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**GUIDELINES
FOR SURVEILLANCE
PREVENTION AND CONTROL
OF TAENIASIS/CYSTICERCOSIS**

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CONTENTS

	<u>Page</u>
PREFACE	
General background	16
Background to these guidelines	16
Specific objectives of these guidelines	18
Summary of sequential steps recommended for the strengthening of taeniasis/cysticercosis control	19
CHAPTER 1 - SYSTEMATICS, BIOLOGY AND PATHOLOGY	
1.1 Introduction	23
1.2 General description of the parasites and their life cycles	23
1.2.1 <u>Taenia saginata</u> (Goeze, 1782) (Synonym <u>Taeniarhynchus saginatus</u>) . . .	24
1.2.1.1 Life cycle and developmental biology	25
1.2.2 <u>Taenia solium</u> (Linnaeus, 1758)	29
1.2.2.1 Life cycle and developmental morphology	29
1.2.3 Principal taxonomic differences between <u>T. saginata</u> and <u>T. solium</u> . .	31
1.2.3.1 Adult worms	31
1.2.3.2 Larval worms	32
1.3 Clinical pathology and symptomatology	33
1.3.1 Adult worms	33
1.3.1.1 <u>Taenia saginata</u> taeniasis	33
1.3.1.2 <u>Taenia solium</u> taeniasis	34
1.3.2 Larval stage	34
1.3.2.1 <u>Taenia saginata</u> cysticercosis	34
1.3.2.2 <u>Taenia solium</u> cysticercosis in pigs	35
1.3.2.3 <u>Taenia solium</u> cysticercosis in humans	35
1.3.2.4 Neurocysticercosis	37
1.3.2.5 Ocular cysticercosis	39
1.3.2.6 Muscular cysticercosis	40

	<u>Page</u>
CHAPTER 2 - DIAGNOSIS	
2.1 Introduction	46
2.2 Parasitological diagnosis of taeniasis	46
2.2.1 Questioning of possible carriers	47
2.2.2 Examination for proglottids and eggs	47
2.2.3 Coprological investigations	47
2.2.4 Perianal swabs	47
2.3 Parasitological diagnosis of human cysticercosis	47
2.4 Parasitological diagnosis of bovine and porcine cysticercosis	48
2.4.1 Limitations of meat inspection in the detection of bovine cysticercosis	48
2.4.2 Differential diagnosis	49
2.4.3 Limitations of meat inspection in the detection of porcine cysticercosis	50
2.4.4 Methods of identifying animal consignments	50
2.5 Immunodiagnosis	50
2.5.1 Introduction	50
2.5.2 Human taeniasis	51
2.5.3 Human cysticercosis	51
2.5.3.1 Methods	51
2.5.4 Animal cysticercosis	54
2.5.4.1 Swine cysticercosis	55
2.5.4.2 Bovine cysticercosis	55
CHAPTER 3 - EPIDEMIOLOGY	
3.1 Introduction	68
3.2 Global distribution of <u>Taenia saginata</u> taeniasis/cysticercosis	68
3.2.1 Changing prevalence	69
3.3 Global distribution of <u>Taenia solium</u> taeniasis/cysticercosis	69
3.3.1 Latin America	69
3.3.2 Africa	74

	<u>Page</u>
3.3.3 Asia	74
3.3.4 Changing prevalence	75
3.4 Factors affecting transmission	75
3.4.1 <u>Taenia saginata</u>	75
3.4.1.1 Transmission from cattle to man	75
3.4.1.2 Transmission from man to cattle	76
3.4.2 <u>Taenia solium</u>	78
3.4.2.1 Transmission from pigs to man	78
3.4.2.2 Transmission from man to pigs	79
3.4.2.3 Transmission from man to man	82
3.5 The dynamics of transmission	82
3.5.1 Stability of the system and its implication for control	82
3.5.2 The infective pattern	82
3.6 Extrinsic factors	83
3.6.1 Egg output	83
3.6.2 Egg dispersal in the <u>T. saginata</u> system	84
3.6.2.1 By the individual	84
3.6.2.2 By faulty sewage disposal	84
3.6.2.3 By deliberate irrigation of pasture with sewage-plant effluents	84
3.6.2.4 In the feedlot situation	84
3.6.3 Egg dispersal patterns from a single focus using the dog/sheep model	84
3.6.4 Ways in which eggs may spread from the site of deposition	89
3.6.4.1 Wind and air currents	89
3.6.4.2 Birds	89
3.6.4.3 Arthropods	89
3.6.4.4 Oribatid and gamasid mites	90
3.6.4.5 Annelids	90
3.6.5 Egg longevity and duration of infectivity of embryos	90
3.6.5.1 Temperature dessication lethal to eggs	90
3.6.5.2 Duration of egg survival in the environment	91

	<u>Page</u>
3.6.5.3 Heterogeneity of infectivity within egg populations	92
3.6.5.4 Factors affecting the ageing process of eggs	92
3.7 Intrinsic factors: immunological regulation	95
3.7.1 Prenatal infection	95
3.7.2 Neonatal infection	95
3.7.2.1 The role of colostrum and maternal transfer of immunity . .	95
3.7.3 Time interval for the induction of immunity	96
3.7.3.1 Number of eggs required to induce resistance	96
3.7.3.2 Acquisition of immunity in the field situation	96
3.7.3.3 The survival of larvae in immunologically competent animals	98
3.7.4 Duration and loss of immunity	98
3.7.5 Sterile immunity	98
3.7.6 Species specific and interspecific immunity	98
3.7.7 Immunity acquired by the definitive host	98
3.8 The role of livestock management in transmission	98
3.8.1 Feeding behaviour	99
3.8.2 Flock management and availability of eggs	99
3.8.2.1 Rearing of animals from birth near infection source	99
3.8.2.2 The introduction of grazing-competent animals	99
3.8.2.3 The rate of egg loss	99
3.8.2.4 Introduction and reintroduction of infected definitive hosts	100
3.9 The role of sewage disposal and egg dispersion	101
3.9.1 Biological treatment	101
3.9.1.1 Oxidation ditch	101
3.9.1.2 Activated sludge process	101
3.9.2 Sand filtration	101
3.9.3 Anaerobic digestion of sludge	102
3.9.4 Drying of sludge	103

	<u>Page</u>
3.9.5 Egg-dispersal from sewage works	103
3.9.6 Measures to prevent the spread of <u>Taenia saginata</u> by sewage and sewage sludge	105
3.9.6.1 In sewage treatment plants	105
3.9.7 Sewage release from treatment plants	106
3.9.8 Guidelines for agricultural utilisation of sewage and sludge infected with eggs of <u>Taenia</u> spp.	106
3.9.9 Control measures in areas other than sewage and sludge utilisation . .	107
 CHAPTER 4 - MEAT INSPECTION, MEAT TREATMENT AND DEVELOPMENT OF SAFE ANIMAL SLAUGHTERING FACILITIES	
4.1 Introduction	126
4.2 Distribution of cysticerci in carcasses	126
4.3 Improvements in meat inspection	129
4.4 Processing of infected carcasses and meat	129
4.5 Prevention of illegal slaughtering and illicit sale of meat	130
4.6 Development of safe slaughtering facilities in village communities and underdeveloped rural areas	131
4.6.1 The site and requirements for village-animal slaughter facilities . .	131
4.6.2 The development of safe slaughtering under austere conditions	137
4.6.2.1 The main requirements	137
4.6.2.2 Design and equipment	138
4.6.2.3 Licensing	141
 CHAPTER 5 - CHEMOTHERAPY	
5.1 Introduction	145
5.2 Cestocides	145
5.2.1 Drugs previously used in <u>T. saginata</u> and <u>T. solium</u> taeniasis, but no longer recommended: Dichlorophen, Trichlorophen and Bithionol . . .	145
5.2.2 Drugs at present used in the treatment of human tapeworm infections .	146
5.2.3 Other drugs that have shown some cestocidal effects	149
5.3 Drugs for the treatment of human cysticercosis	149
5.4 Drugs for the treatment of animal cysticercosis (metacestocides)	150

	<u>Page</u>
CHAPTER 6 - HEALTH EDUCATION	
6.1 Introduction	163
6.2 Target groups	163
6.2.1 Persons likely to infect food animals	163
6.2.2 Persons processing meats for human consumption	163
6.3 Information packages to be disseminated	163
6.3.1 Farmers	164
6.3.2 Campers and tourists	164
6.3.3 Hunters	164
6.3.4 Butchers	164
6.3.5 Food handlers	164
6.3.6 Persons involved in home slaughtering	164
6.3.7 Consumers, cooks and housewives	165
6.3.8 Persons at special risk of infecting livestock	165
6.4 Education of community members in taeniasis/cysticercosis prevention	165
6.5 The role of pharmacists	165
6.6 The role of schools	165
6.7 Training of health workers and school teachers	165
6.8 Further considerations	166
CHAPTER 7 - IMMUNITY AND IMMUNIZATION	
7.1 Introduction	167
7.2 Immunity in cysticercosis	167
7.2.1 Human cysticercosis	167
7.2.2 Bovine cysticercosis	167
7.2.3 Swine cysticercosis	167
7.3 Immunization in bovine cysticercosis	168
7.3.1 Passive immunization	168
7.3.2 Active immunization	168

	<u>Page</u>
7.4 Immunization in swine cysticercosis	168
7.5 Future prospects	168
 CHAPTER 8 - SURVEYS, SURVEILLANCE AND CONTROL	
8.1 Introduction	172
8.2 Planning and collection of data	172
8.3 Ongoing control programmes	173
8.3.1 Control programmes against <u>T. saginata</u>	174
8.3.1.1 Treatment programmes involving safer drugs	174
8.3.2 Proposals for the development of control programmes against <u>T. saginata</u> in Poland and Czechoslovakia	175
8.3.2.1 Poland	175
8.3.2.2 Czechoslovakia	176
8.4 <u>T. solium</u> control programmes	176
8.5 Lessons based on control programmes using animal models	176
8.5.1 A 9-year study on a 3-monthly dosing programme	176
8.5.2 A 7-year study on a 3-monthly dosing programme plus an educational component	177
8.5.3 A 9-year study on a 4-weekly dosing programme with a relatively toxic drug	177
8.5.4 A 7-year study on a 4-weekly dosing programme with safe drugs	177
8.6 Actions applied to epidemic foci of <u>T. saginata</u> infection	177
8.7 Recommended control	178
8.7.1 Justification and motivation to introduce a control programme	178
8.7.2 The objectives of a control programme	179
8.7.3 The strategies required for the introduction and continuation of control programmes	179
8.7.4 Control measures applicable to different epidemiological situations	180
8.7.4.1 Hyperendemic pastoral <u>T. saginata</u> infections	180
8.7.4.2 Endemic urban <u>T. saginata</u> infections	181
8.7.4.3 Epidemic (feedlot) <u>T. saginata</u> infections	181

	<u>Page</u>
8.7.4.4 Hyperendemic <u>T. solium</u> infections	181
8.7.4.5 Endemic rural and urban <u>T. solium</u> infections	182
8.7.4.6 Sporadic or introduced <u>T. solium</u> infections	184
8.7.4.7 Endemic mixed <u>T. solium</u> and <u>T. saginata</u> infections	184
8.7.4.8 Conclusions	184
8.7.4.9 Summary of procedures that may be used in control programmes	185
8.7.4.10 Summary of actions in a short-term control intervention in highly endemic areas of <u>T. solium</u> infections	185
APPENDIX 1 - Worldwide distribution of <u>Taenia solium</u> and <u>Taenia saginata</u> cysticercosis in animals in 1982	188
APPENDIX 2 - Other taeniids of occasional zoonotic importance	198
APPENDIX 3 - Examination and staining of tapeworms	199
APPENDIX 4 - Preparation of antigens from <u>Taenia solium</u>	200
APPENDIX 5 - Techniques for extracting cestode eggs from sewage, herbage and soil . .	201
APPENDIX 6 - <u>In vitro</u> culture	204

PREFACE

General background

The need for the elaboration of strategies and methods for control of zoonoses and foodborne diseases was recognized by the Thirty-first World Health Assembly held in May 1978. In its resolution WHA31.48 on "Prevention and control of zoonoses and foodborne diseases due to animal products", the Assembly invited Member States to formulate and implement a countrywide programme for the control of these diseases as an integral part of national health programmes and requested the Director-General to promote the extension of a network of zoonoses centres in all regions, so that the necessary support can be provided to country health programmes. It also requested further development of national, regional and global strategies, and of methods for the surveillance, prevention and control of zoonoses and foodborne diseases.

Following adoption of this resolution the WHO programme has been considerably strengthened and, at present, strategies and methods for control of selected zoonoses and foodborne diseases are being elaborated, taking into account also different epidemiological situations, such as specific animal-related human health risks in urban areas, large-scale animal production on intensive farms, areas of rapid ecological changes as well as health problems of food production, processing and distribution.

A worldwide network of WHO zoonoses centres is now being developed in order to provide essential technical cooperation to country health programmes with respect to zoonoses and related foodborne diseases. At present, services for such technical cooperation are available in the Region of the Americas through the Pan American Zoonoses Centre. On 1 February 1979, the UNDP/WHO Mediterranean Zoonoses Control Programme with the participation of the Food and Agriculture Organization of the United Nations (FAO) began operations, the principal centre being located in Athens. One of the functions of the zoonoses centres will be cooperation with Member States in planning and implementation of their national programmes for control of specific diseases.

We sincerely hope that the strategies and methods as now being elaborated by WHO, in cooperation with other international organizations, and particularly FAO and the United Nations Environment Programme (UNEP) will facilitate the process of problem recognition, planning, definition and comprehensive countrywide programmes, goals, priority determination, initiation or strengthening of national projects and programmes by adaptation of principles contained in these guidelines.

There is no doubt that prevention, medical treatment and control of zoonoses and foodborne diseases are an important part of primary health care. In the elaboration of the various guidelines due attention has been paid to this important key for the attainment of the goal of "health for all by the year 2000". In addition, successful zoonoses and foodborne disease control projects will contribute to other components of primary health care, including promotion of a safe food supply and proper nutrition, safe water supply (prevention of pollution from animal sources), basic sanitation, etc. (see Article VII-3 of the Alma-Ata Declaration). The strategies and methods will also provide practical guidelines for the intersectoral coordination (Article VII-4 of the Alma-Ata Declaration), community participation, use of appropriate technology and intercountry collaboration.

Background to these guidelines

Over the past few years, considerable activity has been generated to identify the global significance of taeniasis/cysticercosis and to promote research and elaborate better preventive and control measures.

The first meeting of workers engaged on taeniasis/cysticercosis research was held in 1968 by the WHO in Geneva and in Philadelphia (17). An informal discussion on "Cysticercosis/Taeniasis Research" was held in 1971 by the WHO in Mexico City (18). The next meeting was held in 1974 under the auspices of BGA/FAO/WHO at Neuherberg, Federal Republic of Germany as "Consultations on Taeniasis/Cysticercosis Research" (19). The proceedings of

this meeting were published in the Bulletin of the World Health Organization (20). Also in that year, a "Consultation on Field Control of Taeniasis and Echinococcosis" was held by FAO/UNEP/WHO in Nairobi, Kenya (21). A meeting on Project Proposals dealing with various aspects of Taeniasis/Cysticercosis was held in Geneva in 1977 (22). At the subsequent meeting on "Cysticercosis/Taeniasis and Echinococcosis/Hydatidosis Surveillance, Prevention and Control" (23) held by FAO/UNEP/WHO in Warsaw, Poland, in 1978, a strong recommendation was made for the development of international guidelines for the control of these zoonoses. In 1981, a further meeting was held in Geneva by FAO/UNEP/WHO to upgrade knowledge on "Research Requirements in Echinococcosis/Hydatidosis and Taeniasis/Cysticercosis" (24). In 1982, a collection of teaching aids for international training courses "Zoonosis Control" including valuable information on taeniasis control was published in Moscow by the USSR/UNEP project "UNEP Publications and Information Support Programme in the USSR" (9). In that year also, a 5 day meeting was held by FAO/UNEP/WHO in Prague, Czechoslovakia to draft these guidelines.

In addition to the activities of the United Nations agencies, WHO, FAO and UNEP, two international symposia have recently been devoted to these cestode zoonoses. The first was held in San Miguel de Allende, Guanajuato, Mexico in 1981. This was devoted to "Cysticercosis: Present State of Knowledge and Perspectives" (5). The second international symposium was held in České Budějovice, Czechoslovakia, in 1982, and this was devoted to Taenia saginata "Human Taeniasis and Cattle Cysticercosis" (11).

These meetings have highlighted both public health and economic aspects of these zoonoses. It is not easy to define impact of T. saginata and T. solium taeniasis/cysticercosis on human health and agricultural economy. There are many reasons for this. In terms of human health, although infection with adult tapeworms in man are not usually life threatening, the larval stages of these worms may cause severe disease and disability in man. Hospital and surgical costs due to human cysticercosis can be estimated, but deaths, complete or partial disablement and loss to the work force as well as human suffering cannot be equated solely in monetary terms. It is possible to place an estimate on actual monetary losses due to bovine and porcine cysticercosis, carcass condemnation or processing requirements; these may be very heavy in epidemic-type feedlot situations. However, in developing countries, which often have hyperendemic cysticercosis, the losses associated with retarded progress in agricultural development and in exports, may affect the health, welfare and social advancement of a large proportion of the population. This also cannot be quantified solely in terms of money.

Some estimates of losses due to taeniasis/cysticercosis have been reported as follows:

In Latin America, no less than 50% of neurocysticercosis patients require more than one hospitalization and more than one surgical intervention. Surgery may permit the full recovery for work in less than half the cases (15).

In Santiago, Chile, the average hospitalization time for neurocysticercosis patients was 46 days (14). The amount required for medical care for each patient with neurocysticercosis in 1982 in Mexico was US \$2173 (16). It has been estimated that 42,000 to 98,000 of the 70 million inhabitants of Mexico have neurocysticercosis. It was considered that these individuals lost wages of US \$217 per month and that the total amount lost was of the order of US \$255,000.000 per year (16).

In Mexico, about 1.55% of pigs which pass through formal meat inspection procedures, a fraction of the total pig kill, were condemned in 1980 for T. solium cysticercosis. This amounted to 264,000 carcasses. The estimates for the overall loss due to pig cysticercosis for 1980 in Mexico were given as US \$43,300.000 (1).

The proportion of T. saginata carriers requiring hospital treatment was over 20% in Poland (10) and 10% in France (4). It was also assumed that each T. saginata carrier lost one day's work on average in France (4).

In the feedlot situation, T. saginata cysticercosis can cause a crippling economic blow and may prevent the survival of the enterprise, particularly where it is not able to insure against such losses. One such loss was estimated at between US \$500,000 and US \$1,000,000. A livestock producer suddenly experiencing this kind of financial loss may be economically ruined (3).

Recent evaluations of the importance of bovine cysticercosis in Botswana and Kenya have been made (7). Both countries rely on exporting beef, particularly to the countries of the European Economic Commission. Botswana is more dependent on meat exports than Kenya and its cattle prices are much higher. The prevalence of cysticercosis in 1976 at export abattoirs in Botswana and Kenya was about 8 and 20 per cent respectively. Annual losses in Botswana reached £0.5 million while they were about double that in Kenya.

Financial loss from condemnation of meat due to bovine cysticercosis in the Federal Republic of Germany in 1951 was 5,000,000 DM, whereas in 1961 it was 27,000,000 DM (6), in the Netherlands, 9,000,000 Dutch Gulden annually in 1959 (8); in France in 1972, approximately 30,000,000 French Francs (4); in the German Democratic Republic in 1964, approximately 1,000,000 DM (13). An estimate of the increase and decrease of financial losses due to condemnation of meat originating from one feedlot in Czechoslovakia - prior to and after comprehensive measures had been implemented in 1976 - has been made and the results were: in 1974, 85,000 Kcs; 1975, 501,000 Kcs; 1976 - 973,000 Kcs; 1977, 901,000 Kcs; 1978, 80,000 Kcs (12).

Specific objectives of these guidelines

It is intended that these guidelines will contribute to the global control of taeniasis/cysticercosis in that they:

- a) gather together some of the available scientific information on taeniasis/cysticercosis into a comprehensive monograph in order to point out the impact of these parasitisms on human health and to the meat producing industry;
- b) focus attention on the methods available to strengthen control of the taeniasis/cysticercosis complex in its different epidemiological forms;
- c) orient research on the basic information still required and on methods needed to improve the diagnosis and treatment, as well as the surveillance, prevention and control of taeniasis/cysticercosis.

In the first chapter, the systematics, biology, and clinical pathology of T. saginata and T. solium taeniasis/cysticercosis are described. This information is directed towards those senior workers who have the responsibility for the training of medical, veterinary and other biologists involved in the more practical aspects of control. The diagnosis of taeniasis/cysticercosis is dealt with in Chapter 2, emphasizing the unsolved problems of differential diagnosis and the need to improve diagnostic tests for animal cysticercosis.

The third chapter attempts to define the global distribution of T. saginata and T. solium and to describe the factors involved in the transmission of these parasites. Also in this chapter, a description is given of the epidemiology, including methods of transmission, and the role of sewage in the dissemination of eggs.

Chapters 4, 5 and 6 describe the practical aspects of meat inspection and safe slaughtering of livestock, health education and chemotherapy. Chapter 7 describes the progress in the development of immunization and the problems still to be solved.

Chapter 8 is concerned with surveys and surveillance and forms one of a group of chapters that provide the practical guide to methods and evaluations required for the successful introduction of control.

Summary of sequential steps recommended for the strengthening of taeniasis/cysticercosis control

1. Establish the structure of control authority

This should be created following discussions between medical, veterinary, and other authorities on the priorities and strategies. In the early stages there may be a need to achieve liaison through advisory committees with representatives of the community.

2. Define functions of the control authority

Important functions of a control authority include:

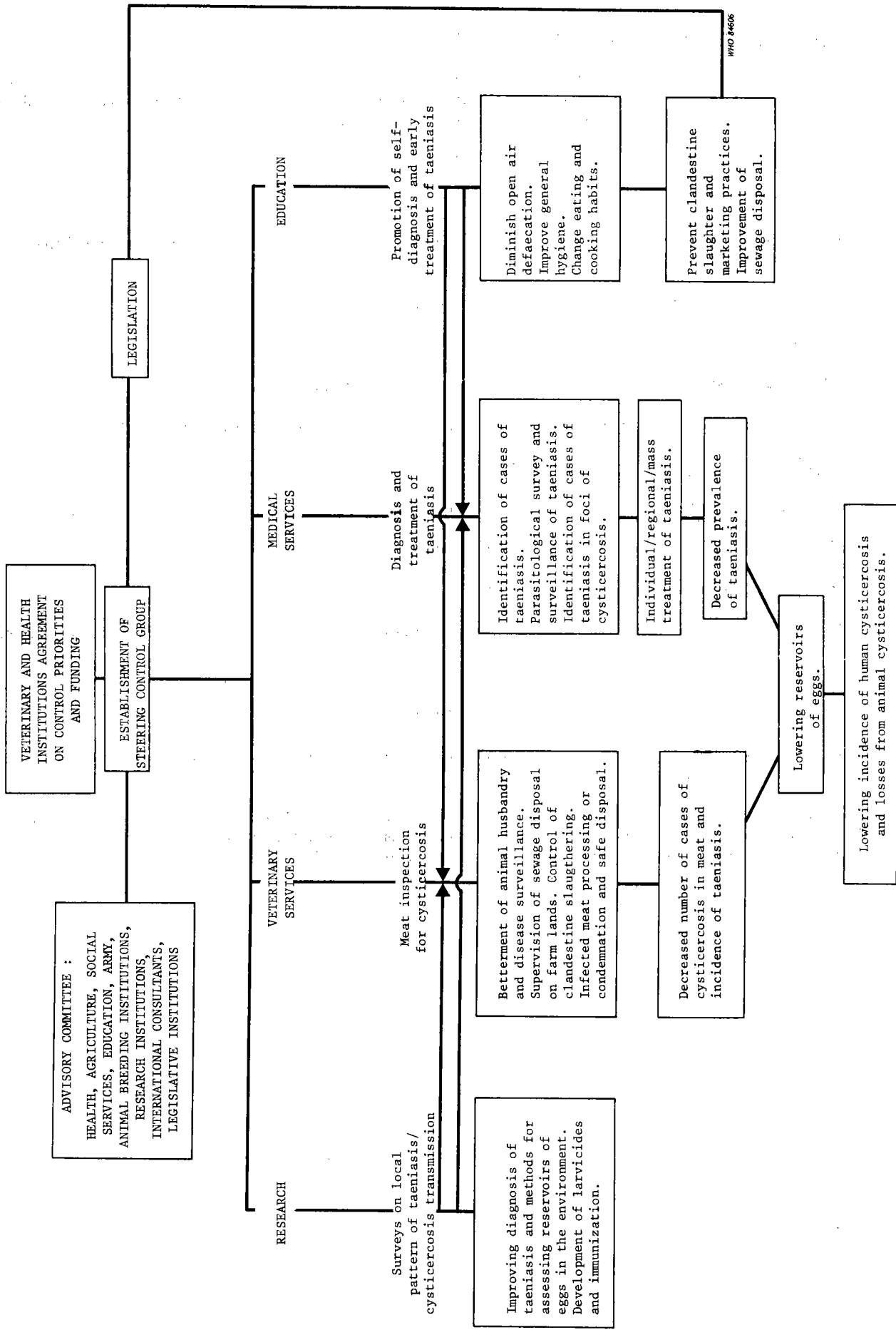
- (a) defining the direction of the technical control measures and the educational components to be adopted;
- (b) responsibility for the long-term funding of the programme;
- (c) setting priorities;
- (d) selecting personnel and organizing training activities;
- (e) collecting and evaluating base-line and continuing surveillance data.

3. Establish long-term control measures

- (a) improvement of public education with respect to health preventive practices;
- (b) improvement of animal husbandry practices;
- (c) strengthening of meat inspection;
- (d) strengthening legislation to prevent clandestine slaughter and marketing practices;
- (e) improvement of sanitation;
- (f) improvement of sewage processing and disposal;
- (g) improvement of the diagnosis and treatment of human taeniasis with readily available drug services.

A schematic view of the type of functional structure, for strengthening long-term actions required for control, is given below. In many countries this type of structure is already part of the normal human and animal health activities.

DIAGRAM OF PRINCIPAL STRUCTURES, INFORMATION FLOW AND ACTIONS
IN LONG-TERM CONTROL OF TAENIASIS/CYSTICERCOSIS



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CHAPTER 1 - SYSTEMATICS, BIOLOGY AND PATHOLOGY

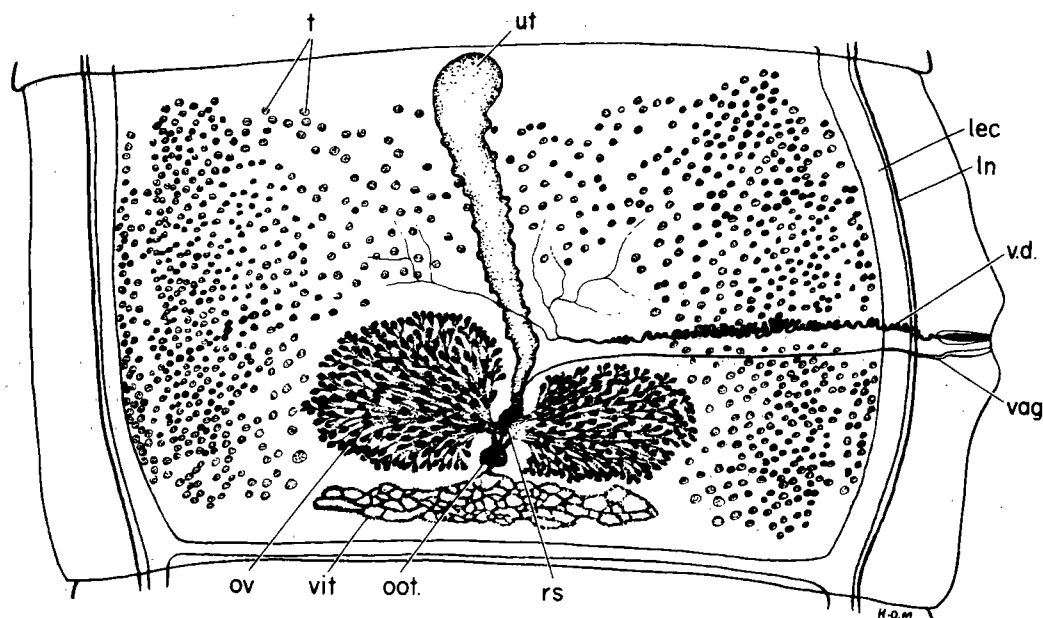
1.1 Introduction

Infections with T. saginata and T. solium are unique among the zoonoses in that they are maintained in nature with man as the sole definitive host. Their life cycles are entirely dependent on the link between man and cattle in the case of T. saginata and man and pigs in the case of T. solium so that any break in these links can result in the total elimination of the organism. There are no other zoonoses where the relationship between man and animals is obligatory for the survival of the infectious agent. For this reason, these zoonoses are sometimes given special status as perfect or euzoonoses (25).

In this Chapter, a description is given of the systematics, biology and pathology of the taeniasis/cysticercosis caused by Taenia saginata and T. solium. Several reviews describe these in great detail (1, 2, 57, 59, 71, 74, 86, 87, 91, 92, 93). Other taeniids of occasional zoonotic importance are given in Appendix 1.

1.2 General description of the parasites and their life cycles

Tapeworms of the genus Taenia (family Taeniidae) and order Taeniidea (Wardle, McLeod, Radinovsky, 1974) are exceptionally large worms. The gravid proglottids are longer than wide, a rostellum may be absent, but is normally present, and is usually armed with a double row of small or large hooks. The genital pores are single and irregularly alternating. There are a large number of testes and the ovary is situated in the posterior part of the segment. The uterus has a median longitudinal stem and, when gravid, has lateral branches.



lec	longitudinal excretory canal	t	testes
ln	lateral nerve	ut	uterus
oot	oötype and Mehlis gland	vag	vagina
ov	ovary	vit	vitellarium
rs	receptaculum seminis	vd	vas deferens

FIGURE 1 - Mature proglottid of Taenia spp (After 78).

The morphology and development of the taeniid egg has been described at both light and electron microscope levels (40, 66, 68). There is an outer envelope or capsule which is usually lost in the faeces (Figure 2). Inside this the inner envelope develops into the embryophore which is made of "keratin" blocks and gives the egg its characteristic radiated appearance. Within these, the oncospherical membrane surrounds the hexacant embryo or oncosphere. The metacestode development stage is a cysticercus, strobilocercus, coenurus or hydatid cyst according to the species (see FAO/UNEP/WHO Guidelines for surveillance, prevention and control of echinococcosis/hydatidosis).

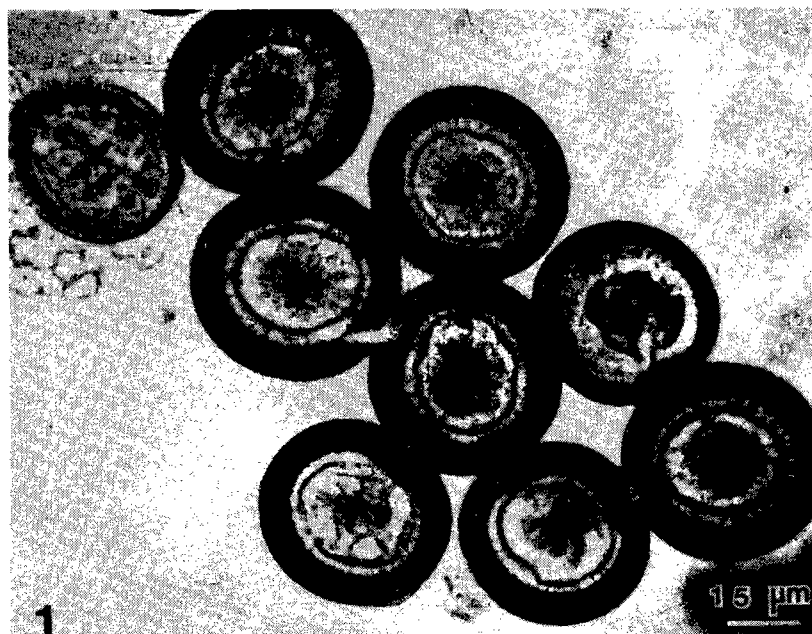


FIGURE 2 - Eggs of Taenia solium (After 21).

1.2.1 Taenia saginata (Goeze, 1782) (Synonym Taeniarhynchus saginatus). The adult tapeworm occurs mainly in the jejunum of man who is the only definitive host. It has never been recorded in nature or established in the laboratory in any other host. The larval form, a cysticercus, is found in cattle (Bos taurus, B. buffelus, B. indicus, B. gruniens). The reindeer (Rangifer tarandus) was reported to be an intermediate host for T. saginata in northern Siberia, USSR (67). In the Philippines (3) an anomalous epidemiological situation appears to exist where human cases were reported to be mainly T. saginata, whereas the local food consisted largely of pork infected with T. solium cysticercosis and raw beef was seldom eaten. A similar uncertain situation has also been reported from an area in Taiwan, where there are no cattle, and where wild goats have been suggested to serve as intermediate hosts of T. saginata (36). Further carefully controlled work is needed to validate these observations.

Sporadic reports of unarmed cysticerci in llamas, pronghorn, oryx, topi and other antelopes, bushbucks, gazelles, wildebeest, and giraffes have been made. In experimental infections, Gazella thomsoni were found to be resistant to T. saginata (20, 52, 76). However an experimental infection of an oryx (Oryx gazella beisa) was successful (76). Experimental infection of African dwarf goats was unsuccessful and cysticerci of T. saginata degenerated in sheep and goats before full larval differentiation took place (7). In some infections, the presence of hooks in the surrounding tissue suggested that they might be T. solium (72).

Man is not normally regarded as a host for the larval phase of T. saginata. However, unarmed cysticerci have been found in the human body (20, 54, 59, 65). One case was reported (1919) in which the larvae were observed in a mammary gland; this individual had an adult worm in the intestine (23) and in two cases the larvae have been seen in lymph nodes (54, 65). In some cases they have been numerous, in others they were found accompanying intestinal T. saginata infection (59). Unfortunately, the majority of reports lack sufficient documentation and are open to question. In any event the phenomenon is extremely rare.

1.2.1.1 Life cycle and developmental biology

Man is infected by the ingestion of raw or undercooked parasitized beef. The common localization of the scolex is the jejunum, about 40-50 cm below the duodenojejunal fissure (61). The strobila may extend to the terminal ileum. Very rarely, proglottids have been found in the gall bladder, appendix and nasopharynx (59). The adult is normally 4-12 metres long. The scolex is without a rostellum and no hooks are present (73). For further morphological details see Figures 3, 4, 5 and Table 1. The adult form shows a strong tendency to morphological abnormalities such as bifurcation of one or several proglottids and variations in the structure of the reproductive organs. These abnormalities may cause taxonomic difficulties (1, 87).

The process of strobilization occurs at the distal part of the neck. The gravid proglottids, 20-30 mm long and 5-7 mm wide, become detached singly from the strobilla and leave the host, usually passing actively through the anus. The pre-patent period from a self infection is 87 days (62).

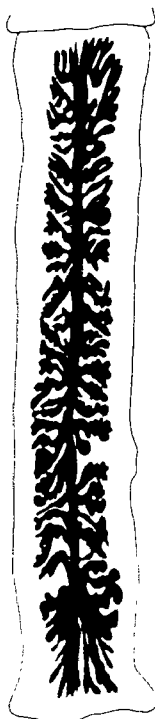


FIGURE 3 - Gravid segment of Taenia saginata (After 86).



FIGURE 4 - Scolex of *Taenia saginata* showing elliptical suckers and absence of rostellum and hooklets. x 80 (After 78).

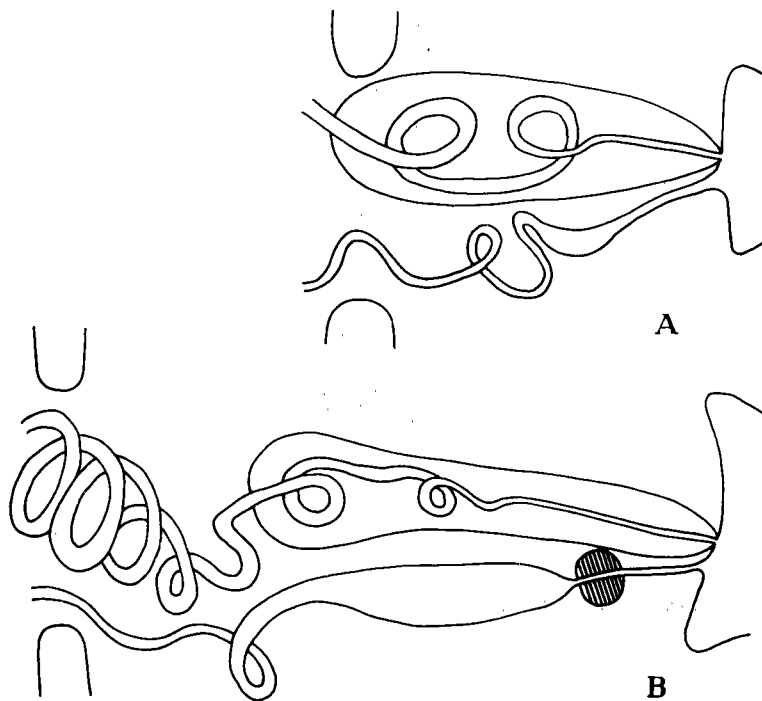


FIGURE 5 - A, genital atrium of *T. solium*. B, genital atrium of *T. saginata*. Note the presence of vaginal sphincter muscle in *T. saginata* (After 86).

The gravid proglottids leave the host spontaneously and usually 6-9 segments migrate spontaneously out of the anus or are shed daily in the faeces. Proglottids are mobile and will migrate a few centimetres over the body, on clothes, bedding or on the ground, shedding eggs in the process. About 750,000 eggs may be expelled daily (33).

Occasionally, a large part of the strobila may be discharged and the expulsion of proglottids ceases for a time. A rapid development of new proglottids then occurs, i.e. 12-27 cm of strobila per day. After an unsuccessful treatment the strobila regenerates within 3 1/2 months. The survival time may be extended, for example, up to 30 years.

There have been several voluntary induced infections with T. saginata taeniasis. In one study (75), the first gravid proglottids of the cestode appeared in the stool at day 87 p.i. For the next 11 days the daily output ranged from 7 to 12. Later their number increased to 10 to 15 in the morning stool, during the rest of the day it was 5 to 10. Three months after the first appearance of proglottids, i.e. at day 175 p.i., the first spontaneous discharge of proglottids was observed. This expulsion was not associated with defaecation. The phenomenon of released proglottids was followed by a characteristic sensation of a creeping movement in the rectum and the anal region lasting from 2 to 10 minutes. The release of a large number of proglottids, either singly or in chains measuring from 40 to 60 cm, was observed during defaecation, accidentally or after drinking a large amount of alcohol; even immature square shaped proglottids could be observed. Following the release of a large band of proglottids, further releases followed after 42 to 68 days. A further voluntary infection was followed for 17 weeks after the initiation of proglottid expulsions. The average number of segments per day was 10.9. However, large variations from one day to the next occurred, with extremes of 3 and 29. There appeared to be a certain periodicity elimination of proglottids (16).

There is an uneven maturation of oncospheres in the last 30 to 50 proglottids. About 50% of the eggs leaving the proglottids contain fully developed and invasive embryos, but this varies within quite wide limits (70). Some immature eggs may develop to maturity outside the host. Eggs may remain viable for several weeks or months in sewage, river, water or on pasture. Infectivity is modified by weather factors (26) (see Chapter 3).

When the eggs are ingested by cattle, the embryo hatches and activates under the influence of gastric and intestinal juices and penetrates the intestinal mucosa to reach the general circulation. The embryos develop in skeletal and cardiac muscles and also in fat and visceral organs. The heart and masseters are commonly affected and, previously, these were regarded as the most important predilection sites. However, several studies have shown that cysticerci are usually found dispersed throughout the musculature and may occur in almost any organ (43, 93). The larvae settle in lymphatic grooves. The wall of the lymphatic capillaries surrounding the larvae thickens with time due to an accumulation of histiocytes and other cells forming the "host capsule" (43, 71).

On day 14 the post infection nodules caused by the cysticerci can be seen with the naked eye and have a diameter of about 2-5 mm, including the surrounding inflammatory tissue reaction; the appearance remains approximately the same until 28 days p.i. (6). This early nodular appearance can easily be mistaken for changes due to other (non-parasitic) agents. The cysticercus, sometimes referred to as Cysticercus bovis, although this term has no taxonomic significance, develops and becomes infective for man in about 10 weeks. The mature cysticercus is an oval bladder (7-10 mm by 4-6 mm), filled with fluid and containing the invaginated scolex of the tapeworm (see Figure 6). Cysticerci begin to degenerate within a few weeks after infection in cattle and, by 9 months, a substantial proportion of them are dead and calcified (Figure 7). However, the longevity of cysticerci depends on the degree of infection and the age of the animal at the time of infection. Infection of neonatal calves may result in prolonged survival of cysticerci (perhaps for the lifetime of the host). Prenatal infections have been recorded but are uncommon (27, 45, 56).

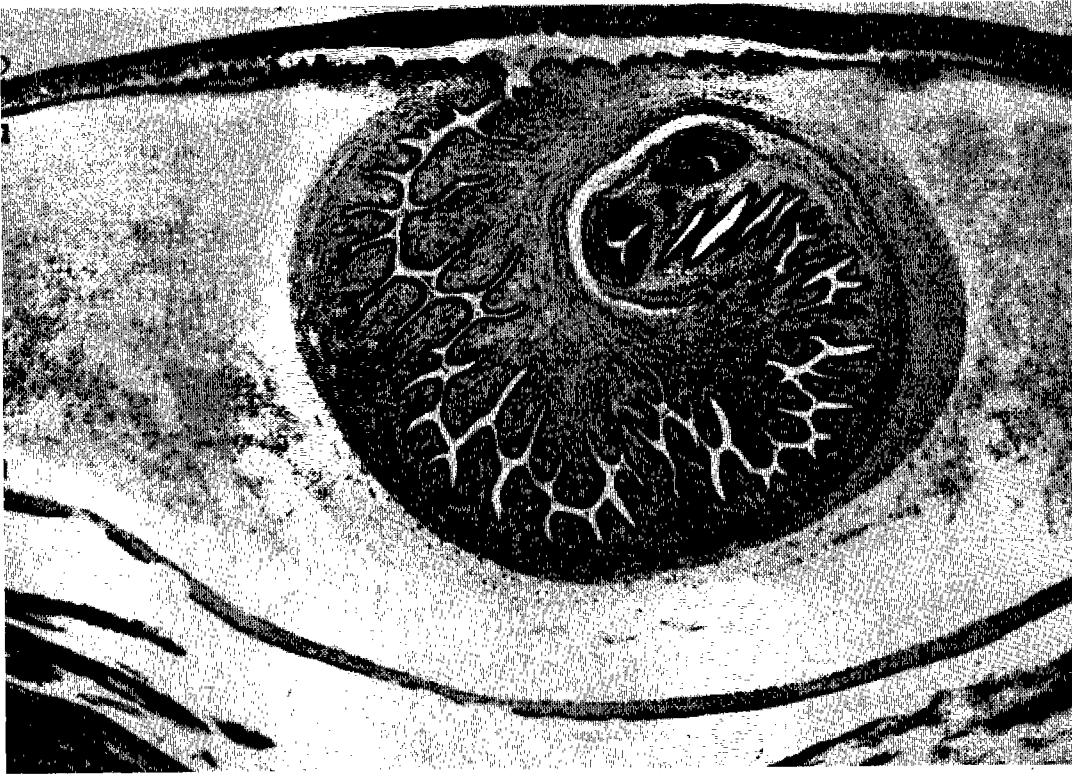


FIGURE 6 - Microphotograph of Taenia saginata cysticercus showing invaginated scolex with two suckers apparent; (a,a) bladder wall; (b) connective tissue capsule; x 28 (After 78).



FIGURE 7 - Degenerated cysticerci of Taenia saginata in the ox heart. One cyst, indicated by arrow, is visible beneath the epicardium (After 78).

1.2.2 Taenia solium (Linnaeus, 1758)

This adult parasite occurs in the small intestine of man. It has not been found in any other host in nature including carnivores. However, it has been established experimentally in the gibbon (Hylobatus lar) (13), the chacma baboon (Papio ursinus) (85) and golden hamster (Mesocricetus auratus) (28, 88). In the latter case the host was immuno-suppressed and the worms failed to become sexually mature.

1.2.2.1 Life cycle and developmental morphology

The adult is usually 1.5-5 metres long but may reach up to 8 metres in length and has been reported to survive for up to 25 years in man. The scolex bears a rostellum with two rows of hooks numbering 22-32. These hooks range in size from 159 to 173 μm (Mean = 165.7 ± 5.0). The gravid proglottids are 7-12 millimetres long by 5-6 millimetres wide, and the uterus has 7-16 lateral branches (Figures 8, 9). The gravid segments which contain about 50 000 eggs, do not leave the host singly and spontaneously (contrast T. saginata), but are voided in the faeces, frequently in chains, of about 5 per day (33). The eggs are 26-34 μm in diameter and indistinguishable from other Taenia eggs.

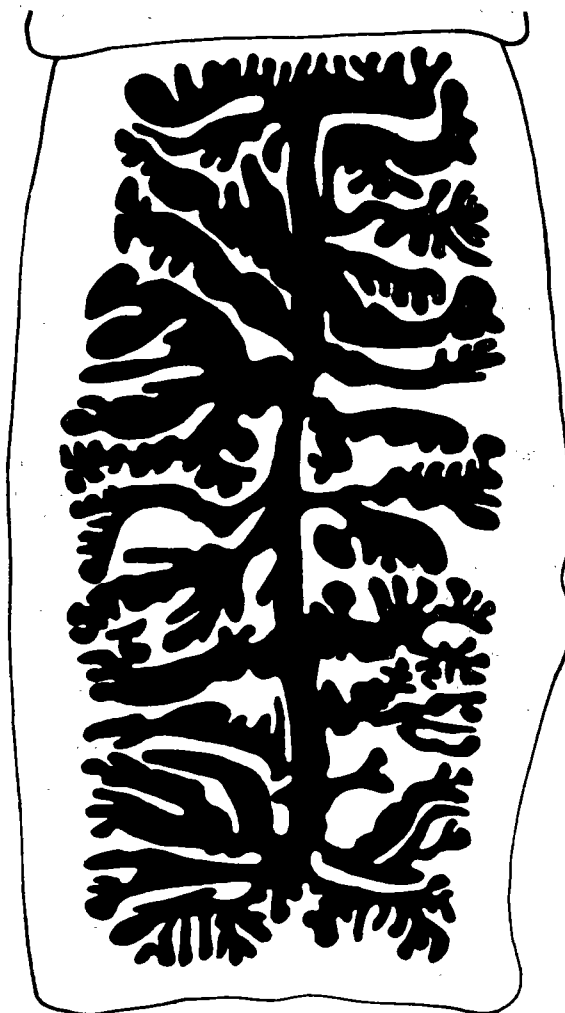


FIGURE 8 - Gravid segment of Taenia solium (After 86).

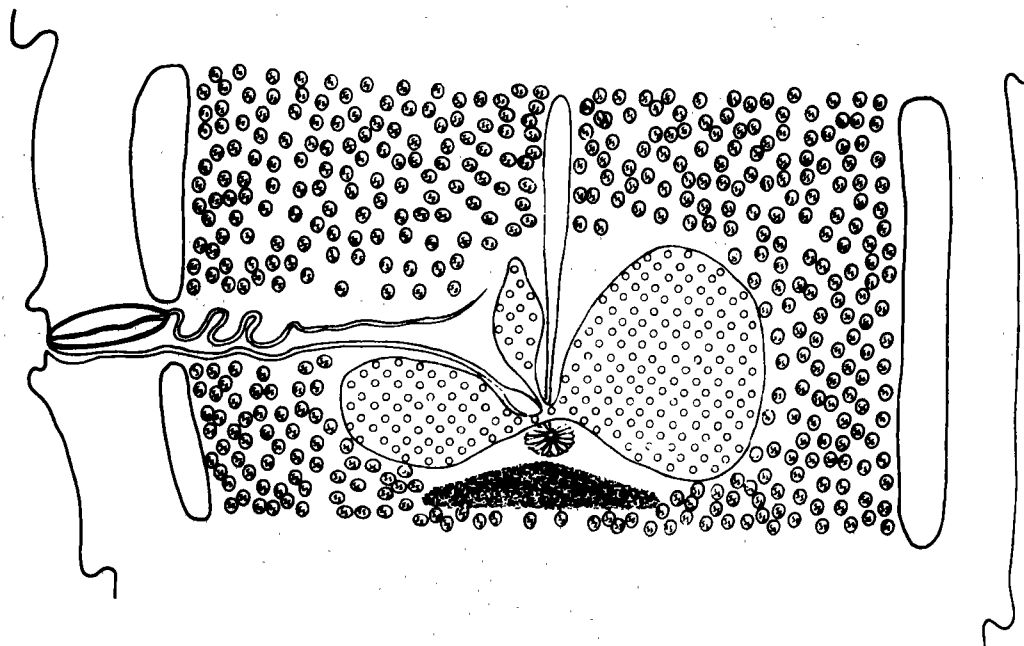


FIGURE 9 - Taenia solium sexually mature segment. (Note the three-lobed ovary) (After 86).

The domestic pig is the main host for the larval stage although infections may occur in dogs, where cysticerci have been found in the brain (22, 24, 31, 37, 39, 44, 48, 49, 60, 95) and occasionally other animals. However, man is also an intermediate host.

Armed cysticerci have been reported in various mammals including monkeys (Ateles geoffroyi, Cercopithecus cephus, C. patas, C. aethiops, Macacus innus, M. cyclopis and Macaca mulatta), bushbabies, bushpigs, camels, rabbits, hares, rock hyraxes, brown bears, cats, foxes, polecats, coatis, rats and mice (1, 30, 35, 50, 87, 89). The identity of these cysticerci have not always been confirmed by adequate taxonomic methods. The existence of "strains" or sub-species has been suggested to explain the different size of hooks of T. solium cysticerci found in pigs, cats, baboons, dogs and man (31). A multilobulate larval form without a scolex, usually designated as Cysticercus racemosus, also occurs with relatively high frequency in human cysticercosis in Mexico. This may or may not be T. solium (see 1.3.2.3).

Man becomes infected with the adult worm by eating undercooked or raw pork infected with cysticerci. The adult normally occurs in the jejunum. The first expulsion of T. solium proglottids takes place between 62-72 days after infection (46). At that time the tapeworms are 218 and 223 cm long. In unsuccessful drug treatment T. solium proglottids have

reappeared within 57-61 days (4). The cysticerci (sometimes referred to as Cysticercus cellulosae, although the term has no taxonomic status), develop primarily in skeletal and cardiac muscle in the pig. The cysticercus becomes infective to man in about 10 weeks. They may survive for the lifetime of the host. Experimental infections of sows have failed to demonstrate prenatal infections (83, 84).

Man, who may also act as an intermediate host, becomes infected with cysticerci by ingestion of eggs from sources such as faecal-contaminated food, hands, water, etc. In man cysticerci develop in the subcutaneous tissues, heart and skeletal muscle, brain and eyes.

1.2.3 Principal taxonomic differences between *T. saginata* and *T. solium*

1.2.3.1 Adult worms

It is of great clinical and epidemiological importance to be able to distinguish between patients infected with *T. solium* and *T. saginata*. This is not a simple matter as sometimes the only material available is a few expelled proglottids which may be in a poor state of preservation. The species can be differentiated only with certainty from the scolex, and sometimes from well developed and properly preserved proglottids.

The principle methods for distinguishing between adult *T. saginata* and *T. solium* are summarized in Table 1 and see Figures 10 and 11.



FIGURE 10 - Scanning electromicrograph of scolex of *T. saginata* (After 21).

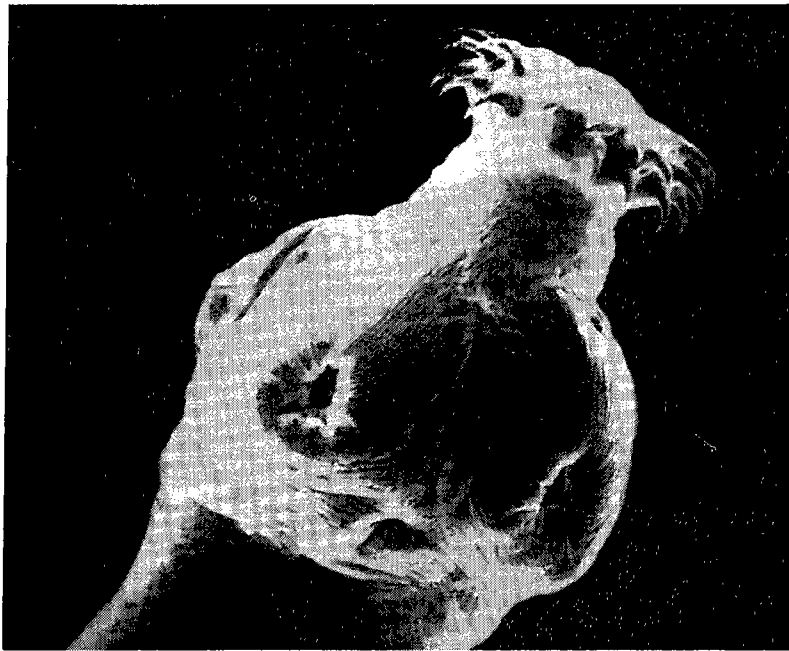


FIGURE 11 - Scanning electromicrograph of scolex of T. solium (After 21).

Different specific protein bands have been demonstrated by polyacrylamide gel electrophoresis in extracts of the strobila of T. solium and T. saginata (12, 41). This technique is not, however, of practical use at present in routine diagnosis.

1.2.3.2 Larval worms

Taenia solium cysticerci are in general larger in size (5 to 20 mm in diameter) than those of T. saginata; the bladder is more transparent, the scolex inside is smaller and has four delicate suckers and a rostellum armed with 22-32 hooks. When the scolex is not available, it is still questionable whether accurate differential diagnosis between T. solium and T. saginata has been noted (71).

TABLE 1 - Summary of morphological differences between adult Taenia solium and T. saginata (After 1, 11, 18, 19, 57, 86, and 87).

	<u>Taenia solium</u>	<u>Taenia saginata</u>
ENTIRE BODY		
Length (m)	1,5-8	4-12
Maximal breadth (mm)	7-10	12-14
Proglottids (number)	700-1000	ca 2000
SCOLEX		
Diameter (mm)	0,6-1	1,5-2
Suckers (number)	4	4
Rostellum	Present	Absent
Hooks (number)	22-32	Absent
MATURE PROGLOTTIDS		
Testes (number)	375-575	800-1200
Ovary (number of lobes)	3	2
Vaginal sphincter	Absent	Present
GRAVID PROGLOTTIDS		
Uterus (number of branches each side)	7-16	14-32
Way of leaving host	In groups, passively	Single, spontaneously

1.3 Clinical pathology and symptomatology

This section merely summarizes some of the clinical pathological features of taeniasis/cysticercosis. More extensive accounts have been recorded (9, 10, 21, 58, 59).

1.3.1 Adult worms

1.3.1.1 Taenia saginata taeniasis

Taenia saginata taeniasis is a non-fatal intestinal infection in man caused by the adult beef tapeworm, Taenia saginata.

Like most helminthic infections, taeniasis may provoke recognizable illness or may cause unrecognizable (subclinical) infection, except for the passage of proglottids which is usually noticeable. The frequency of different symptoms, one or more of which may be present in three out of four patients infected with T. saginata are: abdominal pain (35.6%), nausea (34.4%), weakness (24.8%), loss of weight (21.0%), increased appetite (17.0%), headache (15.5%), constipation (9.4%), dizziness (8.2%), diarrhoea (5.9%), pruritus ani (4.5%) and excitation (3.4%) (59).

Individual reactions to the infection differ widely and may be of a psychological nature as symptoms are often not reported until the patient becomes aware of his parasitism (2, 56, 57, 62). The presence of the tapeworm is often detected by the infected individual as most feel some sensation in the perianal area when the proglottids are discharged. However, there are many cases where the patient is unaware of his infection (29).

Occasionally proglottids may enter bile ducts and the appendix (5, 46, 62). More rarely, they may be aspirated during vomiting and cause obstruction of the respiratory tract (69).

Taenia saginata taeniasis more often causes changes in motility and secretion of the gastrointestinal tract rather than local pathological changes in the intestinal mucosa. In about 70% of the cases gastric secretion is reduced during the infection (2, 56).

In tropical countries, T. saginata often occurs with other species of parasites and the debilitating effect of taeniasis in these circumstances can be severe. There have been several reports of multiple and acute infections with both T. solium and T. saginata (17, 44, 55).

1.3.1.2 Taenia solium taeniasis

Taenia solium taeniasis is a non-fatal intestinal infection in man, caused by the adult pork tapeworm, Taenia solium. The pathology and symptomatology of T. solium taeniasis is usually less obvious than those of T. saginata. The T. solium tapeworms are smaller, their hooks do not do much damage to the mucosa and their proglottids are less active and do not cause abdominal complications such as appendicitis or cholangitis. Taenia solium taeniasis may remain unnoticed by the carrier because of the passive discharge of the proglottids. There is no clear cut evidence associating a greater prevalence of clinical cysticercosis in individuals parasitized with T. solium than in those free from tapeworms (8, 9, 14, 15, 32, 42, 47, 63). It was reported, for example, that the chances of a non-pork-eater becoming infected with cysticercosis was as great as those of a pork-eater among Bantu of South Africa. However, it has been reported in China that 85 (53.8%) of 158 cysticercosis patients had histories of previous tapeworm infections (96). The association of tapeworm and cysticercosis infections in the same individual may vary due to different local patterns of transmission. However, discrepancies may reflect sampling variations and techniques. A particular problem is that the diagnosis of cysticercosis may be made many years after the tapeworm has been expelled.

1.3.2 Larval stage

1.3.2.1 Taenia saginata cysticercosis

Taenia saginata cysticercosis is an infection in cattle with the larval stage, cysticercus, localized mainly in the muscle tissue. Contrary to popular belief it may occur in any organ (94). For a detailed account of the distribution, especially in muscles, see reference 90.

Light or moderate cysticercosis in cattle is usually not associated with any defined clinical picture. Heavy infections e.g. those induced experimentally by 200,000 to one million T. saginata eggs, may give rise to fever, weakness, profuse salivation, anorexia, high temperature (45, 77) and a dose of one million or more eggs may cause death between 14-16 days due to a degenerative myocarditis (77). An increase in the creatinine phosphokinase level in serum has been reported in experimental infections of this order (53). Pericarditis and coronary embolism have been reported in an oryx antelope kept in a zoo and infected with T. saginata (79).

1.3.2.2 Taenia solium cysticercosis in pigs

Taenia solium cysticercosis is an infection in pigs with the larval stage, cysticercus, localized in various tissues. The pig is the normal intermediate host and usually tolerates living cysticerci well. Light or moderate cysticercosis does not usually give rise to any clinical picture. However, sows infected experimentally with 200 000 T. solium eggs showed anorexia, fever, accelerated pulse and respiration, vomiting and diarrhoea (84). An infection of the sow 14 days before birth may cause abortion (84). In pigs the cysticerci may show some predilection for the central nervous system. In one group of naturally infected pigs, cerebral localization was found in 50% of animals with 1-3 cysticerci present in the anconeus muscle, and in 100% of those animals with 7 or more cysticerci in the anconeus muscle (34). In these 60 pigs with neurocysticercosis, cysticerci were occasionally seen in the ventricles. The fact that pigs are usually slaughtered in their first year of life could explain the apparent absence of neurological symptoms.

Other workers do not rate the nervous system highly as a predilection site and suggest that the distribution may depend on host strain and other factors. One worker (90) has reported the following sites in order of priority: (i) fore quarters above the elbows; (ii) hind limbs above the hocks; (iii) psoas muscles and muscles on the ventral surface of vertebrae; (iv) cervical muscles and the intercostals; (v) tongue and its muscles; (vi) heart and the perineal region; (vii) oesophagus and the diaphragm; (viii) muscles of the face and the abdominal muscles; (ix) brain; (x) liver, fat and superficial fascia; (xi) eye ball, conjunctiva; (xii) sexual organs, internal organs not mentioned above and lymphatic glands.

1.3.2.3 Taenia solium cysticercosis in humans

Taenia solium cysticercosis in man is a serious and chronic disease, often fatal because of the frequent cerebral location of cysticerci. There are several thousand publications on T. solium cysticercosis in man and the pathology and symptomatology have recently been reviewed in detail (10, 21, 58, 81, 82).

Aetiology

Human cysticercosis is mainly caused by T. solium larvae, but in South America and South Africa several cases of racemose cysticercosis have been reported. The term "Cysticercus racemosus" is used to describe translucent large vesicles, frequently lobulated or ramifying, having no scolex and usually located in the subarachnoid space or ventricles. These cysticerci, which are only found in the human CNS may reach a large size and become multilobate and give rise to symptoms much more frequently than normal cysticerci, due to their volume and perhaps because they are less well tolerated. The taxonomy of "Cysticercus racemosus" is still a matter of controversy; it could be a cysticercus of T. solium which has degenerated or grown unobstructed by the surrounding tissue, or it could be a sterile coenurus-type larva of T. multiceps, T. serialis (both tapeworms parasitize dogs), or other Taenia (38). The occurrence of normal T. solium cysticerci (C. cellulosae) and "C. racemosus" in the same person, with intermediate developmental stages, suggest that C. racemosus is a degenerative stage of T. solium cysticercus (64).

Infections with typical T. multiceps larvae, so-called coenurosis, are occasionally reported from different parts of the world. Subcutaneous and ocular coenurosis in Uganda is caused by T. brauni (80). Liver cysticercosis in man caused by the larvae of T. taeniaeformis or T. crassiceps has also been reported (see Appendix I).

Pathology

The cysticercus is small, spherical and tends to be located in the subcutaneous tissue, the orbit, muscles, brain tissue, the ventricular cavities, and the large subarachnoid cisterns. Autopsy studies in man have confirmed the presence of T. solium cysticerci in many organs, including the spinal cord, eyes, muscle tissues, myocardium, lungs, peritoneal cavity, intestinal submucosa, thyroid glands and subcutaneous tissues. Cysticerci in the eyes, subcutaneous tissues, musculature, and spinal cord, in order of decreasing frequency, can be diagnosed by clinical examination.

The classification of human cysticercosis according to anatomical localization is presented in Table 2.

TABLE 2 - Classification of human cysticercosis (After 97).

I. DISSEMINATED CYSTICERCOSIS

A. Musculocutaneous

B. Visceral

1. Cardiac
2. Pulmonary
3. Abdominal

II. OPHTHALMOCYSTICERCOSIS

A. Extraocular

1. Palpebral
2. Subconjunctival
3. Orbital

B. Intraocular

1. Anterior chamber

- a. Cornea
- b. Aqueous humour
- c. Iris
- d. Lens

2. Posterior chamber

- a. Vitreous humour
- b. Subhyaloid
- c. Subretinal
- d. Subchoroid

III. NEUROCYSTICERCOSIS

A. Spinal

1. Extrapinal (vertebral)

2. Intrapinal

- a. Epidural
- b. Subarachnoid
- c. Intramedullary

B. Cerebral

1. Mental disturbances

2. Epilepsy

- a. Generalized
 - (1) Convulsive
 - (2) Nonconvulsive
- b. Partial
- c. Complex symptomatology

3. Localized syndromes
 - a. Osterwald-Bruns' IV ventricle syndrome
 - b. Chiasmatic-arachnoid or Cushing's 2 syndrome
 - c. Cerebellopontine angle or Cushing's 3 syndrome
 - d. Local and remote arterial syndromes
 - e. Progressive irreversible mesencephalic syndrome
4. Intracranial hypertension
 - a. Without hydrocephalus
 - (1) Miliary, multiple, or disseminated invasion
 - (2) Acute cerebral edema
 - (3) Large tumor like cysts
 - b. With hydrocephalus
 - (1) Basal meningitis
 - (2) Ventricular obstruction
 - (3) Acute obstruction, which can lead to sudden death

IV. MIXED CYSTICERCOSIS

More than one of the above locations.

There are two major factors which give rise to the symptomatology associated with cysticercosis. The first is the mechanical compression and displacement of tissues caused by the parasite and physical interference with the proper flow of organic liquids, as for example, when it is located in strategic places of the cerebral spinal fluid system. The second major pathogenic mechanism is the inflammatory process that usually surrounds the parasite and which may, in fact, extend to neighbouring structures.

Inflammation may be varied but is predominantly cellular, with numerous lymphocytes and plasma cells. Eosinophils are conspicuous, especially near the surface of the parasite. Some giant multinuclear cells are evident, as well as foamy macrophages near the parasite. Necrosis of adjacent tissues is usually patchy or absent. However, neighbouring vessels show vasculitis, perivascular infiltration of mononuclear lymphoid cells, fibrosis and proliferation of infiltration of mononuclear lymphoid cells, fibrosis and proliferation of endothelial cells with narrowing of, and even obliteration of, the vessel lumen.

1.3.2.4 Neurocysticercosis

Cerebral

The clinical pathology of cerebral cysticercosis depends on the number, localization and stage of development of the parasites and the individual host reaction (58, 82, 97).

The human brain can be invaded by one or by more than 2,000 cysticerci (82); in the majority of cases less than 10 cysticerci are present (9). The cysticerci are localized mainly in the cortex and meninges, in the cerebral ventricles and also in the white matter of the cerebrum itself (Figure 12).



FIGURE 12 - Disseminated cerebral cysticercosis.

The presence of cysticerci on the surface of the brain may cause flattening or compression of the convolutions and inflammation or later on fibrotic changes to the leptomeninges. The affected ventricles may be distended and deformed with signs of granular ependymitis. The cysticerci in the human brain may be of different sizes and stages of development; they can be juvenile, mature or old; each one can be intact, degenerating or dead. Intact cysticerci do not usually provoke much host reaction.

Dying and/or degenerating cysticerci may give rise to a strong inflammatory reaction in the host; a granulomatous response composed of plasma cells, lymphocytes, eosinophils, and macrophages enclosed in a network of connective tissue is built up around the cysticerci. In later stages, the host cells penetrate into the remnants of the parasite. This finally becomes transformed into a glial-connective scar or undergoes calcification. The latter is more characteristic for cysticerci with other than cerebral localization. The equilibrium between the biological potential of the cysticerci and the host reaction is unstable. Frequently some cysticerci degenerate earlier than others and intensify the host inflammatory and immunological response. Clinical improvement resulting from steroid treatment strongly suggests that allergic or inflammatory phenomena play an important role in cerebral cysticercosis.

In terms of clinical pathology, human cerebral cysticercosis can be classified as intensive or of a low intensity; meningeal, parenchymal, ventricular or mixed; recent or chronic; in remission or exacerbated; simple or complicated; asymptomatic, symptomatic or fatal (58).

It can also happen that an acute or severe case of cysticercosis will go into remission with or without treatment, such that the symptoms will disappear for a long time or even permanently (14, 15).

The incubation period of human cysticercosis observed among British soldiers serving in India ranged from less than 1 year to 30 years, with an average of 4.8 years (14, 15); it is usually shorter in infected children than in adults. The youngest child with cysticercosis

was 14 months old. The onset is either insidious (intracranial hypertension) or abrupt (sudden blockage of cerebrospinal fluid by a floating cysticercus). The evolution of human cysticercosis is variable and unpredictable; there are shorter or longer remissions or a steady deterioration of symptoms. Death, often unexpected, may occur at any moment of the disease. The prognosis in cerebral cysticercosis is always serious; the fatality rate in symptomatic untreated cases exceeds 50%. The survival time of human patients varies from a few minutes to 35 years from the onset of the first symptoms.

The symptomatology of cerebral cysticercosis is characterized by 3 basic syndromes: convulsions, intracranial hypertension and psychiatric disorders, occurring separately or in combination (82). Apart from these 3 main syndromes, various secondary or isolated symptoms and signs such as ataxia, dysarthria, neck stiffness, clouding of consciousness, etc., may occur and simulate the most diverse neurological entities (82).

Spinal

Spinal cysticercosis constitutes about 5% of all cases of cysticercosis and is more frequently intra-medullar than extra-medullar. The main symptoms are motor or sensory disorders due to the compression of neural tissue (82).

1.3.2.5 Ocular cysticercosis

Ocular cysticercosis constitutes about one-fifth of human cysticercosis cases. The most common localization is in the vitreous humour and subretinal tissue, but T. solium cysticerci may also invade the anterior chamber, conjunctiva and other eye tissues. Host reactions to cysticerci vary from slight to severe inflammation with complications such as retinal detachment or atrophy, chorioretinitis, and iridocyclitis (51) (Figure 13).

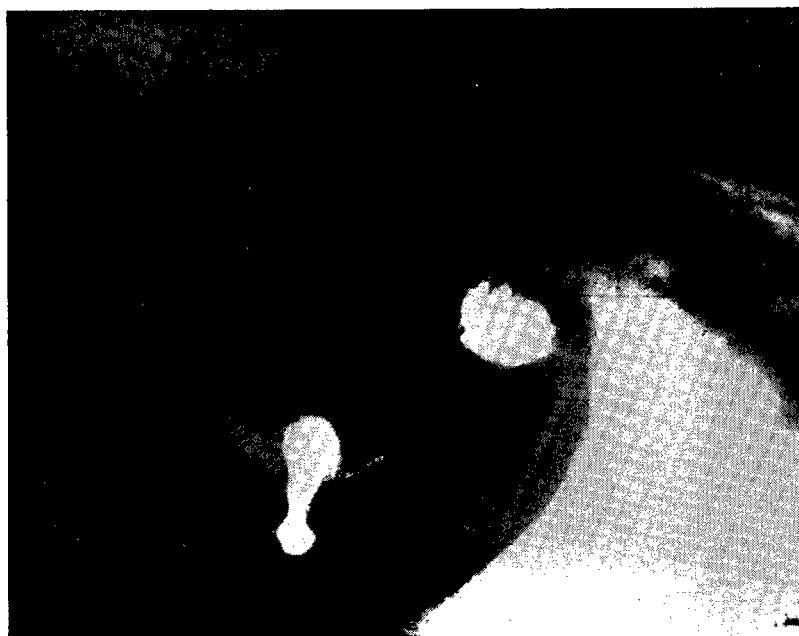


FIGURE 13 - C. Cellulosae with an evaginated scolex located in the aqueous humour in the anterior chamber of the eye (After 97).

1.3.2.6 Muscular cysticercosis

Myocardial cysticercosis in man is common in intensive infections but seldom causes clinical signs. Similarly, subcutaneous and/or muscle localization of cysticerci is usually of negligible clinical importance. Calcified changes in the muscles are frequently diagnosed purely by chance. Subcutaneous nodules are usually asymptomatic.

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CHAPTER 2 - DIAGNOSIS

2.1 Introduction

This Chapter deals with both the parasitological and immunological diagnosis of taeniasis and cysticercosis. Parasitological techniques provide the surest way of diagnosis but immunodiagnosis is increasingly useful in certain instances.

2.2 Parasitological diagnosis of taeniasis

Methods for the parasitological diagnosis of taeniid tapeworm infections and their limitations have been carefully studied over many years. Both questioning of patients and parasitological diagnosis have been used. They form the only methods at the present time for surveys and surveillance of human taeniasis.

Taeniasis is most difficult to diagnose during the first 3 months of infection, before the eggs are produced and the proglottids discharged; X-ray examination of the intestinal tract may sometimes show a ribbon-like contrast defect. Later on, the patient himself frequently reports the discharge of a parasite or brings discharged proglottids for examination (106). The differential diagnosis of T. saginata and T. solium may not be easy as it is based on the examination of mature or gravid proglottids or of the scolex of the tapeworm. The scolex is difficult to find after treatment with modern taeniocidal drugs that cause the disintegration of the proximal part of the strobila. Some of the criteria for the differentiation between T. saginata and T. solium proglottids are of uncertain value (Table 3). For example, counting the lateral uterine branches in the gravid proglottids, although used as a routine diagnostic technique for over a century, has recently been questioned as possibly having limited taxonomic value (142). In routine laboratory practice, if a proglottid has a doubtful character then other proglottids should be sought and examined. A taxonomist should be consulted in case of further doubt.

TABLE 3 - Diagnostic key: adult worms (After 142).

Major features for the distinction of T. solium and T. saginata according to the material available:

1. Scolex	Rostellum armed with 2 rows of hooks	<u>T. solium</u>
	Unarmed	<u>T. saginata</u>
2. Gravid proglottids harbouring a great quantity of eggs:		
	In fresh preparations the number of branches from the central stem of the uterus can be counted; less than 12 branches at one site = <u>T. solium</u> , more than 16 = <u>T. saginata</u> . Specimens having 12-16 branches of the uterus cannot be accurately diagnosed (142).	
3. Mature proglottids having well differentiated sexual organs but containing no eggs. The presence of an accessory lobe of the ovary is diagnostic for <u>T. solium</u> but this can only be seen in stained preparations. Similarly, the presence of a vaginal sphincter muscle is diagnostic for <u>T. saginata</u> but it is normally only visible in stained sections.		
4. Immature proglottids or isolated eggs:		
	If immature proglottids or eggs are the only material available, diagnosis of a tapeworm infection can be confirmed but distinction between the species is impossible. In such cases, the clinician is urged to obtain additional material and, if in doubt, submit it to a parasitological laboratory. New developments that may assist in the differentiation include enzyme electrophoresis but they are not in routine use at present.	

Taenia saginata eggs do not differ morphologically from those of T. solium and for this reason the finding of Taenia eggs in the faeces, or more frequently on anal swabs, does not enable a final diagnosis of the species involved. However difficult, differential laboratory diagnosis between T. saginata and T. solium is recommended (see T. solium cysticercosis) for both clinical and epidemiological purposes, but this should not delay treatment if T. solium infection is suspected.

2.2.1 Questioning of possible carriers

Questioning of patients for T. saginata taeniasis concerning the discharge of proglottids is an important tool in individual cases and in mass investigation of populations (5, 40, 94, 105, 107, 110, 111). It is based on the ability of proglottids of this species to separate from the strobila and be actively discharged through the anal orifice causing an unpleasant creeping sensation in the perianal region (see Chapter 1). This method, if effectively applied, may reveal up to 95% of the infections. However, it has its limitations, and its success depends very much on the cooperation between physician and patient, particularly if there is a fear by the latter that the treatment itself will cause harm.

Both false negative and false positive answers may be elicited unless the questioning is detailed. Confusion with Enterobius vermicularis having similar sensations in the perianal regional may occur. Because the proglottids of T. solium are inactive and are usually shed in short chains during defaecation, the carrier may be unaware of an infection. Questioning is less likely to be accurate and is usually used as an auxiliary method.

2.2.2 Examination for proglottids and eggs

The finding of loose gravid proglottids (usually T. saginata) in the under-clothes or in the faeces provides proof of an infection. This finding is less likely to occur in cases of T. solium infection.

2.2.3 Coprological investigations

In the detection of eggs in faeces many methods are relatively useful and include thin or thick faecal smear and concentration or flotation techniques (33, 40, 41, 55, 67, 91, 97, 105, 106, 119, 138).

Examination of a suspected carrier for eggs may detect up to 90% of infections, particularly if more than one method is used but it also may detect as little as 68% if only one technique is used with preserved faecal material (55).

2.2.4 Perianal swabs

This method is based on the fact that eggs discharged from the proglottid as it emerges from the anal orifice adhere to the perianal region (6, 14, 26, 40, 44, 60, 89, 90, 104, 107, 109, 111, 122). Besides the normal methods using a spatula for scraping the anus, scotch tape has been found useful (119, 138). These methods may reveal up to 90% of the infections with T. saginata but not for T. solium. However, it is emphasized that proglottid expulsion is not necessarily a daily or even weekly occurrence, particularly if partial destrobilization has occurred previously (136).

2.3 Parasitological diagnosis of human cysticercosis

The final diagnosis of human T. solium cysticercosis is made parasitologically by finding a scolex, hooks or fragments of the bladder walls in biopsy or autopsy material. The easiest type of infection to diagnose by biopsy is subcutaneous cysticercosis. However, a constellation of the clinical symptoms and signs plus X-ray, serological and laboratory examinations, if all positive, enables the diagnosis of neurocysticercosis to be made with a high degree of accuracy (30, 72, 120, 140, 152). However, the clinical symptoms and signs occurring in cerebral cysticercosis may not be very characteristic and the differential clinical diagnosis vis-à-vis tumour, vascular and inflammatory conditions, especially in non-endemic areas, may be difficult. Coexisting ocular, subcutaneous or muscle cysticercosis should always be considered (93) (see Chapter 1).

The radiological techniques used in cysticercosis are: simple X-ray examination of the chest, neck and arms (for calcified cysticerci) and of the skull (for calcifications or signs of intra-cranial hypertension). Cerebral angiography, pneumoencephalography and ventriculography were widely used before the introduction of computerized axial tomography, which is the most convenient and safe technique to identify space-occupying lesions in the internal organs, especially in the brain (4, 9, 16, 19, 21, 27, 29, 30, 63, 69, 120, 121, 124, 135).

In the case of cerebral cysticercosis, examination of the cerebrospinal fluid (CSF) is also important; usually the pressure is low, the CSF clear, the glucose level low, the protein level, especially gammaglobulin fraction, raised and there is a marked cellular reaction with a highly significant percentage of plasma cells and eosinophils. Blood eosinophilia is usually present.

2.4 Parasitological diagnosis of bovine and porcine cysticercosis

Surveys and surveillance of bovine and porcine cysticercosis rely heavily on the identification of cysticerci during meat inspection (see Chapter 4). In terms of using the data for surveys, surveillance, and for monitoring control programmes, this method, because many lightly infected carcasses escape detection, must be regarded as a herd or flock diagnostic test of high specificity but low sensitivity.

2.4.1 Limitations of meat inspection in the detection of bovine cysticercosis

There have been several detailed studies to define the limitations of meat inspection in the detection of bovine cysticercosis (24, 28, 85, 87, 98, 107, 137, 141, 145). In a study of cattle grazed on a sewage farm in Australia, the number of infected animals identified by routine meat inspection was relatively low when determined by subsequent multiple slicing of the previously inspected organs (heart, diaphragm, tongue and masseters (Table 4).

TABLE 4 - A comparison of the detection of T. saginata infection in cattle by on-line meat inspection or by laboratory slicing (After 117).

	Number killed	Number of infections	
		Detected by on-line inspection	Detected by laboratory slicing
Aged 10 to 11 months:			
Day 1	66	5	35
Day 2	68	9	21
Day 3	66	34	47
Aged 20 to 21 months:			
Day 1	50	4	20
Day 2	50	0	13

In a 3-day trial of meat inspection detection of T. saginata cysticerci, it was found that diagnosis was improved from the 14% on the first to 72% on the last day of trial. This was due to the increased manpower and vigilance generated by the trial. Meat inspectors were able to detect degenerated cysticerci better than viable organisms (117). Similar results were found in a subsequent survey (74).

In a trial of Tanzanian cattle studied in Kenya very severe limitations were found in the routine meat inspection of animals in that only a very small fraction of the existing cysticerci were detected (192 detected of 12 940 present) using the accepted methods of incision and palpation (85).

A further trial undertaken in Kenya with 80 zebu cattle between 2-12 months of age (145) assess was designed to meat inspection procedures. These included palpation and incision of the ventral aspects of the tongue, extensive incisions of the masseters, visual inspection of the oesophagus, diaphragm, liver and the muscles exposed during splitting of the carcass. The carcasses were then cut into thin slices and examined for cysticerci. The data are summarized in Table 5. The intensity of the infection was important, but even when 20 or more cysticerci were present, the meat inspection success rate was only 78% in a hyperendemic region where 76% of the animals harboured cysticerci. The overall success rate was only of the order of 38%.

TABLE 5 - Meat inspection findings compared with the intensity of infection (After 145).

	Number of cysts found by slicing		
	1-10	11-20	over 20
Number (and percentage) of infected animals detected by slicing	37 (100 %)	14 (100 %)	9 (100 %)
Number (and percentage) of infected animals detected by meat inspection	10 (27.0 %)	6 (42.9 %)	7 (77.8 %)

Despite these limitations, meat inspection is a valuable, specific method of identifying an infection in the bovine. It identifies heavily infected carcasses and even with lightly infected carcasses it serves as an early warning of the status of infection in a community.

2.4.2 Differential diagnosis

In some countries (e.g. in Africa) cysticerci of wild carnivore tapeworms, whose intermediate hosts are normally game animals, may occur in cattle or pigs and need to be differentiated from those of T. saginata or T. solium, respectively. There are several similar-looking macroscopic objects which may be confused with T. saginata cysticerci (117). These are sarcosporidiosis and eosinophilic myositis. The former can almost invariably be differentiated by close examination. True eosinophilic myositis with its multiple lesions

and characteristic gross and microscopic appearance is rare and easily differentiated. The so-called eosinophilic myositis "granulomatous variant" poses a problem. These lesions are difficult to distinguish from T. saginata lesions that no longer contain a cysticercus or a residual cavity.

2.4.3 Limitations of meat inspection in the detection of porcine cysticercosis

Generally, but not invariably, the parasite can be detected ante-mortem by examining the tongue for cysticerci in a relatively large consignment of infected pigs (herd test). Some of the consignment will be heavily parasitized whereas others in that consignment may harbour very few organisms, and as with cattle, not all animals will be detected at meat inspection through examination of the heart, masseters, brain and specific muscles. Nevertheless, the data obtained can be most helpful in surveys and surveillance by determining geographical distribution and identifying hyperendemic foci. Furthermore, because pigs are usually slaughtered below one year of age, they are less liable to be transported long distances, and are readily traced as to origin. Meat inspection may provide an immediate indicator of local transmission of eggs.

2.4.4 Methods of identifying animal consignments

An effective surveillance system requires the establishment of an efficient identification system. This is not always easy, but there is no question as to its value for the surveillance of the food animal cysticercoses. When cysticercosis is found at slaughter, the animal or animals should be traced rapidly to the herd of origin(s). Without identification, the focus may remain undiscovered for long periods. It must be admitted however that limitations of surveillance include the mass dispersion of food animals during their lifetime. Thus, the primary location where they were infected is often very difficult to define.

The value of the information available for epidemiological use is greatly enhanced when animals transported to slaughter are identified with regard to their place of last origin. With cattle a coded number on a printed tag can be fixed to each animal with glue. This tag can be placed on the animal by the owner, purchaser or dealer before it is transported to slaughter. Animals sold through the auction systems can also be identified in the same way. As the tag is stuck on, the name and address of the owner must be recorded. When large consignments are involved from a single herd or feedlot, individual identification is not necessary because records are kept by the transporter and management.

Pigs can be identified using a slap tattoo as the bristles on the skin tend to prevent the adhesion of the paper backed tags used for cattle.

2.5 Immunodiagnosis

2.5.1 Introduction

In both the adult and larval stages of infection with the taeniid tapeworm species of man there is need for an improvement in diagnosis. Serodiagnostic procedures offer a convenient approach and, where appropriate, could be integrated with other serodiagnostic procedures perhaps on an automated basis.

The problems of ante-mortem diagnosis of larval infections in animals for surveillance purposes are obvious, and serodiagnosis should offer the most satisfactory approach on a large scale basis. Unfortunately, experience to date has been that none of the conventional tests has shown an acceptable degree of sensitivity or specificity with naturally infected cattle or pigs.

The serodiagnosis of human cysticercosis is more encouraging and together with detailed clinical examination, including CAT scanning and similar techniques, serological tests offer a useful adjunct to diagnosis. Nevertheless, much more improvement is necessary especially for the application of such tests to seroepidemiology. There is a role for serodiagnosis in the detection of the adult Taenia in man. Sensitive procedures that could detect antigens in faeces or could differentiate T. saginata from T. solium would be very useful in surveillance.

2.5.2 Human taeniasis

Early studies (116, 143) with complement fixation, ring precipitation and intradermal tests using various extracts of adult tapeworms, or cysticerci, failed to prove useful in the diagnosis of adult tapeworms. Some 50% of infections were not detected. More recently the indirect haemagglutination test (78) and the indirect immunofluorescence test (34) using the adult worm antigens, have been employed. However, sensitivity was low in that some 40% of infections were not detected.

Significantly increased levels of immunoglobulin E and immunoglobulin A have been demonstrated in the serum of infected patients (99) and IgE serum levels returned to normal following therapeutic removal of the tapeworm. No antibody specificity could be associated with these increased immunoglobulin levels.

Intradermal tests using antigens prepared from adult T. saginata have demonstrated immediate type skin reactions in a selected group of patients infected with T. saginata. False positive reactions were, however, observed in uninfected patients with hepatic disorders (79).

Cell mediated immune responses, in patients with T. saginata have been detected by leucocytes and macrophage migration inhibition assays (15, 73) and a decrease in lymphocyte reactivity to phytohaemagglutinin has been noted (15). These responses returned to normal after treatment. At the present state of development, immunological tests have little to offer in the diagnosis of taeniasis in man.

2.5.3 Human cysticercosis

Immunological methods for the diagnosis of human cysticercosis can be used for the detection of individual cases or for epidemiological surveys. In the first, sensitivity is more important than specificity, since usually the diagnosis is made on an individual who has symptomatology suggestive of cysticercosis.

For epidemiological purposes, the specificity of the test is an important factor and, to obtain useful data, the sensitivity has to be well defined.

2.5.3.1 Methods

The majority of serological techniques for antibody detection have been employed with varying degrees of success in the diagnosis of human cysticercosis (35). Their main limitation is that the identification of antibodies to larval T. solium does not necessarily imply the presence of the parasite and antibody levels do not correlate with parasite number and anatomical location of the infection. An ideal test would be one that could detect antigens (e.g. RIA or ELISA) but until such a test is developed the diagnosis of human cysticercosis is largely based on antibody detection. The methods of choice at present are the following: enzyme-linked immunosorbent assay (ELISA), immunoelectrophoresis (IEP), indirect haemagglutination (IHA), indirect immunofluorescence (IIF) and complement fixation (CF). Table 6 summarizes the range of sensitivity and specificity of these tests and the antigens that have been used.

TABLE 6 - Examples of sensitivity and specificity of some serodiagnostic tests commonly used in the immunodiagnosis of human cysticercosis.

Test	Sample	Antigen obtained from cysticercosis	Percentage of positive cases				References
			Control	Confirmed cysticercosis	Probable cysticercosis	Neurological patients	
ELISA Enzyme linked immuno-assay	Serum CSF	Antigen B	5 -	79 81	- -	- 9	31
IEP Immunoelectrophoresis	Serum	Crude salt extract	0-13	54-87	47-83	4-24	11, 31, 37, 50, 112, 113, 114
IHA Indirect haemagglutination	Serum	Crude delipidized extract	4-25	10-92	8-53	10-50	54, 65, 84, 123
IIF Indirect immunofluorescence	Serum	Larval sections of fat free extract	0-5	80-95	-	-	23, 65, 66 123
CF Complement fixation	CSF	Crude delipidized extract	0-8	40-80	38-45	0-46	11, 54, 61, 64, 83, 100, 101, 103, 126

CSF: Cerebrospinal fluid.

Antigens

It has been shown by immunoelectrophoresis that preparations extracted from adult and larval tapeworms are very complex when analyzed against hyperimmune sera (20, 31, 53). Different batches of cysticerci also differ in the antigens that can be extracted from them (150). Furthermore, there is some evidence which indicates that there are differences between the normal cysticerci of T. solium (cysticercus cellulosae) and the racemose form (cysticercus racemosus) (see Chapter 1).

The crude salt extract of cysticerci of T. solium is heterogeneous, and up to 8 different antigens are recognized in patient antisera, however, antigen B is usually recognized in 84% of the cases (36).

When using an acid soluble protein fraction of mature proglottids of T. saginata or viable cysticerci of T. solium or of Echinococcus granulosus protoscolices, for intradermal test antigens, it was found that a combination of antigens was the most sensitive for the diagnosis of cerebral cysticercosis (151).

Since cysticerci can be contaminated with bacteria (150) and/or with host components (148, 149), care should be taken when the extracts are being prepared in order to avoid such sources of contamination (38).

Crude extracts of T. solium cysticerci for use in immunodiagnosis have been obtained by subsequent salting out (3M KCl) (36), with sucrose after delipidization with acetone (8) or after the delipidization of pig cysticerci or adult T. saginata (65, 101). The methodology, employed for obtaining the crude salt extract and for the purification of antigen B for the immunodiagnosis of human cysticercosis, is described in Appendix 3.

Enzyme linked immunosorbent assay (ELISA)

The ELISA has been used with antigen B (1 µg/ml protein) (31). The results (see Table 6) indicate that its sensitivity approaches 80% in immunodiagnosis. Crude extracts of cysticerci have also been used in ELISA serology (3, 25).

Immunoelectrophoresis (IEP)

IEP has been recommended for immunodiagnosis since practically no false positive results are obtained. Nevertheless, only 54-87% of cysticercotic patients have been detected by this technique (36). In Mexico, IEP has been used to characterize the immunoglobulins involved in the antigen-antibody reaction by using monospecific fluoresceinated anti-human immunoglobulins on the IEP preparations. In these studies, the majority of antibodies were shown to belong to the IgG and IgM classes, specific IgE and IgA have also been found (36).

Indirect haemagglutination (IHA)

IHA is undertaken following the usual methods and using sucrose extracts of delipidized whole worm of T. saginata or cysticerci of T. solium (8, 62). The correlation between clinical status of neurocysticercosis and the presence of antibodies in the serum and CSF is debatable since conflicting results have recently been published (38, 62).

Indirect immunofluorescence (IFI)

IFI is undertaken using cryostat sections of T. solium cysticerci obtained from pigs (51) or with a fat-free extract (65, 75). Highly specific results have been reported (51) with this method.

Complement fixation (CF)

CF is done with a delipidized crude extract obtained from pig cysticerci. This test is employed only with cerebrospinal fluid because of the false positive results obtained when sera have been studied (101). In some laboratories reliable results have been reported

(102), but in general results obtained with the CF test have been inconsistent. This may be due to the difficulties in the standardization of the test. The evidence indicates that the test lacks both sensitivity and specificity (62).

Limitations in application

A lack of sensitivity inherent in some tests can be due to the use of an inadequate antigen preparation. Most antigen preparations from parasites are complex mixtures of specific and non-specific components (62). Thus the purification of various antigens (perhaps mixing them in optimal proportions) could be ideal for the standardization of antigen preparations. Another source of low sensitivity in serological tests is the existence of patients who are immunologically non-responding (36).

The methods in current use for detecting antibodies have various limitations. These include: (a) lack of sensitivity of immunoelectrophoresis; (b) the fact that indirect haemagglutination does not readily distinguish cross-reactions; (c) the subjective nature of evaluating the indirect immunofluorescence in parasite sections; (d) complement fixation is a complicated technique and sometimes serum samples have anti-complementary activity. The ELISA has several advantages over the other procedures, since the enzyme label on the antiglobulin serum is relatively stable and safe and the reaction can be quantified using comparatively inexpensive equipment. There is some evidence that ELISA is more sensitive than IHA (57) and that it can be used with pure antigens (31) or with crude extracts (3). A modified ELISA can also be used to detect parasite derived antigens in the host serum. Both ELISA and IHA are suitable for use in automated assay systems and thus have a greater potential for routine and epidemiological use.

There are few studies in which intradermal tests have been used for the detection of cysticercosis in man (95, 126, 151). This may be due to an unsupported but established belief that there is a risk of stimulating an allergic reaction, either generalized or localized, at the site surrounding the cysticercus.

Limitations in specificity are due mainly to the presence of cross-reactions between parasites (20, 23, 38, 108, 151). False-positive reactions in immunodiagnostic techniques may be explained also by inapparent extracerebral cysticercosis or a past or resolved infection, or by asymptomatic neurocysticercosis (10, 17, 45, 71, 81, 86, 92, 115, 128).

For epidemiological surveys where large numbers of sera are examined, the test of choice should be simple, inexpensive and show a well-defined degree of sensitivity. These prerequisites are met by the ELISA. Nevertheless, errors could occur depending on the general prevalence of cysticercosis and other co-existing or cross-reacting parasitoses. Sera from patients with hydatidosis react with a crude extract from T. solium cysticerci in IHA (125) and sera from patients with cysticercosis are positive in IHA for hydatidosis (62) and also react with T. saginata antigen (38, 62). In some cases, cross-reactions can be characterized. Sera of patients with neurocysticercosis may form precipitation bands in IEP against an Ascaris lumbricoides extract, the bands nevertheless have different mobilities than those formed against cysticercal antigen (38). Because of cross-reactions among cestodes the limitation of the value of immunodiagnostic tests for epidemiological surveys increases in countries where more than one cestodiasis occurs. Immunodiagnostic tests are best used as a screen for people showing positive results. Confirmation is made by other methods (scan, symptomatology, CAT, etc.). Serology can be regarded as a useful tool as a measure to strengthen the diagnosis of cysticercosis with neurological symptomatology.

2.5.4 Animal cysticercosis

There are similar limitations to the application of serodiagnostic techniques in field infections of cysticercosis in animals as those encountered in humans. Further difficulties arise because of the poor sensitivity of the various tests which means that they are unable to detect the minimal antibody levels produced by light infections (2, 12, 22) or by infection of neonatal animals where the immune response is poor (43, 134). A further complication is that the detection of low antibody levels are affected by interference from non-specific or cross-reacting antigens (22, 49, 57).

It is usually necessary to select an end point in serodiagnosis which is a compromise between sensitivity and specificity. However, the advent of new techniques for the identification and isolation of specific surface antigen of helminths makes it likely that serodiagnostic tests with improved specificity and sensitivity will be developed in the future.

2.5.4.1 Swine cysticercosis

Sources of antigen

Antigens usually have consisted of extracts of cysticerci of T. solium obtained from pigs or occasionally extracts of proglottids of the adult worm. Serodiagnosis of swine cysticercosis has not reached a stage where it is possible to recommend antigen preparations or purification methods.

Serodiagnostic tests

Complement fixation test

This technique was found to give too many false-positive reactions (11) in naturally infected swine. Indeed, in general it is an unsatisfactory test for pig serum because of its high level of anti-complementary activity.

Indirect haemagglutination test

Using antigen from cysticerci, this technique has been found useful in measuring antibody levels in experimentally infected swine with eggs of T. solium (58) but the titres obtained do not correlate with the degree of infection (59). Other studies in Mexico and South Africa (11, 96, 114) have encountered problems similar to those in cattle, namely lack of specificity and sensitivity in lightly infected animals.

Latex agglutination

This has had limited use in Africa (96) and requires further standardization and evaluation.

Other immunodiagnostic tests

Ring-precipitation and agar gel diffusion tests have been used by various workers (8, 11, 59, 82, 96, 129, 139). However, they have proved of little value in the detection of natural infections because of their poor sensitivity.

Immediate type hypersensitivity skin reactions and passive cutaneous anaphylaxis (PCA) tests have been used to measure antibody responses in artificially infected pigs (59). However, false-negative and false-positive reactions were frequent with both tests.

Evaluation

Serodiagnostic tests have proved of little value in the diagnosis of natural infections of T. solium in swine. They suffer from low sensitivity and low specificity and cannot be recommended for use at this time.

2.5.4.2 Bovine cysticercosis

Much work has been done on the serodiagnosis of bovine cysticercosis and the majority of techniques in general use for the detection of immune responses have been employed. Probably all such tests are satisfactory in experimentally infected animals but it is the general consensus of workers that none of them is effective for the detection of field infections.

Sources of antigen

Homologous materials are the most specific for serodiagnostic tests and various preparations of cysticerici, oncospheres and proglottids of T. saginata have been used effectively. An extensive range of shared antigens exists between the various developmental stages of the parasite and host components present in the cysticerici may modify specificity (130).

Antigens from cysticerici

Mature transparent cysticerici collected from freshly slaughtered cattle are commonly used. Suppurating and calcified cysticerici should be excluded. Cysticerici may be separated into fluid and tissue components or homogenized whole and are usually lyophilized for storage. Many workers delipidize this material before undertaking further antigen preparation. The methods of preparing antigens often differ between laboratories. To overcome the difficulties associated with this, the EEC Working Group on Bovine Cysticercosis has recommended the establishment of a standard antigen prepared for the serodiagnosis of bovine cysticercosis (144).

Soluble extracts of cysticerici are prepared in various buffers and they may be used without further fractionation although the protein and/or carbohydrate contents are usually determined and standardized. Fractionation of crude extracts has been undertaken by physicochemical methods including chromatography (56, 76). However, recent studies of taeniid antigens suggest that undue fractionation to produce a single antigen determinant may be unwise from the serodiagnostic point of view and a complex of antigens may be necessary to detect antibody responses to cysticerici (48, 49).

Excretory and secretory products of cysticerici maintained in culture have also been used (57).

Antigens from oncospheres

Activated oncospheres of T. saginata have been used in indirect immunofluorescence tests (77, 131) and in radio-immune assays (7).

Antigens from adult worm

Adult worms are usually obtained following therapy. Generally, antigen preparation from them follows the same procedures used for cysticerici to produce soluble extracts which may be used in their crude form or after further fractionation. Cryostat sections of T. saginata proglottids have been used for indirect fluorescence (32).

Heterologous antigens

Because of the difficulty of obtaining T. saginata adults and metacestodes in some countries, a number of workers have used related taeniids as a source of antigen. All taeniids so far studied appear to have a similar antigen composition (49, 118) and an advantage has been taken of this in the use, for example, of metacestodes of Taenia crassiceps. These can be permanently maintained by serial passage in mice or rats and provide a ready source of antigen for the detection of antibody in bovine cysticercosis (46, 49, 57, 146). The EEC Working Group on Bovine Cysticercosis has recommended that T. crassiceps should be used to prepare a standard antigen.

The metacestode stage of T. pisiformis has also been used in serodiagnostic tests (7).

Immunodiagnostic tests

The literature on the serodiagnosis of bovine cysticercosis has been reviewed extensively (47). As indicated above the main problems in using serodiagnosis of field cases of bovine cysticercosis results from the low antibody levels encountered in natural infections.

Such low antibody levels necessitated the use of many sensitive procedures that are particularly prone to interference from non-specific reactions (22, 48, 49, 57). In deciding on the most suitable technique for field use, it should be noted that those which are intrinsically most sensitive offer the possibility of further improvement in diagnostic accuracy, if the specificity of the antigen can be increased.

The techniques that have been most commonly used include complement fixation (CF), the intradermal test (ID), the indirect fluorescent antibody test (FA), immunoprecipitation (IP) and its variant immunoelectrophoresis (IEP) and counter-current immunoprecipitation (CCI), indirect haemagglutination (IHA), latex agglutination (LA) and more recently the immunosorbent assays using for example fluorescent (SAFA), isotopic (RIA) or enzyme (ELISA) labelled immunoglobulin markers. Cell mediated immunity techniques have also been assessed.

Intradermal tests

These have the advantage that blood sampling is avoided and a decision on their use can be made at the farm. The reaction is of the immediate type and antigens prepared from eggs or from tapeworms (42, 80, 127) or from cysticerci (18) have been used. Positive reactions may occur as early as three weeks after experimental infection (127).

With natural infections positive intradermal reactions correlate fairly well with the presence of parasites (18, 42). However, cattle infected with liver trematodes may give false-positive reactions and a high degree of cross-reactivity in infected animals has been reported using antigens from other larval cestodes and from Fasciola hepatica.

Complement fixation

While this test and its various modifications (e.g. conglutinin complement absorption test) has been used to detect antibody responses in experimental infections (68, 133, 134) it has proved too insensitive for the detection of natural infections (39).

Indirect fluorescent antibody (IFA)

Studies with cryostat or paraffin sections of T. saginata and sera from infected cattle have shown that this technique is insensitive (2, 52, 147). Activated oncospheres have been used for IFA in experimentally-infected animals and it has been reported that antibody can be detected 1 week after infection (131). However, these results have not been translated to field use.

Indirect haemagglutination test (IHA)

The IHA has enjoyed some popularity and a range of antigen preparations has been employed. However, the specificities and sensitivities that have been reported have varied considerably. In experimental infections the IHA, along with ELISA, is one of the most effective techniques for detecting antibody in bovine cysticercosis. However, in natural infections it suffers from an unacceptably low degree of sensitivity and specificity (7, 88, 144).

The IHA test does have some potential in terms of simplicity and the possibility for automation and, when more specific antigens become available, it may prove to be a technique of value.

Immune precipitation tests (IP)

These include agar gel diffusion (Ouchterlony) immunoelectrophoresis and counter-immunoelectrophoresis. These techniques are useful in studies of experimental infections, but in general they are too insensitive to detect natural light infections. Heavy natural infections have been detected by the ring precipitation techniques (132).

Enzyme linked immunosorbent assays (ELISA)

This technique is one of the most suitable for routine laboratory diagnosis and is readily automated. When highly specific antigens become available it is likely that ELISA will be the technique of choice to exploit them. However, at present, while proving useful in experimental infections, using either T. saginata (1, 146), or T. crassiceps antigens (146), ELISA shows poor specificity in natural infections, possibly due to cross-reactions with other parasites of grazing cattle (22).

Cell mediated immunity reactions (CMI)

Studies to detect CMI responses have been carried out on experimentally infected animals, but have not been used to detect natural infections. Positive lymphocyte transformation responses have been followed in calves using T. saginata and T. crassiceps antigen (70). Positive responses were evident one week after infection and remained positive for the several months duration of the study. Uninfected animals failed to respond. Inhibition of macrophage migration has been demonstrated and the responsible lymphokine (MIF) has been demonstrated from the lymphocytes of experimentally infected cattle (13). With the recent developments in CMI techniques, which employ whole blood cultures and automated cell harvest and isotope counting procedures, further attention might be given to these tests as diagnostic procedures.

Evaluation

During the last few decades, much effort has been undertaken to improve methods for the diagnosis of bovine cysticercosis. A standardized, sensitive, specific, simple and inexpensive method, which would produce reliable results in herd testing programmes, or which would enable a rapid and reliable post-mortem diagnosis in the slaughterhouse, would be of great value for the intensified control of cysticercosis. None of the immunobiological tests, used so far for the diagnosis of bovine cysticercosis, have met all of the above criteria. Nevertheless, there may be ways in which these sub-optimal techniques may be usefully employed. For example, they might have applicability as "herd tests" to determine freedom of cysticercosis or as a means to identify groups of infected animals.

Future prospects in immunodiagnosis will include the application of hybridoma and related technologies to the characterization of parasite antigens and the isolation of selected antigens from complex parasite extracts by the use of monoclonal hybridoma-derived antibodies in immunochemical procedures. Hence, although the present immunodiagnosis tests are unsatisfactory, there is every hope that sensitive and specific procedures will be developed in due course.

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CHAPTER 3 - EPIDEMIOLOGY

3.1 Introduction

The life cycle of taeniid tapeworms is complex, involving two hosts and a free-living stage. Throughout this whole system there is heterogeneity. At any one time, the parasite population consists of three distinct subpopulations: adult tapeworms in the definitive host, cysticercus (metacestodes) in the intermediate host, and eggs in the environment. When assessing the epidemiology of these cestodes and thus their stability, all three subpopulations must be taken into account; no part of the life cycle can be considered without reference to the other parts because all are interdependent.

There are several recent reviews describing the epidemiology of transmission of the taeniasis cysticercosis complex (16, 63, 67, 87, 88, 89, 90, 93, 94, 97, 99, 100, 101, 146, 195, 196, 197, 198). An understanding of the important factors in transmission, and their impact on the stability of each parasite system to perturbation, is crucial for veterinary and medical authorities planning control tactics and strategies.

There are obvious logistic and technical problems in studying the dynamics of transmission of T. saginata and T. solium where man is the obligatory host. No such restraints apply to the ovine cysticercoses represented by Taenia hydatigena and Taenia ovis, with dogs and sheep as the definitive and intermediate hosts, respectively. The information on such factors as egg-dispersal, infection pressure and immunological regulation, which can be measured in this system, has relevance as a model to bovine and porcine cysticercosis. However, there is still a need, where it is possible, to measure these effects using these two human taeniasis/cysticercosis systems.

This Chapter describes the geographical distribution and the factors which lead to it and the various events, which support the survival of these parasites in the many ecological (nidal) situations where they occur. Where data are available on T. saginata and Taenia solium these are given emphasis.

3.2 Global distribution of Taenia saginata taeniasis/cysticercosis

Taenia saginata is distributed globally but the infection is particularly important in Africa and Latin America as well as in some Mediterranean countries (193, 196, 197, 198). However, information on its prevalence in man and cattle is incomplete (Appendix 1).

Several sources provide data on the diagnosis of tapeworm infections including mass helminthological surveys in selected groups of the population, and laboratory and hospital records of reported cases. There are a few countries in which mass helminthological surveys are performed regularly and which include a specific examination for taeniasis. In any case, mass surveys for intestinal parasites, such as nematodes, will always underestimate the prevalence of Taenia spp. In the USSR, based on 14.2 million samples, the mean prevalence of taeniasis was 0.6% in 1950 and 0.3% in 46.4 million stool examinations in 1960 (214). The distribution, however, was uneven with up to 1% in the western republics (e.g. Ukrainian, Latvian, Estonian, Lithuanian and Belorussian SSR), and between 8% and 45% in the Caucasian area (southern Dagestan ASSR, western Azerbaidzhan, northern Armenian and eastern Georgian SSR) and in the south-central-Asian republics (The Uzbek, Kirghis and Kazakh SSR) (198, 214).

A few countries have introduced the compulsory notification of human T. saginata infections. However, a survey in the city of Poznań showed that 5 years after the introduction of compulsory notification, as many as 20% of T. saginata cases had not been formally registered (194, 198).

The prevalence of T. saginata in man can be roughly classified into three groups: i) those countries or regions which are highly endemic with a prevalence in the human population which exceeds 10%; ii) those with moderate infection rates; and iii) those with a prevalence below 0.1% or even free from endemic T. saginata taeniasis (198).

The highly endemic areas include Central and East African countries (Ethiopia, Kenya, Zaire). Endemic areas occur in the Caucasian and south-central Asian republics of the USSR and in the Mediterranean (Syria, Lebanon and Yugoslavia). For example, in some parts of

Serbia and Montenegro, up to 65% of children have been reported to harbour T. saginata (205). Europe belongs to the region with moderate prevalence, so also do South East Asia (Thailand, India, Vietnam, the Philippines) Japan and South America.

The prevalence of T. saginata is low in the US, Canada, Australia and some western Pacific countries.

3.2.1 Changing prevalence

The prevalence of T. saginata taeniasis and cysticercosis has been changing. For example, in Germany before the introduction of official meat inspection at the end of the 19th century the prevalence of human taeniasis was about 5% and that of bovine cysticercosis more than 5%. Following the introduction of meat inspection, the prevalence of bovine cysticercosis declined to 0.37% in 1910. For the next 40 years, the prevalence was maintained at 0.3%, but from the decade 1950 it increased to 2%. Some of the increase may be due to a change in meat inspection legislation in the Federal Republic of Germany. Prior to 1961, the statistical data were only based on animals with viable cysticerci. After that date, all animals with cysticerci, irrespective of viability, have been included in the statistics. The present official statistic is about 0.8%.

Taenia saginata taeniasis/cysticercosis were rarely diagnosed in England before 1940, but in 1955 the prevalence of cysticercosis was estimated to be between 0.81 and 3.47% (248). An analysis of 85 publications on taeniasis/cysticercosis from various European countries after 1945, showed that T. saginata became common in the United Kingdom, Denmark and Holland from 1940, in Belgium, Germany, Italy, Yugoslavia, Czechoslovakia and Poland from 1950, and in Sweden, Hungary, Romania and Bulgaria from 1960 (193). The data from various slaughterhouses clearly illustrate this point: Prague 0.32% in 1945; 1.6% in 1955, and 3.1% in 1964; Berlin: about 1% between 1945 and 1959, and 5.5% in 1965; Genoa: 3.4% in 1951 and 8% in 1953; St Polten: 0.6% in 1954 and 2.3% in 1960; Poznań: 0.5% in 1955 and 2.3% in 1962 (198); Halle: 7% in 1962 and 7.3% in 1966 (187).

3.3 Global distribution of Taenia solium taeniasis/cysticercosis

Taenia solium is important in some pork-eating countries and is mainly restricted to regions of low social and economic development (167, 197). It is endemic in Latin America, South Africa and non-islamic South East Asia.

The prevalence of T. solium infection varies greatly according to the regional level of sanitation, pig husbandry patterns and eating habits. It is very difficult to evaluate the prevalence of T. solium taeniasis, as the coproscopical methods used for survey are usually inadequate and, in addition, do not differentiate between T. solium and T. saginata infections (197).

Taenia solium cysticercosis has a wide distribution and has been reported in Central and South America (156, 188), Spain, Poland, the USSR, the Far East and other countries (167). The available data on porcine cysticercosis are summarized in Appendix 1.

3.3.1 Latin America

Available indices point to there being a substantial risk of infection with T. solium to residents of many Latin American countries, although there are no precise data on the overall prevalence (Tables 7-13). Concerning cysticercosis in the human population, (235, 291, 304), the frequent finding of neural cysticercosis in autopsy cases from general hospitals (0.4-3.2%) (220, 304), its notable presence among the patients of specialized neurological institutions (4-6%) (291), and the overall 1% of serological positivity to cysticercal antigens found in the general population of Mexico (304) all indicate an active transmission of cysticercosis in many Latin American countries (235). Although prevalence rates seem to vary among the different countries, or regions within a country (64), little credence should be placed on fine points as the data are not equally representative. However, four additional observations are of interest: a) the fact that a large proportion of neurocysticercosis cases found at necropsy were asymptomatic (34, 80, 170, 220); b) its comparatively low incidence in children (Table 8) (230); c) its remarkable association with immunological deficiencies in young children (Table 9) (229); and d) its indiscriminate incidence in different social, economic and cultural groups, in Mexico (304). These points

have raised speculations concerning the epidemiological value of clinical data, the role of immunological events in this host-parasite relationship (209) and on the mechanisms of transmission less socially discriminative than food habits, such as the ingestion of dispersed eggs (304).

Porcine cysticercosis is also frequently found in the abattoirs of Latin America (Table 10 and 11) causing serious economic losses (5). In Mexico alone, slaughterhouses lost about US \$43,000,000 in 1980 because of carcass condemnation (4). Further, these data are thought to be conservative indicators since ostensibly infected pigs, usually not taken to the slaughterhouse, are killed elsewhere (8).

The high prevalence of pig cysticercosis should be accompanied by quite conspicuous *T. solium* tapeworm infections in man. However, the diagnosis of taeniasis is quite difficult because of its nonspecific and mild symptomatology. Thus, the data in Tables 12 and 13 should be considered as minimal estimates (235).

TABLE 7 - Prevalence on human cysticercosis in some Latin American countries (Modified after 304).

Country	Morbidity Indices (%)		
	Clinical Cases	Autopsy Cases	Serological Surveys
Brazil	3.0, 0.8		
Chile	0.6, 0.9		
Colombia	0.9	0.4	
Costa Rica		0.4	
Ecuador		0.4	
El Salvador		0.4	
Mexico	10.5	2.0	2.4
Peru		0.45	
Venezuela		0.5	

TABLE 8 - Prevalence (Morbidity indices, %) of human cysticercosis in Mexico (After 304).

Clinical Cases		Autopsy Series	Serological Surveys
Surgery	Clinical		
35.0	11.0	3.5	3.8
28.3	8.9	3.2	1.0
25.0	3.9	3.1	
3.1	0.08	2.8	
0.03 ^b	0.03 ^b	2.8	
0.17 ^b		2.6	
		2.6	
		2.2	
		2.1	
		1.6	
		1.5	
		1.3	
		0.9	
		0.8	
		0.38 ^b	
		0.14 ^b	

^b Figures refer to prevalence in children only.

TABLE 9 - Correlation of symptomatology and immune response to anticysticercus antibodies in seventeen pediatric cases with cysticercosis confirmed by autopsy.

Basic Disease	Total number of cases	Symptom associated with cysticercosis (number of cases)	anticysticercus antibodies		
			+	-	Not determined
Cysticercosis	5	5	4	1	0
Leukemia	3	0	0	1	2
Lupus erythematosus	2	1	0	0	2
Ataxia-telangiectasia	1	0	0	1	0
IgA deficiency and lymphoma	1	1	0	1	0
Gastroenteritis	1	0	0	0	1
Hepatitis	1	0	0	1	0
Pneumonia	1	0	0	0	1
Cervical cellulitis	1	0	0	0	1
Poliomyelitis	1	0	0	0	1
Total	17	7	4	5	8

TABLE 10 - Frequency of porcine cysticercosis in slaughterhouses throughout Mexico from 1924 - 1981.

Year	Location of slaughterhouses	%
1924-1928	Several	12.6
1939-1954	Several	4.1
1962-1963	Ferreria, Mexico City	2.7
1964-1965	San Luis Potosi, S.L.P.	4.5
1965-1966	Leon, Guanajuato	4.1
1967	Ferreria, Mexico City	1.9
1967	Netzahualcoyotl, State of Mexico	3.4
1968	Léon, Guanajuato	2.2
1968	Ferreria, Mexico City	1.5
1968	Netzahualcoyotl, State of Mexico	4.7
1969	Ferreria, Mexico City	1.3
1970	Los Reyes, state of Mexico	0.7
1973	Several	0.53
1975	Sonora	0.54
1980-1981	75 Slaughterhouses in 22 states	1.55

TABLE 11 - Frequency of cysticercosis in hogs slaughtered in six abattoirs of Central America and Panama, 1959-1961* (After 5).

Country	No. slaughtered	Condemned for all causes		Condemned for cysticercosis		
		No.	%	No.	% of total slaughtered	% of total condemned
Costa Rica	106, 355	3,063	2.87	2,031	1.91	66.3
El Salvador	71,345	2,032	2.84	1,323	1.85	65.1
Guatemala	121,312	3,803	3.13	2,511	2.07	66.0
Honduras	55,679	1,974	3.51	1,415	2.54	71.6
Nicaragua	87,339	2,440	2.80	1,526	1.75	62.5
Panama	101,612	3,788	3.72	2,822	2.78	74.4
Total	543,672	17,100	3.14	11,628	2.13	68.0

* Source of information: reports of the Veterinary Public Health Services of Central America and Panama; records of six abattoirs of Guatemala City, Managua, San Salvador, San Jose, Tegueigalpa, and Panama City; reports of Veterinary Services of the Ministries of Agriculture of Central America and Panama, 1959-61.

TABLE 12 - Frequency of human Taenia infection in eleven Latin American countries (Modified after 235).

Country	Locality	Period	% Infection		
			<u>Taenia spp.</u>	<u>T. Solium</u>	<u>T. Saginata</u>
Brazil	Belo Horizonte Natal Guanabara, Sao Paulo	1965-68	1.0 (0.2-2.7)		
Chile	Schwager, Concepcion, Santiago, entire country	1958-80	0.2 (0.1-1.7)	0.3	1.9
Colombia	Entire country	1969	0.3		
Cuba	Havana	1967			0.1
Ecuador	Manabi, Canar, Loja	1958-74	1.0 (0.3-1.0)	0.9	
Guatemala	Entire country	1964		1.1	1.7
Haiti	Port de Paix	1964	0.1		
Mexico	Nueva Leon	1970-1971	0.6 (0.1-1.1)		
Panama	Canal Zone	1960			0.2
Uruguay	Entire country	1972			2.5
Venezuela	Central valleys, coast, Lago Valencia mountains, plains, Lara, Yaracuy	1961	0.2 (0.1-0.6)		

TABLE 13 - Frequency of Taenia solium in human stool specimens compared with other tapeworms in Guatemala (After 5).

Year	No specimens examined	Percentage positive		
		<u>Hymenolepis</u> <u>nana</u>	<u>Taenia</u> <u>saginata</u>	<u>Taenia</u> <u>solium</u>
1951	8,114	2.69	2.14	2.07
1952	11,816	2.19	1.33	0.88
1953	13,416	4.70	1.23	0.73
1954	13,720	5.12	1.95	1.34
1955	15,664	3.54	2.46	1.68
1956	17,007	3.68	1.95	1.25
1957	18,140	2.95	1.56	0.74
1958	18,723	2.89	1.52	1.19
1959	18,551	2.42	1.65	1.16
1960	21,934	2.37	1.59	0.80

3.3.2 Africa

Compared with other tropical areas, Africa has very few pigs - the total for the whole continent is less than in Mexico. There are a number of African Muslim countries in the north where pigs are neither reared nor eaten. The only country with more than 1 million pigs is the Republic of South Africa and here there have been several studies of cysticercosis in relation to epilepsy (129, 130, 212). In these studies very low infection rates with adult T. solium were recorded in man and the infection rate in pigs, examined in abattoirs, was less than 1.5%. Only in the Transkei are pigs reared by the local Bantu and here the infection rate is considered to be high. The relatively high prevalence of human cysticerci in the Bantu population in many parts of the country has been attributed to the widespread practice of using tapeworm proglottids as a component of "muti" a medicament used by native herbalists for the treatment of intestinal worms (130). Taenia solium has been recorded from many countries in southern Africa including Zimbabwe where cysticercosis was recorded in 0.45% of 2,148 autopsies (81).

Taenia solium also occurs in Malagassy where 91 out of 34,137 persons with neurological symptoms were diagnosed as having T. solium cysticercosis (14). Between 0.1 and 8.1% of 20,200 pigs slaughtered in different regions of Zaire were infected with T. solium cysticercosis and there are records of human cysticercosis from Zaire (190, 208).

There are several species of Taenia in dogs, cats and wild carnivores in Africa and the cystic stages are found in a wide range of wild animals, including bush pigs and warthogs. Cysticerci are common in human brains in Zaire, Uganda and Rwanda, and T. hyaenae is found in camels and cattle (183, 292). The cysticerci in some of these species are morphologically very similar to T. solium. Because there is less host specificity with the larval tapeworm than with the adult parasites it is possible that some of the infection with cysticerci in humans and domestic pigs are T. solium. On the other hand, a careful study of cysticerci from wild pigs in Africa has shown that they are not T. solium (292).

3.3.3 Asia

The distribution of infection in Asia depends much on raw pork eating habits. The parasite is common in some parts of the continent only. There is limited information on the frequency of T. solium taeniasis/cysticercosis in the two most populous countries: India and China.

Routine stool examination of 250 000 patients hospitalized in northern India between 1964 and 1981 revealed taeniasis in 0,5-2.0% of cases. In labour colonies and slums in which pigs are raised, this figure rose to 12-15%; in these locations cysticercosis was found in 10-12% of pigs (167). Sporadic cases of cerebral, ocular and extracranial cysticercosis in man have been described in practically every part of India (138, 168, 191, 240, 254, 293), but the prevalence seems to be far higher in the northwestern states of Punjab and Haryana (297). Cerebral cysticercosis is the second most important cause of intracranial space-occupying lesions following tuberculosis, and one of the major causes of epilepsy in India (167). A few decades ago, human cysticercosis was quite common among the army troops stationed in India (51, 52). Cysticercosis was observed to be higher among Tibetans, Lepchas and Sikkim Bhotiyas who consume uncooked animal flesh, and low in Nepalese and Indian populations who, even when non-vegetarian, cook their food thoroughly (175). For the same reason, the Chinese population in Asia are not frequently affected by T. solium infection, although some foci of taeniasis/cysticercosis exist in mainland China.

T. solium taeniasis and cysticercosis is common in Indonesia. A very high prevalence of human taeniasis and cysticercosis, causing an "epidemic" of epilepsy and burns, has been reported in a few localities of the Wissel lakes area, West Irian Jaya (267, 277, 280). The prevalence of T. solium infections is also high in Bali, Indonesia (253). In a village in Bali, 3% out of 199 inhabitants had subcutaneous nodules suspected as T. solium cysticercosis; epileptic seizures were reported in another village in 8% of the population; approximately 2% of 548 examined persons had taeniasis; about half of these being diagnosed as T. solium and several pigs were heavily infected with cysticercosis. T. solium infections have also been reported from Thailand, South Korea (177) and Taiwan (23, 133).

3.3.4 Changing prevalence

During the first half of the 19th century, 2% of human autopsies carried out in Berlin revealed the presence of cysticerci (31).

T. solium taeniasis and cysticercosis has disappeared in most of Western and Central Europe, and is also disappearing from Eastern and Southern Europe. In the USSR cysticercosis was found in 0.14% of pigs in 1962 and in 0.004% in 1970 (24, 25). With the exception of some endemic foci in the USSR and Yugoslavia, and occasional sporadic case reports from southern Europe, few foci remain. In Europe in general, improved pig husbandry, changing sanitary habits of the human population and meat inspection have lead to a marked reduction of T. solium in animals and man (22).

3.4 Factors affecting transmission

3.4.1 Taenia saginata

There are three main categories in the pattern of transmission of T. saginata (196). These are: i) hyperendemic, characterized by, for example Kenya, with pastoral farming in areas with a high prevalence of T. saginata taeniasis in man and cysticercosis in cattle; ii) endemic, characterized in, for example Poland, by the existence of a small number of human carriers, a wide dispersal of eggs in the environment and a moderate prevalence of bovine cysticercosis mostly of low intensity; iii) epidemic, characterized by feedlot situations, e.g. in the United States, Czechoslovakia and Canada. These can be caused by a single human carrier, whose close contact with a herd of susceptible cattle can result in a massive outbreak of bovine cysticercosis.

3.4.1.1 Transmission from cattle to man

In pastoral societies raw or rare meat is part of the normal diet. The increase in T. saginata taeniasis in many countries, is associated with the increased consumption of raw and rare beef, even though it may have been examined by the meat inspector service.

The transmission of T. saginata infection from animals to man depends very much on the human habit of eating raw or semi-raw beef dishes like beef tartar shaslik in the USSR (2), basterma in the Near East (182), shishkebab and tikka in India (10), larb in Thailand (38), or pieces of meat simply roasted over an open fire in Central and East Africa (37). There is also the chance of being infected by tasting meat during mixing and cooking (132, 263).

It has been reported (196) from Poland that there is a strong preference in some individuals for raw beef and it may be established in some whole families; furthermore, it is determined by profession (the meat industry, restaurant workers), sex (preparation of food), and marital status (dining out when single). Both the habit of eating raw beef and ready access to it play important roles in transmission. It has also been confirmed that the infection rate in man is closely related to the frequency of eating raw beef (152).

Taenia saginata has been reported in children less than one year of age as well as in people over 80, although the infection is most common in the 20-40 age group. In an urbanized society, for example in Poland, of the 90% of carriers who admitted to eating raw meat, 44% ate it exclusively at home (mostly married women and children), 22% exclusively outside of the home (mostly single men and women), and 24% both at home and in public places (mostly married men) (192, 196). The risk of being infected was 5 times greater in members of a carrier's family, 14 times greater in workers with professional contacts with raw meat, and 40 times greater in raw beef eaters who had already been infected in the past compared to the risk of infection in the general population (192).

Man is usually parasitized by a single T. saginata tapeworm. Only in highly endemic areas do multiple infections exceed 40% of all tapeworm infections, and as many as 150 tapeworms have been recorded in one person (210). Superinfection one week and 2 months after ingestion of the first invasive cysticerci has been recorded (132).

3.4.1.2 Transmission from man to cattle

Man, as the definitive host of the T. saginata tapeworm, is the only disseminator of the eggs. The mean daily production exceeds 150 000 eggs (76), but much higher egg outputs have been reported (308). However, experimentally it has been shown that proglottid and egg output is very variable.

In developed countries, the movement of people in the form of camping and tourism provides the opportunity for the spread of proglottids and faeces in cattle raising areas (6). The uncontrolled defaecation and inadequate destruction of viable Taenia eggs in sewage also play an important role in the spreading of T. saginata infection (198). Most conventional sewage treatment plants do not remove taeniid eggs (115, 150, 250). This is discussed in detail later in this Chapter.

The normal transmission to cattle is accomplished by the contamination of pasture, fodder and water with eggs (6, 118, 248). The direct transmission of eggs can occur when a human carrier is suckling calves using his contaminated hands (139, 282). Oncospheres have been found in finger nail dirt, water used to wash hands and underwear (231).

Hyperendemic pastoral cysticercosis

Hyperendemic pastoral cysticercosis is the common epidemiological picture in the African continent (130). In one study, in the Narok district of Kenya, bovine cysticercosis was present in 53% of the cattle owned by Masai tribes-men and the prevalence of taeniasis among the adult Masai was 28% (74). The Masai eat meat roasted in large pieces over an open fire; they keep cattle near their huts during the day and sleep close to their stock at night. In this situation, the contamination of the manyatas (homestead enclosures) with eggs is heavy.

Endemic urban/rural cysticercosis

It can be concluded that several mechanisms are operative in the effective spread of T. saginata eggs in developed as well as developing countries and this is what makes taeniasis an increasing problem in some parts of the world.

The spread of T. saginata infection has been demonstrated by epidemiological studies in Poland (195). Using "trace-back" methods on almost 10 000 cattle in the Poznań province, it was found that there was a concentration of localities with bovine cysticercosis around urban conglomerations (80%), recreation areas (72%), regions with developed agricultural industry (68%), as well as along rivers, main roads and railway tracks (Figure 14). In 80% of the localities with bovine cysticercosis, not a single human T. saginata carrier had been identified for 5 years (196).

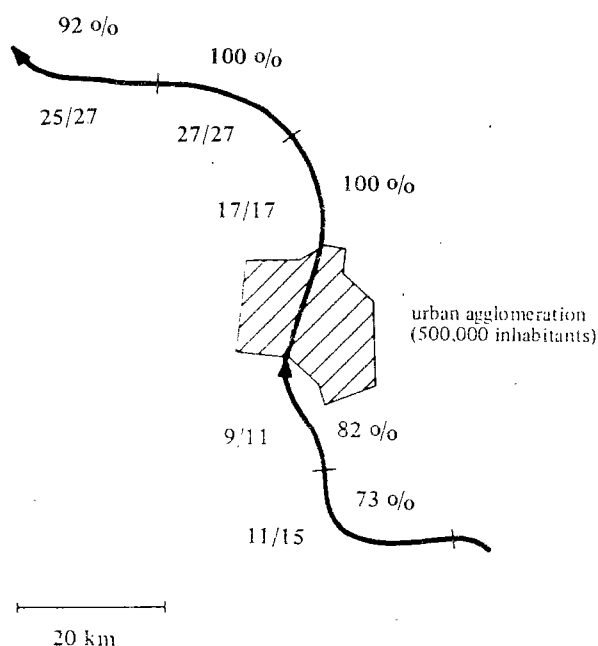


FIGURE 14 - Distribution of *Taenia saginata* cysticercosis along a river near an urban agglomeration (After 196).

- % represents percentage of localities with Bovine cysticercosis.
- Proportions (e.g. 9/11) represent the proportion of number of localities with cysticercosis (e.g. 9) to all localities of under 5 000 inhabitants situated around the indicated areas along the river (e.g. 11).

Epidemic cysticercosis

Epidemic cysticercosis, usually associated with feedlots, is now becoming quite common (26, 121, 160, 166, 178, 206, 207, 215, 216, 217, 218, 238, 239, 257, 258, 278, 296). It may arise either from direct contamination of the feedlot with eggs or from the introduction of contaminated fodder. For example, an epizootic of cysticercosis in the state of Texas in the US involved approximately 6 000 feedlot cattle with infection rates among individual cattle pens varying from 0-4% (239). The course of infection in one feedlot was probably silage contaminated with *T. saginata* proglottids excreted by a laborer, while in another, which had a lower infection rate, a second infected worker, who was in charge of cleaning the water and feed troughs, probably infected the cattle during his work.

In Canada, an attendant with *T. saginata* taeniasis, working for less than four months on the feedlot, infected more than 500 cattle: bovine cysticercosis was diagnosed in 51% of the slaughtered cattle, with high infection rates in 5% of the infected carcasses. It was found that the attendant, an immigrant, failed to observe desirable personal sanitary practices (160).

Intensive cattle husbandry practices is the principal method of animal production in Czechoslovakia. This practice lends itself to epidemic outbreaks from undetected individual carriers and cysticercosis is often transmitted by cattle-farm workers and other agricultural workers. These epidemics are frequently recorded. For example, in Bohemia, in one feedlot, 83% of the cattle developed cysticercosis and 60% in another (166).

3.4.2 Taenia solium

3.4.2.1 Transmission from pigs to man

In many cases, man becomes infected with the tapeworm during festivals when pork is eaten without proper cooking. An example of this is seen among Kapauku aborigines in West Irian, Indonesia, where the pork may be undercooked following placement between hot stones (see Figure 15). Once the infection has been introduced into an area favourable to it, it may become "hyperendemic" as has been the case, for example, in West Irian.

Consumption of uninspected pig meats is undoubtedly a major source of human taeniasis in Latin America (8). However, it is not yet clear what relative roles are played in transmission by inspected and non-inspected pork.

It is important to examine pig slaughtering and marketing methods in endemic zones to identify the various ways human taeniasis may occur. Only about 15% of the pig carcasses in Central American countries are subject to veterinary inspection (5). In some endemic Latin American countries marketing systems vary greatly. The larger establishments sell their animals to slaughterhouses through intermediaries, while owners of smaller numbers of pigs, especially in rural areas, either kill them at home for their own consumption or sell directly to the local market or to intermediaries who may sell them clandestinely (8). Meat inspection is carried out in a strict manner only in the larger slaughterhouses, whereas meat is sold without any control in most of the small villages and hamlets. Moreover, meat inspection in Mexico is under the supervision of three different authorities, each having their own standards and regulations. The Ministry of Health controls about 100 slaughterhouses in large localities throughout the Republic; the Ministry of Agriculture controls all those in which the meat is destined for export; and in villages and small towns, slaughterhouses are under the supervision of the municipality which engages a veterinarian to inspect the meat. However, lay personnel without any training can often be found stamping carcasses, frequently passing meat that is unfit for human consumption. Sick animals, or those affected by conditions that can be detected during ante-mortem inspection (such as cysticercosis of the tongue), may not be offered for sale to a slaughterhouse known to carry out strict inspection. Instead, this meat may be sold illegally to unscrupulous individuals and offered for sale in markets or to small restaurants, totally escaping control (8). This problem is illustrated in Table 14, which compares ante-mortem with post-mortem detection in a rural area of Mexico.

TABLE 14 - Frequency of cysticercosis determined by antemortem inspection compared to local slaughterhouse records in villages in the State of Mexico (After 8).

Village	Antemortem inspection		Slaughterhouse records
	Number of pigs inspected	Cysticercosis (%)	Cysticercosis (%)
Ixtlahuaca			1.09
market	269	9.66	
2 farms	20	20.0	
Almoleya			1.38
7 farms	142 ^a	7.75	
Atlacomulco			0.32
3 farms	26 ^b	30.8	
San Felipe			No slaughterhouse
3 farms	47	6.38	
Isolated hamlets (7)	128	15.62	No slaughterhouse

^a One owner admitted to eliminating whitish segments in stools.

^b Two owners admitted to eliminating whitish segments in stools.

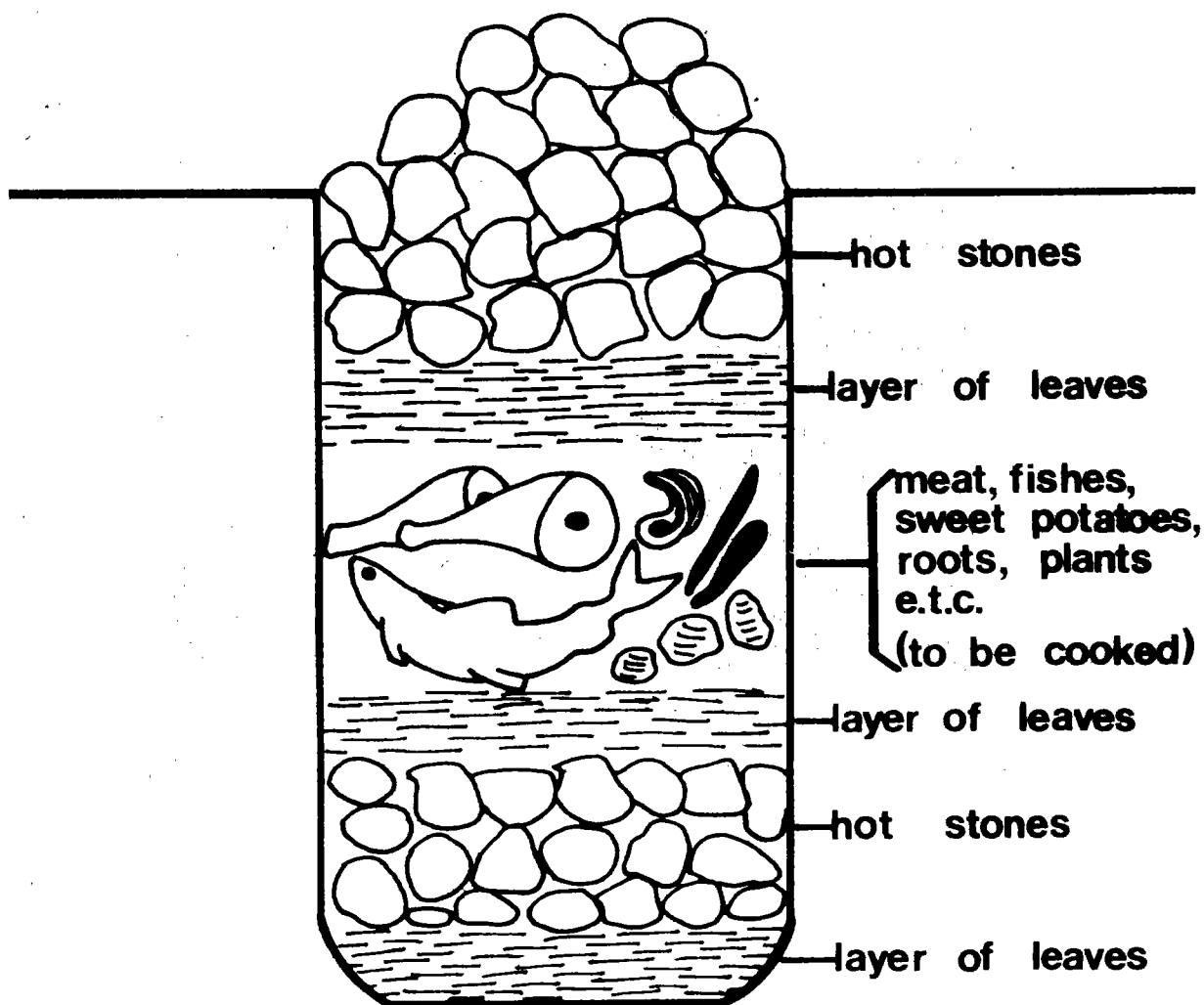


FIGURE 15 - The cooking method (schematic) in Kapauku areas (Irian Jaya).

3.4.2.2 Transmission from man to pigs

The uterus of a mature proglottid carries up to 55 000 eggs. The mature proglottids or strobilar fragments consisting of 5-6 proglottids detach from the strobila and are usually expelled passively with the host's faeces. Coprophagy is a normal activity of all free ranging and scavenging pigs. Indeed, in some parts of the world, pigs may be kept for removing human faeces and in others they may be fed with them deliberately. In many cases, pigs may ingest whole proglottids as well as massive numbers of eggs in faeces. These may result in heavy infections (5, 8, 131, 294). With modern intensive pig husbandry practices, epidemic cysticercosis (feedlot type) is unlikely to occur.



FIGURE 16 - Pig feeding on waste in a rural village (After 8).



FIGURE 17 - Toilet in a village home (After 8).



FIGURE 18 - Outlet of the toilet shown in Figure 17 to the yard (After 8).



FIGURE 19 - Pigs feeding as the outlet shown in Figure 18 (After 8).

3.4.2.3 Transmission from man to man

There are two commonly recognized ways in which it has been suggested that transmission occurs. These are: i) the ingestion of eggs in contaminated food and water; ii) the introduction of eggs from faeces into the mouth by contaminated hands. Airborne infection by draughts and through the ingestion of infected insects has been suggested but remains unproven. In addition, it has been suggested that some sexual practices may result in the ingestion of eggs and sometimes whole proglottids.

Auto-infection by reverse peristalsis of the intestine, once considered to be an important source of infection (149) particularly during treatment, is now largely discounted (300). The external auto-infection with eggs transmitted from anus to mouth or through dirty hands or contaminated food seems to be a more probable way of contracting T. solium cysticercosis, than internal auto-infection (300).

In some societies, for example Bantu people, massive invasion may also be caused by using local medicine prepared from proglottids (129).

With regard to the transmission processes described above, a large serological survey in Mexico failed to show that there were distinctions between social classes and sero-positivity. This draws attention to the fact that very little is known about the relative importance of each transmission process from man to man.

3.5 The dynamics of transmission

3.5.1 Stability of the system and its implication for control

The stability of a biological system describes its ability to return to equilibrium after wide fluctuations in one or more of its population components. Although the response of ecosystems to external perturbation may be modelled theoretically, it has been suggested that stability can only be determined "by giving the system a push and seeing what happens" (33). Stability is an essential part of the description of host/parasite systems and epidemiological studies should include the effects of attempting to disturb the population. The most practical way to do this is to measure the effects of trial control programmes on the system.

3.5.2 The infective pattern

The infective pattern of a parasite within a host population is described by both the mean level of infection and its distribution within the population. Almost all the factors to be discussed in this section contribute towards the mean level of infection within the host populations. As a general rule, the distribution is overdispersed, with most of the animals carrying light infections and only a few harboring heavy worm burdens. This may be described by the negative binomial distribution (11, 13, 47, 48). Usually, this overdispersion increases as the density of the parasite population increases (11, 12, 13). The degree of heterogeneity in the infective pattern can be tested by Fisher's index of dispersion (60) (see Figure 20).

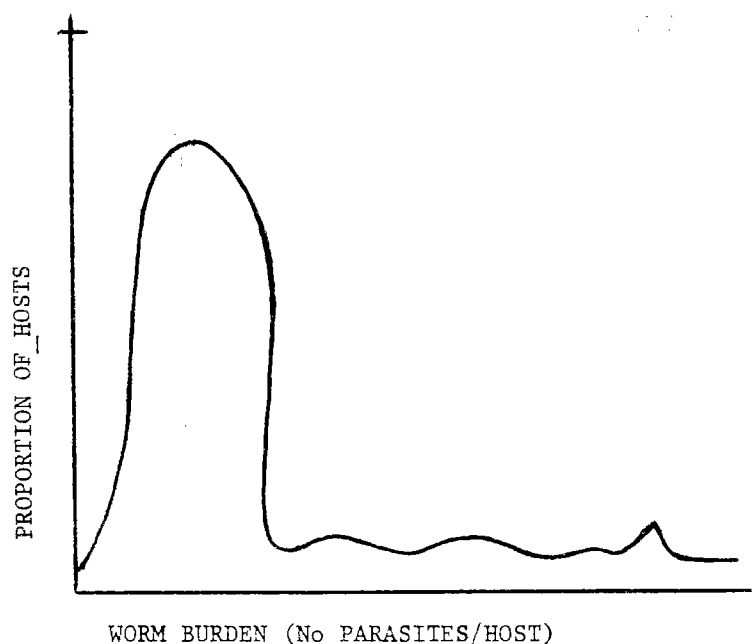


FIGURE 20 - An example of an overdispersed distribution.

Experimental egg feeding and field studies with T. hydatigena and T. ovis have confirmed that these two parasites exhibit marked overdispersion (aggregation) in the intermediate host, both with regard to the number of parasites established and to the number surviving (97, 99, 100, 146). In addition, the indices increase markedly in the experimental situation as the number of eggs ingested at the initial infection is increased. The infective patterns of T. saginata and T. solium have not yet been fully described, but the observations made on the former suggest a similar overdispersion occurs.

Heterogeneity is generated by the interaction of variables within both the parasite and the host populations. The egg population is heterogeneous (99, 100, 146), but virtually nothing is yet known of innate resistance factors involved in generating heterogeneity in the intermediate host populations, such as age, sex, breed, nutritional state, or grazing behaviour.

3.6 Extrinsic factors

It has been postulated that a high biotic potential (egg production) and efficient egg dispersal mechanisms are two of the most important factors contributing to stability in the host/taeniid system (99, 100, 146). They ensure a rapid restoration of transmission after interruption by environmental factors or by treatment procedures in control programmes. Thus, two of the factors conferring stability have already been identified.

3.6.1 Egg output

The egg output of taeniid tapeworms has been described previously in Chapter 1. The daily output runs into several hundred thousand eggs (16, 41, 59, 116, 117, 203, 272, 300). The important epidemiological aspects with both species are the ways in which the enormous numbers of eggs disperse following expulsion in proglottids and faeces, so that they become readily available to the intermediate hosts.

3.6.2 Egg dispersal in the *T. saginata* system

3.6.2.1 By the individual

It has been reported that massive transport of *T. saginata* eggs by man to cattle breeding rural areas may occur inter alia by camping and tourism, especially where toilet facilities are inadequate (6). Egg deposits also occur along rivers, railway tracks and roads (6, 196, 198). As proglottids only travel a short distance, these egg deposit-sites only provide the primary deposition-site from which eggs must disperse to reach the intermediate host (other than by coprophagia in the case of porcine cysticercosis) (8, 294).

3.6.2.2 By faulty sewage disposal

Most conventional sewerage works are only partially effective mainly because of overloading and interference with natural purification processes caused by high concentrations of chemicals (115, 137, 150, 172, 184, 250, 252, 299). *Taenia saginata* eggs can survive in most sewage systems (61). This and other aspects of egg dispersal are discussed in detail subsequently.

3.6.2.3 By deliberate irrigation of pasture with sewage-plant effluents

The deliberate use of raw sewage to fertilize cattle pasture is an important means of dispersing eggs in such a way as to make them immediately accessible (115, 146, 189, 198, 213, 223, 250). Prolonged settling is necessary before effluent can be used for irrigation of cattle pastures (17). This is also discussed in detail subsequently.

Using "tracer" calves, it has been found that eggs dispersed on pasture by deliberate irrigation with effluent, remained available and infective for at least 4 1/2 months (36).

3.6.2.4 In the feedlot situation

The epidemic outbreaks, already described in 3.4.1.2, have special features in egg dispersal. These include the natural spread of eggs from deposited segments, promiscuous defecation, faulty toilet systems and the contamination of fodder and drinking water (see Figure 21).

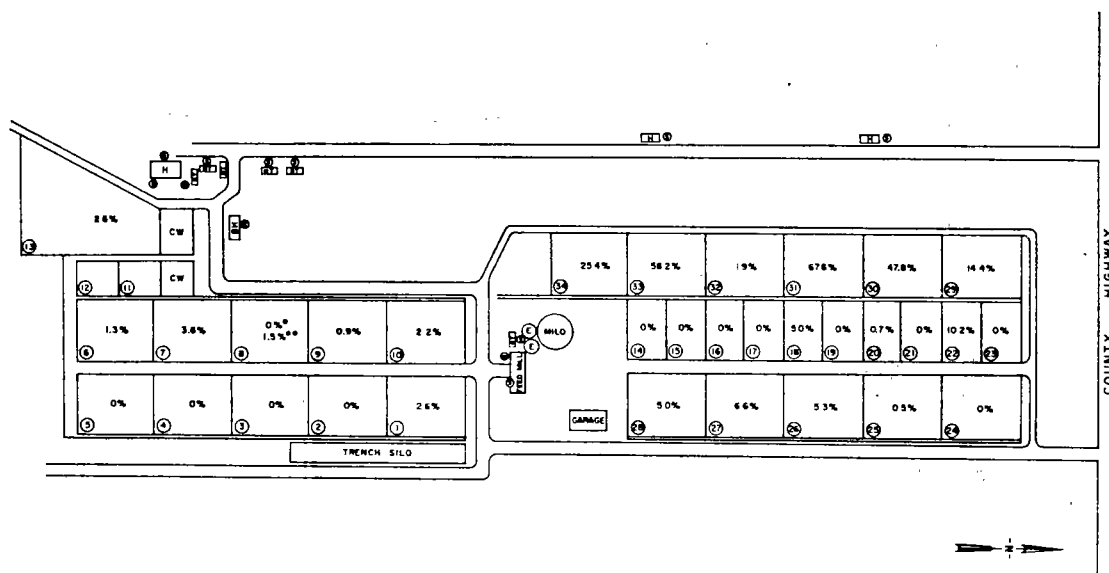
3.6.3 Egg dispersal patterns from a single focus using the dog/sheep model

Accumulating experimental and circumstantial evidence shows that the extent of egg dispersion and its implications for the dynamics of transmission, is much greater than has been suspected. For example, it is now known that sheep grazing at least 80 metres from dogs infected with *T. hydatigena* acquire heavy infections within 10 days (96). In investigations of "epizootic-type" outbreaks of *T. ovis* in New Zealand, it has been found that sentinel sheep that grazed at least 175 metres from the kennels in which the eggs originated became infected (Figure 22).

Circumstantial evidence suggests that some eggs may be dispersed over a considerable distance. For example, in the Styx Field trial in New Zealand, an "outbreak" of *T. hydatigena* cysticercosis on one farm was associated with low levels of infection of farms as far away as 10 kilometres (95). (Figure 23). It was unlikely that these low level infection rates were generated by the presence of an infected dog on these farms; thus, they probably resulted from the dispersal of eggs from the original deposition site. Additional circumstantial evidence comes from an experimental control programme directed against *T. ovis* involving 10 000 farms in New Zealand (146). On many of them, low infection rates (1%) were found in the lambs (Figure 24). When the positions of these farms were plotted, it was found that they radiated from a farm or farms with high levels of infection. The data suggest that these low levels of infection resulted from the dispersal of eggs from the site of deposition over an area of about 30 000 hectares.

Examination of the distribution of these low level infections around the original deposition site suggests that dispersal occurs equally in all directions. This is consistent with experimental studies in which sheep were grazed in a "grazing circle" divided into nine equal subplots radiating from a central ungrazed kennel area which housed four dogs infected with *T. hydatigena* (107). Analysis of the larval counts in the sheep showed no significant differences between the plots, indicating that the eggs were dispersed equally in all directions despite a prevailing southwest wind. The ground slope and height of the grass did not appear to influence the extent of dispersal.

This massive egg-dispersal from a single egg-deposit site with a high intensity over 10 hectares and light intensity over 30 000 hectares highlights the part played by the introduction of a single tapeworm carrier into an egg-free zone, particularly during the course of a control programme when almost all intermediate hosts may be susceptible to infection, reinfection and/or superinfection. At the epicentre an "epidemic" infective pattern occurs (as in feedlot "bovine cysticercosis storms") (239) (see Figure 21) and at the periphery a "light endemic" infective process occurs.



- * 1st Group slaughtered Sept. 17, 1967
** 2nd Group slaughtered April 1968

- S Sludge pit
W Well
H House
HT House trailer
BH Bunk House
E Grain elevator
CW Cattle working area

FIGURE 21 - Bovine cysticercosis storm in feedlot showing pen number and prevalence in each (epicentre of "storm" about pens 30 and 31) (After 239).

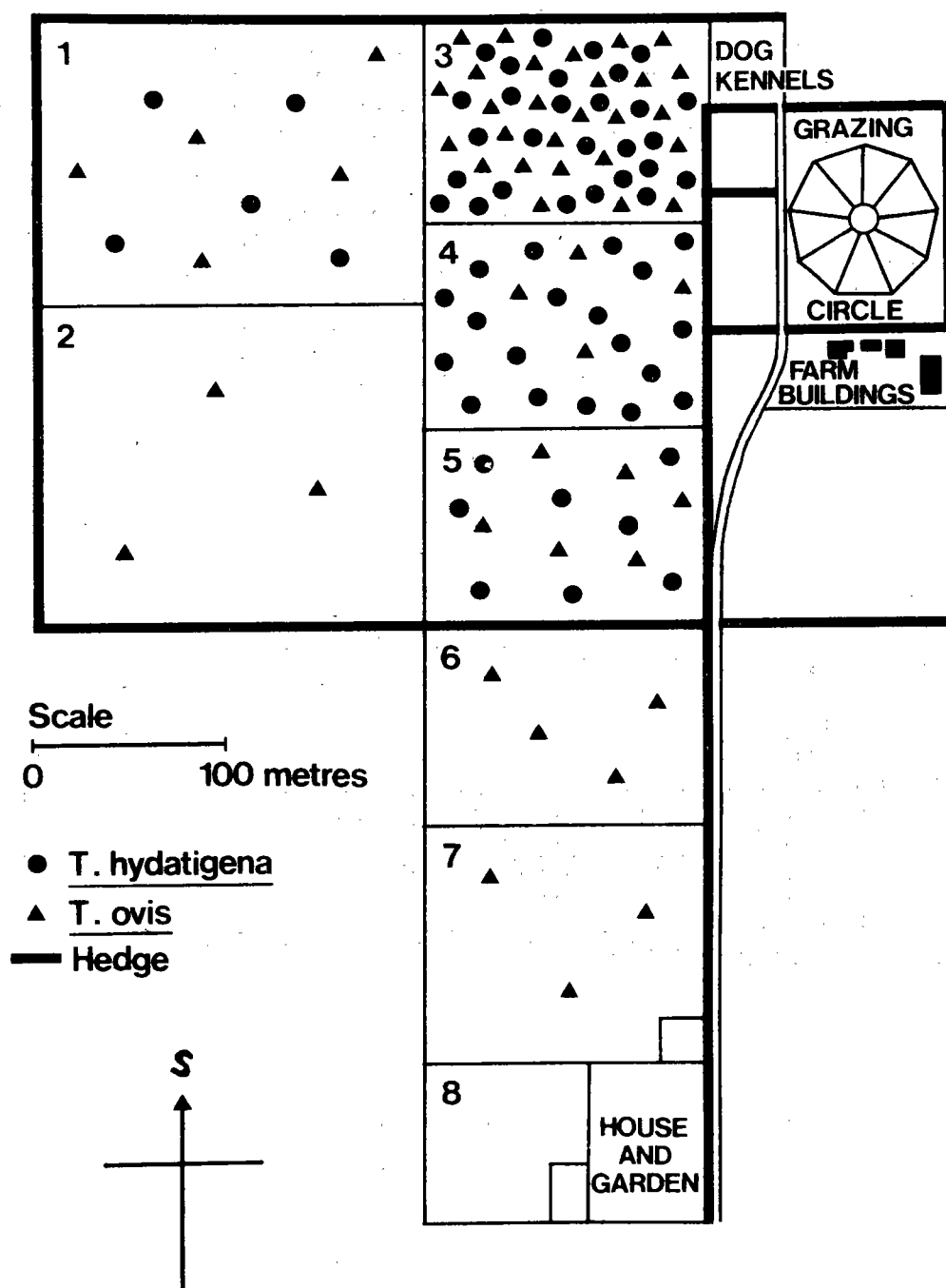


FIGURE 22 - Results of an investigation of an accidental epidemic of *Taenia ovis* cysticercosis (After 146).

This epidemic emanated from the research farm of the Hydatid Research Unit (New Zealand) on to a neighbouring farm. The epicentre was identified as the Unit's dog kennels. Each symbol represents a cysticercus in the "sentinel" lambs used to investigate the outbreak. The grazing circle is an experimental plot for studying the egg dispersal of *T. hydatigena* which also caused cysticercosis in the neighbour's lambs

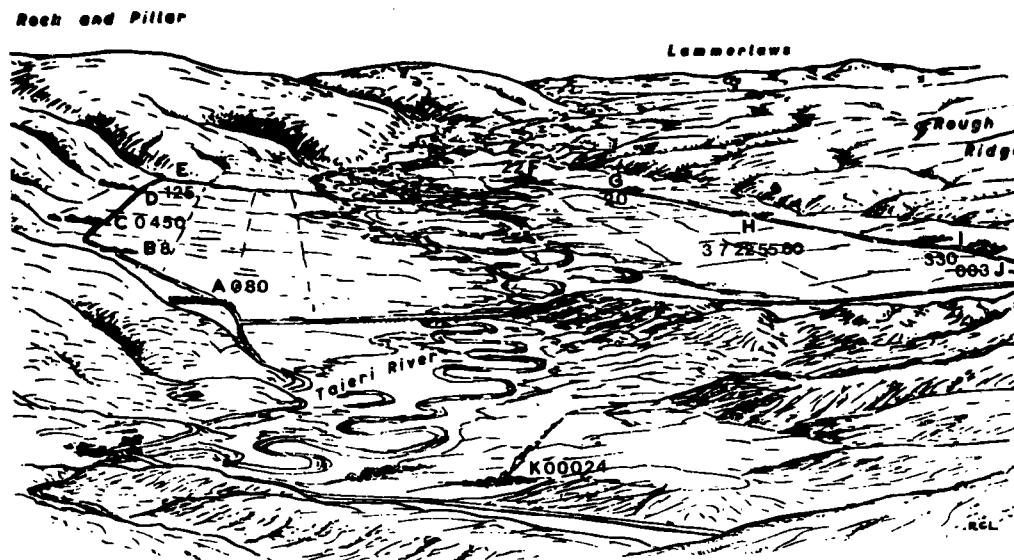


FIGURE 23 - The Styx Valley in New Zealand showing the prevalence of Taenia hydatigena in 1977 when the dogs in the Valley were treated with nitroscanate at 100 mg/kg every month (After 95).

The letters A to E refer to farms lying below the Rock and Pillar Range, the letters F to K to farms below the Rough Ridge Range. These two ranges of hills are contiguous with the Lammerlaw Range and thus there is a barrier to stock movement at the head of the valley. The entrance to the Styx Valley is between farms A and K. The numbers 0 to 60 refer to the prevalence of T. hydatigena in lambs at the times they were drafted from each farm. On farm H, the epicentre of the cysticercosis storm, there were 5 drafts of lambs and the prevalence of T. hydatigena in these was 3, 7, 22, 55 and 60% respectively. The distance between the homesteads of farms H to B and C is approximately 10 km.

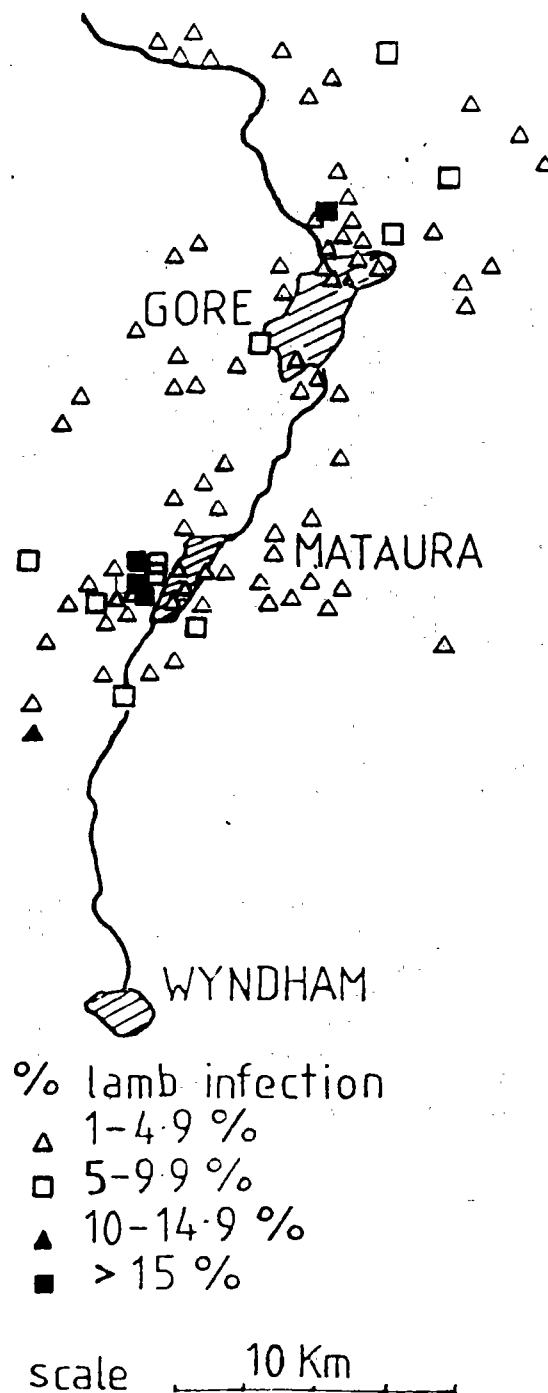


FIGURE 24 - The percentage infection of *Taenia ovis* in lambs on farms in a closely settled region of the South Island of New Zealand (After 147).

The pattern of infection possibly results from the spread of eggs from epicentres (15%) involving a very few infected dogs.

3.6.4 Ways in which eggs may spread from the site of deposition

Many questions arise as to how egg dispersal occurs. Newly shed proglottids are reported to be capable of moving several metres from the faecal mass of T. hydatigena, Echinococcus granulosus and T. saginata (41, 58, 171, 231, 244, 272). However, because in many cases most of the eggs are expelled from the proglottid into the faeces before the latter are voided, and because the distances travelled by the proglottid certainly does not approach that reported for the eggs, there must be agents for egg dispersal. Numerous agents have been suggested in the literature, including wind, birds, insects (particularly flies and beetles), oribatid mites, and annelids (146, 198).

3.6.4.1 Wind and air currents

Although wind has widely been assumed to be responsible for a significant dispersal of taeniid eggs, there is no experimental evidence supporting this assumption. However, there are two main pieces of circumstantial evidence. The first is the occurrence of hydatid cysts in the lung, which purportedly may be derived from the inhalation of eggs (29). Experimental data supporting this concept have been reported (32). Nevertheless, it might be argued that particles the size of taeniid eggs are likely to be coughed up and swallowed before reaching the lungs. The second piece of evidence is the acquisition of T. hydatigena by lambs that grazed downwind of a pasture experimentally sprayed with eggs (273). The prevailing strong winds were thought to be responsible. Unfortunately, no evaluation was made as to whether these infections resulted from "wild" eggs, or dispersal occurred in directions other than that of the prevailing wind.

The evidence against egg dispersal by wind, although also largely circumstantial, is quite persuasive. In the first place, it would seem that eggs would only be available for transport by the wind after the faecal mass had dried up and disintegrated. As freshly voided taeniid eggs are intolerant of desiccation (143), it is probable that the majority of wind-borne eggs are not viable. In addition, taeniid eggs are sticky, and experiments using a wind tunnel have indicated that fresh eggs are not readily transported by the wind (144). The evidence that eggs are dispersed in a uniform radial manner provides an additional argument against wind as an important factor in the dynamics of transmission of the egg. Further studies are required before the significance of wind or air currents in taeniid egg transportation can be assessed.

3.6.4.2 Birds

Seagulls, starlings, rooks, sparrows, and other scavenging birds have been implicated in the transfer of eggs of T. saginata from sewage works to pasture (43, 44, 109, 113, 117, 250), but there is little information on the behaviour of birds other than seagulls with respect to faeces. If birds regularly were in contact with faecal material or picked up other transport hosts, they could represent an important mechanisms for egg dispersal, particularly in long distance dispersion (99). Again this requires further study.

3.6.4.3 Arthropods

Many arthropods have been implicated in egg dispersal, including flies, beetles, mosquito larvae, moths, ants, fleas, cockroaches, oribatid and gamasid mites (99, 111, 112, 144, 145, 146, 198). Of these, the blowflies and dung beetles seem to be the most likely candidates for this role due to their close ecological association with faecal material. Some calliphorid blowflies visit faeces for both feeding and oviposition. It appears that in addition to supplying water, faecal material is an important source of protein, required for the maturation of the ovarioles (20). The total number and proportions of each species are influenced to a great extent by the weather and the freshness of the faeces. The majority of flies visit faeces within the first few hours (say 3 hours) after it has been voided, and as many as 160 flies have been observed to visit a single piece of dog excrement in a dog/sheep experiment (145). The maximum number of eggs observed within a single fly exceeded 5 000 (145, 146). Many workers have observed helminth eggs including T. saginata attached to the outer surface of flies both in the laboratory and in field studies (19, 119, 128, 179, 211, 236, 307).

There have also been many reports of flies carrying eggs internally in both experimental and field studies (119, 123, 128, 176, 233, 274). It has been noted for example that 9% of synanthropic flies caught on a state farm carried helminth eggs in their bodies. The subfamily Sarcophaginae and Musca domestica were the most heavily contaminated (19).

The ability of Calliphoridae to take up eggs internally has been confirmed, and individual flies carrying large numbers of T. hydatigena eggs have been observed. Over 80% of flies that fed on infected dog faeces ingested eggs, the majority of which were voided in the flies faeces within 48 hours (99, 145, 146). Observations on the feeding behaviour of flies on infected faeces indicate that they are not attracted by the tapeworm proglottids so much as by the mucous on the outside of the faeces. This mucous in dog faeces appears to contain the majority of the eggs expelled from the proglottid after its detachment from the tapeworm. The estimate of the time eggs remain in the gut of the fly, varies from 5 h to 14 days (144, 179, 185, 233), but the usual time is about 1-2 days.

Studies on the activity of flies, including houseflies, indicate that they could largely account for the pattern of cestode egg dispersal that has been observed. The majority of flies travel no more than 1.5 kilometers within 48 hours, although small numbers disperse over much greater distances (30, 151, 237, 306). Flies appear to undergo random dispersion from a liberation site unrelated to wind direction, although once stimulated by the odour of an attractant, they fly upwind to contact it (163, 186). Thus, the evidence indicates that blowflies are important agents of taeniid egg dispersal.

It is likely that other insects in contact with faecal material may play subsidiary roles. Many beetles feed on proglottids and pick up eggs externally including those of T. saginata, but more commonly they ingest them with the faecal material (27, 28, 158). There is evidence that the mandibles of beetles destroy many eggs, but a considerable number are ejected intact in their faeces (28, 173). The few studies on the dispersal behaviour of beetles indicate that they do not travel great distances. Nevertheless, it is possible that they may contribute to the short-range dispersal of taeniid eggs. If arthropods are important egg-carriers, and account for short and middle distant dispersal, the spread may well be seasonal in temperate zones.

3.6.4.4 Oribatid and gamasid mites

Oribatid mites are common inhabitants of litter and soil, and as intermediate hosts of a range of anoplocephalid cestodes, are obviously capable of ingesting tapeworm eggs (298, 309). Individual mites appear to be incapable of travelling great distances, but nothing is known of their role in egg dispersal.

3.6.4.5 Annelids

Earthworms have been shown to contain taeniid eggs in areas endemic for T. saginata (15, 157). Thus, they may play a role in egg dispersal, particularly as earthworms are a common food for some birds.

3.6.5 Egg longevity and duration of infectivity of embryos

Most of the studies undertaken to define the longevity of taeniid eggs have used modifications of Silverman's (1974) in vitro hatching technique (245). This has been found to be very useful in defining factors that are lethal to eggs, but it is difficult to extrapolate from these studies to the events that occur in the field situation. However, it is important to obtain an overview of the epidemiological significance of the ageing process on the duration of infectivity.

3.6.5.1 Temperature dessication lethal to eggs

There is evidence from in vitro studies that the eggs of T. hydatigena and T. ovis will not activate after storage for 2-10 days at + 38°C (92). Temperatures lethal to T. hydatigena are + 55°C for 5 min., + 65°C for 2 min., + 65° for 1 min., and + 85°C for 0.5 min. Conversely, there is a high tolerance to cold and some embryos of T. hydatigena

and T. ovis could be activated after storage at -9°C for 170 days (92). However, the eggs of both species are killed within 24 hours at -70°C (92). Grass and soil temperatures do not normally reach these extremes, and thus these may only infrequently be an important epidemiological factor restricting the number of infective eggs in the natural environment.

Studies with T. hydatigena and T. ovis have indicated that the eggs of these species are highly susceptible to desiccation (143). Storage at a relative humidity of 25% for 24 hours at $+4^{\circ}\text{C}$ was sufficient to prevent hatching in most cases. It is considered likely that under most circumstances, desiccation is a more important factor than extreme temperature in causing the death of taeniid eggs in the natural environment.

The absence of surface water at temperatures between $+7^{\circ}\text{C}$ and $+38^{\circ}\text{C}$ significantly reduced the storage time after which embryos of T. hydatigena and T. ovis showed activity in vitro (92). No studies have yet been reported on the combined effects of temperature and humidity in ovine cysticercosis, although data are available for T. pisiformis in rabbits (40). It was found that some eggs survived at low temperatures ($+3$ to $+5^{\circ}\text{C}$) and low relative humidity (32-33%) decreased the survival period to less than 2 months. At high temperatures ($+37$ to $+39^{\circ}\text{C}$) and low (32-33%) or high (89-94%) relative humidities, eggs survived less than one week. Temperature and desiccation can be regarded as independent lethal factors at the extremes of either range.

Under laboratory conditions the viability of isolated eggs of T. saginata is much higher when compared with those inside a proglottid; at temperatures from $+19$ to $+37^{\circ}\text{C}$ longevity varies from 27-29 to 2-3 days, at -4°C it is about 62 to 64 days. The shorter life cycle of oncospheres contained in proglottids can be ascribed to putrefaction processes (270). With regard to humidity, the eggs of T. saginata do not survive in vitro in the absence of surface moisture (248).

There is a difference between viability and the ability to invade and to develop into the larval form. Few investigations on the effects of temperature on the infectivity of eggs have been carried out. In one study, the infectivity of T. hydatigena eggs that had been stored at $+7^{\circ}\text{C}$ for 90 days was found to be greater to sheep than that of eggs stored at -9°C (92). After 273 days some embryos stored at $+7^{\circ}\text{C}$ were still invasive whereas those stored at -9°C failed to invade. This suggests that ageing proceeds at subzero temperatures, but that immature embryos may be inhibited from further development and do not replace the infective organisms.

3.6.5.2 Duration of egg survival in the environment (for summary see Table 15).

In a damp temperature climate (Perm region, Russian Federation) the eggs of T. saginata can survive in the environment for about 10 months and remain viable for 130 days in water; they can survive for up to 70 days at temperature varying from $+4$ to -38.5°C (243). In summer, the eggs are destroyed on the soil surface within two days, however, under the protection of plant cover they can survive for up to 40 days. In a warm climate (Moldavian SSR), eggs (in proglottids) survived on the soil surface in winter and spring for as long as 5 months, 4 months in summer and up to 8.9 months in summer and autumn (234). With the relative air humidity varying from 44 to 96%, eggs contained in proglottids remain viable for a period from 12-13 hours to 1-2 days at a temperature of $+19^{\circ}\text{C}$ to $+37^{\circ}\text{C}$, 35 to 37 days at -4°C and from 24 to 26 days at -30°C (308).

In Azerbaidzhan, the eggs of T. saginata readily survived in winter and late autumn, whereas in summer they died very rapidly; after 7 to 12 days in June, 3 to 6 days in July, and 1-3 days in August (181). In Khorezm region of Uzbekistan, the eggs survived in the environment for 75 to 109 days in winter, 25 to 64 days in spring, not longer than 1 to 4 days in summer, and 3 to 29 days in autumn (1). Near man-made water reservoirs, the eggs survived for up to three months in the warm season and up to 7 months in the cold period (18). In Tajikistan, eggs survived in the foothills and mountain areas for up to 160 to 170 days in winter, 90 to 125 days in spring, and up to 25 to 50 days in summer (169).

In the microclimate of a cattle barn, the longevity of eggs was estimated to be about 18 months (242). Eggs in hay or grass silage lose their infectivity in about 70-90 days (56).

or in about 168 days at 4 to 5°C. Eggs survived at least 16 days at 18°C in a dish filled with liquid manure for 71 days in an underground cistern and up to 150 days on grass (136). They may survive for 6 months in Denmark (136) and a year in the highland of Kenya (53) and in the Ukraine (110). Clearly, low to moderate temperatures with adequate humidity are important for long-term survival.

3.6.5.3 Heterogeneity of infectivity within egg populations

Studies have shown that in vitro embryo activity varies from as low as 5% to 80% or higher in eggs from different "ripe" proglottids of the same or different T. saginata and T. hydatigena (92, 245, 246). This finding, together with other evidence, has led to the hypothesis that freshly voided eggs consist of at least three subpopulations (92). These include immature, infective and senescent organisms, and their ratios vary from proglottid to proglottid. Based on these in vitro studies, it has been suggested that in the natural environment some immature embryos can continue their development and become infective. Similarly, there appears to be a shift from infectivity to senescence in the eggs, with a gradual loss of the ability to infect, and finally to invade. This heterogeneity may account for one of the variables determining the infective pattern in intermediate hosts as well as the "sterile" immunity, which appears to occur in some animals in endemic regions (92).

3.6.5.4 Factors affecting the ageing process of eggs

The identification of factors responsible for the rate of ageing of eggs in the natural environment is of fundamental importance to an understanding of the epidemiology of the cysticercoses. Evidence that temperature is an important factor in longevity is derived mainly from in vitro studies with T. hydatigena and T. ovis (92, 146). For example, it was found that the longevity of eggs of T. ovis was reduced from 150-300 days to 2-10 days by raising the temperature from + 7°C to + 38°C. In vitro egg longevity was inversely related to temperature within this range (Figure 25). It seems likely therefore, that high temperatures accelerate the ageing process.

TABLE 15 - Summary of observed survival times of Taenia saginata eggs stored under various conditions in the laboratory and in the field.

Where aged	Viability or infectivity assay used	Storage conditions	Maximum reported survival (days)	References
laboratory	"survived"	'room temp." dry	30	135
laboratory	<u>in vivo</u> infectivity	2-5°C	95	204
laboratory	"survived"	"room temp."	270-300	243
laboratory	<u>in vivo</u> and <u>in vitro</u>	4-5°C	168	70
laboratory	<u>in vitro</u> using Kamalova's technique	varying - 0-15°C, in proglottids	13-14	270
		0-15°C in free eggs	28-30	
		10°C, in proglottids	35	
		10°C, free eggs	50-54	
laboratory	<u>in vitro</u>	4°C "room temp."	335 60	249
laboratory	<u>in vivo</u>	in silage, 10°C	60-80	56
in field	<u>in vivo</u>	on pasture	101	204
in field	<u>in vivo</u>	on pasture, Kenya	413	53
in field	<u>in vivo</u>	on pasture, winter	159	136
		summer	58	
in field	"survived"	on soil surface in Azerbaidzhan, SSR		270
		winter	51	
		summer	5	
in field	"survived"	on soil, winter	105-225	181
in field	"survived"	in soil, winter (Nov/Dec)	90-165	242
		in soil, spring (March)	45	159
in field	<u>in vivo</u>	in stored hay	21	159

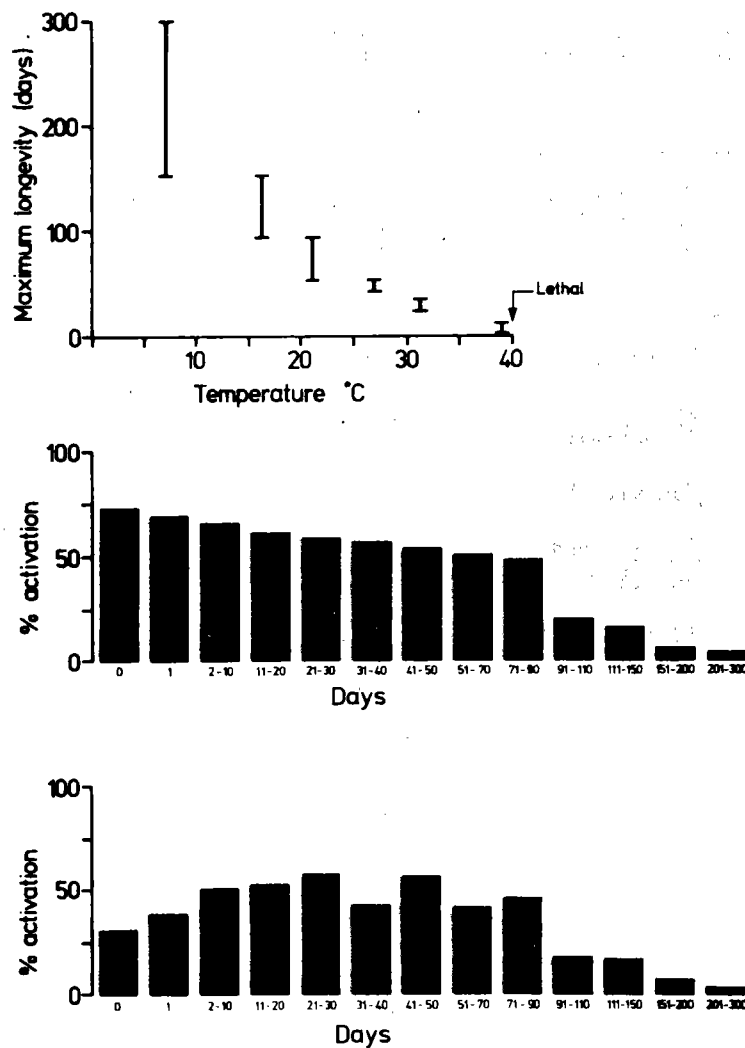


FIGURE 25 - The effect of temperature on the hatching characteristics of Taeniid eggs (After 147).

- Top Range of longevity of Taenia ovis eggs after storage in water at specified temperatures.
- Middle The gradual reduction in activity of T. hydatigena eggs after storage at 7°C for specified periods.
- Bottom The increase followed by a decrease in activity of T. hydatigena eggs after storage at 7°C for specified periods.
- The difference between the two tapeworms may be due to maturation of immature eggs in the bottom example during storage.

3.7 Intrinsic factors: immunological regulation

In the preceding sections, a review has been made of the extrinsic factors that determine the infection pressure. It was found that a high biotic potential, effective egg dispersal mechanisms, and the ability of the eggs to survive under a wide range of weather conditions lead to a high infection pressure. If these were the only regulatory mechanisms, infections with larval cestodes (metacestodes) would be cumulative and could lead to overloading in highly endemic zones, entailing the death of the host population and cessation of transmission. However, the survival of the parasite population is also dependent upon the intrinsic regulatory mechanisms of the intermediate host population.

Some of the earliest experiments demonstrating the importance of acquired immunity to metazoan parasites were carried out with T. saginata in cattle in Australia and Kenya (68, 69, 71, 72, 73, 75, 76, 199, 200, 201, 230, 282, 283, 284). In these countries, it was found in highly endemic zones that calves became naturally infected almost from birth, and gradually acquired resistance (282) demonstrating the difficulty of working with this system experimentally in areas with a high infection pressure.

More recently, an extensive programme on the immunological regulation of the infective pattern has been undertaken with the ovine cysticercoses. Many of the immunological events in this system simulate those occurring in bovine and porcine cysticercosis. It is now generally agreed that acquired immunity plays a central role in determining the infective pattern (63, 87, 88, 89, 94, 97, 100, 101, 103, 146, 221, 222, 225, 284, 302, 303).

3.7.1. Prenatal infection

Several reports from Kenya have been made indicating that T. saginata cysticercosis may be transmitted in utero (108, 163, 164, 284) but this was not confirmed experimentally in Europe (141). The possibility of prenatal infection was studied experimentally with T. ovis in sheep and here it was found that infection could not be established in utero at any stage during pregnancy, irrespective of whether or not the mothers were immune or non-immune to infection (86, 269). Similarly, it was not possible to infect piglets in utero with T. solium (281).

The role, if any, played by prenatal infections in the epidemiology of transmission remains to be determined.

3.7.2 Neonatal infection

In highly endemic zones, lambs and calves may become infected with metacestodes early in neonatal life (79, 83, 224, 282) and such neonatal infections may be associated with the prolonged survival of metacestodes in the host (261). In fact, it has been suggested that neonatally acquired metacestodes of T. saginata may survive for the life of the bovine (83, 282). Ruminants while in utero may be immunocompetent to some antigens but they are unable to respond to others until some time after birth. The extended survival of neonatally acquired metacestodes may be associated with an inability of the neonate to respond immunologically to the infection (261). Indeed, lambs and calves may not be fully competent to recognize all the functional antigens of the appropriate ovine and bovine metacestodes until several weeks of age (83, 104). In addition, while neonatal infections do not interfere with the development of protective immunity to reinfection at a later age, the immune response induced by such reinfection does not affect parasites established during the early neonatal period (82, 241).

3.7.2.1 The role of colostrum and maternal transfer of immunity

A variable degree of immunity to T. hydatigena, T. ovis and T. saginata is transferred maternally via the colostrum (106, 125, 126, 127, 154, 155, 226, 227, 228, 263, 268). Most of these studies included active immunization of the mother. There have been several

failures to transfer immunity to T. hydatigena and T. saginata where the mothers were naturally immune but not immunized (71, 106, 125, 283). There may be host and parasite differences, but from an epidemiological point of view, colostrum-transferred immunity wanes in the absence of impinging egg infections (97).

The role of colostrum in the regulation of larval tapeworm infections in hyperendemic regions is not yet fully understood.

3.7.3 Time interval for the induction of immunity

One of the important factors that determines the infective pattern is the time interval after the ingestion of the first eggs by immunologically competent animals when they remain susceptible to superinfection. Here it has been found with T. hydatigena in sheep that strong immunity was acquired within 2 weeks after the ingestion of eggs (see Figure 26) (105). This is a similar time interval to that required for the induction of immunity by cattle to T. saginata (161, 301). The practical reality of this in endemic zones, is that there is only a very short period in their lifetime (say 2 weeks) when animals can acquire cysticercosis. This important information has, unfortunately, not yet been confirmed for porcine cysticercosis.

3.7.3.1 Number of eggs required to induce resistance

As few as 10 to 50 eggs of T. hydatigena or T. ovis will induce strong resistance to superinfection in sheep (83, 271). This immunity is reinforced by further small doses of eggs. The number of eggs required to induce resistance to reinfection or superinfection to cysticercosis in cattle and pigs has not yet been determined.

3.7.3.2 Acquisition of immunity in the field situation

In a series of field trials using T. hydatigena in the dog/sheep model it was found that lambs gradually acquired immunity from the first few eggs ingested within about one week after birth, and this limited the number of cysts which survive from eggs ingested subsequently. At about 3 months of age, further embryos were rejected. In contrast, immunologically competent lambs introduced to an egg-contaminated pasture at 3-months of age became far more heavily infected within the two-week period before the onset of immunity than those reared there from birth (82, 83, 84, 85, 102). Thus, movement of animal hosts following the acquisition of grazing competence from clean to endemic regions, or the introduction of an infected definitive host to a clean zone modifies the infective pattern in favour of the parasite. Paradoxically, the rearing of animals from birth in close association with infected definitive hosts provides the lightest infective pattern in the intermediate host population.

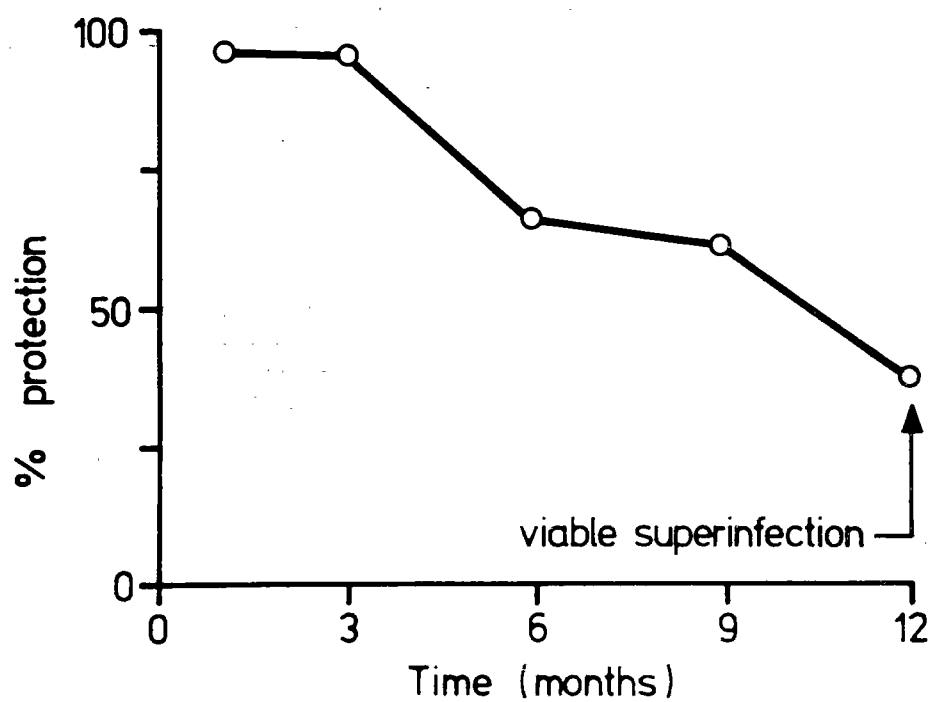
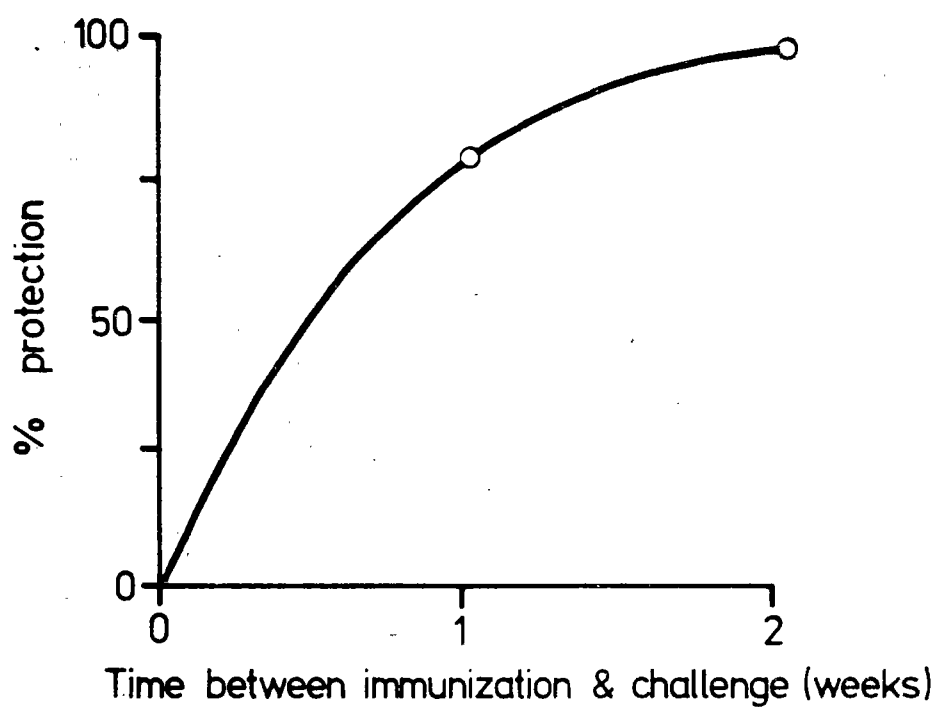


FIGURE 26 - Immune responses by the host to egg infections (After 98, 105, 146).

Top: Time interval for the induction of immunity.

Bottom: Duration of immunity in the absence of impinging egg-infections.

3.7.3.3 The survival of larvae in immunologically competent animals

With T. hydatigena, some cysts may die during the first year, but thereafter the survivors usually remain viable for the lifetime of the host in endemic and non-endemic regions. The survival of T. saginata cysticerci in cattle has been variably described as only a few months or several years (50, 66, 77, 78, 140, 147, 162, 174, 180, 198, 199, 201, 202, 261, 262, 282, 285, 286, 290). It has been suggested that impinging egg infections may modify viability (3, 148, 259, 260). It has also been suggested that this variability may be associated with strain differences (3). This problem remains to be resolved.

3.7.4 Duration and loss of immunity

It was observed in a field trial using the dog /sheep model, that sheep grazed on farms, which experienced sporadic breakdowns in their control measures, were often parasitized with both young and old T. hydatigena. Experimentally, it was then shown that superinfection can occur within 6 months, with survival of the superimposed infection at 12 months after ingestion of the last egg-dose (98). This phenomenon was independent of the presence or absence of viable or dead cysticerci from previous exposures to eggs (see Figure 26). The epidemiological significance of this in ovine cysticercosis is that if animals are intermittently exposed to eggs, the larval population will increase. Thus, in control programmes which allow an intermittent egg production due to inadequate treatment schedules, the larval population may increase to a higher level than would occur if no dosing programme was operative (94). Little is known of the duration of immunity in the absence of impinging egg infection in bovine, human or porcine cysticercosis, but it should be investigated.

3.7.5 Sterile immunity

Not all animals in a herd or flock become infected with dead or viable larvae even in highly endemic zones. It has been postulated that aged embryos of T. hydatigena may retain their ability to invade and thus immunize long after they have lost their ability to reorganize into cysticerci (92). Such a factor may account for the lack of infection in some individuals in bovine, human and porcine cysticercosis in highly endemic regions. This should also be investigated.

3.7.6 Species specific and interspecific immunity

Clearly the ingestion of eggs provides a strong immunity to reinfection with the homologous species. The feeding of eggs of different taeniid species in different sequences may induce a degree of resistance to an heterologous species (82, 287). However, in nature, even species which do not normally inhabit that host may modify the normal parasite burden (57). Metacestodes of T. hydatigena, T. ovis and E. granulosus can coexist in the same animal. Similarly larval T. saginata, E. granulosus and T. solium and T. hydatigena and E. granulosus may occur together in cattle and pigs, appropriately. Based on egg feeding trials, it was considered likely that various taeniid species may survive together in the same host but interactions may be neutral, harmful or possibly beneficial to the parasite (287). It can be concluded that species-specific acquired immunity is much more important than interspecific immunity in regulating the transmission process.

3.7.7 Immunity acquired by the definitive host

While there is evidence in experimental animal models that the definitive host may reject a tapeworm or cause it to destrobilate and that antibody may be present, virtually nothing is known of the importance of acquired immunity in regulating adult T. saginata and T. solium populations.

3.8 The role of livestock management in transmission

The infection pressure describes the proportion of animals in a population that become infected during a given time. It can be measured by grazing sentinal animals at specific intervals after the deposition of eggs (102).

The infection pressure results from egg output, egg dispersal and egg survival and these form the sum total of the extrinsic factors already described in this Chapter. Feeding behaviour and livestock management practices also influence the infection pressure.

3.8.1 Feeding behaviour

The behaviour of animals with regard to the ingestion of faeces of their own and other species will almost certainly influence the acquisition of metacestodes. Both sheep and cattle normally avoid grazing the ground around fecal material (275, 276) but under some ecological circumstances such as adverse climatic conditions, drought, and high stock densities, they may ingest faeces including those of man (294).

The pig is a natural scavenger of faeces and there are many reported cases in which pigs are actively encouraged to act as "sanitary policemen" (8, 294). This may lead to massive infections during the time interval between the ingestion of the first eggs and the onset of immunity.

Self infection by man has been suggested to account for some massive infections of human cysticercosis, where the infectivity of the eggs is quite low (63). Likewise, faecal contamination of inadequately cooked vegetables and other farm products arising from sewage irrigation or improper personal hygiene of food handlers, may be responsible for high infection rates in human cysticercosis.

3.8.2 Flock management and availability of eggs

The infection pressure has been measured in a series of grazing trials with a dog/sheep model using T. hydatigena (90, 91, 102). The questions asked were: what happens (i) when naive lambs are reared near infected dogs from birth; (ii) when after achieving grazing competence - they are introduced for the first time to pasture contaminated with eggs; (iii) when the source of infection is removed; and (iv) when the source of infection is suddenly reintroduced. The answers to these questions are summarized below together with comments on possible equivalent situations in bovine and porcine cysticercosis.

3.8.2.1 Rearing of animals from birth near infection source

Lambs that were reared from birth within about 180 metres of infected dogs gradually acquired grazing competence over the first 5 weeks after birth following introduction to an egg contaminated pasture. During this period they usually ingested only a few eggs and became lightly infected. This model epidemiological situation may simulate that reported for Kenya where bovine cysticercosis is hyperendemic in some areas. This model may also simulate bovine cysticercosis on individual farms in pastoral cattle farming areas in parts of Europe where bovine cysticercosis is endemic.

3.8.2.2 The introduction of grazing-competent animals

In contrast to the first situation many of the naive lambs introduced to an egg-contaminated pasture after reaching grazing competence became heavily infected in a matter of a few days. Under these conditions, measurements of the infection pressure indicated that 60% of the flock ingested eggs every day (see Figures 22, 24 and 27). This is essentially the cysticercosis storm, and applies to an epicentre of grazing of about 10 hectares. Beyond that point, sporadic infections occur over an area of 30 000 ha.

3.8.2.3 The rate of egg loss

As soon as an infected dog is removed or successfully treated, the equilibrium between the gain and loss of eggs and the ratio of infective to senescent eggs is disturbed. In the dog/sheep model, it was found that after 3 and 6 months of the removal of the infected dogs, the incidence of infection declined from 60% of the animals ingesting infective eggs everyday to 6.5% and 3% respectively. Furthermore, there was a continuing reduction in the proportion of cysts surviving from the eggs ingested over this period. This seems to indicate that there was also a decline in the ratio of infective to senescent eggs. Thus, under favorable conditions for survival, the availability of the eggs to the sheep flock declines relatively slowly (see Figure 27).

Assuming there is a similarity between the dog/sheep T. hydatigena model and T. saginata the following situation may apply:

In pastoral bovine cysticercosis in temperate zones, where human defecation habits and the irrigation of pastures with sewage lead to massive egg contamination of a prescribed area, it may be expected that almost all animals within that area will become infected and then acquire immunity to superinfection within 14 days of the ingestion of the first eggs. This immunity will last for at least 6 months while the egg contamination is high and a further 6 to 12 months once the eggs have lost their infectivity or have become unavailable to the animals. The introduction of immunologically naive animals onto the epicentre pastures (10 ha) is contraindicated for up to 12 months from the time of the deposition of the eggs.

3.8.2.4 Introduction and reintroduction of infected definitive hosts

In the dog/sheep model the introduction of infected dogs caused a rapid build-up of eggs, and within 10 days more than half the animals in the flock ingested eggs daily. These studies show that the introduction of infected definitive hosts to areas with grazing competent immunologically naive intermediate hosts, is one of the critical factors giving rise to the cysticercosis storm.

If this reintroduction occurs about 12-18 months after the first infection, then the immunity of the herd or flock may have been lost and reinfection and superinfection will occur, leading to very high cyst counts in some animals, particularly those kept long-term for breeding purposes. This type of situation occurs during control programmes, where the treatment programme directed against the adult tapeworm is inadequate to prevent the occasional breakdown (46).

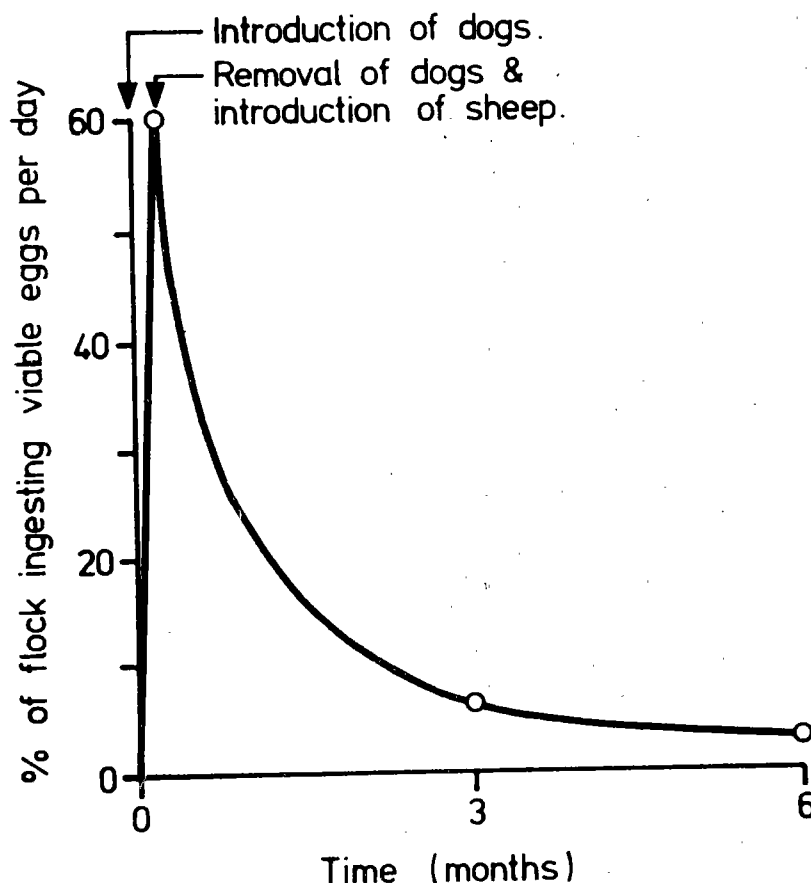


FIGURE 27 - The rapid build-up and slow decline in availability of eggs associated with the introduction and removal of dogs infected with Taenia hydatigena (After 76).

3.9 The role of sewage disposal and egg dispersion

The increasing urban population has placed heavy demands on water resources and gives emphasis to the need for more complete treatment of waste water and re-use of the treated effluent. For example, 187 000 tonnes of dry solids, or 15% of the 1.25 million tonnes produced by the United Kingdom water industry, are disposed of onto grazing land each year (134). Irrigation of pasture with sludge and effluent is a common method of water re-use, but this provides the opportunity for the escape of taeniid eggs.

Almost all types of sewage systems in common use have been studied for their ability to retain animal parasites and there is good evidence that sewage discharges overflowing onto pastures or directly into rivers and their estuaries, disperse animal parasites including taeniid eggs (7, 9, 17, 21, 42, 49, 54, 55, 115, 120, 137, 150, 172, 184, 189, 213, 232, 247, 250, 251, 252, 255, 256, 288, 289, 295, 299, 305). The systems include grit tanks and screens, primary sedimentation tanks, cold sludge digestion, mesophilic sludge digestion for the production of methane, sand filtration, outdoor sludge drying beds, sewage farms, gravity drainage into holding tanks with final discharge of the effluent into rivers, sea or sewage farms. At the village and rural levels, septic tanks, out-houses and pails are used. These latter are of particular importance in the spread of T. solium cysticercosis, when they are emptied onto horticultural land.

3.9.1 Biological treatment

After primary sedimentation the sewage is treated in various ways to decompose suspended solids and organic material with the aid of microbes. At the end of these processes this activated sludge has to be separated from the effluent in secondary sedimentation tanks.

Trickling filter

The efficiency of this process in removing helminth eggs ranges from 0 to 30%. Even under laboratory conditions, it does not exceed 70%, so that this filter cannot be regarded as an effective method of removing eggs from the effluent (184).

3.9.1.1 Oxidation ditch

Even after a 3 months detention time helminth eggs, except those of Fasciola, are not destroyed. This is also the case for Taenia eggs so that the effluent from oxidation ditches also gives rise to a hazard if it is used for agriculture or is fed into rivers (55).

3.9.1.2 Activated sludge process

Observations in practice and laboratory experiments indicate that the activated sludge process has no apparent deleterious effect upon T. saginata eggs. In laboratory scale experiments they survived even 5 months in this process (186, 236).

In conclusion, it can be stated that primary and secondary purification processes in sewage treatment plants can not be relied upon to produce effluent free of viable Taenia eggs (37, 45, 61, 113, 154, 186, 236).

3.9.2 Sand filtration

This process seems to be the only efficient method of removing T. saginata eggs from the effluent of secondary sedimentation tanks. To be effective, the sand filter should have a depth of at least 0.6 m with a sand of 0.5 mm effective size and 2.2 uniformity coefficient (184).

This method of sand filtration is used increasingly as a tertiary sewage treatment at sewage works. It seems to be possible to compensate by this method for the failure of the other purification steps to remove the eggs of T. saginata from the sewage. However, it will be several decades before the majority of sewage works will be equipped with this facility (55).

3.9.3 Anaerobic digestion of sludge

Sludge is the product of primary, secondary and, in some of the more modern sewage works, also of tertiary sedimentation processes in settling tanks. Even if the retention time in settling tanks is in many cases not sufficient for the natural sedimentation of *T. saginata* eggs it seems likely that, in tanks with depths of several metres, eggs trapped by sewage particles will be given additional downward velocity. Thus they should end up in the sludge which consists of pathogens not only from the helminth group but also bacteria and viruses.

In many sewage treatment plants the sludge is subject to anaerobic, mesophilic, alkaline digestion at temperatures in the range of 28° to 34°C. But even under these conditions *Taenia* eggs can survive the digestion process. This digestion is a continuous process whereby raw sludge is fed into the digester once or twice a day and the corresponding amount of digested sludge is removed. This prevents the effluent of these digesters from killing pathogens. Only if a completely unrealistic detention time of 56 days could be achieved would taeniid eggs be inactivated. Even if the eggs are still enclosed in proglottids their viability is only reduced by 54% after 104 days of mesophilic digestion.

Mesophilic anaerobic digestion therefore cannot be regarded as a method by which taeniid eggs can be killed in sewage sludge (39, 45, 54, 55, 61, 62, 65, 114, 184, 232, 264).

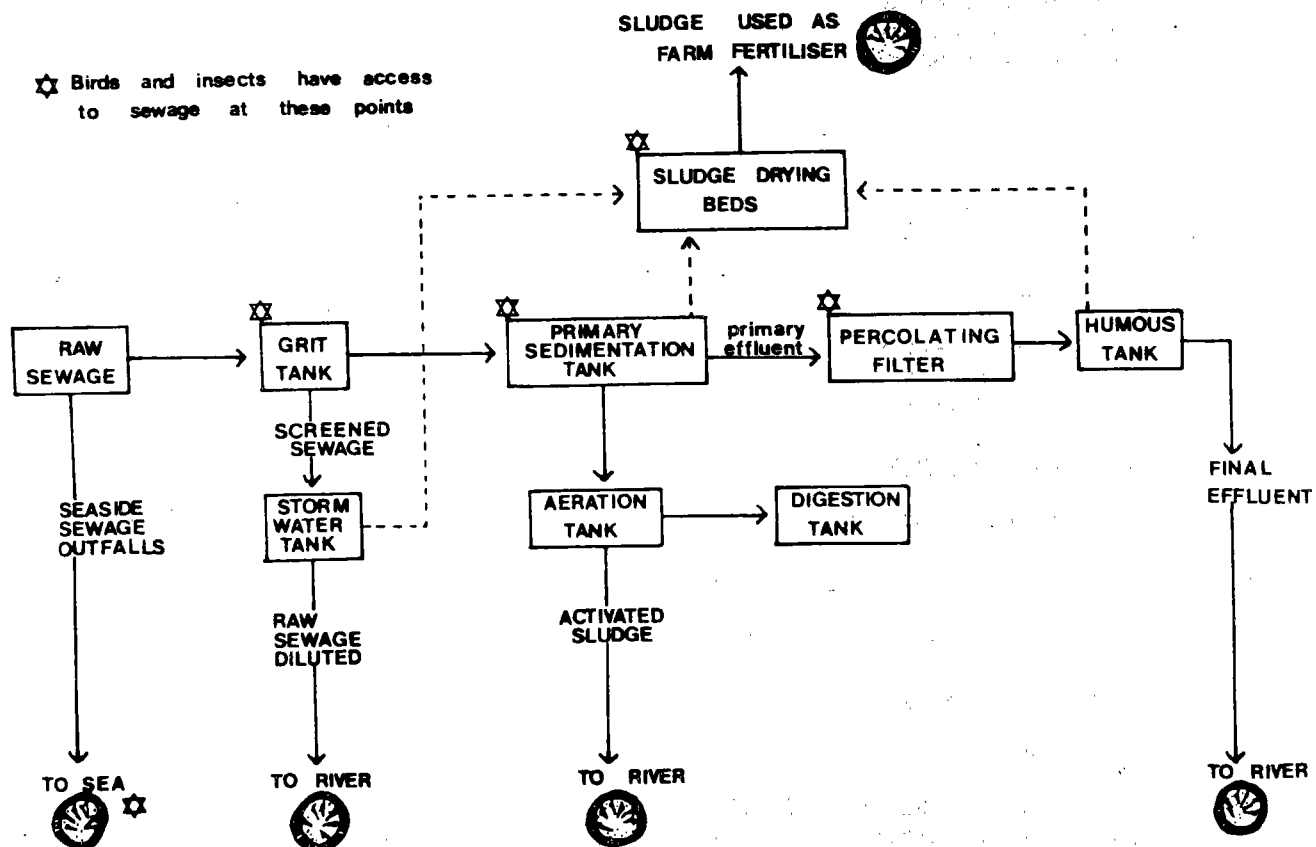


FIGURE 28 - Outlets for egg dispersal from urban sewage systems (Courtesy, Hydatid Research Unit, New Zealand).

3.9.4 Drying of sludge

Drying beds for dewatering sludge have no effect on helminth eggs. The same is true for dewatering sludge with belt presses, chamber-filter presses or centrifuges. These mechanical processes, even if combined with flocculation by addition of chemicals as conditioners, also have no noticeable effect.

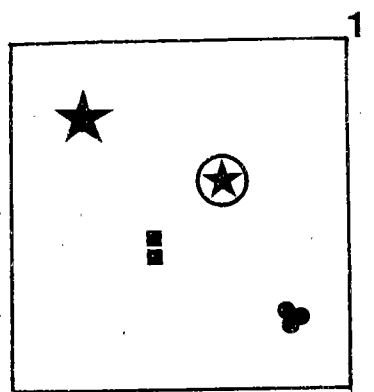
Drying sludge with high temperatures, usually between 100°C and 200°C will destroy the taeniid eggs. This method is very energy intensive and, therefore, can only be used in large sewage works.

The current situation in the field is that conventional sewage treatment is inadequate to eliminate tapeworm eggs from sewage or sewage sludge (264).

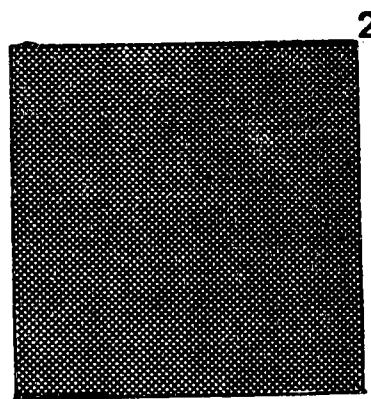
3.9.5 Egg-dispersal from sewage works

Tapeworm eggs settle at the rate of about 0.1 - 0.2 m per hour (184). However, as previously stated, due to turbulence involving overloading and interference with natural purification processes caused by high chemical concentrations (115, 140, 172, 184, 250, 299), most sewage systems permit eggs to pass relatively freely through the effluent. For example, taeniid eggs can survive anaerobic or aerobic digestion for several months (61, 184). Eggs have been found 32 km below the sewage outlet into the Moscow River (289) and 250 metres out into the Caspian Sea at Baku (9). Epizootics attributed to faulty sewage systems have been described in the United States (174, 232, 238), in the Federal Republic of Germany (49) and in the German Democratic Republic (35, 255) and in the United Kingdom (45).

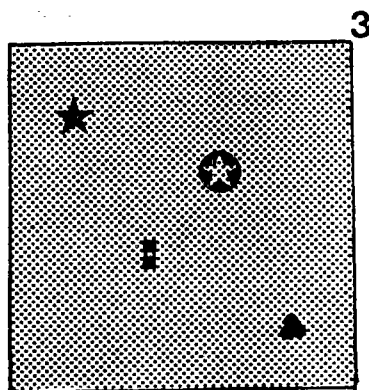
There are several ways in which the eggs of T. saginata can become available to cattle through sewage (Figure 28). In systems which use primary settling tanks, grit tanks, sedimentation tanks or aeration tanks, eggs in the effluent will pass through these systems into rivers or farms using sewage. Flooding of the rivers will ensure that the eggs are dispersed onto pastures. If the outlet falls directly into the sea from a raw sewage collection plant, segments will be present and the eggs can then be disseminated onto pastures by gulls and possibly starlings (43, 44, 45, 46, 113, 117, 189, 250, 251).



Epidemic



Endemic



Natural

- ★ DIRECT CONTAMINATION (MAN)
- ★ STORM SEWER OVERFLOW
- SEGMENTS IN SLUDGE
- BIRD DROPPINGS

FIGURE 29 - Epidemiological patterns generated by egg dispersal from sewage work (After 189).

The second method of dispersal is through the deliberate use of raw sewage to fertilize cattle pastures or pastures which are used for growing cattle fodder, and this is an important method of egg dispersal (115, 189, 198, 213, 215, 216, 217, 218, 219, 226, 250). A similar dispersal will result from the emptying of septic tanks and pails on to pastures (142, 250). Using "tracer" calves, it has been found that eggs dispersed on pasture by deliberate irrigation with effluent, remained available and infective for at least 4.5 months (36) and in silage for up to 4 months at 32°C but in the outer layers eggs survived beyond this time. However, eggs failed to infect when pressed and dried in pellets because the temperature exceeded 50 - 60°C during the pelleting process (36).

The epidemiological patterns which may result from the various methods of sludge and effluent disposal are illustrated in Figure 29 (189). There is a combination of endemic and epidemic patterns associated with the various ways of dispersal of eggs through sewage systems onto cattle pastures. A method for recovering taeniid eggs from sewage sludge is described in Appendix 5.

3.9.6 Measures to prevent the spread of Taenia saginata by sewage and sewage sludge

3.9.6.1 In sewage treatment plants (124, 264, 265, 266)

Sewage

Since the eggs of Taenia survive the various sewage purification processes steps should be taken to free the effluent of eggs. Recommended physical methods for this purpose like electrolysis, ionising radiation or radiation with accelerated electrons have not reached practical importance.

If no other effective methods can be introduced in the near future, all effluents from sewage works, and thus their receiving waters, should be regarded as contaminated .

Cattle having direct access to these receiving waters for drinking purposes must be regarded as potentially at high risk from cysticercosis. The same situation ensues when pastures or forage land are inundated with such infected surface waters (58, 264).

Sludge (124)

In some countries the sewage works are forced by recent statutory legislation to disinfect sewage sludge prior to its utilisation on pasture land, land for forage production or arable land on which crops for raw consumption are grown. Available methods for this purpose are: pasteurisation, irradiation and aerobic-thermophilic stabilisation of liquid sludges, composting of dewatered sludges in windrows or mechanised aerated bioreactors, treatment of sludges with lime.

In general, it is believed that by pasteurisation of sludge for 30 minutes at 70°C it can be regarded as free from infective eggs, including taeniid eggs (264). Recent results of research, which however has to be confirmed, indicate that a very small percentage of taeniid eggs can survive 70°C for 1 hour (46).

Irradiation of sludge is not in general use although a few installations of this kind have been developed in some countries. Radiosensitivity of parasites depends mainly on their development stage. The recommendations issued by a working party of the Concerted Action "Treatment and Use of Sewage Sludge" of the Commission of the European Communities (COST 68 ter) for the required radiation doses are as follows: 500 Krad for liquid sludge and 1,000 Krad for dewatered or dried sludge. According to very recent results a radiation dose of 1.2 Megarads is needed to obtain a 75% kill of Ascaris suum eggs in water (46). These contradictions have to be resolved first and the values for taeniid eggs have to be elaborated before further recommendations can be made.

Aerobic-thermophilic treatment of liquid sludge works in a temperature range of 50° - 65°C. In this range eggs of A. suum are destroyed within the normal interval of 24 hours

between feeding and drawing the vessel. Specific results for eggs of Taenia are not yet available for this new technology. It can be assumed that a 2-step continuous system will result in a reliable disintegration also of T. saginata eggs.

Composting of dewatered sludge in windrows, aerated static piles or mechanised and aerated "bioreactors" is a stabilisation process that relies upon the aerobic breakdown of organic matter by thermophilic bacteria. The sludge is mixed with bulking agents that serve three purposes: to increase the porosity for good aeration, to provide a carbon source and to reduce the moisture content (124).

By properly managed composting processes eggs of Ascaris suum are destroyed in windrows within 3 weeks and in bioreactors within 24 hours provided a temperature of 60°C is maintained for at least 24 hours. There are no specific results available for eggs of T. saginata but it can be assumed that their resistance is not greater than that of A. suum.

Lime treatment of dewatered sludge has an effect on helminth eggs only when quicklime is used. Then temperatures will rise as high as 60° - 70°C and a rapid kill of A. suum eggs is observed within 2 hours. These values may also be sufficient for a destruction of T. saginata eggs. In practice these temperatures are maintained for at least 24 hours and could be kept in this range even longer if the sludge stored in insulated vessels (264, 279).

New experiments with calcium hydroxide, formalin, peracetic acid and some other chemical compounds are indicating that possibly in the future a chemical disinfection of T. saginata eggs in sludge may become possible (46).

3.9.7 Sewage release from treatment plants

The majority of sewage treatment plants in most countries do not yet have the technology described above for disinfection of sewage sludge. Usually, sludge is delivered to farmers in the condition just as it was treated in their plant. In these cases, the sludge is at the best aerobically or anaerobically stabilized and, therefore, has to be considered infected with Taenia eggs. Such sludges, therefore, should only be utilised in agriculture under the guidelines described below.

Like most helminth eggs, the eggs of T. saginata are very resistant to adverse conditions. Work on the survival of these eggs on pastures and under various laboratory conditions indicates that survival times in the environment within the range of 3 to 12 months are probable (39, 46, 54, 55, 58, 62, 65, 114, 122, 124, 153, 184, 232).

3.9.8 Guidelines for agricultural utilisation of sewage and sludge infected with eggs of Taenia spp.

Access of livestock to surface waters which receive effluents from sewage treatment plants must be prevented to avoid the ingestion of taeniid eggs (65).

If sewage is used for irrigation of fields and crops it should not be applied to pasture, land for green fodder (forage) and crops for raw consumption. In case this is unavoidable for local reasons, livestock should not be allowed to graze and green fodder should not be harvested from such areas. The crops of grass and green fodder have to be used as hay or silage or as green pellets (35, 58).

Livestock should not be allowed to graze pasture treated with undigested sludge for at least 6 months. This precaution is particularly necessary because of the longevity of taeniid eggs on pasture. After 6 months the viability of the eggs is greatly reduced. However, the possibility that cattle may be infected cannot be ruled out, especially if the grazing resting period takes place in the winter months. It is, therefore, inadvisable to use undigested sludge on grazing land if the risk of infecting cattle with eggs of Taenia is to be avoided completely.

Livestock should not be allowed to graze pasture with digested sludge for at least 30 days or until there is at least 100 mm growth of herbage, whichever is the longer period. Digested sludge is defined as sludge produced either by storage of untreated sludge for 2 or more years or by controlled anaerobic mesophilic digestion. This advice applies only where the sludge is not mixed with any undigested sludge prior to land application. The resting period is designed to reduce bacterial infection but may be inadequate to prevent infection of cattle with any tapeworm eggs which have survived the digestion period. A resting period for at least 6 months is necessary to reduce the risk of such infections to an absolute minimum.

If these recommendations concerning the disposal of sewage and sludge are not strictly adhered to no control over cysticercosis in cattle can be expected.

3.9.9 Control measures in areas other than sewage and sludge utilisation

In some areas, human defecation in the grazing range of livestock still plays a role and, therefore, must be avoided.

Regional increases of infections of cattle with T. saginata in industrialized countries, to a large extent, are caused by the intensified excursion traffic, involving a growing number of highway picnic areas and camping grounds.

This risk to cattle can only be overcome by the establishment of sufficient sanitary installations which also meet the demands of this mass tourism during the holiday seasons.

On farms, which are not connected to public sewers, the effluents of the occupants should be collected separately from those of the livestock. Generally, the contents of cess-pits or house treatment pits for human sewage should not be distributed on to pastures, meadows or forage growing areas. Preferably, they should be transported to a nearby sewage treatment plant. Where this is not possible, they should be spread on to arable land before the beginning of the crop growing season and immediately ploughed into the soil.

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