

28.  
PART III.

In his "Text-book of Meat Inspection" von Ostertag divides the animal parasites found in meat inspection into (i) those not transmissible to man through the consumption of meat, and, (ii) those parasites transmissible to man through the consumption of meat. In the latter category he mentions but three parasites:

- (a) Cysticercus inermis (bovis) in cattle.
- (b) Cysticercus cellulosae in swine.
- (c) Trichinella (trichina) spiralis in swine.

An endeavour will be made in Part V of this article to show the import of the two first-named parasites on hygiene, with special reference to South African conditions.

The Trichinella spiralis will receive no further consideration in this work, since it is neither a cysticercus, nor has its occurrence in South Africa been recorded.

On the other hand, there is a number of cysticerci found in the viscera and tissues of slaughter animals, including pigs and bovines, which, although meat may be condemned owing to their presence, will not give rise to an adult tapeworm in man. Some of these cysticerci, however, are of importance when arriving at a differential diagnosis, and will be mentioned in that section.

M O R P H O L O G Y , D E V E L O P M E N T , A N D  
L I F E - C Y C L E .

I. CYSTICERCUS CELLULOSAE.

The Cysticercus cellulosa is a round to oval bladder, which in young specimens may frequently be spherical, but in older specimens it generally has an oval or even elliptical shape. The maximum recorded size is 20 mm. by 10 mm.

It consists of (a) the so-called bladderworm capsule, or caudal vesicle, (b) the parasitic head and neck, or scolex. The actual bladderworm is enveloped in a whitish-gray transparent outer connective tissue membrane, formed by the host tissues as a protective reactor against the surrounding muscular tissue of the host. The caudal vesicle consists merely of an outer cuticle and a subcuticular layer. The caudal vesicle is easily removed from the connective tissue capsule, and is of delicate structure, containing a variable amount of fluid. It is very transparent, showing the invaginated scolex inside the bladder. One portion of its wall is narrowly folded to form, what was formerly called, and is still so-called by some writers, the receptaculum scolicis. The scolex is invaginated into the receptaculum, being attached to the fold of the vesicle by its neck portion. The opening or "hilus", into which the scolex is invaginated, is extremely narrow and barely visible. The scolex and its receptaculum, in the early stages of development grow in unison, but after a time the scolex outgrows its receptaculum.

The resultant restriction to the longitudinal growth of the scolex causes it to form a bow or bend into an S-, or 6-shape, as Yoshino (1934) describes it. This constriction causes the comparatively long neck of the scolex to make one-and-a-half complete coils, and transversely folds it in the invagination process to resemble a closed concertina. The neck is transversely striated and contains numerous calcareous corpuscles, which are characteristic of tapeworm tissue. Ransom suggests that the calcareous corpuscles are composed of calcium albuminate. When treated with acid, however, the corpuscles dissolve, giving off gas, and they may, therefore, probably be composed of calcium carbonate.

The size of the head varies with the maturity of the Cysticercus. When mature it measures from about 0.6 mm. to 1 mm. in diameter. The head is spherical in shape. Its dome is formed by a prominence, the rostellum, a strongly muscular structure, which is capable of contraction and expansion. The rostellum measures about 0.36 mm. in height and diameter, and is armed with two rows of hooks. Owing to its contractive and expansive powers the rostellum may sometimes be deeply sunk into the wall of the head, and sometimes protruded into a dome-like proboscis. Four prominent suckers are situated antero-laterally, with the rostellum approximately equidistant from each. They measure from 0.4 mm. to 0.5 mm. in diameter. Leuckart, in describing the range of movement of the suckers, mentions that "the whole four may be raised up like arms, extend in different directions, and then contract. This is very marked when the suckers feel about in front as though trying to fix themselves to some

object situated in front of the head. As often as this motion takes place the apex is observed to sink in, and to remain in this position until it again protrudes and allows the hook-apparatus to unfold itself."

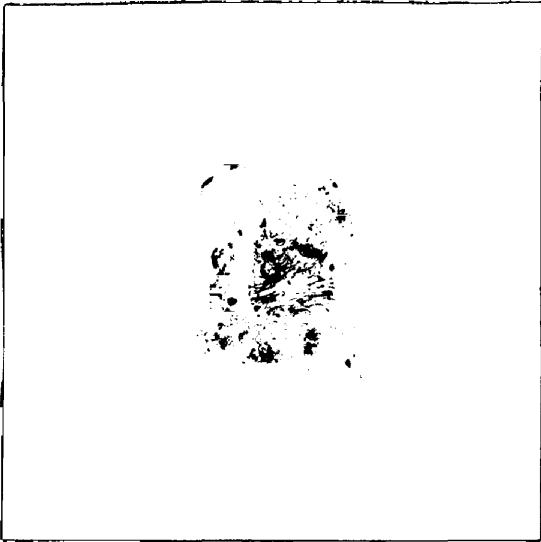


Fig. 1.

*C. cellulosa* head, showing rostellum with hooks, and on the left two suckers prominently, other two suckers less prominent. This scolex evaginated artificially after 28 days cooling.

Photograph by Director of Veterinary Services, Onderstepoort. Magnfn. 40 X

Specimen, Bloemfontein Municipal Abattoir.

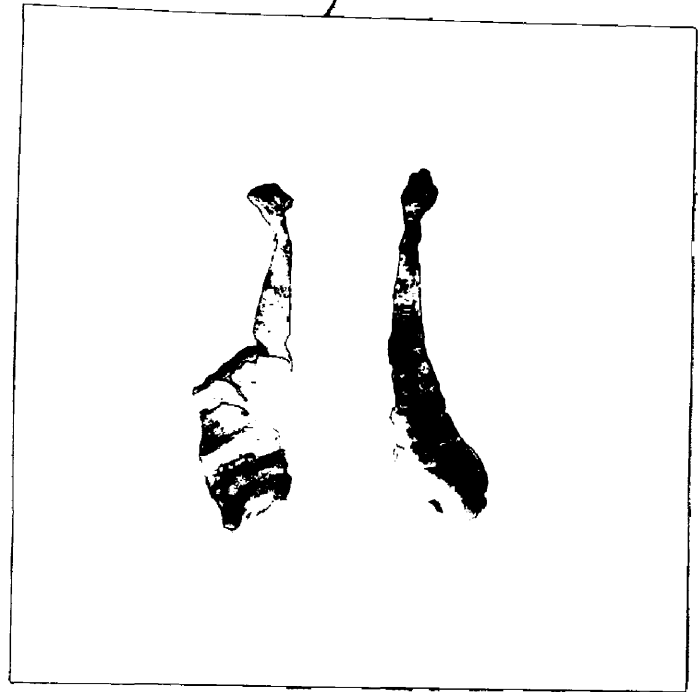


Fig. 2.

Fig. Completely evaginated scolex of *Cysticercus* mentioned under Fig. 1.

Magnfn. 7 X.

The double row of hooks is arranged into a circle on the rostellum. The anterior hooks are the larger, and the posterior, or smaller hooks always individually occupy the spaces between each anterior pair of hooks, thus alternately there are large and small hooks. The shape of the hooks is characteristic and a distinct "handle", "guard" and "blade" can be recognized. The root processes are thick and the tips curved. The total number of hooks in Cysticercus cellulosae is from 22 to 32. Yoshino found the number of hooks in the specimens examined by him to be 22, 24, 26 or 28. The large hooks measure from 0.16 mm. to 0.18 mm. and the small hooks 0.11 mm. to 0.14 mm. (Yoshino's measurements are 0.128 mm. to 0.162 mm., and 0.100 mm. to 0.125 mm., respectively).

In describing the development of the hooks on the rostellum, Yoshino states that they differ in shape according to the development of the Cysticercus cellulosae :- "The initial hooks on the rudiment of the rostellum in C. cellulosae about 40 days old are like needles or spines, and gradually they curve outwards like the horns of cattle!"

The histological structure of the scolex of Cysticercus cellulosae about 40 to 50 days old is similar to that of the mature Cysticercus, and there are recognizable two pairs of excretory canals and very many calcareous corpuscles in the muscular layer developed from the spindle cells in the first cell layer.

In the adult Taenia solium, the head is joined to the body or trochila by a neck, usually four times as long as the head itself.

The strobila is segmented, the segments being called proglottides, which, in the case of the mature segments, are longer than broad. The proglottides are formed behind the neck, in a continuous chain. The anterior segments are the youngest, and push the older, mature and gravid proglottides farther and farther to the posterior of the host's intestine. The total length of the worm is about 3.5 m. and in rare cases up to 8 m.

The structure of the strobila is simple. Externally it possesses a cuticular layer, which contains numerous fine pores, through which the parasite absorbs its nourishment. Immediately below the cuticle is a subcuticular layer, with a layer of cells on its inner surface. Below the cuticle are layers of delicate transverse and longitudinal muscles. The interior of the body consists of the parenchyma, which is divided by a strong layer of transverse muscles into cortical and medullary portions. The cortical portion of the parenchyma contains numerous oval calcareous corpuscles, similar to those mentioned in the description of the scolex, and are distributed throughout the length of the Taenia. They may measure up to 0.019 mm. In the medullary portion are situated the excretory, nervous and reproductive systems. All tapeworms are devoid of an alimentary canal, absorption of nourishment taking place through the pores in the cuticle, and excretion through "flame-cells" and a pair of dorsal and ventral longitudinal canals on either side of the strobila. At the posterior part of each proglottis, each pair of canals is joined by a transverse canal, and in the scolex itself all canals are joined by transverse loops.

The nervous system consists of two large longitudinal and several smaller nerve trunks, which run throughout the strobila. These are joined by several ganglia and transverse commissures at the scolex.

The Taenia solium and all taeniae are hermaphrodite parasites. The male reproductive organs are the first to appear in young proglottides. They consist of:-

(i) Numerous testes, which secrete into (ii) vasa efferentia uniting to form a (iii) vas deferens, which forms a (iv) seminal vesicle, and ends in (v) a cirrus-pouch, containing a cirrus, opening at the genital pore, which lies in a sinus on the lateral margin of the proglottis, close to the genital pore of the female organs. The genital pores are situated on irregularly alternate margins in successive proglottides.

The female generative organs consist of:-

(i) A vagina, opening at the genital pore. It is a narrow tube, bearing (ii) a seminal vesicle, and ends in the (iii) ootype, surrounded by Mehlis' gland, where it is joined by the oviduct and the vitelline duct. (iv) The ovary, which is single and lobed, is situated at the posterior part of the proglottis. (v) The ootype is also in contact with the vitelline gland. (vi) The uterus is characteristic, and one of the main differential diagnostic features of the species. It has a median longitudinal stem with 7 to 12 lateral branches.

Self-fertilization may take place in each individual sexually mature proglottis. Tapeworms may also bend double and the male

products developed earlier in younger proglottides may fertilize the female products developed later in older proglottides.

The embryonic egg-shell is thick and radially striated, spherical, rarely ovoid in shape, and measures 0.042 mm. in diameter. Leuckart's measurements were 0.06 mm. and those of Yoshino 0.043 to 0.068 mm. The embryonic development takes place in the uterus, and the eggs contain a spherical embryo, with three pairs of hooks, the hexacanth embryo. The embryo with its embryonic egg shell is known as the oncosphere. Yoshino (1934) found that under abnormal circumstances the embryo may have 8, 10, 12, 14, 16 or 18 hooks, instead of 6.

Gravid proglottides measure 10 to 12 mm. long by 5 to 6 mm. broad. The gravid segments are passed to the exterior by the human host, in his excretum, and are frequently detached in short chains. The worm may live in man for years, and sometimes more than one individual may be present in one host. Yoshino (1934) intentionally infected himself with Taenia solium and studied many gravid proglottides. He found that the gravid proglottides just discharged moved about, alternately extending their anterior ends then contracting themselves. "During the extensions the eggs are pushed out from the uterus through the anterior end of the proglottis. With the extensions and contractions from 31,000 to 55,300 eggs are evacuated and only 480 to 1,500 eggs remain in the proglottis," he wrote. Leuckart found that the contents of the uterus of each segment was 6 cubic mm., and it held some 53,000 eggs.



Development of Cysticercus cellulosae.

The egg hatches after it has been swallowed by the pig (also by man, the dog, or in at least one instance the monkey, as was reported by Walker), and the hexacanth embryo penetrates into the intestinal wall. The migratory course of the embryo in the body of its intermediate host, the pig, was carefully studied by Yoshino in 1933. This writer experimented upon a number of pigs, which he fed with large numbers of eggs of Taenia solium. He obtained the following results:-

(1) The eggs of Taenia solium hatch in the upper part of the small intestine of the pig and the greater number of freed embryos enter the mucous membrane of that portion, while a smaller number penetrate into the middle or lower parts of the intestines.

(2) The number of hours required for the hatching of the eggs varies, and Yoshino saw freed embryos in the mucous membranes of the intestines 15 to 48 hours after the experimental feeding, and they were also found in the internal organs and muscles within 24 to 72 hours after feeding.

(3) Embryos found in the intestinal wall usually had no hooklets, having lost them by penetrating through the tissues. During the early stages, 15 to 48 hours after feeding, specimens with one or two hooklets could be seen.

(4) The youngest Cysticercus cellulosae or transitional forms found in the intestinal wall were spherical or ovoidal in shape. They consisted of round cells, and under the microscope appeared grayish-white in colour, and measured 0.024 mm. to 0.03 mm. in

length and 0.021 mm. to 0.026 mm. wide. The transitional forms were mostly found in the tunica propria and rarely in the tela submucosa and the muscular layers. In those cases the blood vessels in the tunica propria, into which the transitional forms were about to penetrate, or had penetrated, were congested and enlarged. The youngest Cysticerci cellulosae were rarely found in the abdominal cavity of a pig between 24 and 72 hours after the experimental feeding. Those Cysticerci cellulosae found in the internal organs or muscles of a pig between 24 hours and 72 hours after experimental feeding were light greenish in colour and spherical or ovoidal in shape. They consisted of round cells. Between 24 and 48 hours after experimental feeding, the size of the Cysticercus was 0.024 to 0.042 mm. in length and 0.021 to 0.036 mm. wide. Between 48 and 72 hours after feeding the dimensions were 0.03 mm. to 0.058 mm. long and 0.027 mm. to 0.054 mm. wide.

(5) Between 6 days and 15 hours and 12 days and 15 hours after experimental feeding, the young Cysticerci cellulosae appeared macroscopically as almost transparent and colourless spots, and were difficult to find within the muscles and organs, unless they were detached from them. Under the microscope they were light greenish in colour, and spherical, ovoidal or cylindrical in shape. At 6 days and 15 hours after experimental feeding they were generally solid, but larger specimens were somewhat cystic. Those examined 12 days and 15 hours after experimental feeding were cystic, contained a sticky fluid, and through the cyst wall a spot could be seen, which might have been the rudiment of the

head and its rostellum." (It is extremely unlikely that the last surmised of Yoshino is correct. In such young stages there would be nothing more than a slight thickening of the wall where the invagination will later occur. The scolex is formed much later at the bottom of the invagination or receptaculum).

6. At 12 days and 15 hours after experimental feeding the young Cysticerci cellulosae were quite large and cystic, and contained fluid. The cyst wall became thinner than in younger specimens and consisted of a cuticular membrane and a subcuticular layer. At a point destined to become the receptaculum, a great number of ovoidal cells began to accumulate, and the cuticular layer of that portion became thicker and curved into the accumulated cell-layers.

At 12 days and 15 hours after experimental feeding the young Cysticerci were found in the liver, especially in bleeding areas in the parenchyma. They were also found in the brain, especially in the cortical substance of the cerebrum. Within 12 days and 15 hours after experimental feeding the young Cysticerci cellulosae were found in body muscles and heart muscles and were accompanied by round cell infiltrations.

From the above results Yoshino concludes that the embryos hatch in the small intestine of the pig, penetrate into the intestinal wall, and the majority enter the blood stream by the capillaries in that region. They are then carried to the internal organs and muscles, where they develop into Cysticerci cellulosae. Others penetrate through the

intestinal wall into the abdominal cavity and die there.

On the later stages of development of the Cysticercus cellulosae various observers have recorded as follows:-

Hutyra and Marek:-

At 20 days Cysticercus cellulosae is about the size of a pin head ~~head~~, and the head is visible as a small white point.

At 40 days it appears as big as a mustard seed, and the head may be plainly seen, but it has neither suckers nor hooks.

At 60 days the cyst is as big as a pea, with head with suckers and hooks, but no neck.

After 3 months the "bladderworm" is fully developed and behind the head the transversely striped neck may be seen.

Braun-Seifert:-

The complete development of the Cysticercus cellulosae takes from  $2\frac{1}{2}$  to 4 months.

Monnig:-

The Cysticercus requires about ten weeks for its complete development in the pig. After about two months the bladderworm is already infective as the suckers and hooks are sufficiently well developed to allow the scolex to attach itself.

Yoshino:-

At 20 to 30 days the Cysticercus cellulosae measured 1.1 mm. to 4.1 mm. by 0.8 mm. to 3.2 mm.

At 40 to 50 days dimensions were 3.4 mm. to 8.2 mm. by 2.9 mm. to 6.0 mm.

At 60 to 70 days dimensions were 5.6 mm. to 8.5 mm. by 3.1 mm. to 6.5 mm. At the last named stage it might be fully developed and infective, but may still increase in size and measure 8.0 mm. to 14.5 mm. in length, by 4.5 mm. to 8.0 mm. in width between 254 and 325 days after feeding.

Twenty days after experimental feeding the rudiment of the scolex may become gradually distinguishable.

Forty to fifty days after feeding the scolex has developed fully with four suckers arising from its invaginated surface, and in its blind end the rostellum provided with hooks is formed. It measures from 0.83 mm. to 1.97 mm. in length.

In Cysticercus cellulosae 60 to 70 days old, the scolex

is fully developed and its elongated neck is bent within its receptaculum, showing on its invaginated surface many fold-like septa, because the scolex grows much more rapidly than the receptaculum. According to the development of the bladder the neck of the scolex elongates rapidly, and on its invaginated surface numerous fold-like septa appear. Outgrowing the receptaculum, it bends as a whole into an S-, or 6-like shape and the receptaculum becomes a thin membrane.

The histological development of the head, according to Yoshino, is as follows:-

At 20 days the rudimentary scolex is a simple tube, consisting of cuticle and subcuticular layer. The subcuticular layer may again be divided into an outer (first cell) layer, which directly joins the cuticle, and consists of spindle cells, and an inner layer (second cell layer) of polymorphic cells. At 40 to 50 days the scolex is almost fully developed and is provided with four suckers and the rostellum. In this stage the suckers are hemispherical and measure 0.225 mm to 0.352 mm. in diameter. Still later, at 60 to 70 days, the suckers measure 0.325 mm. to 0.384 mm. in diameter.

## II. CYSTICERCUS BOVIS.

The general structure of the Cysticercus bovis and its resultant adult Taenia saginata resembles the Cysticercus cellulosae - Taenia solium closely, with the following enumerated points of difference:-

- (a) Intermediate host, the ox; very rarely man. Adult host, man only.
- (b) The outer connective tissue membrane is very much thicker

than that of Cysticercus cellulosa, and much more firmly attached to the caudal vesicle.

- (c) The bladder itself is much less transparent, and contains a thicker fluid, which is frequently more turbid than in Cysticercus cellulosa. The scolex is, therefore, less visible.
- (d) The bladder is decidedly more grayish in colour, and very frequently the fluid contents give the bladder a reddish-brown tint. Piettre (1922) gives the opinion that the red colouration may be ascribed to the absorption of haemoglobin from the surrounding muscles. Valade (1927) suggests that the reddish tint apparently results from histolysis of muscle fibres as the result of the excretion of toxic materials by the scolex.
- (e) The Cysticercus bovis usually measures 7.5 mm. to 9 mm. by 5.5 mm. when fully developed.
- (f) The scolex, especially in the adult stage is very much larger than that of Cysticercus cellulosa-Taenia solium. It is 1.5 mm. to 2 mm. in diameter.
- (g) The embryo is a hexacanth (six-hooked) larva, but neither in the Cysticercus nor in the adult stage has the scolex a rostellum and hooks.
- (h) The four suckers are even more muscular than those of Cysticercus cellulosa-Taenia solium, are larger, with unusually thick walls. As compensation for the absence of hooks, the suckers are capable of greater suctorial attachment.
- (i) Pigmentation around the suckers is very well-marked in the adult Taenia saginata, and gives the worm the appearance of

possessing a big black head. Pigmentation occurs to a much less extent in Taenia solium.

- (j) The adult tapeworm is much longer than Taenia solium, and may measure from 4 to 10 m. in length.
- (k) Gravid proglottides are from 16 to 20 mm. in length and from 4 to 7 mm. wide.
- (l) Gravid segments are generally voided singly, very rarely in chains, and may sometimes be liberated spontaneously to the great discomfort and embarrassment of the human carrier.
- (m) The gravid uterus has 15 to 35 lateral branches on either side.
- (n) The embryonic egg-shell is ovoidal, rarely spherical, and measures 0.045 mm. by 0.043 mm.
- (o) Malformations are quite common in T. saginata. These may take the form of specimens with multiplication of the generative openings. (Leuckart) Supernumerary joints, and sometimes duplication of strobilae have been recorded. Palais (1933) described a specimen obtained from Brazil, in which the two strobilae were attached, one at right angles to the other. Leuckart states that he found only one case of malformation in Taenia solium.
- (p) The worm has been known to live in man for 20 years. Very rarely is more than one specimen found in one host, and in that respect Leuckart was correct when he took exception to the name Taenia solium (solitary tapeworm), and pointed out that Taenia saginata was by far the more solitary.

(q) With regard to the development of Cysticercus bovis, Braun (1900), quoting Hertwig, gives the following table:-

Age of Cysticerci in weeks.	Connective tissue cyst.		Cysticerci.		Scolex./mm.	
	Length/mm.	Breadth/mm.	L./mm.	Br./mm.	Natural	Extended Artifi- cially.
4	4.0	3.5	2.25	2.25	0.5	0.7
6	4.2	3.5	3.0	2.5	1.0	1.3
8	4.5	3.5	3.25	2.75	1.5X1.0	2.9
10	5.0	3.75 - 4.0	3.5	3.5	1.75X1	3.3
12	5-6	3.75- 4.0	4.0	4.0	1.8X1.0	3.5
14	6.0	4.5	5.0	4.5	2 X 1	4.0
16	6.0	4.5	5.0	4.5	2 X 1	4.25
18	6.25 X 7.0	4.5	6.0	4.5	2 X 1.25	5.0
22	6.5 - 8.0	4.5	6.0	4.5	2.25X1.75	5.5- 6.25
28	7.5 - 9.0	5.5	7.0	5.0	2.5 X 2	7.0

(Probably includes  
the neck. N.F.V. )

(r) Cysticerci take about 18 weeks to attain full development. It is usually taken that a diagnosis of cysticercosis will be made in meat inspection from the 6th week onwards - both in the case of C. bovis and C. cellulosae.



Second, or adult stage of life-cycle of both species.

If man eats viable measly pork or beef, which may be undercooked, or insufficiently cured in the case of ham, the adult stages of the respective parasites are commenced within him.

The bladderworm is swallowed, and within 24 hours, as a rule, the scolex evaginates from the surrounding caudal vesicle into which it had been invaginated. The evagination is caused by the stimulation of the head by digestive juices which permeate through the "hilus" of the invagination. The head attaches itself to the mucosa of the intestine, by means of its hooks and suckers (Taenia solium), or suckers only (Taenia saginata).

After having obtained lodgment by means of the scolex, the tapeworm grows, and from the neck the strobila develops. The mature and gravid segments are pushed further to the posterior by the younger segments. Self-fertilization may occur within the proglottides, or proglottides may fertilize one another, and gravid segments are voided.

Contrary to the opinions in many text-books, Yoshino (1934), who examined stools for Taenia solium, and Alcaraz (1932), Pardina (1932) and Franzani (1933), who examined stools for Taenia saginata, found that in the majority of cases numerous eggs were found in the faeces, whereas comparatively few remained in the voided proglottides. Pardina explains the fact that the detached gravid segments extrude eggs through a

ruptured uterine branch. Alcaraz, referring to Taenia saginata, explains that segments are expelled singly, causing rupture of the uterus, followed by active expulsion of the ova. Kouri and Basnuevo (1933) found that eggs of Taenia saginata were observable in 80% of stool examinations, in infected cases.

Moore (1916) observed the rate of growth of a Taenia saginata in a student at the Potchefstroom (Transvaal) School of Agriculture. He gave the student a vermifuge, which caused the patient to excrete a length of tapeworm, which, according to its appearance, gave Moore the opinion that the entire worm minus its head and neck had been passed. Some time later, the patient was again troubled with the tapeworm, and a second vermifuge was administered, with the result that the entire worm was passed. The time between the first and second vermifuges was 72 days, and the length of worm passed on the second occasion was 19ft.3in. Moore thus estimated that all but the head and neck grew in that time.

When the pig, or the ox, ingests the eggs of the respective species of which it is the intermediate host, the life-cycle is resumed.

## B.

THE HOSTS AND PATHOGENICITY OF  
CYSTICERCUS CELLULOSAE.

In the adult stage the Taenia solium has only been known to develop in man. Young, immature Taeniae solium may, however, live for a very short period in dogs and possibly in some other carnivores.

Experimentally we tried to infect six dogs, a jackal (Thos mesomelas) and a baboon with Taenia solium at the Bloemfontein Municipal Abattoir. In none of these subjects did ripe proglottides or ova pass in the faeces. Dogs Numbers 1 to 4 were destroyed and examined 90 days, 70 days, 60 days and 30 days, respectively, after having been fed large numbers of C. Cellulosae. Dog Number 5 was killed 3 days after feeding, and dog Number 6 was killed 24 hours after feeding. In not a single case were mature, or immature Taeniae solium, or even evaginated scolices observed.

Similarly, all attempts to infect the jackal failed. At various periods, over four months, he received countless thousands of viable Cysticerci cellulosa. Since infection over a prolonged period did not result, he was finally given some pork containing numerous viable Cysticerci cellulosa, and destroyed two days later. Post-mortem examination revealed several mature Taeniae marginata (hydatigena), and many thousands of Echinococci granulosus, but not a trace of Taenia solium. The infections with T. marginata and E. granulosus had resulted from experimental feedings with numerous Cysticerci tenuicollis and Echinococcus

cysts, which had been administered when we first obtained the jackal, about four months previously.

Infection tests were contemporarily tried on an adult male South African baboon. The baboon was kindly presented for experimental purposes by the Chairman of the Parks Committee and the Curator of the Bloemfontein Municipal Zoological Gardens. He was well housed at the Abattoir, and his diet consisted mainly of fruit, vegetables and bread. He refused to eat meat, whether raw or cooked. At first he was given about fifty Cysticerci cellulosa hidden in bread, but, with the natural wiliness of his kind, he frequently broke the bread into crumbs and removed all traces of cysticerci. Measles were then stuffed into the pulp of bananas by means of a sharp stick or a pencil, and the canal thus formed was again closed over, so that the baboon could neither detect the presence of the measles in the bananas, nor could he notice that the bananas had been interfered with. He took the bananas readily and by this means approximately 750 viable Cysticerci cellulosa and a few C. boyis were fed to him, over a period of four months. In order to ensure that only live measles were fed to him, we always tested viability of the cysticerci from the same pigs in 5% sodium taurocholate solution and by actual infection tests on a human subject, according to Keller's and Iwanizky's methods. At no time did our baboon excrete Taenia segments. Four months after the original feeding the baboon died from acute pneumonia, contracted during a sudden cold and wet spell. A careful post-mortem examination was made, which revealed pneumonia, but not a single tapeworm, mature or immature was found.

Under natural conditions, the baboon is not carnivorous in the true sense of the word, although he may feed on locusts, scorpions and grubs. In a few instances they have been known to attack flocks of sheep, causing wilful destruction. A favourite practice of these marauding troops of baboons is to disembowel sheep, and leave the carcasses on the veld, but it is very doubtful if they will at any time attack and make a meal of pigs. It is, therefore, most unlikely that the baboon will acquire natural infection of Taenia solium. Although our experiments were numerous attempts to infect one baboon, it can reasonably be concluded that the baboon is immune to infection with T. solium, even with attempts at artificial infection. It is also very unlikely that any of the higher anthropoid apes are subject to the parasite. In conclusion, it may be mentioned that in 1932 Clarenburg recorded that he failed to infect various monkeys with Taenia saginata. His subjects were fed several C. bovis, fresh specimens, as well as some which had been preserved in a cooler for three weeks.

In the cystic stage a number of animals have been named as intermediate hosts. Authentically it is accepted that the pig, man, the dog and recently, the monkey are definite hosts. In addition it has been mentioned by some writers that C. cellulosa was found in sheep, goats, cattle, horses, antelopes, deer and bears, "but the identification of the cysticerci was undoubtedly erroneous in many cases." (Monnig, 1934).

The cysticerci found in sheep and goats were very probably C. ovis, which closely resembles C. cellulosa, and has a rostellum

bearing 24-36 hooklets. Von Ostertag (1934) mentions that Giurea examined seven cases of suspected C. cellulosa in sheep and found that they were actually atypical cases of C. ovis.

In cattle and wild buck they may have been the Cysticercus of Taenia hyaenae, a tapeworm from the hyaena. In 1932 Martinaglia encountered a peculiar measles in a bovine carcass at the Johannesburg Abattoir. "The cysticerci were armed and unlike the bovine bladderworm. On further identification Dr. M<sup>o</sup>nnig of the Veterinary Research Laboratory, Onderstepoort considered the hooks of this cysticercus resembled those of T. hyaenae".

It is possible that the cysticerci found in equines, antelopes, etc., were mistaken by some writers for C. cellulosa.

Some years ago, during three years' service in the wilder parts of the Bechuanaland Protectorate, the present writer found what he took to be C. cellulosa in two African bush pigs (Potamochoerus choeropotamus). Both wild pigs were shot by native attendants, and in curiosity the writer inspected the carcasses, which were found to be heavily infested with measles, which closely resembled those of the domestic pig. Unfortunately, owing to his remoteness from civilization at the time, the writer was unable to examine the cysticerci microscopically, or, since it was also impossible to send specimens away, owing to no preservatives being available, it was impossible to have them definitely identified. Dr M<sup>o</sup>nnig mentioned to the writer that Mr. Harris, who was engaged on the Government's tsetse-fly campaign in Zululand, reported similar cases to him. According to Daubney (1936)

up to date there is no record of C. cellulosa from any of the wild pigs of East Africa.

### INFECTION IN THE PIG.

The infestation of the pig with Cysticercus cellulosa is usually of a very heavy and generalized nature. In this respect it often differs from the infestation of the ox with C. bovis.

In the pig "predilection sites" are sometimes mentioned, but that term, in South Africa, is really only applicable in the exceptional cases of light infestation.

At the Bloemfontein Abattoir we made a systematic study of so-called "predilection sites" in order to ascertain whether these sites corresponded with those described by older overseas authors.

During the calendar years 1935 and 1936, 180 pigs were found measly. Of this number the great bulk were grossly infested, and only 30 had less than 10 measles in the routine inspection incisions. The ratio of 5 : 1 heavily to lightly infested carcasses was more or less fairly representative of infection in other parts of South Africa. It is interesting to record that from Swellendam an exception to the rule was reported. The Abattoir Superintendent of that small centre advised me that he had noticed considerably more pigs lightly infested in the Swellendam abattoir than during his previous service in abattoirs in the Transvaal and Northern Orange Free State.

In the subjoined table the ratios of heavily infested to lightly infested carcasses are given for some centres in the Union.

The ratios given are only in respect of such centres where actual observations were recorded and the details were available. A number of superintendents of other abattoirs, who did not keep actual records, advised me that in general the nature of infestation was very heavy, and lightly infested cases were rare.

Table showing ratio of heavy infestation to light infestation.

Ladysmith (Ntl.) 3:1	Rustenburg 100:0.2	Graaff Reinet 12:1
Newcastle..... 7:4	Bloemfontein 5:1	Middelburg (G.) 4:1
Potchefstroom..... 7:3	Kroonstad.... 3:1	P. Elizabeth... 52:1
Germiston..... 3:1	Bethlehem.... 19:1	Queenstown... 19:1
Klerksdorp..... 13:2	Fort Beaufort 8:1	Riversdale.... 7:1
Middelburg (Tvl.) 10:1	George..... 7:3	Uitenhage.... 19:1
Nigel..... 5:1		

The Superintendent of the Fort Beaufort abattoir made the following observation:- 1 cyst 1 carcass; 2-5 cysts 2 carcasses; 5-10 cysts 2 carcasses; over 10 cysts 40 carcasses.

Von Ostertag (1913) gives the following table showing the ratio of heavily infested carcasses to lightly infested carcasses at the Berlin Abattoir:-

<u>Year</u>	<u>Total Number of Measly Pigs.</u>	<u>Extensively Infested.</u>	<u>Lightly Infested.</u>
1895-96	627	304	323
1896-97	509	251	258
1899	325	118	207

Judging from the above table, it would appear that in Germany, about 40 years ago, the ratio of lightly infested pig carcasses to heavily infested pig carcasses was found to be slightly higher in favour of light infestation. Von Ostertag, however, points out that the ratio of heavy infestation is much higher in the case of hogs than in the case of bovines with *C. bovis*.



Le Coultre (1928) gives the following ratio obtained during his investigations in the Netherlands East Indies in 1927:-

Boeleleng: 36 cases; 17 heavily infested; 19 lightly infested.  
 Denpasar : 23 cases; 18 " " ; 5 " "  
 Makassar (1926): 85 cases, all with less than 13 measles.  
 Soerabaia: All cases heavily infested.

In the usual cases of infestation with C. cellulosa, pigs may harbour many thousands of parasites. It is quite common that hardly a fraction of an inch of the carcass may be noticed free from bladderworms.

In order to arrive at a quantitative estimate of the number of bladderworms in heavily infested pig carcasses, I caused a count to be made in small pieces of meat from two heavily infested pigs at Bloemfontein Abattoir. In each case the head was removed, the vertebrae and the bones of the limbs were stripped of meat, and the actual mass of meat itself weighed. The first pig weighed 75 lbs. stripped, and the second, a fairly large pig, 150 lbs. No viscera of any kind were included in the weights. In each case a small piece of pork, 1 inch cubed, was excised from the deep-seated musculature on the medial aspect of the thigh. Each small piece of meat weighed  $\frac{3}{4}$  ounce. In the first piece we found 80 measles, which represented some 128,000 cysticerci in the pig, minus its head, heart, liver, brain and tongue, all sites where many measles might have been found. In the second piece we found 184 measles, which represented some 588,800 cysticerci in the 150 lbs. pig, minus its head and viscera.

Hall (1920) found 70 cysticerci in a small piece of pork which weighed 5 grammes. Thus he estimated that so many thousand measles were to be found in the entire carcass.

Küchemmeister found 133 measles in 17 grammes of pork, representing about 80,000 to the kilogramme or 2½ lbs.

At Bloemfontein we judged all carcasses in which more than 10 cysticerci were found, in the routine incisions, as heavily infested. During the calendar years 1935 and 1936, 150 heavily infested pig carcasses were found. Statistics are not available of the predilection sites in all the heavily infested carcasses. More accurate observations were made in respect of the thirty lightly infested carcasses. Ten heavily infested pig carcasses were, however, carefully surveyed. Measles were invariably found scattered throughout the musculature of the carcasses. They were more densely located in the muscles above the elbow and in the neck muscles. Infection of the thigh muscles (leg of pork) was very heavy, and invariably numerous measles were found in the perineal region. Although in the ten heavily infested pigs, closely examined, a fairly heavy infestation of the masticatory muscles was observed, it was relatively less heavy than would have been the case of gross infestation of C. bovis in the ox. It will be observed that not a single measles was found in the masseters or the pterygoid muscles of the 30 lightly infested pig carcasses. (See predilection sites in light infestations.)

In three of the ten observations Cysticerci cellulosa

were found in the fat and subcutaneous tissues. The abdominal muscles, intercostals and cervicals were invariably infested. As a rule the degree of infestation was lighter in the abdominals and intercostals than in the cervicals, where usually, numerous cysts were found. Other sites in which measles were invariably found in the ten observations were, in order of density:- the psoas muscles; the sub-vertebral muscles; the tongue; the heart; the oesophageal musculature; the diaphragm. In six out of the ten observations cysticerci were found in the brain; in two out of the ten observations in the eyeball and conjunctiva. In none of the special observations were cysticerci found in the testicles of boars, or in the vagina and uterus of sows, respectively. (Of the ten special observations, two were boars, five were sows and three were castrates.) On at least one other occasion in each gender did we find measles in the respective generative organs. Intra-uterine infections of foetuses were never observed, although on a few occasions pregnant sows were inadvertently slaughtered

In the six cases of cerebral cysticercosis, cerebral cysticerci were found singly in 2 cases, six cysts in 1 case, eight cysts in 1 case, and numerous cysts in 2 cases.

#### Predilection sites in light infestations.

In most countries Regulations governing meat inspection lay down standard routine incisions which are to be made into carcasses, with a view to inspection for cysticerci. Such routine incisions are made into a carcass so as to expose surfaces where

measles are most frequently found, without mutilating the carcass. In lightly infested pig carcasses it is quite possible to miss cysticerci, which may be present, but have not been exposed during the routine inspection.

Irvine-Smith (1911), in "The Report of the Director of Abattoirs and Live Stock Market, Johannesburg, 1910-11", mentions that during that year under report two pig carcasses, bearing the abattoir "passed" stamp, were afterwards found in butcher shops to be measly. In the one case measles were found by the butcher himself, and in the other case by one of the Municipal Health Inspectors. Col. Irvine-Smith points out that it would have been difficult to detect measles in those cases, without mutilating the carcasses.

For the inspection of pig carcasses for cysticerci in South Africa, Regulations have been framed under Section 115 of the Public Health Act No. 36 of 1919. (Government Notice No. 2118 of 1924, as amended by Government Notices Nos. 2015 of 1926, 112 of 1929 and 1456 of 1933).

Paragraph 13(1) reads:- "An incision shall be made into each shoulder behind the elbow, except in the case of a carcass intended for export overseas. In the case of a pig carcass intended for bacon an incision shall be made in the fillet (psoas muscle) in lieu of the aforesaid incision."

Paragraph 16 (1) reads:- "Every meat inspector finding evidence of bladderworm disease (measles) in a slaughtered animal during examination in accordance with Regulation 12 (General examination for all carcasses) and 13, shall further make the additional examination of:-

Head:- Inspection incisions into inner and outer muscle of the jaw

Tongue:- Inspection of the surface and incisions into the muscles of attachment and the tongue proper.

**Pluck:-** Examination of the heart and oesophagus.

**Stomach and Intestines:-** Examination of the outer surface of the stomach and intestines.

**Carcass:-** The following inspection incisions shall be made into each side of the carcass:-

Muscles of the shoulder behind the elbow.....	7 incisions
Chuck (by which is understood the muscles on the dorsal aspect of the thora- cic cavity	}..... 1 incision.
Muscular diaphragm.....	
Fillet.....	3 incisions

Apart from the foregoing three incisions must be made into the pillars of the diaphragm."

It will be observed that according to the above Regulations the Meat Inspector is virtually allowed to make only one incision into each shoulder behind the elbow, or in the case of bacon pigs, into the psoas muscles in lieu of those incisions, and three incisions into the pillars of the diaphragm. He is only entitled to make the subsequent incisions enumerated in Paragraph 16(1) after he has found evidence of bladderworms in the routine incisions.

Cysticerci cellulosa are occasionally encountered in most unusual locations, and may very easily be overlooked in routine inspection. In September 1935 I reported an interesting case in the Journal of the South African Veterinary Medical Association-6(3) p. 191. The Senior Meat Inspector at Bloemfontein Abattoir, on examining the submaxillary lymphatic glands of a pig for tuberculosis, found a cysticercus in the gland of one side. I confirmed his diagnosis of C. cellulosa. In none of the legal routine

incisions were cysticerci found, but on making the secondary incisions laid down by Paragraph 16(1), Cysticerci cellulosae were found in the following locations:-

In 7 incisions into the M. Triceps Brachii and M. Deltoideus on each side 2 cysticerci ; Psoas muscles 1 cysticercus. No cysticerci were found in any other incisions. It is plain that but for the fortunate discovery of a cysticercus in the submaxillary lymphatic gland, a very unusual site, the carcass would have been passed as fit for human consumption.

In November 1936, Dr. Bekker, Municipal Veterinary Officer, Pretoria, encountered several cysticerci in a pig's liver. No cysticerci were found in routine incisions. Being in doubt as to whether these bladderworms were C. cellulosae or C. tenuicollis, Bekker sent the liver to Dr. <sup>M</sup>önnig, Onderstepoort. In answer to an enquiry from me as to the identity of the cysticerci, Dr <sup>M</sup>önnig replied:- "The bladderworms in the pig liver sent by Bekker are unfortunately not fully developed. The hooks are still young and imperfect, and so it is not possible to identify them, but the number of hooks coincides with that of C. cellulosae"

For economical reasons it has been customary in most South African abattoirs to condemn all pig carcasses found infected with measles, although instructions in Paragraph 16(2) and (3) do not preclude lightly infected pig carcasses from receiving similar treatment to lightly infected bovine carcasses in cold storage at minus ten degrees Centigrade for 14 days.

In Bloemfontein, therefore, we were afforded the opportunity of studying predilection sites in thirty lightly infested carcasses, which were minutely dissected:-

Measles were found:

In muscles above the elbow only (Triceps etc.)	10 cases.
" " " " " plus psoas	4 cases.
" " " " " " " plus thigh muscles	3 cases.
" " " " " " " plus thigh muscles	5 cases.
" " " " " " " plus cervicals	2 cases.
" " " " " " " plus heart	1 case.
" " " " " " " plus tongue	1 case.
" " " " " " " " plus cervicals	1 case.
" heart only	1 case.
" muscles above the elbow, plus psoas, plus submaxillary lymphatic gland	1 case.
" heart, plus tongue, plus oesophagus, plus cervicals	1 case.

In other words, in 30 specially observed lightly infested carcasses at Bloemfontein, cysticerci were found:-

In muscles above the elbow in	28 cases.
" " of "the thighs	10 cases.
" psoas muscles in	8 cases.
" muscles of the neck in	4 cases.
" the heart in	3 cases.
" muscles of the tongue and tongue itself in	3 cases.
" " " " oesophagus	1 case.
" submaxillary lymphatic gland in	1 case.

According to these observations the muscles above the elbows must overwhelmingly be accepted as the commonest predilection site. In only two cases in the 30 pigs which had less than 10 measles in the ordinary routine incisions, did we not find measles in that location.

In grossly infested carcasses we observed bladderworms in the following organs:-

Liver 3 occasions; kidneys twice; brain 6 times; eyeball twice;

testicle once; vagina and uterus once; stomach and exterior of the intestines once. In all those cases infestation was very heavy, and the commoner sites were "swarming" with measles.

To summarize, judging from our observations at Bloemfontein, I regard the order of frequency of infestation in the various parts of the pig's carcass to be:-

1. The fore-quarters above the elbows (shoulder of pork).
2. The hind limbs above the hocks (leg of pork).
3. The psoas muscles and muscles on the ventral surface of the vertebrae.
4. The cervical muscles and the intercostals.
5. The tongue and its muscles.
6. The heart and the perineal region.
7. The oesophagus and the diaphragm.
8. The muscles of the face and the abdominal muscles.
9. The brain.
10. The liver, fat and superficial fascia.
11. The eyeball, conjunctiva, etc.
12. Sexual organs, and internal organs not mentioned above, also lymphatic glands.

Von Ostertag (1913) gives the following predilection sites:-

Abdominal muscles; muscular portion of the diaphragm; lumbar muscles; tongue; heart; muscles of mastication; intercostal muscles; cervical muscles; the gracilis and the sternal musculature. He mentions that the heart and the brain should be named as frequent locations for the hog bladderworm.

Kukuljevic (1906) mentions that on four occasions he found Cysticerci cellulosa in the eyeball of pigs, and more frequently in the brain.

Hutyra and Marek (1916) mention that Cysticercus cellulosa is sometimes found in the spinal cord. They mention the following order of frequency:- Deep muscles of the shoulder and chest; abdominal muscles; nape and neck muscles; diaphragm;



Intercostals; adductors of the thighs; less frequently in the muscles of the tongue and the heart, "and in very severe cases in the brain, eyes, liver, spleen, lungs, lymphatic glands and fat."

Vosgien (1911) found the following order in the pig:-

"The muscles of the chest, diaphragm, tongue, heart, muscles above the elbows, and less frequently the intercostals, psoas, masticatory muscles and muscles in the vertebral region."

At Boeleleng (Dutch East Indies), in 1927 Le Coultre found the order of frequency of infestation in 29 pigs to be:-

Muscles of mastication; shoulder and the muscles of the upper arm; psoas muscles; neck muscles; vertebral muscles; tongue muscles; abdominal muscles; muscles of hind legs below the patella; muscles of fore legs below the elbow; intercostals; and lastly came the diaphragm, heart and brain.

The Japanese workers Eguchi and Nishiyama (1930) found the predilection sites in infested pigs in the Prefecture Okinawa to be:- Skeletal muscles and heart, and then in the brain, orbit and cheeks. Out of 42 infested pigs they found measles in one case in each of the following locations-Spleen, kidneys, stomach, intestinal wall.

Hertwig (1885) mentioned that Cysticerci cellulosa were rarely found in the liver, lungs, spleen and kidneys.

Irvine-Smith (1910-11) advised the Johannesburg Municipal Council at that time, in his annual report that "the following

parts of pig carcasses are closely examined:- Tongue and heart; muscles of the neck; breast; intercostals; midriff and psoas.

Degeneration of *Cysticercus cellulosae*.

Quite frequently degenerated cysticerci may be found in pigs, although more rarely than is the case with *Cysticercus bovis* in beef.

Von Ostertag states that degeneration usually occurs at an early developmental stage. At Bloemfontein we frequently observed degenerated measles in old pigs, although on one occasion I noticed both caseous and apparently viable cysticerci in a pig of about 12 months old. This observation differs from that of von Ostertag, who states (1934) that all parasites in the case of *C. cellulosae* are affected (simultaneously?) by the process of decay, contrary to the rule in *C. inermis (bovis)*.

Degeneration of the cysticercus takes the form of caseation and calcification - progressive stages of the same degeneration. The fluid contents of the cyst progressively dry to caseation and ultimately to calcification. Progressive atrophy of the cyst itself occurs, and the shape of dead cysticerci is affected. Dead cysticerci appear as elongated, sometimes slitlike structures which, occasionally may be barely visible to the naked eye, appearing as white specks, and sometimes they may be the size of hemp seeds. During the caseous stage of degeneration the pig measles may appear gray in colour, but when calcified it is usually

pure white.

Neumann states that it is usually age that brings about degeneration of the cysticerci, and their transformation into small, round, hard and compact grains, impregnated with calcareous matter and destitute of fluid. The pork butchers (in France) name the disease dry measles. Neumann adds that the degeneration of the cysticerci is centripetal, that is, it begins with the external membrane and finishes with the scolex; and this is most evident in caseous or pseudo-purulent degeneration. When numerous cysticerci have degenerated, the heart and skeletal musculature are found to be sprinkled with white granules. (Neumann).

Under the microscope, a tough connective tissue membrane and a more or less strongly calcified centre may be demonstrated in the calcified structure. (von Ostertag). Sometimes demonstration of the classical calcareous corpuscles and hooks in a degenerated cyst may serve as a diagnostic feature of the former bladderworm.

#### SYMPTOMS IN THE PIG.

Clinical symptoms of Cysticercus cellulosae infection are extremely rare in the pig. The severe constitutional disturbances sometimes met with in the human infection seldom reveal themselves in pigs.

MacArthur (1934), in discussing the incidence of human cysticercosis in the British Army, mentions the prolonged

period after initial infection, before constitutional disturbances occurred in patients he studied. He mentions the fact that the parasites may be present in the human body for several years (e.g. six to eleven years), before cerebral symptoms become apparent. In the case of the pig, in applying MacArthur's remarks on the human disease, it is less likely that cerebral symptoms will develop, since it is seldom that a pig will be allowed to live to that age before slaughter. MacArthur also states that it is his belief that cysticerci while alive, usually enjoy a relative tolerance on the part of the host, but that after their death they act as foreign irritants and bring about the degenerative changes in the tissues of the human host. He makes it clear that severe pathological changes of the infected tissues only appear a number of years after initial infestation.

Some of the older writers, however, have recorded severe constitutional disorders in pigs. Greve, according to Neumann, reported that he noticed in many measly pigs an increased sensitiveness in the snout, which prevented their burrowing. In eating grain off a hard floor they avoided contact with that part as much as possible, by raising the nose and upper lip and prehending the food with their tongues. Tapped slightly on the end of the nose with a stick, the measly pig squealed with pain, while a healthy pig would remain indifferent. Very measly pigs had the snout more or less soft and flaccid.

In a pig suffering from gross infestation with measles,

Sabotta (1880) observed complete paralysis of the tongue, which was invaded by cysticerci. The prehension of food was, therefore, impossible, "and the animal perished from inanition." Florman (1819) saw a very manifest turning round in circles in a case where cysticerci were located in nerve centres. Rehms (1842) witnessed epileptiform convulsions, grinding of the teeth, ptyalism and rabid-like vertigo. At the autopsy Rehms found in the cerebrum and cerebellum an enormous number of cysticerci, "several of which were of exceptional size." Rabid-like symptoms were also noted by Foucher (1874). Vertigo and a form of blindness in which case the brain was softened and contained more than a hundred cysticerci, were observations made by Neubert (1861). Lippold (1875) had a case in which the pig died after presenting all the symptoms of encephalitis. On post-mortem twelve Cysticerci cellulosae were found in the pia mater.

Neumann mentions that in chronic and generalized infections pigs may be feeble, easily put out of breath, have difficulty in following the herd, may later develop diarrhoea, foetid breath, prostration, then death.

Hutyra and Marek mention that in very severe infestations similar symptoms to those described above, may appear, and in addition hoarseness may result owing to involvement of the laryngeal muscles. (It is perhaps possible that in some of these cases the pigs were also infested with Trichinella spiralis, which is known to cause muscular weakness and particularly *hoarseness*.)

Daubney (1936) mentions a case which, quite recently, was brought to the Veterinary Research Laboratory, Kabete, Kenya Colony. The affected animal was fevered and showed all the clinical symptoms of acute muscular rheumatism. It experienced considerable difficulty in rising, and any movement or manipulation occasioned pain. Post-mortem, the carcass was found to be grossly infested with viable Cysticerci cellulosa, and the infestation, according to Daubney, "had undoubtedly been responsible for the clinical manifestations."

Clinical symptoms are not likely to be noticed at abattoirs, since pigs are generally slaughtered within twenty-four hours of their arrival. In practice no cases showing clinical symptoms of constitutional derangement were observed at Bloemfontein, although in some dressed carcasses infestation was so heavy that barely spaces of 5 mm. could be found between the measles. It was, however, noticed that on rare occasions the flesh of heavily infested carcasses had a pale colour and was slightly dropsical.

In living cases the disease is generally recognized only in cases where the parasites are situated in a visible mucous membrane, e.g. in the conjunctiva of the eye, or in the lens. Externally cysticerci may sometimes be seen or felt with the hand in the tongue, mostly at the edges on the under surface, or in the fraenum linguae. Sometimes also cysticerci may be felt in the folds of the rectum, or in the anal ring. In heavily infested pigs cysticerci may be seen "bubbling" out of