopsy, or have died before the death of the patient, and are soft and macerated. Their presence excites catarrhal inflammation, causes occlusion and, secondarily, a purulent cholangitis, a dilatation of the ducts, and subsequent atrophy of the liver, or the formation of multiple abscesses. When limited to the gall bladder, they cause enlargement and inflammation of that organ. The dilatation of the ducts is usually general; sometimes local sacculated dilatations are observed, in which worms lie rolled up.

The symptoms—if the worm has recently migrated into a duct—are like those of hepatic colic. Later, the symptoms and signs of obstructive jaundice occur, and then those of purulent cholangitis. A history of an attack of worms, the presence of the parasite in the ejecta, and the age of the patient furnish valuable corroborative evidence. Further, intestinal and nervous symptoms due to worms are said to be present.

3. *Echinococcus (Hydatid Disease of the Bile Ducts).*—Either an hydatid cyst may press upon one or more of the ducts, causing occlusion of them, or complete obliteration of their lumen, or entire destruction of them (Leroux); or the sac may ulcerate into the ducts or bladder, and the vesicles pass by this route into the intestines, with symptoms of hepatic colic; or, finally, it may cause occlusion, dilatation, and inflammation of the biliary passages. This process may terminate in suppuration and gangrene of the cyst, and is usually fatal. The symptoms of obstructive jaundice of a high degree, and of the local inflammatory changes, indicate this pathological condition. The presence of hydatid hooklets in the ejecta from the stomach or bowels, a previous history of a painless enlargement of the liver, and the results of tapping or exploratory puncture, would confirm one's opinion of the presence of hydatid disease. Finally, the gall ducts are seriously invaded in that rare manifestation of hydatid disease known as multilocular echinococcus. In this instance the walls of the ducts are thickened, hard, and rigid, and the lumen is effaced, by the presence of the vesicles in the tissues. Secondary inflammation, suppuration, and dilatation, etc., may arise in these cases. The symptoms of this manifestation have been considered in the section on Occlusion of the Ducts.

It is interesting to note that the bile, some authorities believe, is capable of killing these parasites.

*John H. Musser.*
*Norman B. Gwyn.*

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[2] Boston Med. and Surg. Jour., August 4th, 1898.
[3] See Trans. Path. Soc., vol. viii., and Am. Jour. of the Med. Sciences, July and October, 1884, for cases of chronic catarrhal jaundice by the writer.
[4] Deutsch. med. Wochen., 1895, No. 15.
[5] Amer. Journ. of the Med. Sciences, November, 1901.
[6] Bulletin of University of Pennsylvania, September, 1901.
[7] Jaundice is used in a general sense. For a further discussion of symptoms and effects, see *Icterus*.
[8] See Pathological Society's Transactions, Philadelphia, 1877-78, Am. Jour. of the Med. Sciences, July, 1884.
[9] In cases of cancer of the gall bladder and ducts, calculi are often passed.





[10] Numbers record frequency of the presence of a stated fact in the seventy-eight cases.
[11] *Loc. cit.*
[12] Boston Med. and Surg. Journ., March 7th, 1901.
[13] Lancet, February 16th, 1901; Med. Chron., 1896.
[14] Johns Hopkins Bulletin, January, 1900.
[15] Lomer: Ueber einen Fall von congenitaler partiellen Obliteration der Gallengänge. Virchow's Arch., Band 99, p. 130.
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**GALLIC ACID.**—By exposure, to the atmosphere, of galls in the presence of water, chemical conversion of the tannic acid of the galls takes place, resulting in the formation of gallic acid, $HC_7H_5O_5.H_2O$. This body is official in the United States Pharmacopœia under the title *Acidum Gallicum*, Gallic Acid, and presents itself as "white, or pale fawn-colored, silky, interlaced needles, or triclinic prisms; odorless; having an astringent or slightly acidulous taste; permanent in the air. Soluble at 15° C. (59° F.), in 100 parts of water, and in 5 parts of alcohol; in 3 parts of boiling water, and in 1 part of boiling alcohol. Also soluble in 40 parts of ether, and in 12 parts of glycerin. Very slightly soluble in chloroform, benzol, or benzin" (U. S. P.). On heating, the acid first loses its water of crystallization, then melts, and finally is decomposed, and consumed without residue.

Gallic acid is purely but feebly astringent, and seems practically devoid of any other physiological property. Taken internally, it does not poison, nor constipate, nor even disorder the stomach unless in excessive dosage. It does not coagulate albumin, and so, when swallowed, is readily absorbed. After absorption it appears speedily in the urine, as is demonstrable by chemical tests. *Therapeutically*, the only reputation of gallic acid is for internal giving for the control of hemorrhages from inaccessible parts—for which purpose the efficacy of the medicine is esteemed very differently by different practitioners. Since, in the application in question, the acid must act by local contact as presented to the bleeding vessel in solution in the blood, it is evidently necessary for success that the charge of acid to blood shall be as great as possible. Full and frequent doses, therefore, are required by the indication. Gallic acid has been given without untoward effect in dosage of 0.65 gm. (gr. x.) every three hours, unremittingly, for three weeks. It may be prescribed in pill, powder, or mixture. *Edward Curtis.*

**GALLICIN** $[C_6H_2COOCH_3(OH)_3]$ is prepared by heating a methyl alcohol solution of gallic or tannic acid with strong sulphuric acid, or by passing dry hydrochloric acid gas through the solution. It crystallizes in rhombic prisms or fine needles, which are freely soluble in water and alcohol. It is used as an antiseptic, non-toxic dusting powder, and, in solution, in conjunctivitis.

*W. A. Bastedo.*

**GALLOBROMOL**—dibromogallic acid $[C_6Br_2(OH)_3COOH]$—is a colorless or slightly grayish-red powder, composed of fine acicular crystals, and obtained by the action of bromine on gallic acid. It is slowly soluble up to ten per cent. in cold water (Merck), and dissolves readily in boiling water, alcohol, or ether. It has been used as a bromide in neurotic conditions and epilepsy, but has been found by Lépine to cause in a dog slowing of the heart, depression of respiration, fever, hæmoglobinuria, convulsions, and death. It is of more use locally, as an antiseptic and astringent, as in eczema, or in gonorrhœa, cystitis, or epididymitis. For cystitis it is used as an irrigation in two to four per cent. solution; for urethritis as an injection; and for eczema as a lotion, ointment, or dusting powder of one to two per cent. strength.

*W. A. Bastedo.*

**GALLOFORMIN** $[C_6H_2(OH)_2COOH(CH_2)_6N_4]$ is a condensation product of gallic acid and hexamethylene tetramine. It forms very hard, refractive, acicular crystals, soluble with difficulty in water, alcohol, ether, and glycerin, and insoluble in benzol and fixed oils. It is very unstable, readily yielding formaldehyde gas, so is used as an antiseptic both internally and externally. It is decomposed by heat, acids, or alkalies.

*W. A. Bastedo.*

**GALL, OX.**—Fel Bovis.—"The fresh bile of *Bos Taurus* L. (class *Mammalia*; order *Ruminantia*)," (U. S. P.)

A brownish-green or dark green, somewhat viscid liquid, having a peculiar, unpleasant odor, and a disagreeable, bitter taste.

Specific gravity: 1.018 to 1.028 at 15° C. (59° F.).

It is neutral, or has a faintly alkaline reaction on litmus paper.

A mixture of 2 drops of ox gall and 10 c.c. of water, when treated, first, with a drop of a freshly prepared solution of 1 part of sugar in 4 parts of water, and afterward with sulphuric acid, cautiously added, until the precipitate first formed is redissolved, gradually acquires a brownish-red color, changing, successively, to carmine, purple, and violet.

*Purified Ox Gall, Fel Bovis Purificatum* (U. S. P.).

Fresh ox gall, *three hundred cubic centimetres*.... 300 c.c.
Alcohol, *one hundred cubic centimetres*..... 100 c.c.

Evaporate the ox gall, in a tared porcelain capsule, on a water bath, to about *one hundred* (100) *grams*, then add to it the alcohol, mix the whole thoroughly, and set it aside, well covered, for three or four days. Then decant the clear solution, filter the remainder, and, having mixed the liquids and distilled off the alcohol, evaporate the remainder to a pilular consistence.

A yellowish-green, soft solid, having a peculiar odor, and a partly sweet and partly bitter taste.

Very soluble in water and in alcohol.

A solution of 1 part of purified ox gall in about 100 parts of water behaves toward sugar and sulphuric acid in the same manner as the solution mentioned above.

An aqueous solution of purified ox gall should be clear, and should remain transparent upon the addition of an equal volume of alcohol (evidence of proper purification).

This complex substance in its crude condition consists of about ten per cent. of solids and ninety of water.

The most important solid constituents are the *sodium salts* of *taurocholic* and *glycocholic acids*, and several not very well distinguished coloring matters (*bilirubin, biliverdin*, etc.). Besides these it also contains a number of decomposition products, *cholesterin, urea*, etc., and some *fats* and *mucus*.

Further than to show its practical identity with that of the human subject, the study of the specific composition of ox gall is unimportant.

For the same reason the study of its action pertains wholly to physiology. We know that bile has no business in the stomach, although it appears that its entrance there, in certain morbid conditions, may exert a stomachic effect, without seriously inhibiting digestion, and its therapeutic use may be serviceable in this way. It must, however, be remembered that the properties of the bile itself are subject to change in the stomach, so that suitable measures must be taken in its administration (see below), when the intestinal action is desired.

It is equally well established that bile in the circulation acts as a poison, although there are some facts to suggest that its antitoxic action there may at times more than counterbalance such objection.

It is then in the intestine and in the liver that we must look for the beneficial effects of the administration of bile. In the former it is a valuable antiseptic, peristaltic stimulant, chemical synergist of certain purgatives, and promoter of the absorption of fat. None of these processes requires discussion. All can be effected by ox gall, properly administered, as by the natural secretion. Upon the liver, the drug has the effect of a direct cholagogue, that is, an agent increasing the actual secretion of bile, and about the only one known. Since the constituents of the bile decomposed in the intestine are returned to the liver to be again recombined, we should naturally expect this increase to be produced. It appears, how-

ever, that the increase is greater than the ratio thus accounted for, and it is apparent that the bile salts exert a stimulating effect upon the secreting mechanism. The following concerning the use and administration of the drug may well be reprinted from the last edition of this work.

The action of ox gall in assisting the absorption of fats and oils, and its aid in maintaining intestinal antisepsis, has suggested its use as a proper means of treating typhoid fever. Dr. Adolph Zea reports the result of ten cases in his own ward, and forty-eight cases treated by medical friends, as very gratifying. His method of conducting the case is as follows: If the case is seen early, a dose of calomel is given to relieve the digestive tract of its contents; alcohol in the form of whiskey is given at first as a stimulant, and, if additional stimulation is required, strychnine, caffeine, ammonia, camphor, or small doses of quinine; dilute muriatic acid in large quantities of water as a beverage, and fel bovis purificatum siccum, in doses of two to four grains, three to six times a day in pill form or capsule. The diet consists of fluids—milk, gruel, beef-tea—in small quantities frequently given. The milk should always be boiled, but may be given hot or cold according to the wish of the patient. Preparations of beef extracts and juices may also be given.

The benefit of this treatment is shown in a reduction of the temperature after the drug has been given for a few days, and a freedom from all distressing abdominal symptoms and complications. Convalescence is also thought to be more rapid than under any other line of treatment.

It has been very properly pointed out that the enclosing of the dose in *keratin* tends to prevent changes in it by the acid gastric juice, in its passage through the stomach.

Its injection into the rectum, in twenty-grain doses well diluted, tends to clear that organ of fæces.

*Henry H. Rusby.*

**GAMBOGE.**—Cambogia.—"A gum resin obtained from *Garcinia Hanburii* Hook. f. (fam. *Guttiferæ*)" (U. S. P.). (The family is now called *Clusiaceæ*.) This genus comprises about forty species of Eastern tropical evergreen trees with yellow juice. Other species yield the Mangosteen fruit and bark, and the Kokum butter. The gamboge tree is a native of Cambogia, Siam, and Cochin China, whence the supply of the gum resin for European and American consumption is obtained; but there are besides several other species of *Garcinia* in India, China, and the Asiatic islands, which supply similar products, if not exactly the same. Gamboge is collected by cutting or wounding the twigs or trunks, when the bright yellow latex flows slowly out, and is collected in vessels, usually bamboo joints, fastened at the lowest part of the incisions. Here it slowly hardens, or is perhaps dried over a fire, until a solid mass results, of the shape, usually cylindrical, of the containing vessel. The bamboo is then split off, and the gamboge is packed in large boxes for transportation.

That thus collected in bamboo joints is known as "pipe-gamboge." Saigon, or "purse" gamboge, is collected in pockets of leaves or cloth, six or eight inches long by three or four broad. It is usually a little darker than the former. When run or massed into large blocks or tubs, it is called "cake gamboge," or "gamboge in sorts."

The pipe gamboge is preferred, not only because it represents the typical quality, but because it is almost invariably pure and clean. The large cakes are liable to extensive adulteration with stones and pieces of iron. Being often formed in tubs or boxes, the gamboge is very apt to come into contact with nails or other metal, which turns it dark for a considerable distance from the offending body.

Gamboge has been used in China and India as a pigment for many centuries, and appeared as a purgative in Europe early in the seventeenth century. Its use in medicine, however, has always been insignificant in comparison with its consumption as a yellow paint, for which use it is hardly excelled by any pigment.

The best of that which reaches us is in cylindrical pieces, usually hollow at the centre, 2 to 5 cm. (1 to 2 in.) thick, longitudinally striate on the surface; fracture flattish-conchoidal, smooth, of a waxy lustre, orange-red; inodorous; taste very acrid; powder bright yellow, sternutatory, free from starch.

Gamboge should yield not less than seventy per cent. of resin and not over three per cent. of ash.

It does not dissolve in water, but forms a very fine, smooth, yellow emulsion with it, and it is wholly soluble in potassa solution.

Gamboge contains about seventy-two (Christison) per cent. of yellow resin called *gambogic acid*, an orange-yellow, tasteless, and odorless mass, soluble in alcohol and ether, but not in water, having the purgative properties of gamboge, but less intensely than the crude gum resin itself. It also contains fifteen or more per cent. of *gum*, a little water, and some impurities. Its activity is proportional to the percentage of resin in it.

Action and Use.—This is one of the most violent of hydragogue cathartics, producing abundant watery stools and considerable griping, on which latter account it is not often now given alone, or for its full effect. It is, however, frequently added in small doses to the other cathartic combinations, and experience has proved its usefulness. It is especially valuable in such conditions as lead colic and seasickness, where the bowel requires powerful stimulation.

The full dose of gamboge is about 0.3 gm. (= gr. v.), but less is advisable in compositions; the maximum daily quantity is stated by the German Pharmacopœia to be 1 gm. It is an ingredient in the compound cathartic pills (*Pilulæ Catharticæ Compositæ*, U. S. P.), each of which contains about a quarter of a grain.

*W. P. Bolles.*

**GANGLION.** See *Bursæ*. (*Surgical.*)

**GANGRENE. (PATHOLOGICAL.)**— The term gangrene is loosely applied by the clinician to any form of local death of tissue occurring within the living body, in which the necrosed area becomes discolored, resembling more or less tissues which have been burned. By the pathologist it is used to indicate a necrosis accompanied by putrefactive processes. A number of designations are used partly as synonyms and partly to express different varieties of this condition: mortification, putrescence, putrefaction, sphacelation, etc.; but the essential idea of gangrene is that of necrosis accompanied by putrefaction. The presence of putrefactive or saprophytic bacteria is, therefore, to be regarded as the most distinctive feature of gangrene.

Gangrene may be either *primary* or *secondary*. In primary gangrene the condition is due directly to the infection of the tissues by some specific bacterium and is to be regarded as a specific affection. In secondary gangrene there is first a necrosis due to some other cause with a subsequent infection by putrefactive bacteria. According to its manner of origin gangrene may be *traumatic* or *inflammatory*, and according to its behavior it may be *circumscribed, diffuse, spreading, phagedenic*, etc. Clinically, various forms occur: *thermal, toxic, infectious, neuropathic, diabetic, senile, hospital, idiopathic*, etc.

Primary Gangrene.—A number of specific infections may be included under this head: infection with the Bacillus aërogenes capsulatus, B. œdematis maligni, B. diphtheriæ, B. anthracis, B. coli communis or closely related organisms, and probably a number of other imperfectly known bacteria. Any one of these may produce severe inflammatory processes followed immediately or very quickly by gangrene, which is apparently due to the originally infecting bacterium, though in some cases there may be a secondary infection by saprophytes.

Secondary Gangrene.—This is the more common form. The preceding necrosis may be caused by circulatory changes, pathological conditions of the blood-





vessels, burns, freezing, mechanical injury, pressure, corrosive poisons, intoxications, infections, etc.; the secondary infection of the dead tissue being caused by various forms of saprophytic bacteria.

When gangrenous tissues are exposed to the air their fluids may be lost by evaporation and become hard and dry (*mummification, dry gangrene, gangræna sicca*). If evaporation does not occur and the dead parts remain moist, the condition is known as *moist gangrene* (*gangræna humida, sphacelus*). Between the moist and dry forms there is no hard-and-fast line; dry gangrene may develop from a moist gangrene through subsequent evaporation; or by the absorption of fluids from the surrounding tissues a dry gangrene may be converted into the moist form. If the gangrene is very foul-smelling it is usually spoken of as *putrid* or *septic gangrene*. The formation of gas in gangrenous parts gives rise to the condition known as *emphysematous gangrene*. If the tissues affected contained much blood before death, they become black or greenish in color (*black gangrene*); if anæmic, they may remain light in color though always discolored to some extent (*white gangrene*). Clinically *warm* and *cold gangrene* correspond to these forms respectively, the presence of heat depending upon the flow of blood in the neighboring tissue, the warmth being most marked when there is a severe reactive inflammation about the gangrenous area. Black gangrene may become a cold form by the complete shutting-off of the blood supply.

*Dry Gangrene.*—The evaporation of fluids from the surface of gangrenous tissues exposed to the air gives to the dead part an appearance somewhat resembling that of mummy tissue. The drying of the umbilical cord may be taken as a physiological prototype of this process. Putrefaction goes on very slowly in the dried mass and may cease entirely. Only rarely, however, does mummification of necrosed tissues occur without some putrefactive changes. There is almost always an odor about the parts involved in dry gangrene and this is in itself an evidence of the occurrence of putrefactive processes. The odor, however, is always much less marked than in the case of moist gangrene. Dry gangrene occurs most frequently in the parts of the body most exposed to evaporation; gangrene of the tips of the ears, nose, fingers, and toes is almost always of this variety. The loss of the epidermis is a favoring factor.

In the great majority of cases dry gangrene is due to arterial or venous obstruction through embolism or thrombosis, whenever the collateral circulation is insufficient to keep up the nutrition of the affected part. It occurs frequently after freezing, the peripheral vessels being occluded by thrombi. Severe burns, as well as the effects of strong corrosives, are frequently followed by dry gangrene. It is as a rule found in ergotism and the symmetrical gangrene of Raynaud's disease, and occurs frequently in diabetes and in cases of senility with vascular changes, especially in individuals whose general nutrition is lowered. The fœtus papyraceus is considered by some authors to be an example of dry gangrene, the mummification of the dead fœtus being caused by premature loss of the amniotic fluid and the pressure exerted upon the former by its living twin. In the absence of putrefactive changes this condition can hardly be regarded as being of the nature of gangrene.

*Moist Gangrene.*—This form occurs very frequently after severe traumatism to the extremities, especially contusions and crushing with resulting great injury to the blood-vessels. It follows obstruction of the venous circulation more quickly than that of the arterial. Diabetic gangrene is not infrequently of this form, senile more rarely so. It may occur in the course of the acute infectious fevers, either in the skin or in the mucous membranes. It forms a feature also of certain skin diseases. Decubitus (bed-sores), malum perforans, hysterical gangrene, noma of the mouth and genitals are varieties of moist gangrene. The internal and external female genitals may suffer moist gangrene from mechanical injury received during severe labor or as the result of infection following childbirth. Of the internal organs the lungs are most often affected. Pulmonary moist gangrene may follow infarction, non-resolution of croupous and purulent pneumonias, inspiration pneumonia, pulmonary abscess, atelectasis, bronchiectasis, new growths, etc. Pressure upon the trachea or bronchi, or upon the branches of the vagus by œsophageal diverticula, tumors or aneurisms not infrequently gives rise to pneumonia followed by moist gangrene. Embolism or thrombosis of the mesenteric arteries with infarction of the mesentery is always followed by moist gangrene. Intestinal obstruction, intussusception, strangulated hernia, obstruction or strangulation of the appendix usually lead to moist gangrene of the affected parts. Traumatic injury to the pancreas or inflammation of this organ from unknown causes may give rise to moist gangrene (gangrenous pancreatitis). Torsion of the pedicle of new growths, floating spleen, kidney, etc., may by shutting off the blood supply cause a necrosis which through secondary infection often becomes gangrenous. Infiltration of the perineal tissues with urine, excessive œdema, extreme passive congestion, are also conditions leading to moist gangrene. Gangrenous inflammation of the urinary bladder may be caused by long-continued retention of urine.

*Gross Appearances.*—Dry gangrene is usually circumscribed. The affected part becomes discolored, yellow, brown or black, though in rare cases the dead tissues may appear bloodless and pale. The consistence of the part may be hard and tough. In advanced stages the necrotic area resembles leather or mummy skin. An odor of putrefaction is usually present in the early stages, but is never very marked. The process of mummification may be preceded by the formation of vesicles or blebs which rupture leaving the corium denuded. Evaporation is in this way greatly aided. In many cases the skin remains intact, and in this event the amount of putrefactive change may be very slight.

Moist gangrene is characterized particularly by a foul odor and progressive softening of the affected area. The color is usually reddish-purple in the early stages, but later becomes dark brown or black from the changes occurring in the blood pigment. If hydrogen sulphide is formed, the color becomes greenish from the formation of a hydrogen-sulphide compound with the iron-containing blood pigment (pseudomelanosis). Blebs are usually formed in the skin; these contain dirty-brown fluid which derives its color from broken-down blood pigment. Ultimately the entire part affected becomes very soft and partially liquefied. With the growth of putrefactive bacteria in the dead tissues the various phenomena of putrefaction are presented exactly as in the cadaver. Hydrogen sulphide, ammonia, indol, skatol, fatty acids, amins, carbonic acid, and other gases which give rise to the very marked fœtid odors characteristic of this process are formed, and as the result of gas formation a local or widespread emphysema may occur. The fluids arising from the liquefaction of the dead tissues or from the infiltration of lymph are also discolored by the destruction of the blood pigment.

Between the living and dead tissues in both dry and moist gangrene there is usually a more or less sharply marked line of demarcation which represents the point at which necrosis and putrefaction cease. At this boundary line there is very frequently present a zone of inflammatory reaction, particularly in dry gangrene and those forms of moist gangrene due to vascular changes. In other varieties of moist gangrene, particularly in that occurring in diabetes, neither the inflammatory zone nor a sharp demarcating line is present. In advanced stages of moist gangrene sequestration of the dead tissues from the living may occur, and the former either be cast off, absorbed, organized, or calcified, etc. When internal the gangrenous area usually becomes encysted. In hard parts, cartilage, bone, etc., the process of sequestration is much slower than in softer tissues.

*Microscopical Appearances.*—The differential diagnosis of moist gangrene from other forms of necrosis by means of the microscope depends entirely upon the presence of

putrefactive bacteria and the chemical products of putrefaction. Sections of tissues in a state of dry gangrene show a marked shrinking of the cells and disappearance of the nuclei, the changes resembling very much those occurring in the horny layer of the epidermis. If putrefactive changes have been slight, the nuclei may stain faintly, even for some length of time after the advent of necrosis; and the outlines of the cells, though greatly shrunken, may still show. In advanced stages of evaporation the dry tissues become hyaline and horn-like, resisting cutting. In the blood-vessels disintegrated red blood cells are found, often forming brownish or yellow hyaline clumps. If moist gangrene preceded the evaporation, the chemical products of decomposition as well as evidences of greater disorganization of the tissues will be present.

In moist gangrene the tissues show either a simple, cheesy, coagulation, or liquefaction necrosis; or, as is usually the case, all of these forms of necrosis may be present in different parts of the sections. Necrosis of the parenchymatous cells first takes place, the nuclei disappear, and the cells become fluid or granular. Fatty degeneration of an extensive degree is often present. Muscle cells lose their striations, swell, and finally fragment or liquefy. Zenker's necrosis is usually present to a greater or less degree. Adipose tissue and nerve sheaths break up into free fat or fatty acids. Axis cylinders may either fragment or fibrillate. Connective tissue, yellow elastic tissue, fascia, cartilage and bone are changed more slowly, but all tissues may ultimately become liquefied. Hemorrhages are present in the early stages, usually by diapedesis from the early degenerative changes in the vessel walls. Rupture of the damaged vessels may also occur. Disintegration of the extravasated blood takes place, and brown or yellowish granules of hæmatoidin and hæmosiderin are formed from the diffused hæmoglobin. If hydrogen sulphide is present, black granules of hydrogen-sulphide-hæmosiderin are formed (pseudomelanin). Crystalline pigments derived from hæmoglobin may also be present. Fatty-acid crystals, tyrosin, leucin, cholesterin, crystalline and amorphous phosphates and carbonates may be formed as intermediate or end products of the putrefactive process. The coffin-lid crystals of calcium phosphate are often abundant. By means of proper staining methods the presence of putrefactive organisms in large numbers may be demonstrated. If the process has advanced slowly and the reactive inflammation is marked, the dead tissues may contain large numbers of leucocytes which also necrose ultimately, but retain their staining power much longer than the tissue elements. At the line of demarcation there is often an extensive formation of fibrin in the lymph spaces and also coagulation of the blood in the blood-vessels. Beyond this, toward the living tissue there is a more or less well-marked zone of inflammation. If the gangrenous process comes to a standstill, granulation tissue may be formed at the line of demarcation gradually encapsulating the dead area. The latter may shrink away from the border and be cast off as a sphacelus or slough, or it may be gradually disposed of in the slow process of healing by organization. If internal, the encapsulated mass of dead tissue may undergo calcification or liquefy, in the latter case forming a cyst.

Varieties of Gangrene.—In the circumscribed form the line of demarcation shows a zone of marked inflammatory reaction, and the necrosed part is either cast off as a slough or encysted. In the diffusely spreading forms there is no limitation, and the process advances until the death of the individual occurs or the necrosed portion, together with the cause of the gangrene, is removed from the body by surgical operation. In these cases the tissue resistance is either greatly lowered or the poisons produced by the infecting bacteria infiltrate the surrounding lymph spaces causing a spread of the necrotic process, or the bacteria have the power of invading and destroying tissue not previously damaged. In the circumscribed form the infection is less virulent or the surrounding normal tissues are able to resist the spread of infection. In metastatic gangrene bacteria are carried through the blood or lymph and set up secondary foci of inflammation and gangrenous necrosis. This can happen only in the case of primary gangrene, due to infection with a specific organism.

*Senile Gangrene.*—This is usually of the dry, circumscribed form, and is due almost wholly to disturbed circulation from arteriosclerotic changes, thrombosis, embolism, etc. Chronic wasting diseases, poor nutrition, weakened heart's action, exposure to cold, etc., are favoring factors. The lower extremities, more often the left, are chiefly affected.

*Diabetic Gangrene.*—The gangrenous processes which occur rather frequently in connection with diabetes are more probably the result of arterial disease than of some more obscure cause dependent upon or associated with the altered metabolism existing in this disease. Wallace (St. James' Hospital) examined twenty-four cases, in twenty-three of which he found decided atheroma. The views most commonly held at present incline toward the belief that gangrene never occurs in diabetes without the presence of arterial changes sufficient in themselves to have caused it. The extremities are chiefly affected and the dry form is more common, but moist gangrene is not infrequent. It has been stated that diabetic gangrene differed from other forms in that no sharp line of demarcation or zone of inflammatory reaction is present. Recent observations show no essential differences between diabetic gangrene and any other form due to arterial obstruction. Cutaneous gangrene, moist gangrene of the lungs, etc., have also been observed in association with diabetes, but must be regarded as coincidences. Favoring factors, such as disturbed nutrition, central nervous disturbances, etc., no doubt exist in diabetes, but the primary cause of the gangrene which occurs in this disease is to be sought in other conditions than the disturbed metabolism.

*Gangrene with Acute Infections.*—Gangrene may occur as a rare complication of any one of the acute infections, particularly in measles, varicella, scarlatina, diphtheria, typhus, typhoid fever, and malaria. In varicella and scarlatina it usually occurs several weeks after the attack. The gangrene is usually multiple but not symmetrical. The skin and adjacent structures are more frequently affected than the extremities, and usually no previous vascular disturbance is noticed. It occurs more frequently in cachectic children, but also in those apparently in good nutrition. The gangrenous process may affect the eyelids, conjunctiva, ears, mucosa of mouth, lips, and adjacent structures (noma, cancrum oris), external genitalia, particularly those of the female. The term noma has come to be applied to all of these forms, as well as to spontaneous gangrene of these regions occurring without any relation to the acute infectious fevers. It is undoubtedly a specific infection and a number of micro-organisms have been described, but the diphtheria bacillus seems to be the one most constantly present.

Spontaneous gangrene is reported also as occurring in pertussis, acute rheumatism without apparent cardiac involvement, beri-beri, influenza, croupous pneumonia, erysipelas, catarrhal jaundice, and in association with infantile syphilis. In the majority of these cases no bacteriological examination was made, and the exact nature of the process remains unknown. In the case of erysipelas, a number of instances are reported in which gangrene was caused by long-continued application of cold to the affected parts. Under these circumstances the resulting thrombosis of the peripheral vessels is sufficient to account for the gangrene.

*Multiple Gangrene.*—There are three classes of multiple gangrene:

1. Raynaud's Disease. In this condition there are previously well-marked vascular disturbances in the extremities as shown by syncope, asphyxia, or hyperæmia. The gangrene is often symmetrical, and is usually slight in extent, being confined to the fingers or toes, more rarely to the tips of the ears or nose tip. The disease occurs





chiefly in neurotic and poorly nourished individuals of early adult life. It has been regarded as a gangrene due to trophic disturbances of central origin, but the necrosis is to be looked upon as secondary to vascular phenomena of vaso-motor origin.

2. Multiple Spontaneous Gangrene Occurring in Young and Middle-Aged Individuals without Obvious Cause. These cases of so-called idiopathic gangrene have been reported in large numbers. In very few of them was a bacteriological or pathological study carried out, and it is very probable that the majority were due to vascular obstruction or specific infection.

3. Multiple Spontaneous Gangrene with Acute Infections. Multiple patches of gangrene, not symmetrical, occur as complications of acute infections, measles, typhoid, typhus, scarlatina, diphtheria, and malaria. The skin and adjacent tissues are more frequently affected than the extremities. No previous vascular disturbances have been observed. In typhoid fever the complication of gangrene occurs most often in the male, and is found in order of its occurrence in the left leg, carotid region, mesentery, and cheek. In the majority of these cases an endarteritis is found at autopsy, while in other cases the gangrene seems to result from the toxic action of the products of the typhoid bacillus. Weakened circulation and impaired nutrition are favoring factors.

*Neuropathic Gangrene.*—In parts of the body affected by sensory or motor paralysis slight injury, such as long-continued pressure, very frequently produces gangrene. This occurrence has been explained as being due to the removal of trophic nerve influence, but it has not yet been conclusively proved that the complete cutting-off of the nervous supply of a part is in itself sufficient to cause gangrene. The cause is much rather to be sought in circulatory disturbances and secondary infections. Raynaud's disease and other forms of symmetrical gangrene have been regarded as neuropathic affections, but are probably dependent upon vascular disturbances.

More properly to be regarded as neuropathic are those cases of hysterical gangrene in which under mental excitement, hysterical crises, or apparently under the control of the will gangrenous areas are formed in the skin. These are usually sharply circumscribed, and are preceded by various vascular phenomena which make it evident that vaso-motor disturbances play the chief rôle in their production. In many of these cases there have been, however, undoubted evidences of fraud on the part of the patient, and it has been shown that the gangrenous areas were self-inflicted and were produced by applications of hydrochloric acid, acetic acid, Paris green, caustic potash, green soap, concentrated brine, or by methods unknown. The gangrenous areas in these cases are irregular, of varying depth of loss of tissue, and do not correspond to the course of either vessels or nerves. The existence of true hysterical gangrene cannot be regarded as an impossibility, but it is to be explained on the hypothesis of vaso-motor disturbances and not as evidence of removal of trophic influence.

Lepra mutilans, noma, acute decubitus, etc., have also been regarded as examples of neuropathic gangrene, but the majority of conditions so considered have been found to depend upon vascular and nutritive changes or specific infection. Multiple gangrene of the skin is also said to occur in excessive iodism, and it is probable that some of the supposed hysterical cases may be explained by this fact.

*Traumatic Gangrene.*—This is frequently produced by rupture of the inner arterial coats. Simple contusion over an artery without injury to the skin may cause rupture of the inner coat with resulting thrombosis and gangrene. Circumscribed rupture of the inner coat occurs especially in the case of fractures. The intima may be rolled up within the vessel blocking the lumen. Dislocations, especially those of the shoulder joint, through injury or compression of the vessels may cause gangrene secondary to thrombosis. In severe trauma with resulting disorganization of the tissue gangrene results from secondary infection of the dead part. In the case of open wounds without destruction of tissue primary gangrene may be caused by direct infection with specific bacteria.

*Hospital Gangrene.*—This form of wound gangrene, so common and so disastrous in its results during the Civil War, has practically disappeared. It represented a specific infection, the cause of which is not known.

*Emphysematous Gangrene* (Gangrene Foudroyante, Gaseous Cellulitis, Gas Phlegmon, Infective Emphysema, etc.). In gangrene with gas formation the Bacillus aërogenes capsulatus is the most commonly occurring specific cause. The colon and proteus bacilli are doubtful factors. Facultative anaërobic bacilli resembling colon bacilli may produce the condition, and other forms of bacteria have been described as causal agents, but their exact relation to the process is not clear. The B. aërogenes capsulatus is widely distributed in soils, dust, etc., and is present in the intestine and probably in other parts of the normal living body. Gaseous gangrene may also be produced by infection with anthrax and malignant œdema, but it is probable that some of the cases regarded as malignant œdema in the human body were in reality cases of infection by the B. aërogenes capsulatus.

The organism enters through open wounds, particularly those associated with contusion; but may follow ligation of arteries, or the avenue of infection may be through the uterus after abortion or delivery. The infection is very virulent; at the point of entrance there is a rapid necrosis with gas formation. The entire surface of the body may become emphysematous. At autopsy the internal organs have a characteristic sponge-like appearance from the formation of numerous small gas bubbles throughout the tissues. In these numerous bacilli may be found. The blood in the heart and great vessels is foamy. It is probable that some of the cases of supposed air embolism are due to infection with this organism. The presence of gas cysts or foamy blood in the cadaver several hours after death cannot be regarded as of great pathological significance, inasmuch as this organism, which is probably frequently present in the normal body, may develop under favorable conditions with great rapidity in the dead body.

*Toxic Gangrene.*—The most familiar form of gangrene due to poisons is that produced by ergot. The ends of the extremities are chiefly affected, the gangrene is usually of the dry form, and is caused by the action of the ergot in producing contraction of the peripheral vessels with thrombosis. Sloughing gangrene of the endometrium, bladder, and skin may also be produced by long-continued medicinal use of ergot.

*Roentgen-Ray Gangrene.*—Gangrenous dermatitis has followed prolonged exposure to *x*-rays. The condition develops several weeks after exposure and is slow in healing. The exact relation of these cases to the alleged cause is not yet apparent.

*Carbolic-Acid Gangrene.*—Dry gangrene has been produced in a number of cases by prolonged application of carbolic-acid dressings, even when weak solutions were used. The fingers and toes were the parts affected in the majority of cases; in one instance the eyelids were injured.

*Gangrene of Pancreas.*—Traumatic injuries of the pancreas or inflammatory conditions of this organ may lead to gangrene. Self-digestion by the pancreatic juices is probably the first step in the process, infection from the intestine the second. Fat necrosis is usually present.

*Idiopathic Gangrene.*—According to recent observers the so-called idiopathic gangrene occurring in children is always secondary to arterial thrombosis. In the new-born it is frequently associated with congenital syphilis. Gangrene of penis and scrotum in the new-born has been observed a number of times in connection with thrombosis of the renal and spermatic veins. The cause is unknown. In the adult gangrene of the same region occurs from primary infection, or rarely as the result of embolism or thrombosis. The gangrene of the extremities observed in cases of premature labor is probably due to thrombosis or possible primary infection.

*Sequelæ.*—Besides the end products of decomposition

mentioned above, ptomaïns are produced in the gangrenous area. These are for the greater part diffusible and readily absorbed into the circulation, producing the systemic effects of gangrene. The intensity of the general symptoms in any case will depend upon the amount and character of the poisons produced in the gangrenous tissues, the amount and rapidity of the absorption, and the resistance of the patient. The intoxication may be so severe as to cause death, or the gangrene may progress until death is brought about by the involvement of vital parts, or the gangrenous area may become circumscribed, be cast off as a slough, or organized, calcified, or encysted. Portions of dead extremities may drop off spontaneously, or through operative procedures the gangrenous portion may be removed. *Aldred Scott Warthin.*

**GANGRENE. (SURGICAL.)**—The term gangrene, and its synonyms, mortification and sphacelus, are employed by the surgeon to denote the death and, in most cases, the subsequent decomposition of a circumscribed portion of tissue on some exposed part of the body. Necrosis is a term extensively used by surgeons to denote the death of a circumscribed portion of bone, whilst pathologists employ it to express the death of a portion of tissue, belonging to some internal organ, that has been cut off from its necessary blood supply. Such necrosis is unaccompanied by bacterial decomposition; it is absorbed and replaced by the formation of blood-vessels and new tissue.

ETIOLOGY AND PATHOLOGY.—A general division of the causes of gangrene into traumatic, physical, and infectious may be made, but it is evident that, whether the local death of a part is produced by mechanical violence or by other causes, the result must be the same—namely, an interference or arrest of the nutrition of the part due to obstruction of the circulation. Nutrition is interfered with, or arrested, by *obstruction in the arteries*, such as occurs in cases of gunshot wounds; by ruptures due to mechanical violence; by compression or ligature; by disease of the arterial coats; by pressure of a tumor in the adjacent tissues, or by a thrombus; by *obstruction in the capillaries*, which may produce complete anæmia of the part, and which is due to pressure upon the capillary walls by tumors, by extravasated blood or fibrin, or by superficial pressure from bandaging. The observation that tight bandaging would occasionally produce gangrene is as old as Hippocrates, who distinctly refers to it. Anything, therefore, which will produce long-continued stasis in the capillary circulation of a part,—whether it be mechanical violence, inflammatory change, the internal administration of certain drugs, the action of chemicals, or some obstruction in the veins sufficiently pronounced to prevent completely the return circulation,—must necessarily result in gangrene of that part.

Let us now examine these causative states somewhat in detail. Obstruction to the arterial circulation occurs in consequence of gunshot, lacerated, and incised wounds, whenever the artery is torn or cut, and this obstruction results in gangrene whenever the collateral circulation fails to become established. The plates accompanying this article, from the "Medical and Surgical History of the War of the Rebellion," show cases of this kind with great distinctness. Pressure upon arteries during the treatment for aneurism has also produced gangrene. Surgeon Fessenden, of the Marine Hospital Service, has reported a case* in which compression was applied to the popliteal artery, just above an aneurism of that vessel, for one hour, when pulsation ceased in the tumor; three days later, it was noticed that sensibility was lost in the foot and leg, which became very much discolored, and there occurred blebs on the foot; a day later the entire foot and leg were gangrenous, and amputation was performed.

Coagula (*thrombi*) may form in the arteries as a result of chronic endocarditis or endarteritis. Obstruction to the capillaries is a prolific source of gangrene. It is in them that the effect of diminished cardiac power is most manifest, especially in the parts remote from the heart. Chronic exhaustive diseases, senile and general debility, therefore, are important factors in the production of gangrene. Gangrene from the administration of ergot is produced by the effect of the drug on the arterioles through the vaso-motor nerves, whereby these vessels are permanently diminished in calibre. The experiments of Holmes (1870) showed the effect of ergot upon animals to be manifested in the capillaries, as witnessed in frogs, and Péton (1878) observed the contraction of the retinal vessels in man. Péton believes that this effect is produced, independently of any influence upon the vaso-motor system, by the direct action of the drug upon the muscular fibres. Nikit, however, in 1878, denied this, and his investigations have led him to confirm the usually accepted theory. In recent years we have learned to distinguish some infectious causes of gangrene, and also to recognize the fact that carbolic-acid solutions are, in certain cases, competent to induce this condition. Farther on, we will consider these matters more in detail.

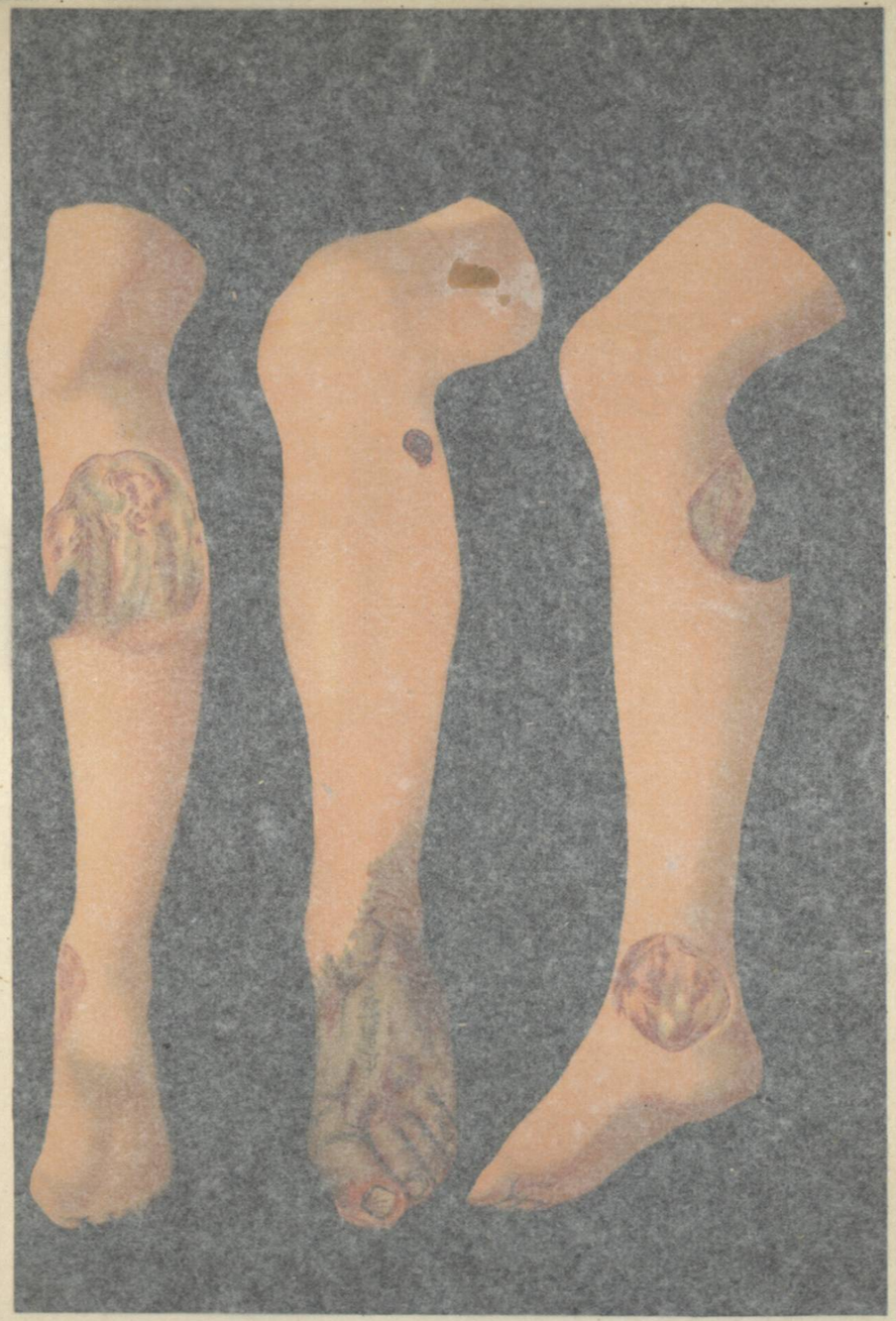
Ergotism, as a cause of certain epidemics of gangrene in man, was first described by Dodard in 1676, then by Saviard in 1694, and by Noel in 1710. The disease appeared in Switzerland in 1676, according to Langius and Quassond. It also appeared in Dauphiné in 1709. Duhamel, in the "Mémoires de l'Académie Royale de Paris" for 1748, states that the disease was accompanied by very great mortality, "not more than four or five out of one hundred and twenty who had been attacked escaped with life." Péreira (1840) thinks that this affection was known at a still earlier period, and he quotes a passage from Sigebert to support his views (South): "1089, a pestilential year, especially in the western parts of Loraine, where many persons became putrid in consequence of their inward parts being consumed by St. Anthony's fire. Their limbs were rotten and became coal-black, they either perished miserably or, deprived of their hands and feet, were reserved for a more miserable life." It is stated that "the bread which was eaten at this period was remarkable for its deep violet color."

Notwithstanding the general concurrence of opinion as to the effects of ergotism on man, it has often been denied that it produced any such effect upon animals. Block, in 1811, fed nine pounds of ergot daily to twenty sheep for four weeks without any visible effect, and twenty sheep of another lot ate thirteen and a half pounds daily for two months without injury. Thirty cows took twenty-seven pounds daily for three months, and the only apparent effect was to injure the quality of the cream (Péreira). Tessier, however, in 1776, visited those countries in which the epidemic had prevailed, or was then present, and found that, although the quantity necessarily varied, yet it finally produced the gangrenous affection ("Mémoires de la Société Royale de Médecine," 1776, 1777–78). Instances are not wanting of the prevalence of gangrene as an epidemic among animals in the United States. Dr. Salmon, Chief of the Bureau of Animal Industry of the Agricultural Department, in a recent report on this subject (1885), has shown conclusively that many so-called epidemics of the "hoof-and-mouth disease" of cattle are really epidemics of ergotism. He found much ergot in the heads of "red-top" grass, in timothy, and in the chess or "cheat," as well as in rye; and in the particular epidemic in Kansas which called out the inquiry, the ergot was found in the hay fed to the diseased animals in the proportion of about one to every seventy-five pounds. In these cases there were sloughing ulcers of the mouth, ulcers in the rectum, with diarrhœa, a temperature of 101° to 104° F., and a line of demarcation above the hoof in some cases as high as the middle of the leg, and not infrequently the ends of the tails became gangrenous and dropped off. In an exhaustive review of the history of epidemics of gangrene from ergotism, Dr. Salmon cites many instances to show that nearly all the domesticated animals have suffered from the effects of this poison. As bearing upon the question of treatment, it is interesting

* U. S. Marine Hospital Reports, 1882, pp. 160–162.







FIGS. 1 AND 3 SHOWING EFFECTS OF HOSPITAL GANGRENE.
FIG. 2 GANGRENE OF FOOT AFTER SHOTWOUND OF LEG.
(FROM THE MEDICAL AND SURGICAL HISTORY OF THE WAR OF THE REBELLION.)