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Taenia, Taeniasis, and Cysticercosis

THE TAENIASES OF MAN, infection by the beef or pork tapeworms, are common in some areas but are typically not a major public health problem. They are, however, a major veterinary problem because infected cattle and pigs are not suitable for human consumption and there is considerable financial loss and wastage in endemic areas. The taeniases are of special interest to sanitary engineers because their transmission depends on the ingestion by cattle or pigs of inadequately treated human feces.

Description of Pathogen and Disease

The medical and veterinary pathology, immunology, and therapy of taeniasis have been much studied, and a brief summary is given in the following sections. The epidemiology, in contrast, is poorly understood.

Identification

Taeniasis is an infection with the adult stage of the beef tapeworm (*Taenia saginata*) or pork tapeworm (*T. solium*). The adult worm is attached to the wall of the small intestine and typically causes no symptoms. There may be irritation at the site of mucosal attachment and, rarely, abdominal pain, nausea, weakness, loss of weight, increased appetite, headache, and intestinal obstruction.

Cysticercosis describes an infection with the larval stage of *T. saginata* or *T. solium*; in man, only the larval stage of *T. solium* can infect. Human cysticercosis is a severe somatic disease involving many different organs and tissues in which encystment may occur. The manifestation of symptoms depends on the number of cysticerci and the tissues or organs involved. Cysticercosis is most common in muscles, the brain, and the heart.

Diagnosis of taeniasis is based on the recovery of gravid proglottids or eggs from the feces or perianal region. Differential diagnosis cannot readily be made between *T. saginata* and *T. solium* by the examination of *Taenia* eggs in the stool. Recovery of the gravid proglottids and a count of the main lateral arms of the uterus (7–13 on each side in the case of *T. solium* and 15–30 in the case of *T. saginata*) is the specific pretreatment diagnosis. Diagnosis of cysticercosis usually awaits excision of the larvae and microscopic examination, although serological techniques are available and radiology may be useful.

Treatment for taeniasis is by oral drug therapy, with niclosamide, praziquantel, or other suitable agent. Treatment of cysticercosis is usually surgical, by attempting to remove the cysts. Fenbendazole and praziquantel are under trial for the drug therapy of human cysticercosis.

Occurrence

T. saginata and *T. solium* occur in almost all countries where beef or pork are eaten raw or undercooked (figures 34-1 and 34-2). *T. saginata* has its highest prevalence in East and Central Africa, in the Middle East, and in Latin America. *T. solium* is most frequently found in Southeast Asia and Latin America. Both are quite common in East Europe, where *T. saginata* and *T. solium* coexist, although the former is by far the more common. In some areas the prevalence of infection of man by adult worms is low (about 0.01 percent), whereas the prevalence of cysticercosis in cattle may be substantial (about 10 percent).

Infectious agent

Worms of the genus *Taenia* are cestodes or tapeworms. The adult *Taenia* worm lives attached to the wall of the small intestine; its body winds back and forth in the lumen of the small bowel. *T. solium* is usually between 2–4 meters in length, whereas *T.*

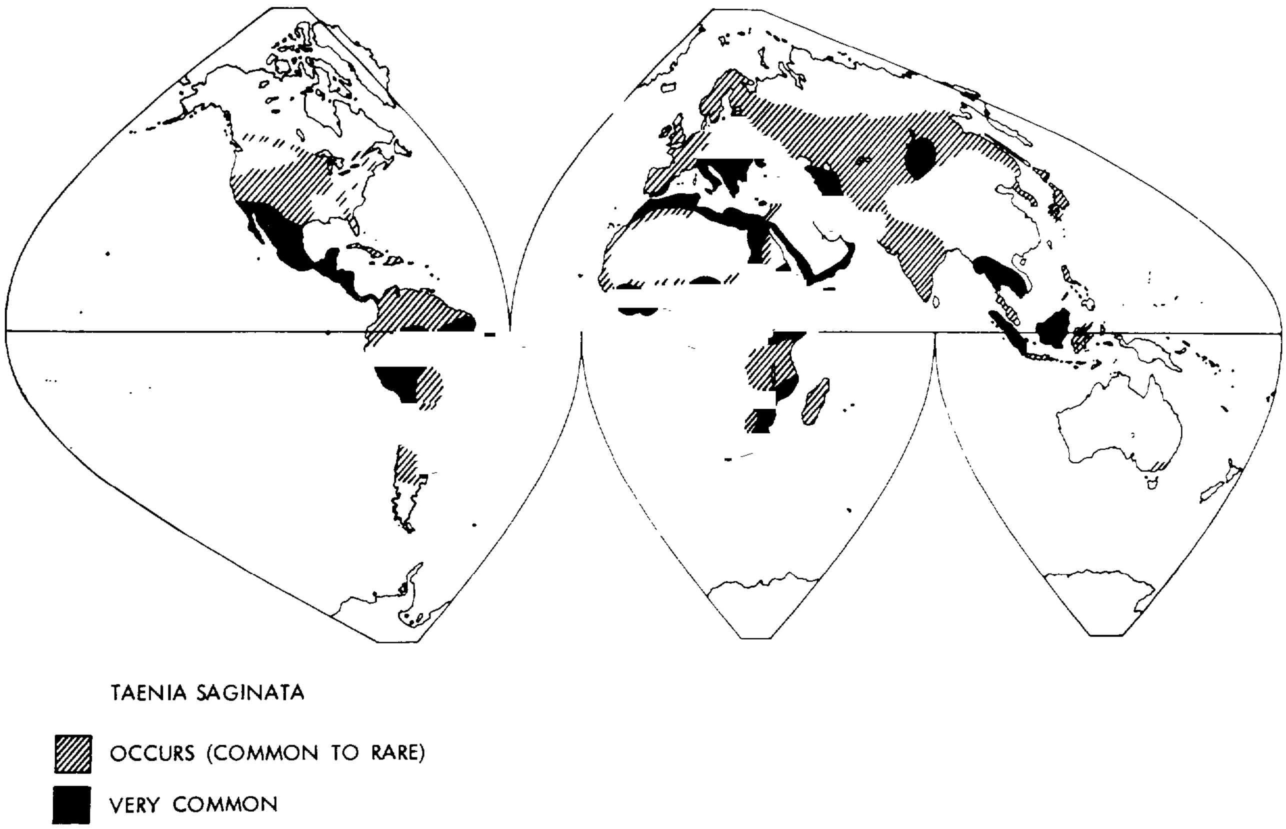

Figure 34-1. *Known geographical distribution of* Taenia saginata. The infection may occur in areas as yet unrecorded

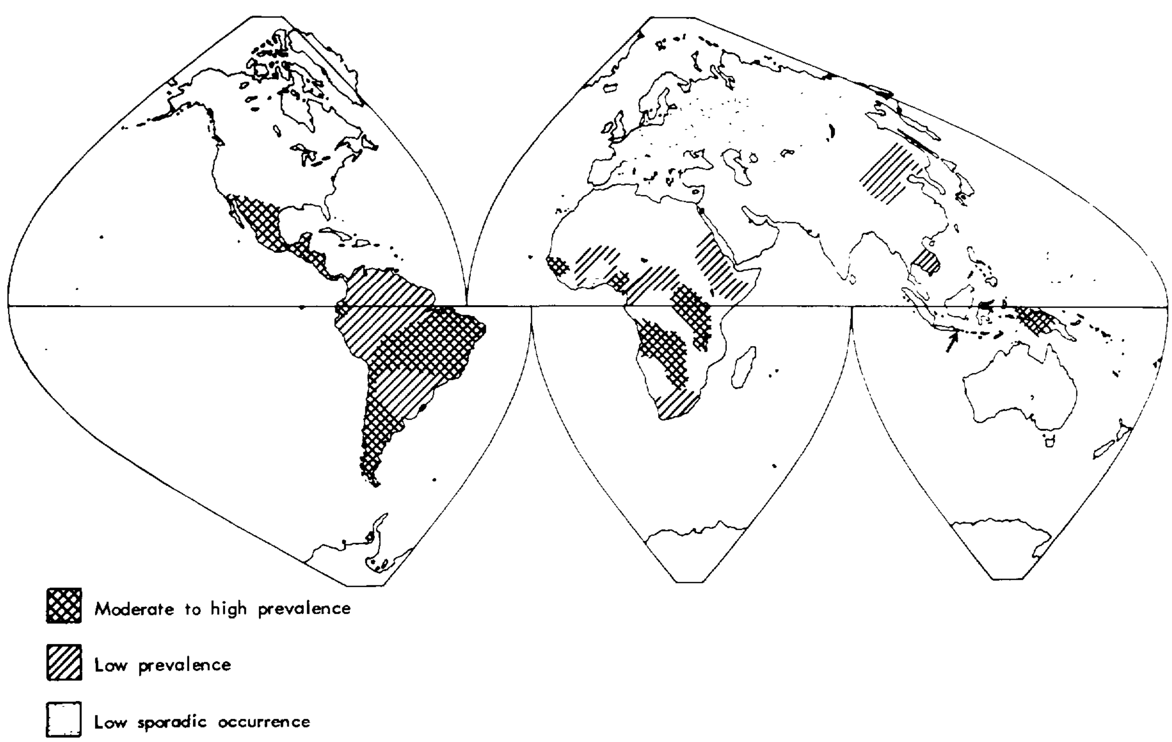

Figure 34-2. *Known geographical distribution of* T. solium. The infection may occur in areas as yet unrecorded

saginata under favorable conditions can reach a length of 15 meters or more but is usually not more than 6–10 meters long (figure 34-3).

The adult tapeworm consists of a scolex 1–2 millimeters in diameter, which bears four suckers that are attached to the gut wall (the scolex of *T. solium* also has a ring of hooks—see figure 34-3), and an area just behind the scolex that is a region of active cell division, the neck. From the neck the chain of proglottids (segments) is generated. The number of proglottids is 800–1,000 for *T. solium* and 1,000–2,000 for *T. saginata*. Each mature proglottid is roughly square and measures 10 by 12 millimeters. The mature proglottids have completely formed female and male sexual organs and are followed by the gravid proglottids, which consist essentially of a uterus distended with eggs. The gravid proglottids break off from the chain, usually pass out complete in the feces, and release the eggs in the soil. The number of eggs per proglottid can be 3×10^4–9×10^4 for *T. solium* and 8×10^4–1×10^5 for *T. saginata*. The eggs are roughly spherical and measure 30–70 micrometers in diameter.

Reservoirs

The adult stage of *T. saginata* lives only in man; the larval stage lives in cattle and can possibly also infect buffalo, giraffe, llama and reindeer. The adult stage of *T. solium* lives only in man; its larval stage lives in pigs and can also infect man, apes, dogs, and possibly cats and sheep.

Transmission

The adult tapeworm passes about 8×10^5–1×10^6 eggs a day inside gravid segments. The eggs of the tapeworm that are passed in the stool are immediately infective to the intermediate host. The eggs of *T. saginata* cannot be distinguished readily from those of *T. solium*. When mature eggs are ingested by the intermediate host (cattle for *T. saginata* and pigs for *T. solium*) and reach the duedenum, hatching of the oncospheres occurs. An oncosphere is a term for the embryo within the egg. The embryo escapes from its shell, penetrates the intestinal wall, enters lymphatic or blood vessels, and is carried into the voluntary muscles where it develops into a mature bladder worm, known as a *Cysticercus bovis* (in the case of *T. saginata*) or *C. cellulosae* (in the case of *T. solium*) within 60–75 days.

The longevity of *T. saginata* cysticerci in the intermediate host depends on the host and on the type of tissue involved. In the liver, lung, and heart some cysticerci degenerate as early as 20 days after infection. It is usual to find living and dead cysticerci in the same host. Calves may differ from cattle in the maximal survival time of cysticerci, which may be 21–30 months.

When raw or undercooked infected beef or pork is eaten by man, the larval tapeworm attaches itself to the mucosa of the jejunum, where a mature worm develops in 5–12 weeks.

Human infection with *C. cellulosae* is caused by the ingestion of *T. solium* eggs. This may occur via contaminated food or water (heteroinfection) or via contaminated fingers when they are introduced into the mouth by patients who have the adult worm in their intestine (external autoinfection). Internal autoinfection—where the eggs are carried by reversed peristalsis back to the stomach and hatch—has been postulated, but there is no firm evidence that it occurs.

One cysticercus ingested may give rise to one adult hermaphroditic tapeworm and so may be enough to transmit the infection. One egg of *T. solium* ingested can give rise to one larva in the tissues. Although each egg is potentially infective to the animal host, there is an indication that a minimal dose is needed to cause cysticercosis. In previously unexposed calves 30–100 eggs developed 3–8 cysticerci, respectively, and 500 eggs produced 60–80 cysticerci (Jepsen and Roth 1949). The infective doses of *Taenia* eggs for cattle and pigs vary according to the previous history of infection, since immunity is developed in the intermediate host.

Prepatent and incubation periods

T. saginata reaches maturity in the human intestine within 6–10 weeks from ingestion. *T. solium* reaches maturity in 5–12 weeks. An incubation period cannot be stated because symptoms may never develop.

Period of communicability

The adult worms of *T. saginata* and *T. solium* can live in the human intestine up to 25 years or more. As long as the adult worms are present, infective eggs will be passed in the feces, and thus the possibility of transmission persists.

Resistance

Man is universally susceptible. There is no evidence for the development of immunity against *Taenia* infections in the human host. Unlike the adult worm, which is weakly immunogenic, the larval stage of *Taenia* produces an active immunological response in cattle or pigs, and there is also an immunological response in man to infection by *Cysticercus cellulosae* (Flisser, Pérez-Montfort and Larralde 1979).

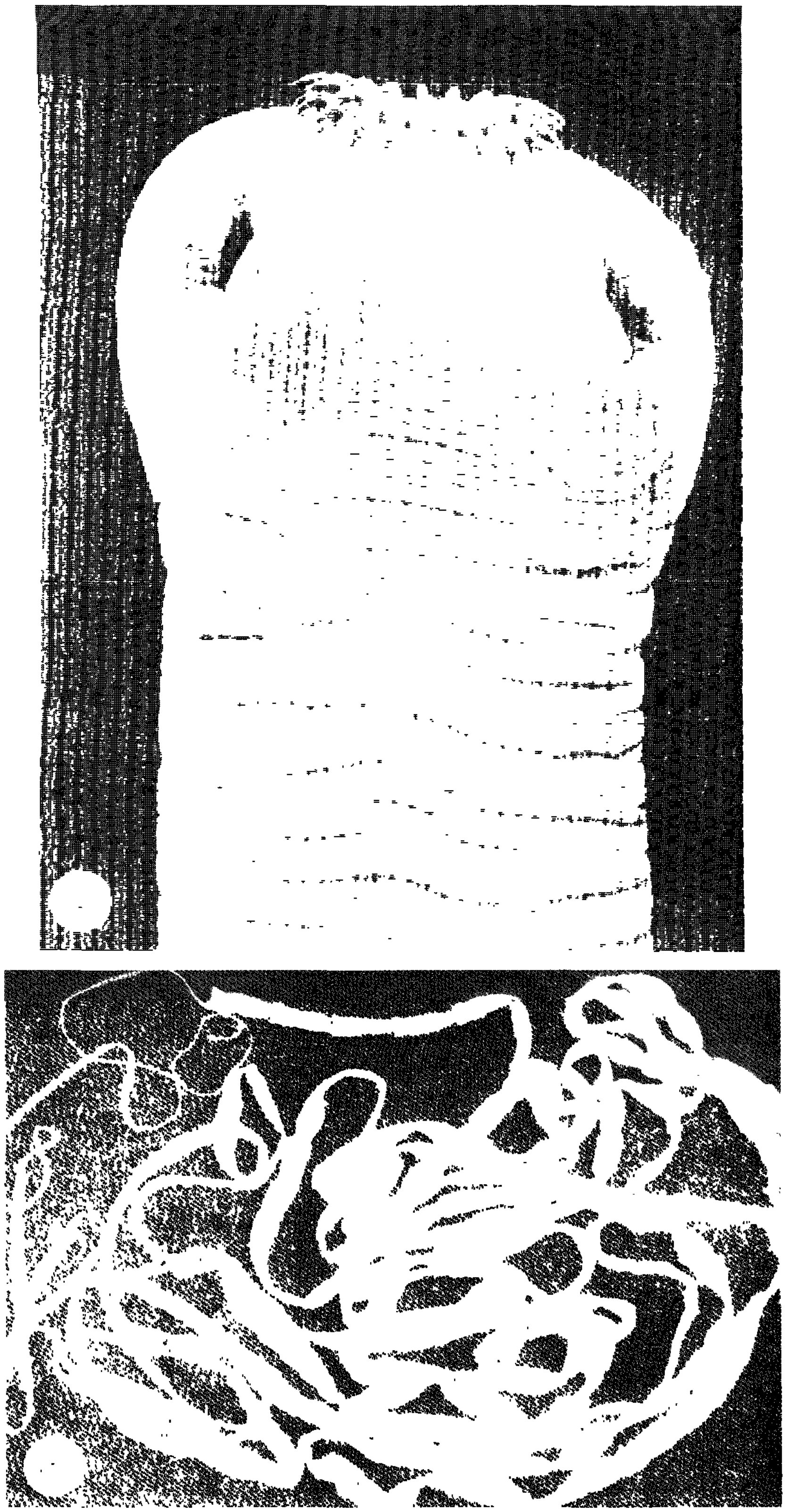

Figure 34-3. T. solium *and* T. saginata. (a) The head (scolex) and neck of *T. solium*-type under scanning electronmicroscopy, showing two of the four suckers and the two rows of hooks that aid attachment to the wall of the small intestine. *T. saginata* has the four suckers but no hooks. Scale bar = 0.1 millimeters. (Photo: A. Jones, Commonwealth Institute of Helminthology, St. Albans, UK.) (b) An adult *T. saginata*, several meters long. (Photo: Wellcome Museum of Medical Science)

Epidemiology

The epidemiology of taeniasis is not well documented. This is partly because it is not a major public health problem, even in areas where it is common, and also because it is a difficult infection to survey. Eggs are excreted intermittently in proglottids (Štěrba and Dyková 1979) and are not evenly distributed in the feces. Therefore, a single stool survey will grossly underestimate the prevalence of infection in man. The prevalence of infection in cattle or pigs is also difficult to measure. Serological techniques are under development; in the meantime, the only method is to slaughter and minutely inspect the carcases for cysts. Routine inspection of carcases at abattoirs underestimates the prevalence of infection (Rickard and Adolph 1977).

To maintain their life cycles, *T. saginata* and *T. solium* require two essential and specific conditions. First, cattle and pigs must eat human feces or fodder contaminated by human feces; second, beef and pork must be eaten raw or undercooked. The first condition is essential for transmission from man to animal and the second for transmission from animal to man. It follows that taeniasis is especially prevalent in communities where large herds of cattle or pigs are kept in close proximity to houses, where there is indiscriminate defecation by humans or the application of fecal products to pasture (or both), and where meat is not always thoroughly cooked. Simanjuntak and others (1977) described endemic taeniasis on Bali (Indonesia) and its relationship to the consumption of *lawar*, a dish of spiced minced pork often eaten uncooked, and the lack of adequate excreta disposal systems on the island. Fischer (1938) described how the outside pit latrines on farms in Germany in the 1930s were cold and unpleasant in winter and so encouraged the use of the warm cowsheds, often adjoining the house, for defecation by the farmer and his family. He recommended that latrines be made more accessible and more attractive than the cowsheds and that educational campaigns should encourage infected individuals to report for treatment and should discourage the eating of raw beef.

In developing countries, infection of cattle and pigs with *Cysticercus bovis* and *C. cellulosae*, respectively, is very common in communities where these animals have ready access to human excreta. Thus, 11 percent of slaughtered cattle in Sokoto State (Nigeria) had *C. bovis* infection (Dada and Belino 1979). Up to 80 percent of cattle in some East African herds are infected (WHO 1979).

In developed countries *T. saginata* infection remains common, especially in East Europe (Hajduk and others 1969; Sinnecker 1958), whereas *T. solium* is very rare. In the USA there are at least 200,000 cases of *T. saginata* infection in man, mainly in the west and northeast (Warren 1974). Taeniasis is more common in wealthy than in poor communities in the USA, presumably owing to higher meat consumption and more sophisticated recipes (steak tartare, for example). The prevalence of cysticercosis among slaughtered cattle in the USA is 0.05–0.08 percent.

Beef tapeworm has been attracting increased interest in Britain (Crewe and Owen 1978). It was very rare prior to 1945, but there is evidence of an increasing prevalence since that time. The overall prevalence of bovine cysticercosis is estimated at 0.1 percent, with a resultant economic loss to the beef industry of over US$1 million a year (Crewe and Owen 1978).

The modes of transmission of beef tapeworm in Britain and other industrialized countries remain uncertain and controversial. The link from cow to man is readily explained by the eating of undercooked beef; the link from man to cow is more difficult to explain in a society in which nearly everybody defecates into a sanitary toilet. Two main explanations have been propounded. First, that the increasingly widespread application of sewage sludge to pasture land provides the necessary opportunities for cattle to ingest fecal material of human origin. Second, that birds, especially seagulls, feeding on trickling filters and sludge drying beds pass the *Taenia* eggs or proglottids unharmed through their guts and excrete them later on pasture. Both these transmission mechanisms are theoretically possible, and *T. saginata* eggs have been isolated both from sludge applied to pasture and from gull droppings (Crewe 1967; Silverman and Griffiths 1955). It remains unresolved, however, which mechanism is the more important, and this uncertainty is a major constraint to policy formulation on sludge treatment prior to pasture application or other possible control strategies.

Human cysticercosis can be a very severe disease and occurs following the ingestion by man of *T. solium* eggs. Man accidentally takes the place of the pig in the normal pork tapeworm life cycle. Human cysticercosis occurs wherever there is endemic pork tapeworm infection (figure 34-2), and especially where taeniasis prevalances in man are high and sanitation and hygiene are poor. Thus cysticercosis is to be expected among poor people who keep pigs and eat pork.

The highlands of West Irian (Indonesia) and Papua New Guinea are ideal sites for endemic *T. solium* and consequent human cysticercosis. West Irian was free of *T. solium*, however, until the introduction of infected pigs from elsewhere in Indonesia during 1971. This introduction caused an epidemic of taeniasis and cysticercosis in certain areas. This in turn led to an outbreak of severe burns from open fires sustained during epileptic fits caused by *Cysticercus cellulosae* cysts in the brain (Gajdusek 1978).

Control Measures

Control rests upon denying cattle and pigs access to inadequately treated human excreta, meat inspection, and encouraging thorough cooking of beef and pork.

Individual

There are no specific prophylactic drugs available for *Taenia* infections. Compulsory mass diagnosis and treatment campaigns carried out in Poland, Bulgaria, and the USSR have successfully reversed a rising incidence of taeniasis. Other measures, such as improved meat inspection and excreta disposal, have to be taken in conjunction with mass chemotherapy to prevent reinfection.

There is no immunological control technique against taeniasis in man. There is, however, a possibility of immunizing cattle against infection, and research is in progress.

A comprehensive system of meat inspection at abattoirs, and the discarding of parts or all of infected carcases, is an essential element in tapeworm control programs. Most industrialized countries, and some developing countries, have a meat inspection system, but effectiveness depends on the training and supervision of the inspectors, on their ability to withstand inducements to overlook infected carcases, and on the absence of an alternate meat distribution system that circumvents the registered abattoirs. These conditions may be very difficult to achieve.

Environmental

Long-term reduction in transmission of *Taenia* depends on improved sanitation and sanitary education. Disposal of feces in a way that prevents any contact between the infective eggs and the intermediate host will break the life cycle and, together with chemotherapy and meat inspection, will help to eliminate the disease. The use of night soil or sludge as a fertilizer on pasture, or disposal of effluents into rivers that are a source of drinking water for cattle, necessitates adequate treatment. Educational programs should cover sanitary education, prevention of illegal slaughter and unsupervised meat distribution, meat inspection, and cooking habits.

Occurrence and Survival in the Environment

The information available on *Taenia* eggs in the environment is less extensive than for *Ascaris* eggs and has recently been reviewed by Lawson and Gemmel (1983). Survival of *Taenia* eggs is dependent primarily on temperature and moisture, with greatly reduced survival times in hotter and dryer conditions. Survival times in various environments are less than those of *Ascaris* eggs (chapter 23).

In water

Taenia eggs have been isolated from river water in the USSR (Bukh 1945: Usacheva 1951) and elsewhere. *Taenia* eggs have also been isolated from seawater near sewage outfalls in the USSR (Amirov and Salamov 1967) and from coastal and riverine beaches (Amirov and Salamov 1967; Iwańczuk 1969).

Survival in water is temperature dependent, with longer survival at lower temperatures. Laboratory experiments on *T. saginata* eggs in normal saline at 2–5°C showed survival of up to 168 days (Froyd 1962), between 95 and 116 days (Penfold, Penfold and Phillips 1937), and up to 335 days (Silverman 1956). In saline at room temperature, survival times were reduced to about 60 days (Silverman 1956). Suvorov (1965) reported that survival times of *T. saginata* eggs in water increased as temperature fell from 37°C to −4°C, at which temperature eggs remained viable for 63 days. Survival then decreased with lower temperatures and was 17 days at −30°C.

Jepsen and Roth (1949) demonstrated that *T. saginata* eggs were still infective to calves after storage in water for 33 days at 18°C, and Hajduk and others (1969) reported that *T. saginata* eggs survived in river water in the German Democratic Republic for 35 days. Livingstone (1978) reported that *Taenia* eggs survived in seawater for periods similar to *Ascaris* eggs.

Eggs in proglottids are more resistant to ovicidal chemicals than are free eggs (Gall and Wikerhauser 1968), but free eggs survive longer in water than eggs in proglottids (Suvorov 1965).

In sewage

Taenia eggs are found in sewage deriving from any community with endemic taeniasis. They may be present only in very low concentrations, and they may be still retained in their proglottids, thus making detection difficult. *Taenia* eggs have been isolated from sewage in the German Democratic Republic (Kalbe

1956; Sinnecker 1958), Japan (Liebmann 1965), South Africa (Nupen and de Villiers 1975), the USA (Wang and Dunlop 1954), the USSR (Vassilkova 1941), and elsewhere.

Jepsen and Roth (1949) demonstrated that *T. saginata* eggs remained infective to calves after 16 days at 18°C in sewage, and Hajduk and others (1969) reported that *T. saginata* eggs survived in sewage in the German Democratic Republic for 20 days.

In sludge

Taenia eggs are concentrated in the sludge of sewage treatment plants. Newton, Bennett and Figgat (1949) found that 30–46 percent of *Taenia* eggs survived for more than 6 months in sludge at 24–30°C. Hajduk and others (1969) reported that *T. saginata* eggs survived in dung from cowsheds in the German Democratic Republic for 71 days.

On pasture

T. saginata is transmitted from man to cattle when cattle ingest infected human feces. This may occur when feces, sludge, or night soil are deposited accidentally or deliberately on pasture or are added to silage that is later fed to cattle. The survival of *T. saginata* eggs on pasture and in silage is therefore of epidemiological importance.

Some reported survival times are listed in table 34-1. Survival is inversely related to temperature above 0°C, and *T. saginata* eggs may survive for 6 months under cool, moist conditions. Under hot, dry conditions survival is unlikely to exceed 2 months.

Inactivation by Sewage Treatment Processes

Taenia eggs respond to sewage treatment processes in the same way as *Ascaris* eggs, and the probable efficacy of various treatment technologies may be judged from chapter 23. Data from Britain (Silverman 1955; Silverman and Griffiths 1955), India (table 22-4), the USA (Greenberg and Dean 1958; Newton, Bennett and Figgat 1949), the USSR (Vassilkova 1936), Federal Republic of Germany (Liebmann 1963, 1964), and other countries confirm that most removal takes place by sedimentation and that tapeworm eggs are concentrated in the sludge. Waste stabilization pond effluent should contain no *Taenia* eggs.

Table 34-1. *Some studies on the survival of* Taenia *eggs in grass, silage, and soil*

Country	*Site of eggs*	*Temperature or season*	*Survival (days)*	*Source*
Australia	Grass	July–September	57	Penfold, Penfold and Phillips (1937)
Denmark	Soil	February–July	159	Jepson and Roth (1949)
Dem. Rep. Germany	Grass	ND	180	Hajduk and others (1969)
USA	Hay	1–30°C	22	Lucker and Douvres (1960)
USSR				
Nakhichevan (Azerbaydzhan)	Grass	Winter (10 to −16°C)	30	Abbasov (1965)
	Grass	Summer	60	
Samarkand (Uzbekistan)	Soil	Autumn and winter	180–210	Babaeva (1966)
	Soil	Spring	45–105	
	Soil	Summer	"Several days"	
Vologodskaya Province	Hay	Winter	210	Shepelev (1961)
	Soil	Summer	180	
Fed. Rep. of Germany	silage	10°C	80	Enigk, Stoye and Zimmer (1969)

ND No data.
Note: All experiments used *T. saginata* eggs except those of Abbasov (1965) and Shepelev (1961), which used *T. hydatigena* eggs.

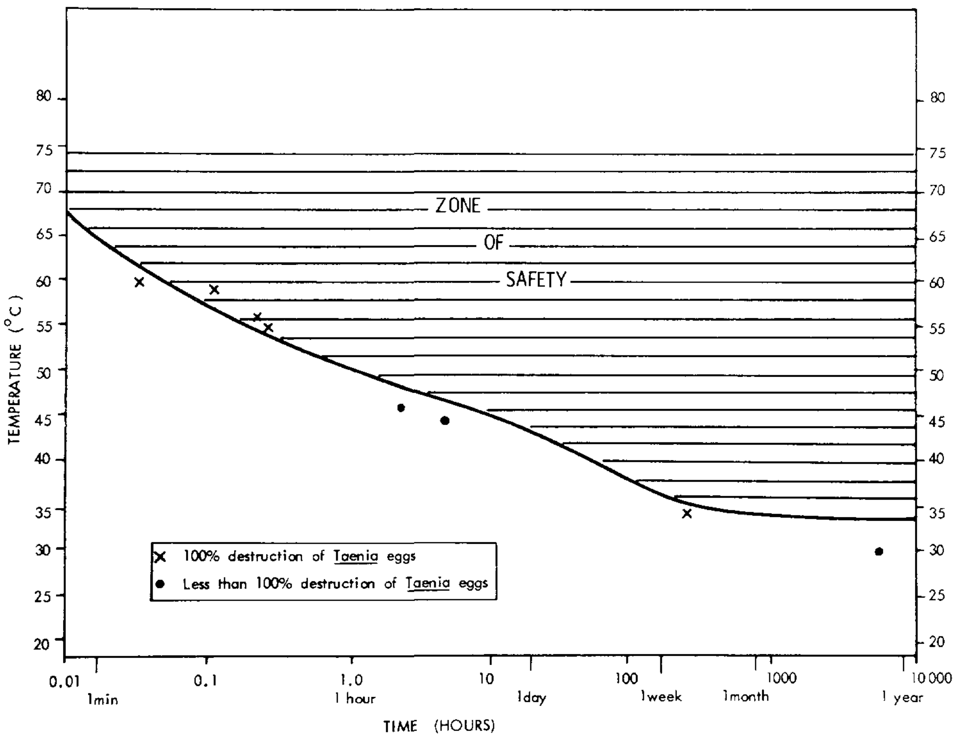

Figure 34-4. *The influence of time and temperature on* Taenia *eggs*. The points plotted are the results of experiments done under widely differing conditions. The line drawn represents a conservative upper boundary for death

Inactivation by Night Soil and Sludge Treatment Processes

Time, temperature, and desiccation are the principal lethal factors acting on *Taenia* eggs during the treatment of night soil or sludge. Mesophilic digestion is generally thought not to eliminate *Taenia* eggs (Liebmann 1964; Pawłowski and Schultz 1972), although contrary evidence is given by Silverman and Guiver (1960).

For elimination of Taenia eggs, night soil and sludge must be stored for a protracted period or be heat-treated by thermophilic composting. Necessary storage times depend on ambient temperatures; 1 year may be required in temperate regions, whereas 6 months is probably adequate in the tropics. If the stored sludge becomes extremely dry (moisture content <10 per cent), *Taenia* egg destruction is hastened.

Time-temperature requirements for the inactivation of *Taenia* eggs have been reported by Allen (1947), Silverman (1956), and other workers cited above. These data are plotted on figure 34-4, and comparison with figure 23-2 shows that *Taenia* eggs are more readily destroyed than *Ascaris* eggs. Any night soil or sludge treatment process that destroys *Ascaris* eggs may be assumed also to destroy *Taenia* eggs.

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