CYSTICERCOSIS (TAENIA SOLIUM).

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I.—INTRODUCTION.

For some years the Consulting Physician to the British Army, Colonel W. P. MacArthur, has called attention in the Annual Report on the Health of the Army to the importance of excluding cysticercosis infestation as a cause of epilepsy. In the reports of 1929, 1930 and 1931, he mentioned several cases and pointed out that the importance of cysticercosis as a cause of epilepsy was not sufficiently realized, either in the Service or by practitioners in the tropics.

In 1932, a special investigation was ordered by the War Office. It was laid down that all cases of epilepsy which occurred in soldiers previously healthy who had served abroad should be sent to the Queen Alexandra Military Hospital, London, for special investigation. Colonel R. Priest investigated those cases sent in between August and December, 1932, twenty-six in all, and this work has been continued since then by the writers. Not only epileptics, but many other cases of nervous and mental disease have been examined to exclude cysticercosis. An important part of the work was the tracing of all previously recorded cases of cysticercosis, whether diagnosed in the Army or after they had been discharged or transferred to the Army Reserve. With the assistance of the Secretary

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of the Royal Hospital, Chelsea, and the Ministry of Pensions, the whole of each patient's documents have been available. In all such cases the history has been traced from the day of joining the Army to the time of writing (except for three cases not traced later than 1912, 1925 and 1927 respectively) or to the time of death. Therefore our series includes all the published cases of cysticercosis in soldiers, their wives and children, from 1892 to 1934. The material of other authors has been freely used, and the references to all the previously published cases in English medical literature since 1892 will be found in the bibliography at the end of this paper. In many cases, material information was not available at the time of first publication, but has since been traced with the aid of military documents. In other cases, the patients have been traced up to the present date, or to the date of their death. In the course of the investigation, 258 cases have been gone into; 214 of these have attended the Queen Alexandra Military Hospital, Millbank. The remaining 44 patients are those which have been traced from the published records and documents, those that were visited in other hospitals or epileptic colonies and those diagnosed elsewhere whose skiagrams were sent to us for inspection.

II.— Preface.

The recognition of cysticercosis in man is not a new development nor, except in England, America and in those continental countries where sanitation has reached a high level, is it a rare disease. Cobbold of “filaria” fame, in his book on entozoology, published in 1863, gives a good account of the disease with some very shrewd comments on the risk of infestation by uncooked vegetables, water, flies, etc. He stated that over one hundred deaths had been recorded as having been caused by cysticercosis of the brain. Griesinger, a distinguished psychiatrist, collected fifty-six cases of cysticercosis with cerebral symptoms in 1862. He then stated that epilepsy due to cysticerci in the brain is in no way distinguishable from true cerebral epilepsy. Cysticercosis, or somatic tæniais in man, however, became almost a forgotten disease, especially in England and America, owing to the rarity both of indigenous cases and of Tænia solium Linnaeus 1758, until the publication of Colonel Mac Arthur's work in 1933 and 1934. Our English textbooks only refer to it very briefly as a condition of extreme rarity.

Even neurological textbooks, except for the time-honoured reference to a cysticercus in the fourth ventricle, do not give the disease any prominence as a cause of nervous or mental symptoms. Foreign textbooks give an extremely good account of the disease. Oppenheimer (1910), and the theses of Volovatz (1902), Vosgien (1911), Schmitte (1928), contain much valuable information. To the modern practitioner the disease is almost unknown. It has become to a great extent a tropical disease, found in this country chiefly among soldiers, their wives and families, who have served in the countries where sanitation has not reached the same standard as in England.
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III.—DEFINITION AND SYNONYMS.

By cysticercosis (κύστις bladder, κέρκος tail) is meant the presence of cysticerci in the tissues of man or animals. Cysticerci are the larval forms of certain cestodes.

There is no satisfactorily proved case of Cysticercus bovis in man, so that for all practical purposes human cysticercosis is always due to the presence of Cysticercus cellulosae in the tissues. Human cysticercosis, therefore, results from man becoming the intermediate host of Taenia solium instead of only the definite host, the resulting disease being known as cysticercosis (Taenia solium) or somatic taeniasis. The word cysticercosis applied to pigs is synonymous with “swine measles” in England, in France with “ladrerie”; in Germany the Cysticercus cellulosae in pigs is called “finne” and the disease in man “finnen Krankheit.” The word is often written “Zysticerken.” In Holland the cysticerci are known as “gortleid.” In Italy, pigs infected with cysticerci are termed “lazaioli.” The ancient Greeks called the disease in pigs “chalaziasis” (χάλαζα hailstone), from the resemblance of the cysticerci in pork to hailstones. The Romans referred to the cysticerci as “glandines,” and the disease among pigs as “morbus glandulosus.” There was much confusion in earlier days, and the word “measly” in England and “ladrerie” in French, are often applied to other conditions. Cysticercosis is said to be generalized when cysticerci are found all over the body, and localized when they are confined to a single organ, such as the eye, heart, brain, etc. In our experience cysticercosis in man is nearly always generalized.

IV.—HISTORICAL.

(a) Recognition of Cysticercosis in Animals.

Cysticercosis in animals has been known for centuries. The Egyptians, according to Herodotus, recognized cysticercosis in beef. Aristophanes in “The Knights” refers to it and to the method of examining the pig’s tongue and mouth for the characteristic vesicles, a practice which is in vogue to-day and is known in France as “langueyage.” Aristotle, in the “History of Animals,” gives an excellent description of cysticercosis in the pig. He states that it is only found in young pigs; a fact which is borne out by modern experience: experiment shows that older pigs cannot be infested with the larval form of Taenia solium.

Plutarch stated that the reason the Jews did not eat pork was probably a religious one; but that the fear of catching some disease, such as “humors” or “eruptions,” was probably an additional reason. Tacitus, quoted by Ostertag, says that the fear of “lepra arabum” was one of the reasons, apart from the religious one, that caused the Mosaic laws against pork. The Koran apparently copied the Jewish laws against pigs. Curiously enough pork was considered a great delicacy by the Romans, but they had excellent slaughter-houses, meat booths and meat inspectors. The Greeks also had market police (“agoramoi”), whose duty it was to prevent the sale of diseased meat.
The first laws regarding meat inspection in Great Britain appear about 1153 (Ostertag). Haworth, in his book on meat inspection (1918) refers to a statute of Edward II (1302), in which the sale of "swine flesh meazled" was prohibited. In the time of Richard III (1484) came good men of the Mystery of Butchers to petition the Lord Warden among other things "That the Wardens (of the butchers craft) be authorized to search for all manner of boores and hoggges brought hider here to be sold or occupied and all such boores and hoggges as they finde mesels or otherwise unwholesome for mannys body, frealy to seize them and forfeit them and order them to be cast away."

Meat inspection was carried out by the craft guilds and the Worshipful Company of Butchers. It is extremely improbable that anything but a perfunctory inspection was made until recent times. Until 1862, probably one-fifth of the common meat of the country, including pork, came from animals which were considerably diseased, and there was no effective obstacle to such meat appearing on the market. Modern legislation began in 1835 when the municipal corporations made it lawful for the council of any borough to make bye-laws. Meat inspectors were known as "carniters," "flesh conners," etc. Meat infested with measles could be sold in a special place called a measly booth, provided it was not too heavily infested. In France, until recent times pigs were inspected by special men called "langueyeurs," whose duty it was to examine the tongue and mouth of the pigs for any evidence of infestation with cysticerci.

The present high standard of meat inspection in England is due to the fundamental fact that only a two-grade basis exists; whereas in many European countries there is a three-grade basis. The two grades are: (a) Meat which is unconditionally passed as fit for human consumption; and (b) all other meat which is condemned as unfit. In countries with a three-grade standard, two grades accord with the English requirements, whilst the intermediate grade allows of meat, which would be condemned and destroyed in this country, being sold under defined conditions, either in the fresh state or after having undergone an approved form of treatment. In certain countries on the Continent the intermediate grade includes parts of the carcase which have suffered from measles. The sale of this meat is restricted to special premises which receive the name of "Freibank." It is intended for consumption by the actual purchaser and no hotel, restaurant or eating-house keeper may purchase it, since the character of the meat could not be declared to the consumer.

In the United States of America, the intermediate grade is a comparatively recent development; it is limited in its application and the method of sale differs from European practice. Pig carcases showing a minor degree of infestation with Cysticercus cellulosae may be approved for sterilization after having undergone a process of pickling or refrigeration with the removal of the recognizable affected parts. Food thus treated may only be sold under declaration.
In England it is not permissible to use any carcases showing generalized cysticercosis for human food. Howarth (1918) states that meased pork is only rarely met with but the slightest sign of the presence of parasites would result in condemnation.

(b) Recognition of Human Cysticercosis.

In 1558 Rumler found in the dura mater of an epileptic priest small pustulous tumours. "The skull having been opened numerous vesicles were found on the dura mater. This was destroyed in numerous places through which the brain protruded."

In 1650 Paranolus saw cysts on the corpus callosum of a patient who had died in a fit. "A priest became unconscious at the end of mass and died in an apoplectic attack. Some time afterwards when the skull was opened there were found in the corpus callosum several small round white bladders which were regarded as the cause of death." Leuckhart quotes the case observed by Wharton (1656): "de glandulis sanis varas corporis partes occupanibus in milite," as obviously referring to bladder worms. A further study, however, of Wharton's own description of the glands which were removed shows that he stated that "they consisted of wholly solid glandulous and white flesh." Colonel MacArthur considers that this identification as cysticercosis is erroneous and that the bodies in question were undoubtedly fibromata or lipomata.

(c) Recognition of the Parasitic Nature of the Cysticercus.

Hartman in 1685, working on cysticerci in a hare, suspected the parasitic nature, for by plunging the cysticerci into warm water he found they moved. He gave them the name of the "bladder worms." In 1693 Redi and Malpighi, working on pigs, and Tyson, working on antelopes, confirmed the observations of Hartman. Goeze, in 1784, described the bladder worm in the pig. In 1786 Werner found bladder worms in the pectoral muscles of a soldier similar to those found by Goeze in the pig and gave them the name of "finna humana." In 1809 Rudolphi gave the bladder worm the name Cysticercus cellulosae, which is still used.

(d) Recognition of the Connection Between the Cysticerci and Tapeworms.

In 1885 Kürchenmeister produced evidence that the Cysticercus cellulosae was the larval form of Taenia solium by giving a prisoner condemned to death, cysticerci from a pig and recovering a Taenia solium from his intestine after death. This experiment was confirmed by many others. Since then the study of cysticercosis has entered on a new phase and reports of human cysticercosis have appeared in medical literature from all over the world. Cobbold in English medical literature appears to have been the first to draw attention to the danger of human infestation resulting from the ingestion of tape-worm eggs. In the "Entozoa" 1864, he gives a description of cerebral cysticercosis now recognized as a classical one. He draws attention
to the fact that the eggs of *Taenia solium* may be conveyed to the human host by means of water or flies.

Notwithstanding that our methods of diagnosis became more efficient on account of the use of X-rays, little was added to his description over a period of seventy years. Unfortunately Cobbold's work has been almost forgotten and although occasional cases of cysticercosis were reported in English medical literature, the full significance of the condition, especially in connection with epilepsy, was not realized until the publication of Colonel MacArthur's papers "Cysticercosis as a Possible Cause of Epilepsy," 1933, and "Cysticercosis as seen in the British Army," 1934. These two papers marked a definite advance in our knowledge of the methods of diagnosis, dissemination and pathology of the disease. Foreign literature nevertheless abounds in reports of human cysticercosis. Bruns, in 1906, described certain signs which he considered pathognomonic of a cysticercus in the fourth ventricle. Moss, at Vera Cruz, 1911, described eosinophils in the cerebrospinal fluid as being diagnostic of the disease. We have been unable to demonstrate this in any of our patients though we have records of two such cases published in England.

V.—NATURAL HISTORY AND DEVELOPMENT.

(a) The life-history and description of *Taenia solium* is dealt with in the helminthology textbooks so that a short account of the life cycle with special reference to the presence of the larval state in men is all that is attempted here.

Man is the exclusive host of the adult tapeworm and it is the pig that usually acts as the intermediate host. The worm is attached to the upper part of the intestine by means of four suckers and a double row of alternating large and small hooks; the segments or proglottides grow down from the head till the worm may have as many as 800 or 900 segments and be two or even three metres in length. The proglottides are passed during defaecation usually in groups of 5 or 6 and each proglottis may contain from 30,000 to 50,000 eggs. *Taenia solium* and *Taenia saginata* Goze, 1782 can be distinguished by the respective number of the lateral branches of the uterus which in *Taenia solium* presents 7 to 12 such branches and in *Taenia saginata* 15 or more. The eggs are set free by rupture of the proglottis, they are spherical and contain a minute hexacanth embryo which is about 14 μ in diameter. The eggs can live at any rate for three weeks on grass or soil, probably longer. When ingested by the intermediate host, usually the pig, but not infrequently man, the hexacanth embryo escapes and with the assistance of its hooks makes its way through the intestinal wall and passes into the blood-stream or the lymph channels eventually to find some resting place in the tissues. Brumpt holds that the great majority of hexacanth embryos die soon after entering the blood-stream and only a few remain to develop into cysticerci.

On arrival in the tissues; the cells in the centre of the embryo proceed
to liquefy and the embryo increases in length, finally consisting of a mass of peripheral cells with a central cavity. Then a small invagination takes place in the wall of the embryo; at the bottom of this invagination a scolex or head is produced complete with hooks and suckers, thus forming a spherical bladder with a single invaginated head. The rate of growth in pigs (and presumably it is the same in man) has been found by experiment to be as follows (Gerlach). At nine days after infestation the larva forms an oval vesicle 0·033 by 0·24 millimetre. At twenty days it is as large as a pin's head with the rudiment of a scolex visible. At thirty-two days the ellipsoidal cyst measures 1 to 6 by 0·7 to 2·5 millimetres, the rudimentary scolex being about the equator. At forty days the size is that of a mustard seed, the scolex having rudiments of hooks and suckers, and traces of surrounding fibrosis appear. At sixty days it is as large as a pea, complete with hooks and suckers surmounting a neckless scolex. At one hundred and ten days the scolex has a complete neck. The mature cysticercus forms an ellipsoidal, semi-transparent cyst measuring from 6 to 12 by 5 to 10 millimetres, the scolex showing through as a whitish spot; the rostellum, armed with 22 to 24 hooks alternating in two rows of different sizes surmounting 4 suckers. The whole constitutes the fully formed scolex of the future Taenia solium. It must be understood that these measurements refer to experimental rearing of bladder worms in the pig, which is the normal host, the same does not necessarily apply in the case of man, who is the accidental host.

In many of our cases the size of the fully mature cysticercus has been much larger than 10 millimetres; in one case it was 25 millimetres in length. Experiments in pigs show that cysticerci of equal age were not of equal size in different parts of the body, and there are sometimes larger and smaller bladder worms side by side, yet one cannot distinguish them either in age or in phase of development. The size in man is usually, on an average, about that of a pea or small bean, but it is very variable. In the situations where pressure is equal on all sides, such as the eye, the cyst is spherical. In the muscles, where it usually lies in the long axis between the fibres, it is ovoid or elliptical. In those organs where it cannot develop freely it becomes very irregular, e.g. at the base of the brain, where it may assume a racemose form.

This racemose form occurs at the base of the brain where the cysticercus is compressed between the hemispheres and the base of the skull, and as a result is flattened and elongated and pushes prolongations in all directions wherever there is a free surface. It is completely deformed and instead of being ovoid or spherical, which is the usual form in the cerebral hemispheres, it resembles a bunch of grapes with secondary bladders joined by a pedicle. These forms can attain great length up to twenty to twenty-five centimetres, but the head remains constantly small. It would appear that the bladder of the cysticercus in its racemose form develops at the expense of the head. Frequently in these forms the head cannot be found, hence
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they are termed "acephalocystic forms." The racemose form apparently does not calcify.

These forms were first recorded by Louis and Calmeil in 1835, but Zenker in 1882 gave the best description which is abridged above and called the form Cysticercus racemosus. He divided them into four groups, Festonée, Pleurivesiculée, Acineuse, Formes en Grappe. No case of Cysticercus racemosus has been found in our series.

(b) Location and Number of Cysts.

These are very variable. The largest number of cysts was recorded by Black (1903) where over 3,000 in all were found post mortem in a Kaffir who died insane. The case was not diagnosed before death. In our series, the largest number reported in the brain was 300. With the increasing use of radiology in the diagnosis of cysticercosis it has been found that the numbers of cysts may be much greater than was at first supposed. Where the diagnosis rests upon the finding of a single cyst there is now good reason to believe that many more will often be found if systematic X-ray investigation is undertaken, but cases do occur where the number of cysts demonstrable is very small. The general opinion is that the optimum sites for the parasites are above the diaphragm level in the arms, muscles of the trunk, neck and in the brain. This has been so with most of our cases, but sometimes where infestation has been heavy numerous calcified cysts have been found in the muscles of the thigh. The larva of Taenia solium can live for a long time in man. A case has been reported of a woman who had a cysticercus living in her eye for twenty years. In most of our cases the cysticerci were dead, degenerated or calcified when removed.

(c) Methods of Infestation in Man.

Man may become the host of the larval form of Taenia solium by the ingestion of food or water contaminated directly by human excreta or indirectly by flies. As each tapeworm segment may contain from 30,000 to 50,000 eggs, the possibility that food or water may become contaminated, in countries where sanitation is bad, is obviously considerable. It is also possible for the host of a tapeworm to infect himself either from his contaminated hands or clothing or by regurgitation of ripe proglottides of Taenia solium into the stomach.

(To be continued.)