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Parasitic zoonoses

Report of a WHO Expert Committee with the participation of FAO

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WITH THE PARTICIPATION OF FAO

Geneva, 14–20 November 1978

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PARASITIC ZOO NOSES

REPORT OF A WHO EXPERT COMMITTEE WITH THE PARTICIPATION OF FAO

A WHO Expert Committee on Parasitic Zoonoses with the participation of FAO met in Geneva from 14 to 20 November 1978. The meeting was opened by Dr Z. Matyáš, on behalf of the Director-General of WHO. Dr M. Abdussalam was elected Chairman, Dr B. Rosický and Professor C. W. Schwabe Vice-Chairmen, and Professor E. J. L. Soulsby Rapporteur.

1. INTRODUCTION

The Committee recognized the global importance of the parasitic zoonoses and the major impact they make on the health and the economy of many peoples. In providing a contemporary view of this group of diseases, the Committee brought up to date the relevant parts of the third report of the Joint FAO/WHO Expert Committee on Zoonoses (1), reviewed several additional topics (including ecological considerations, improved methods of surveillance, and prevention and control in general) and examined other problems of specific parasitic zoonoses that had not been dealt with in the aforementioned report. In this connexion, the Committee considered that important arthropod and pentastomid parasites of vertebrate animals that infect man also merit extended treatment, because of their medical significance and common occurrence in warm climates and among impoverished populations. These are discussed in section 9 of the present report.

Of particular value to this Committee were reports of special groups convened by WHO, alone or jointly with FAO, to consider research, practical control programmes, and other aspects of major parasitic zoonoses, such as echinococcosis (hydatidosis), taeniasis (cysticercosis), and diseases covered at present by the WHO Special Programme for Research and Training in Tropical Diseases (see below). The WHO Expert Committee on Fish and Shellfish Hygiene (2) and that on Microbiological Aspects of Food Hygiene (3), both convened with the participation of FAO, dealt with parasitic diseases transmitted through food.

As some of the most important parasitic zoonoses, such as leishmaniasis, trypanosomiasis, schistosomiasis, and filariasis, as well as malaria, are included in the Special Programme for Research and Training in
Tropical Diseases, and are dealt with, too, by other expert groups of FAO and WHO, the present report is concerned mainly with the zoonotic aspects of such infections.

The Committee noted with satisfaction the Organization's expanding cooperation with Member States, both individually and in groups, in zoonoses control through the proposed expansion of the network of WHO collaborating centres and WHO zoonoses centres and the development of strategies and methods for the surveillance, prevention, and control of zoonoses and food-borne diseases.

The Committee stressed that such efforts are essential since, quite apart from the morbidity and mortality and the consequent human suffering they cause, parasitic zoonoses are responsible for great economic losses, particularly in draft animals, meat, milk, and other foods and products of animal origin. The developing countries suffer much more severe losses than do the industrialized countries, partly because they have less well-developed public health and veterinary services and partly because of their unfavourable climatic and environmental conditions. Parasitic zoonoses also hamper rural development programmes, reduce meat exports, and in general slow down socioeconomic development.

In both national and international health planning, the important role of domestic animals and wildlife as reservoirs and transmitters of parasitic diseases must be taken into account. This matter has been neglected in many countries, on the one hand because the role of animals in the spread of human diseases has not been sufficiently appreciated, and on the other because the administrative and legislative provisions for interprofessional collaboration are inadequate and manpower and other facilities are lacking.

Public health and veterinary authorities should jointly plan a comprehensive countrywide programme, define its goals, determine its priorities, and integrate it into the national disease control and primary health care programmes.

Parasitic zoonoses present a special medical challenge. They include several of the most widespread and serious infections of man, and on the basis of the experience of the past 40 years, it may be presumed that they will make an increasingly significant contribution to the burden of human disease in the future. Almost all of the parasitic zoonoses are pathobiologically complex in their immunological and physiological relationships to their hosts and are epidemiologically complex in their transmission cycles. Involving many species of animals other than man, they provide examples par excellence of the critical need today to promote and nurture broader and more effective interdisciplinary relationships.
in research and in disease control efforts, particularly between the several branches of the medical, veterinary, and related professions.

The majority of species of animal parasites producing infections in man are shared with other vertebrate animals and are classed, therefore, as agents of zoonoses. However, many of them have been reported infrequently or only locally, while others are relatively unimportant from both the public health and the economic point of view. For these reasons the Committee decided to consider in the body of this report only the more important parasitic zoonoses or those that present especially interesting epidemiological or pathobiological features of potential public health interest.

Zoonoses have been defined as “Those diseases and infections [the agents of] which are naturally transmitted between [other] vertebrate animals and man” (4). In spite of some objections that this definition could be considered to embrace toxins and poisons acquired from animals, the Committee recommended that it should be retained because of its wide acceptance and common usage throughout the world. It was, however, proposed that FAO and WHO should keep this matter under review in the light of scientific developments and practical requirements. Apart from parasitic infections that fit this definition, there are other parasitoses shared by man and other vertebrate animals but not ordinarily transmitted from one to the other. Rather, their agents live saprozoically in certain environments and both man and animals are infected from these sources. An example is strongyloidiasis. Because these shared infections are of interest to both physicians and veterinarians and are commonly dealt with by zoonoses control programmes, the Committee discussed the more important of them. Some ectoparasites of animals, such as ticks, mites, and fleas, that attack man or establish themselves in human habitations, are dealt with briefly in section 10, even though the infections they cause cannot be classed as zoonoses. They have been discussed in greater detail by other expert groups (5–8) of FAO and WHO and in specific publications. Various classifications of zoonoses based on their epidemiological features and the type of environment in which they occur have been proposed. The very large number of zoonoses calls for a classification, especially for teaching purposes. Therefore, the increasingly used classification appended to the third report of the Joint FAO/WHO Expert Committee on Zoonoses (1) has been reproduced as Annex 1 of the present report.

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5 The Committee noted, in fact, that in some governmental organizations, all human health problems associated with animals are handled as part of programmes on zoonoses investigation and control.
2. SOCIOECONOMIC ASPECTS

Zoonoses with reservoirs of infection in domestic animals impose a particularly serious burden of ill health on vast numbers of people who live in rural areas and earn their livelihood through animal farming and other forms of agriculture. In some countries this high-risk group comprises up to 90% of the total population. Close association of people with their animals occurs throughout large areas and often under unsatisfactory sanitary conditions. Parasitic zoonoses are particularly prevalent in rural populations of tropical and subtropical countries. Especially among the children in such areas, parasitic zoonoses exact a double price by exacerbating the vicious circle of protein-energy malnutrition and infection. For not only do many of them produce debilitating febrile or anorectic illnesses, or both, in infants, but they markedly reduce local sources of already scarce animal protein by affecting food-producing animals as well. A recent study compiled by the United States National Academy of Sciences (9) directed attention to this dual significance of many zoonoses. Other serious losses of high-quality protein occur through the rejection of meat, fish, and other animal products because they are known to be commonly infected with harmful zoonotic parasites. Such losses may have an extremely serious impact, particularly when they interfere with food exports, as, for example, in areas where hydatidosis, cysticercosis, or trichinellosis is known to be prevalent. The Committee stressed, therefore, that for these reasons alone parasitic zoonoses constitute very important, yet generally neglected, targets for primary health care efforts throughout large areas of the world.

Also little understood is the further immense effect on a community's health and economy that these zoonoses cause through their infection of animal species, such as cattle, buffaloes, horses, camels, yaks, and llamas, that still provide approximately 85% of the world's total draft power (10). In the not atypical situation of India, cattle alone account for a largely irreplaceable 54% of the energy used for crop production, and fully 30% of energy used for all purposes in rural areas (16% of it from burning cattle dung as cooking fuel, 14% from the animals' work). Attempts to protect and care for these exceedingly valuable animals, which are often a major capital investment, subject millions of rural people all over the world to high risks of contracting parasitic zoonoses, particularly those transmitted through close contact with animals and animal wastes.

The trapping of wildlife for human consumption, as in parts of Africa, raises the question of the dangers that may be created by known or newly recognized zoonotic parasites. In fact, all people living in rural or semi-
rural areas, and quite large occupational groups, are already being exposed to many parasitic zoonoses that have wild-animal reservoirs. Occupational groups at especially high risk include forest workers, hunters, and pastoralists, whose activities ordinarily take them into areas in which wildlife is abundant. Moreover, in the case of some vector-borne zoonoses, even urban populations may be exposed to new wildlife infections—particularly under epidemic conditions, when vector infestation is at a high level.

Hazards to urban populations from parasitic zoonoses result not only from such causes and from the infections that are acquired from meat, fish, and dairy products (see page 18 for an example of the effect of technological changes in food processing), but also directly from the large populations of feral animals and livestock that are found in many of the world’s cities. In this connexion, the Committee also drew attention to the complication that parasitic zoonoses such as toxoplasmosis, larva migrans, and hydatidosis introduce into the otherwise desirable relationships afforded man by his pets and companion animals. Such relationships are of particular value for large numbers of city dwellers, who would otherwise spend their lives removed from almost all contact with nature, and for sections of the population such as children, the elderly, and the physically or mentally infirm.

This obviously complex socioeconomic impact of parasitic zoonoses urgently demands a more detailed study with fuller documentation of its true importance, worldwide or country-by-country, than has yet been undertaken anywhere. The true direct health significance of these infections at the national and local levels still frequently remains obscured by high prevalences of fevers, diarrhoeas, dermatoses, and encephalitides of unknown origin. Better estimation of such direct human health effects (as well as those more indirect health effects produced by loss of draft power for food-crop production and of protein foods of animal origin) will provide the only rational basis for determining the priorities of zoonoses control in the allocation of the often restricted resources available for disease prevention and primary care.

Baseline data collected for this purpose can also be used for determining the most effective and economical approaches to the prevention and control of these human diseases, which often are preventable in man only through their control in animals. The Committee therefore recommended that socioeconomic evaluation should be an essential part of all programmes for the control of parasitic zoonoses and that more public health and veterinary workers should be trained in the requisite epidemiological and economic methods. The Committee noted the increasing availability
of courses providing this type of training and reiterated the relevant recommendation made by a Joint FAO/WHO Expert Committee on Veterinary Public Health in 1975 (11).

3. FACTORS INFLUENCING PREVALENCE

3.1 Ecological considerations

Given suitable circumstances, man is probably susceptible in a varying degree to a very wide variety of infectious agents which have their natural reservoirs in other types of animal, from poikilotherm vertebrates and invertebrates to homiotherm animals. Either the circumstances have not existed for man to encounter many of these pathogens in the past, or the more or less rare encounters have not been recognized or recorded. Some parasitic infections—anisakiasis and angiostrongyliasis, for example—had become fairly commonplace before their etiologies were correctly determined. And in the case of toxoplasmosis, a prevalent and commonly recognized parasitic infection, important features of the zoonotic relationships and the parasite's life cycle remained undetected for a long time.

As human populations expand and efforts to improve their conditions of life continue, man can be expected to turn to account hitherto unexploited territories and natural resources. Harnessing the power of rivers, constructing roads and pipelines through virgin or thinly populated areas, and clearing or irrigating and cultivating new lands will all cause the human species continually to enter unaccustomed ecosystems in which potential human pathogens form part of the biotic community. Recently recognized human infections with such animal haemoproteozoa as the babesias, simian plasmodia, and trypanosomes have occurred in this way—at least, in some instances.

Additional possibilities for increased human exposure to animal parasites occur whenever wild or domestic animal species or breeds are brought into the proximity of man or when man wanders into a natural focus of infection.

A natural focus can be defined as the larger or smaller portion of a certain landscape consisting of biocenoses which have developed in the course of a long evolution and in which the infectious agent circulates as a component of the biocenose and can reach man or his domestic animals. Hence, natural focality is considered to be a general biological phenomenon, whereby the infective agent, which is a member of an ecosystem established by evolution or human activity, spreads to man and domestic animals by various routes under favourable ecological conditions. The
phenomenon is clearly demarcated geographically and seasonally, in
connexion with its dependence on the presence of certain local fauna. On
some occasions the causative agents can even be disseminated directly
among the human population. This may be considered as the demonstra-
tion of a certain degree of adaptability on the part of the pathogen to
prevailing conditions in the human population.

Even today numerous natural foci of parasitic zoonoses exist in their
primary form in vast areas of all the continents but, under the influence
of man's economic activities, in many places the ecosystems have changed
as a result of agricultural development into fields, meadows, gardens,
pastures, and plantations of various trees and crops. The long-term and
repeated influence of man's activities on a certain habitat (biotope)
through the cultivation of fields, perennial forests and grasslands, the
burning of forests, the creation of pasturage and intensive hunting or
game-keeping result in the formation of stabilized proclimax ecosystems
in various types of landscape.

The following examples will serve to illustrate the significance of
human activities in increasing the importance of parasitic zoonoses.
Water resources development—e.g., dam construction and irrigation
schemes—is taking place on a large scale and usually increases the danger
of water-related parasitic zoonoses such as schistosomiasis, trypano-
somiasis, paragonimiasis, fascioliasis, and dracunculiasis. The present-
day spread of towns and cities into previously uninhabited areas contain-
ing natural foci of disease leads to increased human contact with these
foci. In certain settled regions there are areas of carefully cultivated
forest where conditions are highly suitable for the persistence of certain
parasitic zoonoses. In such areas wildlife populations are sometimes kept
at a very high level owing to the removal of predators, supplementary
feeding, and artificial rearing. Foci of trichinellosis, toxoplasmosis, and
myiasis have been found in such situations.

It is strongly recommended that in planning development projects
advice should be sought from epidemiologists and ecologists to minimize
the resulting health risks.

3.2 Effects of human settlements

One of the very important considerations in the epidemiology of
zoonoses are the synanthropic animals which live in and around human
settlements and related constructions (living-quarters, storehouses, stables,
cowsheds, lairages, and enclosures for the initial storage of agricultural
products). The animals concerned include rats, mice, other rodents, bats,
some birds, and lizards, which form permanent or intermittent independent and semi-independent populations. The burrows and nests of synanthropic vertebrates have an important influence on the composition and development of some parasite groups.

Large human settlements (urban agglomerations) are suitable not only for synanthropic animals but also for some other animals of primary importance in the transmission of parasitic zoonoses. The changing fauna in urban areas can be divided into the following categories:

1. companion animals with which humans come into close contact—the recognized household pets, and also riding horses;
2. synanthropic animals coming into contact with humans and their food;
3. food-producing animals; and
4. wild and semi-wild animals.

In both urban and rural settlements, various animals are becoming increasingly popular as household pets and may begin to constitute a source of infection for their owners. For this reason, it will be necessary to investigate the role of pets in the sporadic dissemination of parasites. This is especially important in towns, where pets are kept in apartments. Thus man comes into close contact with animals whose origins are exceedingly diverse and of which a thorough microbiological examination would be an unusual procedure—if not to say impossible.

It has become clear that large wildlife reserves, national parks, and other protected regions, as well as smaller sanctuaries in various countries, provide conditions for the perpetuation of various parasite species. The transport of exotic animals to zoological gardens may lead to the importation of exotic parasites and parasitic zoonoses. Furthermore, the unrestricted importation of aquatic plants by aquarium suppliers could lead to the introduction of molluscan vectors of helminths.

3.3 Fluctuation in animal populations

The dynamics of wild, synanthropic, and other animal populations, including those of disease vectors, show the influence of such factors as food supplies, climate, and hydraulic changes. These fluctuations directly affect the extent and spread of zoonoses.

In recent years the introduction of large-scale intensive units in animal production has greatly increased the density of animal populations per unit area. At present in some countries there exist, for example, large-
scale units for as many as 50,000 head of pigs, feed-lots for 50,000-100,000 head of beef cattle, dairies handling 2,000 cows or more, and units containing over 2,000,000 broiler fowls. These populations may fluctuate dramatically in certain circumstances.

From the general ecological point of view one may consider the livestock in large-scale breeding units as an unstable, artificial population of domestic animals which is maintained through human care and the application of zootechnological and prophylactic veterinary methods. An example is known of an outbreak of cysticercosis infection among cattle in a large unit in the USA transmitted by a single human carrier of *Taenia saginata*; a similar incident has been reported involving the occurrence of serious mange in a large-scale milk-cattle unit in Central Europe due to *Sarcoptes scabiei* transmitted by a sole farm worker.

### 3.4 Human behaviour and food habits

Human behavioural patterns are often significantly related to man’s risk of acquiring parasitic zoonoses. Hydatidosis provides several good examples of such behavioural influences. (For a full discussion of this disease, see section 6.1.) The pastoral Turkana people of north-western Kenya are a population group that is one of the most heavily infected in the world with *Echinococcus granulosus* (12). For reasons still largely unknown, the incidence of hydatid infection among them appears to be considerably higher than among their related pastoral neighbours, who share superficially similar cultures. Because, through religious custom, human dead are exposed to hyenas and dogs (a practice also sanctioned by the religion of some related people), human infections help to perpetuate the transmission cycle, and the Turkana thus act as reservoirs of echinococcal infection. While their relationships to dogs appear to be close, the apparently focal hyperendemic pattern of distribution of hydatidosis in the tribe (though as yet unrecorded in detail) suggests that some specific local practices may be responsible for the very high infection levels. For example, it has been reported that dog faeces may be incorporated into some indigenous Nilo-Hamitic remedies. This is known to have been practised in the similar pastoral society of ancient Egypt (and, as some 19th century investigators claimed, was also once customary in Iceland). These local practices demand full investigation, and the Committee was pleased to note the initiative being taken in this respect through a combined FAO/WHO/UNEP effort. The chances of success in such an endeavour would be considerably enhanced if a WHO regional zoonoses centre were established in East Africa.
Other instances in which human behaviour definitely increases or decreases the risk of acquiring hydatidosis have been demonstrated in New Zealand and the Eastern Mediterranean area. In New Zealand, the risk of infection is approximately 6 times greater among the Maori population (a Polynesian people) than among New Zealanders of European origin (13). This risk has been shown by multivariate analysis to be associated more with the Maoris' relationships to dogs than with their sheep husbandry practices. The specific sources of risk have not been studied in detail, but it is not surprising that they should be more related to the parasite's life cycle in the dog than in the sheep, for the dog is an indigenous domestic animal among Polynesians, while sheep (and Echinococcus) were introduced into their society comparatively recently by Europeans. The Maoris' customs regarding dogs are different from the Europeans' and are long established, while their sheep husbandry follows the European pattern.

In the Eastern Mediterranean area, two other behavioural factors related to hydatidosis have been identified (14, 15). One is the lower risk of infection among Moslem Arabs than among Christian Arabs in Lebanon, a phenomenon that is related to Moslem cultural beliefs about the uncleanliness of the dog. (The risk of hydatid infection in Beirut is about 21 times greater among persons who own dogs than among those who do not.) Similarly, a higher risk of infection in Lebanon exists among shoemakers and shoe repairers, which is probably related not only to the fairly universal practices among these artisans of moistening their thread with their lips and holding tacks in their mouths, but more especially to the practice of preparing leather by batting hides in a boiling solution of dog faeces (of which the proteolytic enzymes soften the hides). Similarly, in the western USA, the comparatively recent spread of hydatidosis in sheep-raising areas has been closely associated with nomadic sheep husbandry, a practice peculiar to certain ethnic groups or sects, such as persons of Basque origin, Navajo and Zuni Indians, and Mormons. Californian Basques, for example, are over 1000 times more at risk of contracting hydatidosis than other Californians (16).

Some current modes of recreation (seaside sports, camping, tourism, mountaineering, hunting, fishing, riding, etc.) result in a closer contact of man with parasites on a large scale, with increased risk of infection, in regions where the human population has no naturally acquired resistance. It is very significant that while indulging in these forms of recreation people often change their place of abode, sometimes living under very primitive hygienic conditions and thus increasing the possibility of exposure to parasites and also to various vertebrate carriers and vectors of diseases.
Many tourists travel from temperate to subtropical and tropical regions and risk exposure to parasitic zoonoses. Rapid means of transport bring back the infected persons, mostly during the incubation period, to their homes in various parts of the world, in which the diseases in question, owing to their sporadic occurrence (e.g., trypanosomiasis, various helminth infections, and malaria), often remain unidentified.

Food and water play an important role in the transmission to man of the parasitic zoonoses, and some food habits increase the risk of infection. The WHO Expert Committee on Microbiological Aspects of Food Hygiene (J) grouped food-borne parasites into two categories:

1. Parasites of which the infective stages occur naturally in food (meat, fish, molluscs, crustacea, etc.)—e.g., *Taenia* spp., *Diphyllobothrium* spp., fish-borne trematodes, *Trichinella, Anisakis, Gnathostoma, Angiostrongylus, Capillaria, Toxoplasma, Sarcozystis*, and *Linguatula*.

2. Parasites that are derived from the environment (soil, water, etc.), from animals, or from food handlers, and whose infective stages occur as contaminants in food—e.g., *Echinococcus* spp., *Fasciola, Dicrocoelium, Fasciolopsis, Ascaris, Toxocara, Dracunculus, Trichostrongylus, Trichuris, Moniliformis, Toxoplasma* (oocysts), *Giardia*, and *Entamoeba*.

The first group consists entirely of zoonotic parasites and the second group largely so. Their transmission to man depends on the consumption of insufficiently cooked food or recontamination of food after cooking. Unfortunately, these conditions frequently obtain, since in many societies food habits and tastes favour the consumption of undercooked or raw food.

Another possibility for the propagation of such parasites is provided by the feeding of contaminated food to pet animals (for example, toxoplasmosis may infect cats and echinococcosis may infect dogs in this way).

There are a number of problems associated with the endemicity and transmission of food-borne parasitic zoonoses, depending on the interplay of factors within the classic epidemiological triad of host, causative agent, and environment. While a suitable environment and a susceptible host population, in juxtaposition, ensure the completion of the biological cycle of the causative agent of a parasitic zoonosis, other factors may alter the pattern and maintain the endemicity within a racial, ethnic, or religious group, or within a geographical population. Sociocultural factors may exert a strong influence on the maintenance of foci, despite the availability of methods for their prevention and control. Deeply rooted cultural practices and traditions often defy any change, even one aimed at improving health and wellbeing. Food habits—in all their global diversity—sometimes defy logic, and this is particularly significant with
food-transmitted parasitic zoonoses. Even where a particular species of parasite is rare, a lowering of public health standards can quickly raise the rate of infection. And even in areas with good health conditions, many species not listed in official reports are likely to be present in small numbers.

Religious rituals and tradition in some geographical areas account for the occurrence of certain food-transmitted parasitic zoonoses. For instance, in the Eastern Mediterranean, the consumption of raw sheep and goat livers has accounted for cases in man of halzoun, a nasopharyngeal disease caused by immature stages of Linguatula serrata, which are found in the liver and hepatic and other lymph nodes of these animals.

The consumption of wild watercress in Cuba, France, and other countries accounts for the numerous human cases of fascioliasis that are regularly reported.

Technological development has likewise contributed to the increased occurrence of some food-transmitted parasitic zoonoses. An example is anisakiasis, which has been disseminated more widely following the introduction of refrigeration facilities in commercial fishing vessels. Before fishing vessels were equipped with these facilities, the haul was immediately gutted at sea to prevent spoilage, and this prevented the anisakine larvae from migrating from the gut to the flesh of the fish. With the availability of refrigeration, the fish catches are kept intact and gutted only on reaching the processing plant. Normal refrigeration temperature, smoking and pickling do not kill the larvae of anisakines, and since certain national groups, such as the Dutch, eat raw or pickled herring as a delicacy, the human cases of anisakiasis reported are predominantly from the countries concerned. (However, deep-freezing does kill Anisakis marina (section 4.3, page 29). See also section 8.2.2, where anisakiasis is treated at length.)

Lack of fuel for adequate cooking, as in the Arctic, has forced communities living in these areas to eat raw meat of bears and other wild carnivores. This, together with cannibalism among the arctic carnivores, has contributed to the maintenance of a sylvatic trichinellosis cycle and a high incidence of human infection.

There is at present a trend to reduce certain forms of meat processing—for example, to use less salt, less smoke, and less heat treatment. This helps to preserve the nutritive value of the food but it adds to the possibilities of survival of pathogens.

3.5 Environmental pollution

Pollution of the environment can have an important influence on the existence and survival of parasites. The main problems are associated
with faecal pollution of the water supply, the soil, and the vegetation, especially in market gardens.

In polluted water reservoirs and streams, various parasites and vectors of parasitic zoonoses (Diphyllolothrium, Fasciolopsis, Schistosoma, Heterophyes, Dracuncula, etc.) may develop and persist.

The parasitological problems associated with sewage have become important in almost every part of the world. For instance, the increase in cysticercosis in cattle in Europe may be attributable in large measure to the irrigation of pastures with sewage effluent.

Soil pollution, primarily by eggs and larvae of different helminths and by protozoan cysts, is a scourge of some rural and urban areas. This is particularly hazardous where night-soil or inadequately treated sewage sludge is used for manuring crops, especially plants consumed raw. Our knowledge about the control of such large-scale pathogen dissemination is still limited. Also the effect of air pollution and the influence of synanthropic vegetation in rural and urban areas on the incidence of parasites and parasitic zoonoses are practically unknown.

The large quantities of animal wastes from animal-breeding establishments (pigs, poultry, cattle, etc.), dairies, abattoirs and carcass-disposal plants constitute another health hazard that must be taken into account.

4. PRINCIPLES OF SURVEILLANCE, PREVENTION, CONTROL, AND ELIMINATION

The methods of socioeconomic assessment of zoonoses are in large part those of epidemiological surveillance. Surveillance has been defined as the “exercise of continuous scrutiny of and watchfulness over the distribution and spread of infections and factors related thereto, of sufficient accuracy and completeness to be pertinent to effective control” (17). If properly pursued, this process can provide veterinary public health agencies with an overall intelligence and disease-accounting capability, which not only can give an early warning of the unexpected occurrences of diseases but also can indicate less dramatic changes in their prevalence and their potential effects on the community. Moreover, surveillance yields valuable data for epidemiological studies designed to identify important determinants of diseases that may then be susceptible to manipulation. Thus it is an essential prerequisite to the rational design and evaluation of any disease control programme.

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4.1 Collection and dissemination of information

It is obvious that the objectives of surveillance of parasitic zoonoses can be fulfilled only if the data are reasonably complete and reliable and that the information reaches the authorities concerned with control soon enough to be used as “information for action”. The Committee therefore stressed that surveillance should go beyond the passive reporting of diseases and include also active surveys in human and animal populations and specific follow-up investigations of outbreaks and sporadic cases, with rapid dissemination of interpreted findings. An explanation of and commentary on the statistical information is essential for producing the necessary impact on decision-makers. Such surveillance information should be disseminated through national or local epidemiological bulletins, a number of which have been published in recent years by various health and veterinary services.

Organization of the collection of data on parasitic zoonoses requires cooperation between veterinary and public health agencies and especially their epidemiological (including statistical) and laboratory services. The coordination of these services should be strengthened generally, but particularly in countries in which veterinary services are not attached to ministries of health, or veterinary public health units in such ministries do not exist to facilitate overall medical-veterinary collaboration. (See the report of a Joint FAO/WHO Expert Committee on Veterinary Public Health (11) on this subject.) Multidisciplinary interministerial committees have been established in some instances with respect to specific zoonoses campaigns to promote close links.

Methods for coding and manual, mechanical, or electronic processing of surveillance information have been developed but need to be more widely disseminated and shared. Specialist advice is available, too, from FAO, WHO and other sources, and can be resorted to for the development and strengthening of national surveillance programmes for parasitic zoonoses, as well as for the provision of better quality information for international disease intelligence purposes. The Committee supported the recommendation of the above-mentioned Joint FAO/WHO Expert Committee on Veterinary Public Health (11) for enhanced international surveillance activities for zoonoses generally.

The Committee believed also that public health authorities should be aware that this active prevalence survey approach to disease intelligence is a method in which veterinary authorities are particularly experienced, since it has constituted the mainstay of most of the successful livestock
disease control and eradication programmes for almost a century. Repeated or one-time surveys should be planned with the advice of statisticians, particularly with regard to sampling, and other specialists such as economists. Moreover, these surveys should seldom be restricted to disease data only, but should also include factors relating to the social and economic implications of the disease. Where serological, haematological and other laboratory tests are used, the reagents employed should be standardized as far as possible and the tests evaluated for specificity and sensitivity. The Committee noted particularly that little has been done to assess the specificity for surveillance use of diagnostic tests for parasitic zoonoses, and little understanding yet exists among veterinary and public health workers of the magnitude of the general problem posed by false positive results when tests of even quite good specificity are used to survey diseases of low prevalence. It has been shown (18) that only a test with a specificity of 99.995% provides a reasonably accurate indication of the level of disease when the true prevalence is below 0.07%.

Notification of the presence, incidence, and distribution of disease is often made to the appropriate authorities by veterinarians, physicians, and others, but seldom as effectively as it could be if the best sources of such information were properly organized. While case-notification procedures have been the traditional intelligence approach of public health, they have been less developed in the surveillance of animal infections. However, the Committee's view was that they should be promoted by veterinary authorities in the future to the maximum extent possible as a supplement to prevalence surveys, and particularly as a means of learning of new occurrences or outbreaks of diseases and of providing better data banks for epidemiological research.

In many parts of the world, the number of professional health personnel available for notification purposes is inadequate, and reporting may have to be augmented by medical and veterinary assistants or even by religious, political, and administrative leaders, teachers, and others. Short-term training can be given to laymen to enable them to recognize the principal signs of parasitic zoonoses in man or animals and to report them promptly to the responsible public health or veterinary authorities, or to both.

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8 "Test and slaughter" (or prevalence survey coupled with quarantine or other approaches) was first demonstrated successfully against rinderpest in Europe in the 19th century and applied on an immense scale by Daniel Elmer Salmon and his immediate successors in the USA, beginning in 1884, in successful programmes for the regional eradication of contagious bovine pleuropneumonia (bovine mycoplasmosis), equine venereal trypanosomiasis (dourine), and the then-important zoonosis glanders.
With respect specifically to surveillance of parasitic zoonoses, the Committee emphasized the availability of certain major sources of notification data that are not commonly utilized to the fullest advantage.

4.1.1 Diagnostic and parasitological research laboratories

In general, insufficient use has been made of diagnostic laboratory data for case-control and other analytical studies to identify disease determinants in addition to the specific infectious or other etiological agents with which laboratory diagnosis is directly concerned. Programmes should be developed for prompt reporting from medical and veterinary laboratories of "case abstracts" that, besides diagnoses, include at the minimum such relevant epidemiological information as date, address, age, sex, and race (or breed). The special facilities of veterinary laboratories should be utilized also for public health work (19).

4.1.2 Hospitals, clinics, and dispensaries

These sources can also provide, through immediate incidence reports and clinical record banks, surveillance data for human and animal cases of parasitic zoonoses that may be studied by methods similar to those applicable to laboratory case data. Public health officials should be aware in this regard of the existence in some countries of computerized clinical data banks for large veterinary teaching hospitals similar to those for some human hospitals. (For example, the Veterinary Medical Data Program of 13 major veterinary teaching hospitals in Canada and the USA now includes over 2 000 000 computerized case records.) Of particular value would be comparisons of human and veterinary surveillance data for parasitic zoonoses from laboratories and hospitals in the same geographical areas. These could lead, for example, to the recognition of specific parasitic zoonoses that otherwise would be overlooked in either the human or the animal population.

4.1.3 Food inspection services

A third extremely valuable source of notification data on parasitic zoonoses available to veterinary epidemiological services is that associated with food inspection, particularly the ante-mortem and post-mortem examination for diseases and abnormalities of slaughter animals. Veterinary food inspection services should fulfill two purposes: exclusion from the human food chain of dangerous or unsuitable foods, and the identification

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and tracing of the place of origin of animals affected by zoonoses (and other diseases). Food inspection services are also an excellent source of case-control data for basic epidemiological research on parasitic zoonoses.

4.1.4 Special surveys

Special surveys or the monitoring of the prevalence of infection are extremely useful, especially where mass control programmes are envisaged. Either the total population of a given area or a representative sample selected by the application of statistical methods is examined. Usually, skin tests or other immunodiagnostic procedures, as well as the examination of blood smears and excretions (e.g., faeces), are suitable. Such surveys have been used for a long time in the control of parasitic infections (e.g., malaria, trypanosomiasis, and hookworm) and in zoonoses control in animals (brucellosis, tuberculosis, etc.).

The Committee believed, on the basis of experience in the Americas, that an eventual network of WHO regional zoonoses centres (with FAO participation) would spur all such surveillance activities immeasurably, thus facilitating the prevention and control of these diseases.

4.2 Application of immunological principles and methods

It has been argued that the demonstration of a parasite, or of its developmental stages, is the only satisfactory evidence on which to base a diagnosis. Nevertheless there are a number of parasitic infections in which developmental stages are not excreted (e.g., hydatid disease and larva migrans), or in which such stages are detected only with difficulty (e.g., toxoplasmosis), and alternative methods of diagnosis are needed. Further, in surveys for epidemiological and control purposes, techniques are necessary which permit the rapid processing of large numbers of samples, often taken during other, unrelated, procedures (e.g., during vaccination) and of small size (e.g., finger-prick blood samples). Immunodiagnostic tests serve these needs. They may detect specific antibody in serum or plasma samples, using an antigen prepared from the parasite in question, or such an antigen may be injected intradermally into the patient to detect immediate or delayed hypersensitivity responses.

Since in certain parasitic infections in which the organisms (e.g., trematodes, nematodes, and some cestodes) do not multiply in the host minimal infections may not stimulate a response sufficiently strong to be detectable by an immunodiagnostic test. In this respect, the level of sensitivity of different tests varies. Some, such as those based on immunodiffusion in gels (precipitation tests), are positive only when substantial
levels of antibody are present, whereas others, such as radioimmune assays, will detect minute quantities of antibody. The detection of a high titre in a quantitative serological test may be indicative of a recent infection or a heavy burden of parasites. For maximum reliability the use of more than one serological procedure is desirable.

4.2.1 Sources of antigen

A major problem in the immunodiagnosis of parasitic infections is the provision of adequate amounts of specific antigen. Antigens may be prepared from different stages of the life cycle of a parasite, but more sensitive antigens are usually prepared from the stages involved with the pathogenesis of the infection (e.g., from larval stages of *Toxocara canis* for use in the diagnosis of visceral larva migrans). Some human parasites may be difficult to obtain, and related forms must suffice (e.g., *Dirofilaria immitis* from the dog for the diagnosis of human filarial infections). Parasites that are grown in laboratory animals may be contaminated with host material (e.g., alveolar hydatid cysts). With the increasing use of microtechniques, enzyme-linked techniques, and radioimmune assays, minute quantities of antigen can meet the needs of many hundreds or thousands of tests. This encourages the hope that the antigenic analysis of parasites will lead to the identification and isolation of specific diagnostic antigens which can be used in such microtechniques.

Antigens produced by parasites grown in defined media offer the advantage that in many cases excreted and secreted antigens of the stages associated with infection in man would be available. Such antigens are only available for some protozoa. Helminth life cycle stages have been cultured in complex media and contamination with host protein in the medium must be dealt with.

There is need for further studies on the antigens of parasites of zoonotic importance with the aim of isolating specific antigens for use in immunodiagnostic tests. A list of types of antigens used for immunological tests is found in Table 1 of Annex 2.

4.2.2 Standardization of antigens

There are few parasitic zoonoses for which standards for a diagnostic antigen are available. Though such standardization is a complicated and laborious process, ultimately it must be done if surveillance and control schemes are to be operated efficiently. Some of the steps involved include selection of a test with which to standardize antigens, the standardization
of this test, the production of the antigens in sufficient amounts to permit performance of the test independently by several laboratories in different locations with coded samples of test sera and antigens, and independent evaluation of the results.

The problems of obtaining sufficient amounts of antigen makes standardization difficult in some cases; nevertheless the increasing use of micromethods may overcome many of these problems.

The Committee recommended that FAO and WHO should expand the programme for the preparation of international standards and reference reagents for the diagnosis of the major parasitic zoonoses.

4.2.3 Sources of samples

Traditionally, serum samples have been obtained for the purpose of individual diagnoses using tests in which the amount of serum needed per sample involved millilitre quantities, whereas with microtechniques only microlitre amounts are required. These latter techniques permit the mass collection of samples from man and animals by simple means (e.g., finger- or earlobe-prick). Also, such samples may be dried on filter paper, mailed to a central diagnostic laboratory, and subsequently eluted with saline for use in a diagnostic test.

A topic little explored in immunodiagnosis is the use of whole blood or lymphocytes in tests to detect specific antigen-induced lymphocyte blastogenesis. Microtechniques and automated procedures would permit this approach to be used as an adjunct to serodiagnostic tests or as an alternative to them when delayed hypersensitivity responses predominate in an infection.

4.2.4 Selection of immunodiagnostic test

The choice of test is frequently determined by the accessibility of a diagnostic laboratory, the availability of ready-made test kits or reagents, the requirements of field surveys, or the exigencies of diagnosis for control purposes.

In some countries batteries of tests may be performed in a central diagnostic unit on a single serum sample, thus providing a comprehensive picture of the reactivities and permitting a clearer evaluation of the disease condition. Some tests have been developed which will allow a determination of the immunoglobulin class of the specific antibody in the sample. These include indirect immunofluorescence techniques using standardized preparations of parasites (e.g., freeze-dried sections of Toxoplasma), or
parasite antigens adsorbed on to inert particles (defined antigen sphere substrates (DASS) technique), or enzyme-linked immunosorbent assays (ELISA), in which the reacting antibody can be characterized by the use of heavy-chain, specific antisera to human immunoglobulin classes and subclasses. Information derived from such a test may be valuable in assessing, for example, infection of the fetus in congenital toxoplasmosis (IgM indirect fluorescence test), the recent nature of infection in acquired toxoplasmosis, or the efficacy of treatment in hydatid infection. A list of immunodiagnostic tests for the detection of antibodies in 10 zoonoses is given in Table 2 of Annex 2.

Reagents and test kits available from reputable commercial or institutional sources offer the advantage that some degree of standardization has been used in their production, so that the results obtained with them are comparable over a period of time and in different areas. However, there is no national or international quality control in the production of commercial reagents.

Where financial exigencies do not permit commercially available reagents to be used, recourse may have to be had to simpler tests which, though somewhat crude and not standardized, may serve the immediate needs of the investigator. For example, the incubation of parasite larvae in test serum or blood may result in visible precipitates on the parasite, or adhesion of cells to it, providing evidence of specific antibody in the sample. As interim measures these techniques could meet a diagnostic need where no alternative exists, and a useful purpose would be served if information about such techniques were provided to persons working in remote areas.

Immunodiagnostic techniques designed for mass testing and lending themselves to automation are becoming increasingly available. They often rely on radioimmune assays and provide objective data which can be used satisfactorily in epidemiological surveillance and control studies. The development of such techniques permits the mass examination of animals (e.g., for trichinellosis in abattoirs), and they may offer great advantages over the more conventional tests.

Developments in assays for cell-mediated immunity, involving micro-techniques for whole-blood culture to assess specific antigen-induced lymphocyte responsiveness and its evaluation by automated techniques, offer the possibility of using these procedures for immunodiagnosis where cell-mediated immunity reactions predominate in parasitic infections or where antibody levels are too low to be detected by serological tests.

Hitherto, immunodiagnostic tests have been used primarily to detect antibody or skin sensitization. A positive reaction may persist for long
periods—sometimes years after active infection has cleared or the parasite has been eliminated. Further, such tests usually do not provide information on the level of infection in a host. Increasingly, therefore, attention is being directed to the detection of antigen and antigen-antibody complexes, which provides a more direct measure of the biomass of the parasite in a host and, inter alia, allows an assessment of the potential immunopathological aspects of an infection. Radioimmunoassays and ELISA are the preferred techniques for such tests and their further development should be encouraged.

4.2.5 Immunization against parasitic zoonoses

Attempts at immunization against cutaneous leishmaniasis have been reported from the Middle East and the USSR, but the results have been equivocal.

The development of immunizing agents from *Trypanosoma cruzi* infection (Chagas' disease) in man has been under intensive study in recent years. A variety of agents (avirulent strains, radiation-attenuated infective stages, various antigenic extracts of these or culture fluids, killed epimastigotes or microosomal fractions of the parasite) have been evaluated. In many instances, the results indicate that a high level of immunity can be produced in experimental hosts, but the application of this approach in human beings is subject to severe limitations. The drawbacks involved include the difficulty of predicting the virulence for man of strains avirulent for animals, of assessing the lack of infectivity of so-called killed or irradiated suspensions of organisms or extracts of them, and of assessing the role of prior sensitization with avirulent forms in the production of chronic manifestations of Chagas' disease.

With the pathogenic African trypanosomes, immunity to a homologous strain of parasite can be produced experimentally in animals by various means (e.g., inoculation with radiation-attenuated trypanosomes or chemically inactivated forms, followed by treatment of the consequent slight infection). However, the propensity of such trypanosomes to undergo antigenic variation with the relapse of the infection precludes field utilization of these techniques at present. Extensive research under way in Africa on immunological control of animal trypanosomes is likely to have important implications for trypanosomiasis control.

In some zoonoses due to helminths, research has reached a stage that indicates that control of infection in animals by immunization might be feasible. This is especially so with the larval cestodes of, for example, bovine cysticercosis, against which the passive immunization of newborn
calves has been successful and active immunization in older cattle has been achieved with antigens of homologous and heterologous taenids. Though more work is necessary, in some cases the studies have reached a point where limited field trials in endemic areas of bovine cysticercosis are justified.

Studies of immunization against adult cestodes (e.g., *Echinococcus* spp.) are less advanced. Radiation-attenuated infective stages, antigens produced *in vitro*, and the introduction of developmental stages by abnormal routes all induce a measurable level of protection. However, this is not sufficient for practical purposes.

Recent developments in culture techniques permitting the prolonged *in vitro* growth and development of parasitic organisms (e.g., trypanosomes, malarial parasites, and cestodes) will permit a more effective evaluation of the protective capacity of various antigens, including those derived from animals.

### 4.3 Parasitic zoonoses transmitted by food

The role of food and food habits in the epidemiology of parasitic zoonoses has already been mentioned in section 3.4 (page 15 *et seq.*). The following is an extended discussion of the factors involved in relation to control measures.

Several factors contribute to the continuing or increasing importance of food and drink as vehicles of parasitic infections—for example: the worldwide distribution of foods, previously consumed only in certain regions, and their parasites; improved storage procedures that preserve taste and nutrients but also pathogens; renewed interest in recycling human and animal waste in the food chain; and consumer preferences for raw or undercooked foods. In order to control parasites and their hosts in food and drink there is a need for rapid, reliable, reproducible methods, such as those that have been developed for isolating, culturing, identifying, and estimating the pathogenicity of food- and drink-borne bacteria.

Theoretically, human faecal containment is adequate to interrupt transmission of most of the food-transmitted parasitic zoonoses, but this is not so in areas where these diseases are endemic because of sociocultural practices or because of the widespread use of night-soil as a fertilizer for vegetable crops and fish-ponds.

In slaughter animals the conventional detection methods normally rely on the direct visualization of the parasite (e.g., trichinoscopy, gross inspection for *Taenia saginata* and *T. solium* cysticercosis). However,
simple, inexpensive, automated laboratory procedures such as the ELISA test would give additional important information for a well-based judgement of meat.

Another interesting development is the potential use of serological tests for screening food animals on the farm for the presence of specific disease agents. Provided the tests are highly specific, seroepidemiological surveys can be carried out, permitting a constant surveillance of the degree of infection in a certain area which would serve as a basis for control programmes, including meat inspection. A positive result in an animal on the farm or in a herd would indicate the need for rejection or for reexamination with a direct method at the abattoir.

In contrast to the detection procedures used in slaughter animals, individual examination of fish or shellfish is impracticable. If a public health hazard is suspected, therefore, mass treatment is a more feasible approach. For example, the large-scale deep-freezing of Herrings was adopted in the Netherlands after it was established that many of these North Sea fish were infected with *Anisakis* sp. (see section 3.4, page 18, and section 8.2.2., page 82 et seq.).

Most of the current national legislation already contains provisions for the treatment of meat and other foods infected by parasites. These include freezing, canning, cooking, and salting. A treatment method at present being developed is radioactive irradiation.

It is, however, essential to stress that one of the most important measures for controlling food-borne parasites is health education aimed at making the public aware of the dangers of eating raw or undercooked food, especially that of animal origin. This should play a significant role in national programmes for the prevention and control of food-borne parasites.

In view of the importance of parasitic zoonoses, especially in the developing countries, it is recommended that WHO, in collaboration with FAO, encourage and assist Member States to carry out surveys on the health and other socioeconomic consequences of food-borne parasites. The results of these surveys are crucial for adequate channeling of the available funds and professional expertise to tackle the problems where they are most pressing. Hitherto, many countries have been handicapped in their prevention programmes by lack of information.

National public health authorities should develop objective prevention and control programmes against food-borne parasitoses based on the results of the above surveys and other information. Essential components of these programmes include: (1) inspection and laboratory activities,
(2) evaluation and licensing of food-production and -processing techniques, and (3) health education directed at food producers, processors, and consumers.

The solution to problems associated with food-transmitted parasitic zoonoses should be viewed from a sociocultural perspective. Recommendations for prevention and control should not merely take the form of a bald statement such as "avoid eating raw food". It is reasonable to assume that there are other deep-rooted practices within a social and cultural milieu that contribute to the diversity of food habits. A thorough study of food production and certain dietary practices which contribute to the endemity of some of the important food-transmitted parasitic zoonoses should be carried out.

4.4 Prevention and control of parasitic zoonoses under different conditions

During the last few decades there has been a noticeable change to intensive methods of animal husbandry in most parts of the world. Too often the methods developed for efficient production have ignored the public health and economic aspects of animal hygiene. This has resulted in the creation of conditions highly favourable to an exchange of infections and parasites and their eventual transmission to man by contact or through animal products, particularly food. Another consequence of intensive methods of production has been the expansion of commerce in animal products, in live animals, and in animal feeds, which has increased the risk of the spread of infections and parasites over long distances.

Other recent developments which may create or worsen existing conditions favourable to the spread of zoonoses—for example, urbanization, natural focality, migration, and other socioeconomic phenomena—have already been dealt with in section 3 (page 12 et seq.).

The increased use of immunosuppressive measures for the treatment of various diseases, as well as in connexion with the transplantation of organs, has enhanced the risk of converting inapparent zoonotic infections in individuals into severe clinical, and at times fatal, diseases (e.g., toxoplasmosis and strongyloidiasis).

The above-mentioned factors are operative almost everywhere in the world, but their influence has been felt particularly strongly in warm climates and in developing countries. As these developments are linked closely with economic factors, it would be unrealistic to expect a halt in their progress purely for health reasons. Efforts should therefore be made to develop effective and reasonably priced methods of zoonoses surveillance and control which would be applicable in the existing circumstances.
One of the most important organizational requirements of zoonoses control is close collaboration between the animal health and public health services dealing with these diseases. Unfortunately, this vital link in government machinery is still missing or weak in many countries.

Government planners and policy makers should be made aware of the huge reservoir of human diseases in the animal kingdom. Moreover, some of these diseases may cause serious economic losses and undermine the main sources of high-quality protein foods.

Many of the existing methods for the control and prevention of zoonoses require large capital outlay and costly operations for farm improvement techniques, waste disposal, bush clearing, drainage of marshes and other water control measures, improved human and animal housing, etc. Some of these operations may be made cheaper or even self-supporting—for example, by the recycling of wastes and the generation of electricity in water-management schemes. Even these economically feasible operations need to be made simpler and less costly so as to bring them within the reach of countries with limited resources. Recent developments in chemotherapy (e.g., for the elimination of tapeworms and their cysts) have raised hopes of providing cheaper and easier methods of control. Similarly, cheaper methods of vector control and the elimination of invertebrate intermediate hosts (e.g., molluscs) need further improvement for general and safe field application.

For many parasitic zoonoses, long-term control measures are required in order to keep their prevalence within tolerable limits. However, in some cases (for example, those of echinococcosis, taeniasis, trypanosomiasis, and fasciolopsiasis) the initial reduction may be achieved more efficiently and at less cost by a mass campaign.

Some parasitic zoonoses, such as *Taenia solium* infection, usually show a smouldering or low sporadic incidence. However, the introduction of this parasite into previously uninfected populations, whose food habits and environmental conditions favour transmission, may cause serious epidemics.

Severe problems occur from improper food control. For example, in many countries animals are slaughtered on the occasion of religious or other festivals in the absence of any proper meat inspection, with disease consequences for humans (e.g., taeniasis and pentastomiasis) and for animals (echinococcosis in dogs).

The importation of aquarium plants may introduce snails, suitable to complete the life cycle of several zoonotic parasites, into countries with appropriate ecological conditions but free of the parasites, thus giving rise to the danger of creating new foci.
Achatina fulica, a snail which enters into the life cycle of Angiostrongylus cantonensis, is bred for human consumption in some countries and was widely disseminated for food purposes throughout the Pacific islands prior to the Second World War. Since then, wild populations of this snail have become established.

With all zoonoses that occur in urban areas, health education of the public is one of the most effective preventive measures. It should be concerned with explaining the hazards that pets and other animals kept in towns constitute for their owners and their surroundings. However, it is imperative to proceed cautiously and with respect for special sensibilities, because often there are great emotional ties between owners and their pets. There is also a good case for imparting health education about the role of synanthropic mammals, birds, and arthropods. The control of vermin, including arthropod pests, should receive high priority. The possibility of controlling animals undesirable in urban areas, and the level of control attainable, depend on socioeconomic conditions. Improvement in the living standard of urban people in itself gradually leads to the elimination of a number of phenomena undesirable from the aspect of public health. Nevertheless, even new cities whose construction embodies the principles of modern architecture pose some public health problems related to animals which must be solved by municipal administrations, primarily by their public health and veterinary services.

The comprehensive and complicated problem of zoonoses cycles in nature and in the human environment necessitates special knowledge on the part of physicians and veterinarians. In recent times, the increase in avian to the Second World War officers and the general population of the importance of zoonoses, as well as the augmentation of diagnostic facilities, has thrown light on many facets that were previously underestimated or unknown. Appropriate knowledge of the zoonoses in various regions and of the danger for different population groups must be considered as one of the essentials of primary health care.

4.5 Occupational hazards

Some zoonoses have significantly higher attack rates for workers in the course of their occupation than for the rest of the population. Well-known examples are the occurrence of hydatidosis and naso-ocular myiasis in shepherds in endemic areas. Other examples are trypanosomiasis in hunters and others working in endemic areas, cutaneous leishmaniasis and schistosomiasis in agricultural and irrigation-canal workers in endemic areas, mucocutaneous leishmaniasis in rubber plantation workers
in neotropical forests, dracunculiasis in water-carriers, cutaneous larva
migrans in tea-plantation and other orchard workers, cercarial dermatitis
in paddy-field workers and clam-diggers, and tick and mite infestations
in animal handlers. Sometimes not only the workers but also members
of their households are exposed. Cooks and housewives are particularly
at risk of contracting diseases due to the handling and tasting of uncooked
food (e.g., taeniasis, trichinellosis, and toxoplasmosis). Laboratory
workers must be considered at risk when dealing with parasites. For
example, leishmaniasis has occurred in laboratory workers, Toxoplasma
infection is common in people working with this agent, and those work-
ing with *Ascaris suum* may not only acquire the adult parasite but also
suffer from severe allergy to the worm.

The investigation of claims arising from the occupational origin of
zoonoses is not always simple, since the occupational disease does not
differ in its clinical features from the same disease contracted under other
conditions (e.g., through eating and drinking, sport, and other forms of
recreation). All available information, particularly on the presence of the
same infection in animals or animal products and the chances of signifi-
cant contact, etc., should be carefully considered. In these investigations,
the physician, the veterinarian, and the laboratory worker should work
closely together.

The best way of eliminating the risk of zoonotic occupational infec-
tions is to rid the reservoirs and vectors of the agents concerned. This
ideal goal may take time to achieve and may be difficult or unattainable
under some circumstances. In such cases, one has to consider improving
the working environment, wearing protective clothing and shoes, provid-
ing specific immunization or chemoprophylaxis, and adopting safe occu-
pational practices. In particular, safe laboratory practices should be
introduced when work is undertaken with parasites which involve a risk
to human health—e.g., *Echinococcus spp.* in carnivores.

In many cases, the improvement of living conditions on farms may
contribute to the control of zoonoses—for example, the incidence of
cysticercosis is reduced by the introduction of cesspools. In most instances
the adoption of more rational farming techniques and the introduction
of professional (including health) education greatly contribute to the
control of occupational hazards.

Special guidelines about zoonoses as occupational hazards for farm
workers and others are urgently needed; they should provide advice on
simple preventive measures.
4.6 FAO/WHO cooperation with Member States

Ever since their creation, FAO and WHO have been active in promoting national and international measures for the prevention and control of zoonoses (20). Much work has been done in developing and standardizing methods of surveillance, including socioeconomic assessment, and in promoting control of the major zoonoses and strengthening related food hygiene programmes. Training and education at all levels have also received considerable attention. In at least one region (the Americas) there has been a large-scale programme of cooperation with Member States in field projects.

In 1973, the WHO Executive Board at its 51st session accepted the Director-General's suggestions for the further development and reorientation of this programme (resolution EB51.R25). These proposals covered, among other aspects, the strengthening of field activities, the creation of more regional centres for the provision of training and services, the development of food hygiene programmes, and the elaboration of methods of assessment of the social and economic implications of zoonoses and food hygiene programmes. They also included the strengthening of education and training at all levels, and of veterinary public health administrations in ministries of health. The scope of the programme was widened to include aspects of environmental conservation and improvement, the selection of animal sentinels for monitoring harmful materials, and the removal or recycling of animal wastes.

The foregoing trends in strengthening cooperation with and between Member States in zoonoses control and food hygiene have been developed further during the last two or three years, and efforts are being made to encourage field programmes particularly in regions other than the Americas, where they are already well developed.

The Thirty-first World Health Assembly discussed the prevention and control of zoonoses and food-borne diseases due to animal products and, in resolution WHA31.8, invited Member States:

"(1) to formulate and implement appropriate countrywide programmes for the control of zoonoses as an integral part of national health programmes;
(2) to strengthen cooperation between national veterinary and public health services in improving the surveillance, prevention and control of these diseases;
(3) to collaborate further in ensuring the appropriate development of zoonoses centres wherever they are required, and their contribution to national health programmes."

At the same time, the Health Assembly requested the Director-General to continue to increase technical cooperation with Member States, including the development of national, regional, and global strat-
egies, and of the methods for the surveillance, prevention, and control of zoonoses. It further asked for the extension of the network of zoonoses centres in all regions, in cooperation with UNDP, FAO, and other agencies. The main objectives and components of the programme have been described in the Director-General’s report to the Thirty-first World Health Assembly (21).

5. PROTOZOAN INFECTIONS

5.1 Toxoplasmosis

Toxoplasma gondii is now known to be a coccidian parasite (Apicomplexa) of which the definitive hosts are the genera Felis and Lynx; the intermediate stages occur in a wide range of animals, including important domesticated species, and in man. The tissues of the intermediate hosts may be invaded during 3 stages of the life cycle of the parasite: the sporulated oocyst derived from the faeces of infected cats, the vegetative form (endozoites, tachyzoites), and the cyst form (bradyzoites, cytozoites). The relative importance of the oocyst and cyst stage in the transmission of infection to nondelines varies according to the host concerned.

Toxoplasmosis in man may occur as a congenital or as an acquired infection. Individuals in close contact with oocyst-excreting cats, or those dealing with raw meat, are at a greater risk of acquiring an infection than the general population. Congenital infection is associated with abortion, death of the newborn infant, or disease involving hydrocephalus and other central nervous system changes and ocular disorders. The frequency of congenital infection varies from area to area. There is evidence that the severity of congenital infection differs with the duration of infection of the fetus, more severe lesions resulting from early infection in the first trimester of pregnancy.

Acquired infection in man is usually less severe, being manifest variously by lymphadenopathy, chorioretinitis and general malaise, but acute generalized toxoplasmosis may result, especially in persons undergoing immunosuppressive therapy.

Fatal epidemics have been reported in swine, rabbits, mink, and chickens. Abortion in sheep and goats is an important manifestation of infection in many parts of the world.

5.1.1 Role of the felines in toxoplasmosis

The parasite undergoes a coccidian cycle in the epithelial cells of the small intestine of cats. Within the Felidae, only the genera Felis and Lynx
have been shown to serve as definitive hosts. Oocyst excretion in the faeces lasts up to 3 weeks, depending on the form of the parasite that induced the infection in the cat. Reinfection of cats may lead to renewed excretion of oocysts for a short while in animals which have not developed high antibody titres, in young cats, or in those which become infected with other coccidia (e.g., *Isospora*). *Toxoplasma* oocysts sporulate to the infective stage within a few days and they may survive thereafter in moist soil for up to 18 months. They are killed quickly by boiling water or by a 10% formaldehyde solution in 24 hours. Earthworms and arthropods may serve as mechanical vectors of oocysts.

Epidemiological evidence suggests that predation by cats on infected rodents containing cysts (and possibly tachyzoites), and the feeding of raw meat containing these stages to cats, are the major sources of feline infection. The role of birds in feline infection requires further evaluation. Stray, or feral, cats may show a higher prevalence of *Toxoplasma* infection than household cats.

Surveys on some islands in the Pacific with and without cats indicated that human and animal toxoplasmosis was virtually absent on cat-free islands. There is increasing evidence that a single infected cat may provide sufficient contamination of the environment with oocysts to result in widespread infection in herbivores (e.g., sheep). There is also evidence for oocyst-derived human infections.

In domiciles where cats are present and where a woman is pregnant and is serologically negative for *Toxoplasma*, it is recommended that any oocyst-excreting cat should be removed. In addition, it is important that cats should not be fed raw meat that has not been frozen or be allowed to hunt for food. Experimentally, the excretion of cysts by cats can be stopped by the administration of 10 mg of 2-sulfamoyl-4,4'-diaminophenylsulfone per kg of bodyweight, but the effect of this treatment under natural conditions remains to be studied.

5.1.2 Other modes of transmission

The consumption of raw or undercooked meat or meat products is an important, probably the major, source of human infection. It is recommended that pregnant women should not eat raw meat, particularly pork or mutton—not even taste a sample during its preparation for cooking—so as to avoid the possibility of acquiring infection. Contamination of utensils and hands with infective stages in the preparation of food constitutes another possible source of infection. The relative importance of the type of meat (e.g., pork, mutton, beef, or game) may depend on factors such as strain of organism, type of livestock production (e.g.,
intensive breeding of rabbits), eating habits (e.g., raw or well-cooked food), and religious or cultural restrictions on the types of meat consumed.

According to Sommer et al. (22) Toxoplasma cysts in meat survive at +4 °C up to 3 weeks. They are killed if the meat has been kept frozen at −15 °C for longer than 3 days and at −20 °C for longer than 2 days. Meat that has been heated in all parts up to 65 °C, and kept at that temperature for 4-5 minutes or longer, generally does not contain viable Toxoplasma cysts; neither do meat products prepared with salt and nitrates.

5.1.3 Congenital toxoplasmosis

In normal circumstances congenital infection can occur only when a woman has a primary exposure during pregnancy. Transplacental transmission from a chronic infection is believed not to occur. Infection prior to conception is considered to provide protection against the birth of a child with deformities from which it might otherwise have suffered if the mother had been infected during pregnancy. Reactivation of a chronic infection in a pregnant woman may possibly lead to abortion, but there is controversy as to whether or not this ever occurs.

Clinical manifestations in an infected mother are rare, but a temporary parasitaemia may lead to infection of the placenta and subsequently of fetal circulation. The majority of congenital infections are nonfatal and clinical manifestations occur in up to 10-15% of cases. If diagnosis can be established in the neonatal period, therapy can prevent further multiplication of the organism and thereby additional tissue damage may be prevented. To this end, a pregnant woman should have a serological test made as early as possible in pregnancy to establish whether she has acquired an infection before or during pregnancy.

Indirect immunofluorescent techniques, which detect antibodies of the IgM class in the fetus or the newborn, are applicable to the diagnosis of congenital toxoplasmosis. The demonstration of such antibody indicates that the fetus has responded to an infection in utero. Other serodiagnostic tests which measure only IgG antibodies or fail to differentiate the immunoglobulin class of Toxoplasma antibodies are of value in diagnosis only when it is possible to demonstrate that a rising titre occurs or if high titres persist beyond the time when maternally acquired antibodies should have disappeared.

The preferred treatment of congenital infections is a combination of sulfonamides and pyrimethamine. In addition, spiramycin is of value. These are effective against the trophozoite but not against the cyst form. Pyrimethamine should not be used during the first trimester of pregnancy. The search for effective drugs needs to be continued.
5.1.4 *Acquired toxoplasmosis of humans*

Postnatal transmission of *Toxoplasma* to man is almost exclusively by the oral route—by the ingestion of meat containing cysts or trophozoites or contaminated by oocysts. The evidence that animal contact is important in transmission is explicable on this basis. There is no evidence of transmission by blood-sucking insects but accidental self-infection of laboratory workers is known and blood transfusion and tissue and organ transplantation are recognized as sources of infection.

The diagnosis of acquired infection is based on isolation of the parasite, serodiagnostic techniques, and histopathological examination of biopsy material. Isolation is facilitated by the inoculation of mice with suspect tissue or fluids. To demonstrate parasites in ascitic fluid in the mouse several blind passages may be necessary.

The isolation of the parasite need not necessarily imply clinical disease since the organism may persist in the tissues for years after infection.

A variety of serodiagnostic tests are in use. Tests which differentiate the immunoglobulin class of antibody have the added advantage that the recent nature of the infection or a recrudescence may be determined. Such tests include the IgM indirect fluorescence test (IgM-IFA) and ELISA. Other tests of value in diagnosis include indirect haemagglutination, direct agglutination and complement fixation. The Sahin and Feldman dye test, which utilizes living *Toxoplasma* organisms, is still in use in a number of laboratories but is being replaced by techniques in which reagents are noninfective and more standardized. Several of the tests have been adapted to microtechniques and automation and thus are of value in mass testing.

A standard reference serum is available for the diagnosis of toxoplasmosis by the dye test. A new reference serum for other serological methods should be prepared for widespread distribution.

Screening for *Toxoplasma* antibodies is important not only to protect the unborn children of pregnant women but also to determine the prevalence of antibody in swine, sheep, and other domesticated animals. To this end the evaluation of a purified antigen, specific for *Toxoplasma*, for use as a skin-test reagent, would be highly desirable.

Serodiagnosis is being offered with increasing frequency to nonpregnant and above all to pregnant women, and to newborn infants. In some cases public services are organized for this purpose.

The consumption of raw or undercooked meat should be discouraged, but if it is unavoidable the meat should be deep-frozen quickly and kept
at temperatures for the periods indicated in section 3.1.2. (This procedure does not, of course, destroy all pathogens in meat.)

5.1.5 Related organisms

Among the coccidia closely related to *T. gondii* is the recently described parasite *Hammondia hammondi*, of which the oocysts are also excreted by cats and are morphologically indistinguishable from those of *Toxoplasma*. In mice, which are the intermediate hosts, the thin-walled cysts are found in the heart and skeletal muscles and not in the brain. Experimental transmission from mouse to mouse has not been successful.

Further research is necessary to determine the relationship between *Toxoplasma* and *Hammondia* and its possible significance for the serological diagnosis of toxoplasmosis.

5.2 Sarcosporidiosis

Sarcosporidia, which for a long time had an uncertain taxonomic status, are now known as coccidia (Apicomplexa) with an obligatory two-host transmission cycle, involving mostly herbivorous animals as intermediate hosts and carnivorous animals, man, and monkeys as definitive hosts. Sexual development in the small intestine of a final host leads to the production of sporulated oocysts or mainly free sporocysts, which are excreted with the faeces. The infection of intermediate hosts occurs when infective stages are swallowed. After asexual intracellular multiplication in various internal organs, the parasite invades striated muscle cells, where cysts are formed containing the infective cystozoites.

Several species of *Sarcocystis* occur in domestic and wild animals, and prevalence rates may be very high. For example, in various countries of Europe 61–99% of slaughtered cattle were found to be infected. In Austria and the Federal Republic of Germany prevalence rates in pigs of 7.4% and 5% respectively have been reported.

It is now known that several *Sarcocystis* species can produce disease and death in animals under experimental and natural conditions. Man can act both as a final and as an intermediate host for *Sarcocystis* spp.

5.2.1 Man as final host

According to present knowledge man is the final host for one *Sarcocystis* species from cattle (S. bovihominis) and another from pigs (S. suihominis). After infection by eating cyst-containing raw meat derived from these animals, man excretes sporocysts that are indistinguishable from those formerly ascribed to *Isospora hominis*, which is now commonly regarded as an invalid species. Intestinal sarcosporidiosis in man
may lead to clinical symptoms. Experiences of volunteers infected with
*S. suihominis* indicate that after consumption of uncooked, cyst-containing
meat, symptoms can occur such as abdominal pain, diarrhoea, fever,
tachycardia, and an increased respiration rate. Individuals may also
develop high serological titres when tested with homologous antigen.
*S. suihominis* is regarded as more pathogenic for man than *S. bovihominis*.

Sarcocystic infections can be diagnosed in the final hosts, including
man, by faecal examinations with a flotation method or with the thio-
mersal (Merthiolate)-iodine-formaldehyde concentration (mrc) pro-
cedure.

5.2.2 *Man as intermediate host*

Several cases of human infection with the cystic stages of *Sarcocystis*
in muscle have been reported from Africa, Central and South America,
South-East Asia, and Europe. Evidence suggests that man acts as the
intermediate host for several species of *Sarcocystis*. From morphological
and experimental findings, it would appear that *Sarcocystis* cysts in
monkey and man in South-East Asia are similar and that the dog may
serve as the definitive host. Further studies to establish the definitive
hosts of the human (muscular stage) parasites and the natural intermediate
hosts are necessary.

As a rule the cystic stage in man is nonpathogenic and reports of
cases have arisen as a result of incidental findings at biopsy or autopsy.
There are, however, a few records suggesting that sarcocystic infection
in man may cause such damage as muscle necrosis and denervation
atrophy. To determine the true prevalence of cystic infection in man
improved diagnostic procedures need to be developed.

The control of sarcocystic infection in man has to be considered from
two aspects: (1) to prevent intestinal infection where man acts as the
final host, and (2) to prevent muscle infection where man acts as the
intermediate host. To prevent intestinal infection, meat must be sub-
jected to control procedures similar to those outlined for toxoplasmosis
with regard to cooking and freezing. The detection of *Sarcocystis* in
meat (cystic stage) is possible during routine inspection procedures such
as trichinoscopy. Microscopic examination of the cyst wall can differen-
tiate 3 species of *Sarcocystis* in the musculature of cattle. Greater sensi-
tivity can be achieved by tryptic digestion of inspected meat. Ultra-
structural studies indicate that differentiation is possible at this level.
Control measures to prevent human infection with the cystic stage will
depend on further elucidation of the parasitic life cycle.
5.3 Leishmaniasis

Hitherto, the speciation of the leishmaniae has been based on the type of clinical manifestation, but this distinction is not absolute; visceral forms may produce cutaneous lesions, and cutaneous forms may visceralize. However, recent developments in the typing of strains by isoenzyme and DNA buoyant density techniques have greatly assisted in gaining an understanding of the epidemiology of leishmaniasis. The majority of the leishmaniae are zoonoses involving wild or domestic mammals (rodents, marsupials, edentates, and canines) as the reservoir hosts. Some forms (e.g., Indian kala-azar, infantile kala-azar of Iraq, and visceral leishmaniasis of Kenya) were previously considered to be nonzoonotic infections, but this assumption was based largely on the absence of evidence that an animal reservoir existed. Recent information indicates that they may be zoonotic infections involving rats in Iraq and dogs in Kenya. The resurgence of kala-azar in India is associated with the infection in dogs, but the role of these animals in the disease requires clarification.

The only known vector is the sandfly, and there is considerable evidence that the resurgence of leishmaniasis in man in various parts of the world is associated with the discontinuation of measures to control malaria vectors, which had also reduced sandfly populations.

The visceral infection is associated with a domestic or semidomestic transmission pattern involving vector breeding-places close to the home, with dogs, foxes, rodents, etc., as reservoir hosts. The cutaneous infection is more associated with the intrusion of man into the zoonotic cycle of many wild mammals in previously undeveloped areas, such as the extension of cities, the establishment of desert settlements, or the construction of roads and habitations in virgin forests and in the wilderness. The transfer of infection from wild mammals to domestic dogs may result in the creation of a new reservoir of infection after the wild-mammal reservoir has disappeared.

The zoonotic aspects of leishmaniasis require further study and the relationship of various strains in various reservoir mammals to human infection requires clarification. For example, the different strains of the parasite in the dog in relation to visceral leishmaniasis of man in Europe, the Middle East, and North Africa and the absence of this form of the disease in man in Senegal require clarification. Some strains of parasites in animals may be nonpathogenic to man and a possible source of immunizing agents, while some may vary in their virulence to man according to the animal host. The variation in vertebrate susceptibility, the
host preference and biting habits of vectors, and the characterization of strains of the parasite are topics requiring further study. An important need is for more effective immunodiagnostic tests for man and animals. Increased specificity for the genus and preferably for the species of organism is required of tests based on skin reactions (e.g., the Montenegro test). These considerations apply also to serological tests, and enzyme-linked and radioimmune assay techniques using defined antigens of individual Leishmania species offer possibilities for large-scale sampling for epidemiological surveys, immunodiagnosis of active infections, and the evaluation of therapeutic measures.

Control measures vary according to the ecological aspects of the infection. In urban environments the control of dogs and rodents and the application of insecticides have proved effective. Large-scale rodent control in steppe country has eliminated infection, but in remote sylvatic areas, such as the forests of South America, reservoir host and vector control would be impossible. Immunoprophyaxis using attenuated strains would be an alternative approach in such instances.

5.4 African trypanosomiasis

African trypanosomiasis has been one of the major causes of the underexploitation of approximately 7 000 000 km² of land and is responsible for some of the most serious obstacles in the social and economic development of the continent. The importance of this disease is indicated by the fact that an estimated 35 000 000 people are at risk.

There is strong evidence that Trypanosoma rhodesiense infection is a zoonosis and the organism has been recovered from naturally infected game animals and domestic cattle. The latter are considered incidental reservoirs, whereas game are more important since they occupy the same ecological setting as the tsetse fly. Infection can persist for long periods in game animals such as the bush buck, bush pig, buffalo, elephant, hippopotamus, water buck, duiker, and crocodile. Because of these wild-animal reservoirs, infection with T. rhodesiense is an occupational hazard for honey collectors, woodcutters, charcoal-burners, fishermen, hunters, members of trypanosomiasis control units, and any other persons who enter game country in endemic areas.

Previously the main obstacle to confirmation of the zoonotic nature of the infection has been the difficulty of differentiating T. rhodesiense from T. brucei, which could be done only by exposing volunteers to infection. This technique is regarded as the ultimate criterion in the case of human infectivity, but the blood incubation infectivity test (BIII),
which distinguishes between *T. rhodesiense* and *T. brucei*, is now used in field surveys of animal trypanosomes. Such surveys have revealed variation in prevalence rates of *T. rhodesiense*—for example, in game animals.

While the test represents an important advance, there is nevertheless an urgent need for serological and other tests which would distinguish between the *T. brucei* subgroup trypanosomes and permit detailed surveys of their prevalence in animals.

Although *T. rhodesiense* occurs in animals, the epidemiological significance of this requires further study. For example, epidemics of *T. rhodesiense* sleeping sickness that have occurred in eastern Africa are generally regarded as being caused principally by interhuman transmission. Probably animals serve to introduce the disease into a previously uninfected area; hitherto this was considered to be due to human carriers. Isolated human infections probably derive from direct transmission from game to humans. Further aspects of the epidemiology of infection include investigation of whether other members of the *T. brucei* group can cause disease in man and the role of different species of tsetse flies in their transmission of the parasite from animals to man. The species of vector is no longer a valid criterion by which to distinguish human infection; nevertheless the efficiency with which flies transmit infection merits further investigation (22).

The relationship of *T. gambiense* to an animal reservoir is much less certain. Epidemiological evidence suggests that in most places transmission is entirely interhuman, and the parasite has never been isolated from a naturally infected animal. The pig has been suggested as an animal host and *T. gambiense* is readily transmitted from pig to pig by cyclical passage. However, there is no unequivocal evidence that the animal acts as a reservoir in nature. Investigations are complicated by the fact that human infections may be mild and difficult to detect in the chronic state. Further, the isolation of *T. gambiense* is much more difficult than that of *T. rhodesiense*, because small laboratory animals are usually not susceptible and monkeys have to be used for primary isolations in the field. Moreover, as there is no absolute guarantee of cure with the drugs available for treating *T. gambiense* infections, the use of volunteers is not justifiable.

The diagnosis of infection is based on the demonstration of the parasite in the blood and cerebrospinal fluid, the results of nonspecific tests (including the formol gel test), the increase in the number of cells and amount of protein in cerebrospinal fluid, and the determination of IgM levels in serum, as well as the findings of specific serological tests. Since organisms may be plentiful in *T. rhodesiense* infections but scarce in those
due to *T. gambiense*, concentration techniques (e.g., by DEAE cellulose columns) may be helpful in diagnosis. There is, however, a pressing need to develop sensitive and specific immunodiagnostic tests for human infections and also to detect the animal reservoirs of the human parasites. Recent immunochemical studies of the pathogenic animal trypanosomes should greatly assist in this regard.

No new trypanocides have become available for field use in the past two or three decades. This is an area in urgent need of research, since none of the drugs in current use is entirely satisfactory, some having serious side-effects in man; while in animal trypanosomiasis drug resistance is an increasingly serious problem.

In tsetse control, the technique of releasing sterile males holds promise as a means of dealing with small residual fly populations following the application of other methods of tsetse control. Its further development should be encouraged.

### 5.5 American trypanosomiasis

American trypanosomiasis, or Chagas' disease, is a zoonosis that appears to be confined to the Americas. Attempts to detect the presence of *Trypanosoma cruzi* in primates in southern Asia have been unsuccessful. Trypanosomes found in Asian primates have not been identified as *T. cruzi*; however, a few cases of trypanosome infection reported in humans from India and Malaysia, although not caused by *T. cruzi*, require further study with regard to their zoonotic potential. *T. cruzi* has been found in bloodsucking reduviid bugs and in man and many other mammalian hosts in South and Central America and the southern parts of the USA. It is estimated that at least 7,000,000 people are infected with *T. cruzi* and that some 35,000,000 are exposed to the risk of infection.

There are two cycles of transmission of *T. cruzi*: a domestic cycle and a feral cycle. Human infection occurs essentially in rural areas, where poor socioeconomic and sanitary conditions are coupled with housing constructed of mud, grass, and cane, which provides excellent breeding-places for triatomids. Under such conditions infection is readily transmitted between animals and man; however, endemic foci can exist in the absence of infected animals. In some areas man himself is the major reservoir.

Transmission by triatomid bugs is the most important means of human infection; blood transfusion may play a role and transplacental infection is known to occur. A large proportion of intrauterine infections
result in fetal death. The animals found naturally infected in the domestic cycle include dogs, cats, pigs, rats, mice, guinea-pigs, and rabbits. In certain endemic areas, the dog and the cat are more frequently infected than man, although overall the number of infected cats and dogs is low compared with that of infected people. Guinea-pigs may be of special importance in some areas, such as Bolivia, Ecuador, and Peru, because these animals are reared in people's houses. Although it has been found possible to infect cattle, goats, and sheep, and their role under natural conditions has not yet been determined fully, it is likely that they play only a minor part, if any, in the epidemiology of the disease.

The efficiency with which *T. cruzi* is transmitted from animals to man appears to be quite variable. For example, in the southern USA animal triatomid infection is extensive in certain areas, but evidence of widespread human infection is lacking. This is in contrast to the widespread nature of human infection under apparently similar circumstances in South America. It has been suggested that the feeding and defecation habits of the triatomid vectors may in part be responsible for these differences. The possibility of intertriatomic transmission of *T. cruzi* may be a complicating factor in the epidemiology of Chagas' disease, and this requires further study.

In the feral cycle, *T. cruzi*, or trypanosomes morphologically similar to it, have been found in many wild animals, including edentates (armadillos and anteaters), marsupials (opossums), carnivores (ferrets, foxes, and racoons), wild rodents (water rats, agoutis, squirrels, etc.), monkeys (*Cebus* and *Alouatta*), and bats. In most of the feral areas wild animals have little contact with man and hence they are not reservoirs of immediate danger to him. Nevertheless, with the construction of dwellings that provide the habitat for the triatomid, such feral infections may rapidly become domestic in nature. Little is known of the vector species involved in the transmission of *T. cruzi* among wild mammals, or of the invasion of human dwellings by sylvatic species of reduviid insects. The importance of naturally infected domestic and sylvatic animal species also remains to be evaluated.

The pathogenicity to man and domestic animals of various *T. cruzi* strains, *T. cruzi*-like strains, and *T. rangeli* requires study. There is a need to develop simple methods for the differentiation of *T. rangeli* from *T. cruzi*. Since the former species is now thought to be only rarely pathogenic, it could be disregarded in epidemiological studies if the epidemiologists could know for certain that they were dealing with it and not *T. cruzi*. 

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Serodiagnosis of Chagas' disease can be made with a high degree of specificity and sensitivity. The complement fixation, indirect haemagglutination and indirect immunofluorescent tests are in common use. Within a year following treatment, previously positive diagnostic tests become negative, and hence they are useful adjuncts for assessing the efficacy of therapy. Other serodiagnostic tests include latex agglutination, which has been recommended for epidemiological surveys, and a direct agglutination test using enzyme-treated epimastigotes. An IgM antibody which binds to host tissue (the endocardial-vascular-interstitial factor—EVI) occurs in serum from patients with heart lesions in Chagas' disease. Further study of this antibody is indicated in respect of its autoimmune nature and its value in assessing or predicting the severity of heart involvement.

Treatment of Chagas' disease is complicated by the need to kill intracellular as well as cellular parasites. The 8-aminoquinolines and nitrofurans affect circulating trypanosomes but do not affect intracellular forms. Nitrofururylidene compounds offer promise for treatment, but further research is necessary for the development of effective therapeutic agents.

5.6 Malaria

Malaria as a zoonosis occurs very infrequently in nature. The experimental infection of man by mosquitoes has been achieved with several species of malaria parasite of monkeys (Plasmodium brasilianum, P. cynomolgi, P. inui, P. knowlesi, and P. schweizti). Only three species have been implicated in natural infections of man: one (P. cynomolgi), transmitted under semilaboratory conditions, two infections with P. knowlesi from Peninsular Malaysia, and one infection with P. simium from Brazil have been reported.

There is good evidence of close similarity or identity between several simian and human plasmodia, which suggests that the original source of simian infection was man. The most suggestive evidence is that simian infection in Central and South America did not occur prior to the arrival of Europeans in the New World. Thus, P. brasilianum and P. simium of South America are considered to be derived from the human P. malariae and P. vivax respectively. P. brasilianum and P. malariae are serologically identical. P. rodhaini of chimpanzees is considered to be synonymous with P. malariae, and P. schweizti and P. reichenowi of African apes are indistinguishable from P. vivax and P. falciparum respectively.
Human infections deriving from simian hosts are usually mild, self-limiting and of little or no public health importance. Similarly, the role of nonhuman primates in maintaining foci of infection after malaria has been eradicated is considered to be minimal. It will only be possible to assess the true role of simian malaria when methods of identification are based on isoenzyme and DNA characterization or immunological techniques.

5.7 *Pneumocystis carinii* infection

*Pneumocystis carinii* is widely distributed in many countries and is one of the etiological agents of interstitial plasma cell pneumonia, particularly in infants and in individuals who have undergone immunosuppression.

Outbreaks have occurred in orphanages and other institutions in which undernourished infants have been congregated. At the present time infection has become more frequently recognized in individuals with diseases such as leukaemia who receive high levels of steroid therapy or patients who have been subjected to prolonged treatment with immunosuppressive agents for malignancies or the prevention of graft rejection.

The taxonomic status of the parasite is still in doubt, since ultrastructural studies suggest that the spore wall is fungal in nature, whereas the internal structures show protozoan affinities.

The mode of transmission is unknown. Spread by direct contact with active cases is suspected. Some nurses in close contact with infected individuals had higher levels of antibody to *P. carinii* than the general population.

The organism has been demonstrated in a wide range of mammals, particularly rodents. It has been found in the lungs of rodents caught in traps in the homes of patients or in institutions in which the infection is epidemic. The dog has been incriminated as a possible reservoir host for man. Chronic infection of rats can be activated to clinical pneumonia by cortisone, and possibly intercurrent debilitating diseases may activate subclinical infections in man.

The serodiagnostic techniques of choice are the complement fixation test and the indirect immunofluorescence test. A latex agglutination test has been used to detect infection in rats. The sensitivity of these tests depends on the length of time the infection has persisted in the patient.

Direct demonstration of the parasite is also possible. However, special stains, such as the Gomori silver stain and the Giemsa stain, are necessary to visualize the parasite. When the parasites are scanty concentration
methods are necessary. The use of collagenase digestion for releasing and concentrating cysts from brush border lung aspirates or lung biopsy material is recommended. Cysts for use as antigen can be isolated from homogenized infected human or rat lungs by sucrose gradient centrifugation.

Pneumocystosis pneumonia can be treated effectively with antifolate compounds such as sulfadiazine, and with pyrimethamine and stilbamidine compounds such as pentamidine. Further studies are required to clarify intraspecific and interspecific transmission, the influence of malnutrition and other stress factors, and pathogenesis in man and animals.

5.8 Babesiosis

Human infection with *Babesia* species has been reported from North America (Mexico and the USA) and Europe (France, Ireland, Scotland, the USSR, and Yugoslavia). Approximately 30 proved cases have been documented, but medical records suggest that the infection may have occurred in man for several decades. In the majority of cases babesiosis was initially diagnosed as falciparum malaria, since the trophozoites of *Plasmodium falciparum* resemble certain forms of *Babesia* and cross-reactions between *Babesia* and *Plasmodium* species occur in serological tests.

In the Scottish and Yugoslav cases that were fatal, infection was ascribed to *B. divergens* and *B. bovis* respectively (both of cattle). The cases in the USSR were also fatal but the species of *Babesia* has yet to be identified. In the USA *B. microti* (of rodents) has been incriminated in several cases which were recovered from Nantucket Island, and an infection with an organism shaped like a Maltese cross suggested *B. equi* as the cause in a case reported in California.

The infections involving *Babesia* species of large-animal origin occurred in individuals who had been splenectomized previously or unassociated reasons. Those involving rodent *Babesia* occurred in persons with intact spleens.

The clinical manifestations vary from fatal fulminating fever with jaundice, anaemia, and haemoglobinuria, to mild fever with sweating and malaise, to asymptomatic infection detected only by serodiagnosis.

The prevalence rate of asymptomatic infection is unknown. It has been suggested that because of the widespread nature of *Babesia* species, the range of hosts infected by them and the frequent contact of man with ticks, in which infection may persist for some time, human infection is probably more extensive than has hitherto been recognized. The frequency
of human infection could be assessed by more extensive epidemiological studies using serodiagnostic procedures to identify the species of Babesia involved, and by the isolation of parasites by subinoculation of blood into susceptible hosts.

5.9 Amoebiasis

There is little evidence that Entamoeba histolytica infection of man represents a zoonosis. While animals, particularly dogs and primates, can be infected and show clinical symptoms, human disease is primarily associated with contamination of water and food by man. Dogs infected with amoebae only have trophozoites in their intestines.

The infection may be an occupational hazard for persons dealing with animals, such as veterinarians, animal keepers in zoos and assistants looking after nonhuman primates for laboratory use.

5.10 Giardiasis

The increased incidence of giardiasis in travellers and persons at holiday sites (e.g., ski resorts) has raised the question whether this infection is a zoonosis. Large-scale outbreaks are usually traceable to the contamination of water supplies by man, but recently some have been traced to contaminated water reservoirs, of which the epidemiological aspects indicate that wild-animal infections may play a role. Campers and trappers have become infected in remote uninhabited areas where faecal contamination by humans is considered unlikely. Many animals are known to be hosts of Giardia species but hitherto the infections have been considered to be host-specific. However, experimental infections of man and animals with cysts of Giardia obtained from beavers suggest that giardiasis may be a zoonosis.

5.11 Balantidiasis

Organisms morphologically similar to Balantidium coli occur in man, swine, and nonhuman primates. Disease in man may be caused by the contamination of water supplies with pig faeces. For example, an outbreak on an island of the Truk group in the west Pacific following a typhoon, when pig faeces were widely disseminated, indicates that balantidiasis may be a zoonosis. In the highlands of Irian Jaya (West Irian, Indonesia) the infection rate in man is parallel to the size of the pig population and there is some evidence that the protozoan may be adapting to the human habitat. In Iran, however, human infection has been found to be common where there is no pig-rearing.
Although many antiamoebic drugs (e.g., paromomycin, carbarsone, and oxyclozanide) show activity against *B. coli*, the drugs of choice are the tetracyclines; both oxytetracycline and chlorotetracycline are effective.

6. CE HODE INFECTIONS

6.1 Echinococcosis (hydatidosis)

Heightened scientific interest in echinococcosis in recent years has resulted in the recognition that this zoonosis now constitutes a public health problem of nearly global dimensions. It is believed that there are relatively few countries in which cestodes of the genus *Echinococcus* are entirely absent. The prevalence of their larval cysts in man in a number of countries is higher than was previously assumed, and instances of continuing spread of some forms of the infection are known, as in the case of *Echinococcus granulosus* infection in the western part of the USA. Also, *E. multilocularis* has been detected increasingly in various countries (e.g., Iran and areas adjoining the USA) in which it had not previously been reported. At the same time, prospects for the control of echinococcosis have been improved through the development of several effective control strategies.

The epidemiology of this zoonosis and experience with its control in New Zealand and Tasmania were specifically reviewed in considerable detail during a FAO/WHO Interregional Seminar in 1970 (24) and, since then, several new, well-designed regional and national control programmes have been initiated, in some of which novel adjuncts to control have been introduced. A recent major breakthrough has been the development of highly efficacious drugs for the treatment of infected dogs.

A meeting of research workers dealing with echinococcosis (hydatidosis) was convened in 1966 (25). It identified the several specific areas in greatest need of further research, and since then there has been good progress, especially in diagnostic methods and in achieving an understanding of some of the mechanisms involved in the echinococcal parasite interactions with their definitive and intermediate hosts. The Committee felt that the convening of a similar research meeting in the near future would be of great value.

6.1.1 Epidemiology

At present 4 *Echinococcus* species are regarded as valid—namely, *Echinococcus granulosus*, *E. multilocularis*, *E. oligarthrus*, and *E. vogeli*.
E. granulosus, of worldwide distribution, is for the most part maintained in a domestic transmission cycle involving the dog as final host and livestock as intermediate hosts. In some areas the life cycle is sylvatic; in others both wild and domestic animals are involved. In man, the metacestode stage (= infective larva) causes hydatidosis, the so-called “unilocular” type of echinococcosis.

E. multilocularis (= Alveococcus multilocularis), which is confined to the northern hemisphere, matures in foxes, cats, dogs, and other carnivores; intermediate hosts are mainly microtine rodents and occasionally domestic mice. In man, the metacestode causes the “alveolar” type of echinococcosis, or “alveococcosis”.

E. oligarthrus, a species occurring in Central and South America, characteristically uses wild Felidae, such as the puma, the jaguar, the jaguarundi, the pampas cat, Geoffroy’s cat, and the ocelot as definitive hosts, and agoutis and possibly other rodents as intermediate hosts. E. oligarthrus is suspected to cause disease in man.

E. vogeli involves in its cycle the bush dog and the domestic dog as final hosts, and the paca and possibly other rodents (the agouti and the spiny rat) as intermediate hosts in Central and South America. It has been shown that E. vogeli is responsible for human infections.

The Committee concurred with the recommendation of the meeting of echinococcosis (hydatidosis) research workers referred to above (25) that, to avoid further taxonomic confusion, minor morphological variants within the genus Echinococcus should be informally designated “strains” until their epidemiological and taxonomic status could be fully clarified. For one such recognized strain—the “horse strain” of E. granulosus metacestode in the United Kingdom and parts of western Europe—dogs and possibly foxes serve as the definitive hosts, while sheep (and possibly man) are relatively resistant to infection with the cystic stage. Physiological as well as minor morphological differences between the “horse strain” and the classic sheep strain of E. granulosus have been demonstrated. It is now possible to distinguish these strains by the electrophoretic separation of isozymes. Of similar epidemiological interest may be the hyaena-transmitted and lion-transmitted strains of E. granulosus occurring in Kenya and South Africa respectively, also the sylvatic strain of E. granulosus utilizing the wolf (or dog) and reindeer as hosts in the Arctic.

Elucidation of differences in the host ranges and susceptibilities of Echinococcus parasites in different geographical areas is of vital importance for the future prospects of hydatidosis control. The Committee strongly recommended, therefore, that more well-designed cross-infection studies should be carried out using parasites obtained from different hosts.
and different geographical areas. Moreover, studies on differential diagnosis by means of laboratory methods (separation of isozymes and soluble proteins) should be encouraged.

New information is available on the dynamics of transmission of taeniid infections. Using the *Taenia hydatigena* model, it was shown that eggs were deposited in clusters in and around the faecal mass or near faecal segments excreted by a final host. Large numbers of eggs were dispersed over an area within a 25-metre radius of the site of deposition, and some eggs were found as far as 80 metres away. The expelled eggs consist of juvenile, infective and "senescent" organisms. It has been suggested that these senescent organisms may induce immunity if they are ingested first. This may be one of several possible reasons for the fact that in man and in domestic animals prevalence rates of larval cestode infections are almost invariably less than 100%. Thus, larval cestodes appear to survive only in a proportion of the intermediate host population, and it is only this proportion that is of epidemiological significance.

The importance of socioeconomic and cultural factors for the perpetuation of the infection was already stressed at the above-mentioned meeting (25). Since then, such factors have been identified as responsible for high transmission rates of hydatidosis among Eskimos, among Basques and Indians in the USA, among the Turkana in Kenya, and among Maoris in New Zealand (see section 3.4).

Hydatidosis may be an occupational disease of certain groups—e.g., shepherds and their families in endemic areas and shoemakers and shoe repairers in the Middle East for the reasons given previously (section 3.4). The infection is by no means restricted to rural and pastoral areas but may be found also in urban dogs, if these are fed with infected offal.

Since many of the epidemiological key factors have now been identified, it is possible to construct transmission "flow charts" from which gaps in knowledge concerning control and research in a given area can be determined. The Committee urged (as did the participants in the 1966 meeting) that great attention should be paid to the collection and evaluation of relevant epidemiological baseline information prior to the institution of specific measures for echinococcosis control. Special guidelines should be worked out for the various epidemiological situations. However, lack of such information should not hold up the application of general public health measures such as the control of stray dogs, the proper inspection of animals at abattoirs (in the case of *E. granulosus*), and health education.
6.1.2 Host/parasite relationships

Recent advances have also been made in elucidating certain mechanisms of host/parasite interactions in echinococcosis. This has resulted chiefly from efforts in immunology and immunochemistry, marked improvements in techniques to cultivate Echinococcus spp. in vitro, ultrastructural studies and, to a lesser degree, studies of other aspects of parasite physiology and biochemistry. Some specific antigens have been localized histologically in hydatid tissues, and previous findings on the chemistry of various stages of the parasite are beginning to be linked significantly to the results of immunological and physiological research.

Interesting findings have emerged concerning the survival of echinococcal parasites in immunologically competent hosts. While host immunoglobulins are found within some apparently intact hydatid cysts but are absent from others, the mechanisms governing their entry and persistence within cysts are still unclear. In the Committee's view, an area of research much in need of pursuit (for such reasons, as well as for understanding questions of cyst nutrition and growth, and chemotherapeutic action) is that of permeability control and transport across the hydatid cyst wall.

Host complement, which is excluded from a healthy cyst by intact germinal membrane, has been shown to be responsible for lysis of protoscolices by normal serum. Complement is activated by unidentified components of hydatid cyst fluid, and its ability to attack the cyst germinal membrane from the inside has possible implications for the treatment of certain cystic infections. Complement studies have also suggested a possible mechanism for the development of anaphylaxis in some patients following "leakages" of cyst fluid or its intradermal use for hydatid diagnosis. A beginning has also been made in understanding the importance of, and the mechanisms responsible for, cellular immunity in echinococcosis. Macrophages have been activated by specific and nonspecific mechanisms and lymphocyte transformation has been demonstrated in the presence of echinococcal antigens.

Immature (i.e., nonfertile) cysts have now been produced in vitro from protoscolices and oncospheres, the former in a defined medium, and the in vitro development of adult worms from protoscolices has been compared with the early in vivo development, as revealed in detailed studies, of the parasite in its definitive host. In vitro studies have also been used in a few instances to demonstrate physiological differences between parasite species and strains.
6.1.3 Diagnosis

Noteworthy improvements in immunodiagnosis have been made (26). Several tests with a high degree of specificity and sensitivity (e.g., the indirect immunofluorescent test, passive haemagglutination, immuno-electrophoresis, and latex agglutination) for the clinical diagnosis of the disease have been introduced or improved in many laboratories in various parts of the world that provide diagnostic services. Moreover, new techniques have been extensively evaluated and promising results have been achieved with radioimmunoassay methods, with ELISA, and with other methods. ELISA is regarded as a relatively simple method with a high sensitivity superior to that of some other serological procedures. Further appraisal of this test under various laboratory and epidemiological conditions is therefore recommended.

On the basis of recent experience it is now widely accepted that the sensitivity and the specificity of the diagnostic procedure can be improved by the simultaneous application of two or three methods (partly measuring different classes of antibodies). They include, for example, immunoelectrophoresis and the double diffusion test for the arc 5 antigen, the indirect immunofluorescent test, passive haemagglutination, and other particle agglutination tests (latex and bentonite). The relatively insensitive complement fixation test is being increasingly restricted to the postsurgical prognosis of E. granulosus patients (i.e., its titres may decline rapidly following the successful removal of cysts). The intradermal (Casoni) test is still in wide use, since it is simple to perform. This test often lacks specificity, however, and therefore, wherever possible, it should be replaced by the better serological procedures.

The interpretation of serological results requires the consideration of many factors, such as the organ localization of the metacestode, the period that has elapsed since surgery, the age of the patient, and the Echinococcus species/strain that is involved. It is stressed here that serological reactivity may be weak in hydatidosis of the lung, eye, and brain and in cases of echinococcosis in children. Further, it has been shown that Norwegian Lapps infected with E. granulosus exhibited lower titres with the same antigen than did patients from southern Europe. In some cases of human echinococcosis no circulating antibodies are detectable, despite a positive intradermal test.

The Committee noted that defects in the design of studies intended to compare the reliability of diagnostic tests for hydatidosis are still commonplace and therefore the results of many comparisons are invalid or difficult to interpret.
More research is required on the improvement of antigens by their fractionation and chemical characterization, although several antigens (arc 5 antigen and antigen B) have been purified during the last few years. Previously, it was assumed that purified arc 5 antigen was specific for *E. granulosus*. Recently, however, antibodies against arc 5 antigen were demonstrated in the sera of patients infected with *E. multilocularis*, *E. vogeli*, or *Cysticercus cellulosae*. Moreover, arc 5 antigen was found in both larval *E. granulosus* and *E. multilocularis* as well as in larval *Taenia hydatigena*. Therefore, the use of arc 5 antigen in serology does not allow a diagnosis specific for each *Echinococcus* species and its value at the genus level now appears to be in doubt. It is being increasingly recognized that infected individuals elaborate antibodies to different combinations of echinococcal antigens; this suggests that purified antigens may decrease rather than increase test sensitivity.

IgG levels seem to be generally increased in hydatid patients, while elevations of IgM, IgA and IgE levels are less constant. No significant correlations have been observed between levels of these serum globulins and antibody titres detected in the indirect haemagglutination and complement fixation tests.

It appears that only part of the immunoglobulins in hydatid disease are parasite-specific: in *E. granulosus* patients titres of total serum IgE remained nearly constant after the initiation of chemotherapy with mebendazole, whereas parasite-specific IgE levels decreased gradually. This finding, together with the determination of circulating antigens and of immune complexes in hydatid patients, may be of practical significance for the evaluation of the status of the infection.

Little has been done to assess the specificity of diagnostic tests for animal hydatidosis and little understanding yet exists among most workers of the magnitude of the general problem posed by false positive results when tests with even quite good specificities are employed for the serological surveillance of populations.

The diagnosis of human cases of hydatidosis has been improved considerably by the perfection of the techniques of tomography, scintigraphy, and ultrasonography.

It should be stressed that a particular need exists to distinguish *Echinococcus* from other taeniid eggs.

6.1.4 *Control*

Extensive health education is the basis of effective control. It should be implemented by every available means—for example, by teaching
in schools, and by displaying posters in public places depicting the life cycle of the parasites and the means of breaking this life cycle.

There are two main measures for the control of *E. granulosus*, with several methods of application:

1. The prevention of dogs from gaining access to raw offal at abattoirs and on farms and to dead animals in the field—an essential measure, even though it requires an enormous effort in terms of legislation, education, and manpower.

2. Diminution of the parasite biomass by reducing the dog population, or by mass treatment programmes, or by both.

Continued progress in echinococcosis control has been made in New Zealand and Tasmania, and these programmes have served as a model for the national campaign in Cyprus, as well as for regional programmes covering Argentina, Peru, and Uruguay, among other countries. Detailed epidemiological analyses of data from the New Zealand control programme have indicated some of the types of epidemiological information most useful to the planning and continuous evaluation of control efforts. It has also been shown to be useful to undertake specific multivariate statistical analysis, such as stepwise multiple regression and path analysis, for the identification of environmental and host factors that either require special attention when control is initiated or may become important as control efforts progress.

In Cyprus, a New Zealand/Tasmania type of control programme based on periodic aecoline testing of all owned dogs and a varied and intensive educational effort (dog-feeding practices, control of animal slaughter, etc.) has been complemented by a successful campaign for eliminating stray dogs with euthanasia syringe guns (30,000 dogs were eliminated in 2 years), obtaining the owners' acquiescence for the destruction of *Echinococcus*-positive dogs and spaying female dogs. The result has been a rapid and appreciable decrease in the prevalence of cystic infections in Cypriot livestock.

In the future, control or eradication prospects may be considerably heightened in some countries by the judicious use of recently developed effective drugs for the treatment of *Echinococcus* infections in dogs, such as praziquantel, micronized mebendazole, nitroscanate, and fospiracet. However, there is need for caution in the mass use of such drugs. For example, following their use, although infection with *E. granulosus* is eliminated, there is a temporary but marked increase in the excretion of viable eggs in dog faeces, which may lead to heavily contaminated foci.
of infection. This should be taken into account and dogs should be treated under supervision.

Serious impediments to hydatidosis control exist in countries in which wildlife infections with *Echinococcus* occur, or presumably occur. In such situations, detailed epidemiological and cross-infection experiments are imperative preliminaries to the planning of possible control programmes in order to determine whether the parasites in different hosts are biologically distinct, or whether there are ecological barriers to interhost transmission.

The Committee believed that there are now suitable methods for the effective control of hydatidosis in many countries in which the necessary degree of citizen cooperation can be attained. For countries in which dog- and fox-transmitted rabies also occurs, veterinary public health programmes against the two diseases may with advantage be undertaken simultaneously, and this may provide the opportunity for establishing veterinary public health units in health departments and ministries, thus creating a valuable mechanism for intensive continuous liaison between agricultural and health services which did not previously exist. It is recommended that FAO and WHO should give full assistance and encouragement to countries considering hydatidosis control, particularly in ensuring that fully adequate epidemiological data are collected prior to the initiation of control. Only in this way can available techniques of data analysis be employed for determining specific facets of control that require local emphasis, and for continuous monitoring, evaluation, and prompt modification of control efforts.

In contrast to *E. granulosus*, no progress has been made in the development of control programmes against *E. multilocularis*, which causes disease in man that is usually lethal. With new methods, such as the treatment of foxes with medicated food pellets, it may be possible to reduce the mass of parasites in the final hosts and subsequently in the intermediate host population and in man. Reduction of the microtine rodent population would also be useful but is virtually impossible in many areas.

For individual protection the following recommendations may be of value in different epidemiological situations. Avoid close contact with dogs, foxes, cats, and other carnivores that are possibly infected, and do not consume raw vegetables and fruits that might have been contaminated with carnivore faeces. If dogs are fed with animal organs, these should be thoroughly cooked, or deep-frozen at \(-18 \, ^\circ\text{C}\) for at least 48 hours, which would kill any cysts that might be present. Persons who have had contact with infected dogs should be examined by serological methods. *Echinococcus* eggs can only be destroyed by heat; no effective chemical disinfectant is available.
6.1.5 Treatment

In addition to the progress already mentioned in the development of highly effective drugs for treating Echinococcus infections in the definitive hosts, experiments indicate the relative efficacy of benzimidazole compounds against the metacestodes of E. granulosus and E. multilocularis in rodents. It is now clear that these drugs have to be applied in high oral doses over relatively long periods of time. It has been shown that cysts of E. granulosus can be severely damaged or even killed by long-term treatment with mebendazole or fenbendazole. Metacestodes of E. multilocularis are inhibited in growth during long-term treatment but usually resume proliferation thereafter.

Mebendazole has also been used for the treatment of echinococcosis in man. The regression of hepatic and lung cysts of E. granulosus has been documented in some cases, but in others information on repeated treatment has suggested that further work is required on effective treatment schedules and on adverse reactions in the host, as well as on pharmacokinetics.

Patients with E. multilocularis infections have been treated with high oral mebendazole doses for periods ranging from 30 days to 3½ years. In some cases signs of stabilization of the disease were observed, while in others the patients died. It can be concluded that this long-term mebendazole treatment induces no gross side-effects, but the effect against larval E. multilocularis in man is still uncertain.

It was emphasized by the Committee that chemotherapeutic trials in larval echinococcosis have taken place only over the last 4 years, but that they showed sufficient promise to merit active encouragement, particularly in the form of international cooperation in the recording and evaluation of results.

6.1.6 Recommendations

The Committee recommended that the following steps should be taken in combating echinococcosis:

1. Health education should be improved on a worldwide scale, and surveillance and control programmes should be urgently implemented in highly endemic areas. There is special need for the development of an effective preventive and eventual control programme against E. multilocularis.

2. Echinococcus strains and their infectivity for man should be further investigated.
(3) More details of the life cycles of South American *Echinococcus* species and their role in public health need to be clarified.

(4) Immunodiagnostic tests should be standardized, and standard sera as well as antigens should be provided by reference laboratories. Antigen and serum banks should be established in different geographical areas.

(5) Studies on the immunization of final and intermediate hosts should be encouraged.

(6) The development of drugs effective against the larval *Echinococcosis* stages should be supported.

(7) There is need for a drug that would be effective against both intestinal stages and eggs, as well as for an ovicidal disinfectant.

(8) FAO and WHO should designate one or more collaborating centres for hydatidosis research besides making it an important part of the work of the proposed zoonoses centres.

### 6.2 Taeniasis (cysticercosis)

The two parasites of major importance in taeniasis are *Taenia saginata* and *T. solium*. In their adult forms both are obligatory parasites of man and there is no evidence that nonhuman primates, carnivores, or other mammals serve as their final hosts in the natural transmission cycle. Experimentally *T. solium* has been established in the gibbon and the chacma baboon.

The larval stage of *T. saginata* (*Cysticercus bovis*) mainly occurs in cattle and, more recently, it has been reported in the reindeer. Detailed studies of cysticerci found in African wild ruminants such as the giraffe, the wildebeest, and the antelope have indicated that these animals are not hosts for *T. saginata* larvae. The role of the water-buffalo in transmission requires further investigation.

The pig is the main host for the larval stage of *T. solium* (*Cysticercus cellulosae*) but man may also be infected and this may lead to muscular, neuro-ocular and cerebral cysticercosis. Human infection is usually associated with poor personal and environmental hygiene. Canine infection is rare and plays no part in transmission, except where dogs are a source of human food.

#### 6.2.1 Epidemiology

Gravid segments are passed at defaecation but may also be passed at other times. Cattle ingest eggs deposited on pasture and swine ingest those
deposited on soil. Man may be infected with *T. solium* eggs from contaminated vegetables or unwashed hands. Reinfection by the transport of eggs from the bowel to the stomach by retroperistalsis is considered to be rare.

Inadequate processing and disposal of sewage, especially on sewage farms, may play an important role in the dispersal of tapeworm eggs. In some cases, raw sewage and human faeces may be spread on cattle pastures or discharged into rivers, estuary waters, or the sea. Birds, especially sea birds, and coprophagous beetles may also be concerned in the dissemination of eggs.

New data on transmission dynamics have been worked out, using as models those *Taenia* species that infect dogs, and it has been demonstrated that immunity plays an important role in the regulation of larval cestode populations in intermediate hosts. Nonimmune populations can be readily infected even if only a single *Taenia* carrier contaminates the environment. For example, sudden and violent outbreaks of cysticercosis have occurred in cattle feed-lots contaminated with *T. saginata* eggs (see section 3.3, page 15). The rapidity of pasture contamination and the short period required for the infection of grazing animals have been experimentally demonstrated with *T. hydatigena* infections in sheep. The epidemiological role of prenatal infections of calves with *T. saginata* needs to be further investigated.

6.2.2. *Prevalence of the parasites*

The adult stage of *T. saginata* is cosmopolitan in distribution. Highly endemic regions (prevalence rate exceeding 10%) occur in some African countries south of the Sahara, in Eastern Mediterranean countries, and in parts of the USSR. There is a moderate prevalence in Europe generally, in most of the Indian subcontinent and southern Asia, in Japan, in the Philippines, and in much of Latin America, though some foci of heavier infection exist here and there. Australia, Canada, and the USA are generally regarded as low prevalence areas (below 0.1%).

The larval stage of *T. saginata* (*C. bovis*) occurs almost all over the world. In European countries it is found in 0.3-4.0% of slaughtered animals. However, an increase in prevalence is being reported from many countries. High prevalence rates occur in Africa; in some East African countries rates of 30-80% have been noted. In general, the prevalence of *C. bovis* parallels that of *T. saginata*.

*T. solium* infection is mainly restricted to regions of low socioeconomic development in central and southern Africa, Mexico and Central and South America, and southern Asia. In some areas a high endemicity is
reported. For example, in Mexico City, 1.9% of all human deaths are caused by cysticercosis, and in 3.5% of all autopsies performed T. solium cysticerci are found. In Europe, T. solium has virtually disappeared from many countries, and only sporadic cases of human cysticercosis—mainly in southern Europe—are observed.

It has still not been determined whether the so-called Cysticercus racemosus is an abnormal form of C. cellulosae. Occasionally infections with larval T. hydatigena, T. ovis, T. multiceps, and T. taeniaeformis have been described in man.

6.2.3 Life span of adults and eggs

In the absence of treatment, the adult stages of T. saginata and T. solium may persist for several years in infected humans. Usually only one parasite is present but multiple infections can occur, as can mixed infections with T. saginata and T. solium.

6.2.4 Life span of cysticerci

Although most T. saginata larvae undergo degeneration and calcification 9–12 months after infection, a number may remain viable for considerably longer periods. In East Africa, viable cysts may be found in cattle several years after the probable time of infection. There is evidence to suggest that cysticerci may live longer in animals that are infected prenatally or when newly born.

The life span of T. solium larvae (C. cellulosae) in the pig has not been determined in detail although degenerated cysts are less common than with T. saginata larvae. However, for food purposes swine are usually slaughtered at a much earlier age than cattle and a greater proportion of viable cysticerci would be expected. Although the life span of C. cellulosae in man is not known, it is suspected to be some years. Degeneration and calcification eventually occur.

6.2.5 Immunity and immunization

Animals that have acquired an oral infection with Taenia eggs are capable of developing a strong immunity to reinfection. This immunity appears mainly to be mediated by humoral antibodies since it can be passively transferred by serum or colostrum.

Experiments in sheep with a related parasite have shown that soluble antigens, which were released by oncospheres, induced a high degree of immunity to oral challenge infection with homologous eggs. Subsequently
antigens collected during in vitro cultivation of oncospheres have been successfully used for artificial, parenteral, homologous immunization of sheep against T. ovis, of calves against T. saginata, and of rabbits against T. pisiformis.

Further improvement in culture techniques has resulted in the production of highly immunogenic preparations which in field trials have induced a long-lasting, high degree of immunity in sheep to infection with T. ovis. In addition, passive transfer of immunity from ewes to lambs was demonstrated which protected the offspring until active immunization was possible.

Although initial experiments with T. saginata in cattle were less successful, these and other results further support the possibility of developing vaccines against cysticercosis.

6.2.6 Host/parasite relationships and in vitro cultivation

Recently many aspects of cysticercosis have been studied, particularly problems related to the finding of laboratory host animals. In vitro cultivation of one Taenia species (T. crassiceps) from the cysticercus to the strobilar stage has been achieved. Also, in vitro techniques have been successfully used to collect functional antigens from oncospheres.

6.2.7 Diagnosis

Adult T. saginata and T. solium can be distinguished by various morphological criteria. The identification of single proglottids has proved difficult, but recently it has been found that enzyme electrophoresis of glucose phosphate isomerase distinguishes clearly and constantly between T. saginata and T. solium, in both their larval and their adult form. As this method requires only small amounts of material it may become a valuable tool in differential diagnosis.

Human cysticercosis is usually diagnosed by radiological examination, supporting evidence being obtained by the use of serological techniques such as the indirect immunofluorescent test, the passive haemagglutination test, and precipitation tests. Cross-reactivity with Echinococcus antibodies represents a major problem in this serological diagnosis. As recently shown, the cross-reaction can be eliminated by the use of an antigen prepared from whole T. solium in the micro-ELISA test. The sensitivity of this test was 73%, compared with a sensitivity of 77% in the passive haemagglutination test.
The diagnosis of cysticercosis in cattle and swine is based on the inspection of meat. It is probable that a substantial proportion of infected carcasses are not detected by the present meat inspection techniques and it is unlikely that the situation would improve by increasing the number of incisions in the so-called sites of predilection. Since the detection and processing of infected carcasses is an important control measure, it would be desirable to seek more satisfactory methods for determining the presence of cysticercosis. The routine serodiagnosis of bovine or swine cysticercosis has not yet proved possible despite the use of the newer enzyme-linked and radioimmune assays.

6.2.8 Chemotherapy

Important advances have been made in the chemotherapy of animal cysticercosis. Praziquantel, which is highly active against adult cestodes (including Echinococcus species), is also larvicidal. Of special interest is the marked efficacy of this drug at a single dose rate (50–100 mg per kg of bodyweight) against larval T. saginata in cattle. There is some evidence that the drug is less effective against younger organisms. Also, a benzimidazole derivative (albendazole), at a rate of 50 mg per kg of bodyweight was shown to have an effect against C. bovis in cattle. These compounds should be evaluated for swine cysticercosis.

No information is available on the possible effect of these or related drugs on human cysticercosis, and further studies are required.

The Committee recognized the importance of chemotherapy in cysticercosis and recommended an intensification of research.

6.2.9 Control

The methods usually employed for control are the treatment of infected persons, meat inspection, health education, and adequate sewage treatment and disposal.

In many countries T. solium has been controlled by meat inspection, by improvement of living conditions—especially sanitation—and by the proper housing of pigs. In the case of T. saginata, however, meat inspection has not been so successful because of the difficulty of detecting all lightly infected carcasses, and it is to be emphasized that the finding of dead cysticerci is not proof of the safety of the whole carcass. Furthermore, the maintenance of cattle under pasture conditions makes the control of bovine cysticercosis more difficult than that of swine cysticercosis.

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There is strong evidence that mass travel, the migration of workers, problems of sewage disposal (such as sewage farming and disposal of sewage sludge), etc., have led to an increase in the prevalence of *T. saginata*. In defined foci of infection, mass treatment of humans may control infection, but in endemic areas, combined approaches are necessary. Studies of the effect of mass treatment of infected persons and cattle should be undertaken and further work on the development of vaccines should be encouraged.

In many countries, the freezing of lightly infected carcasses is used to render meat fit for human consumption. To be effective, freezing must persist for a sufficiently long time. Treatment varies considerably from country to country, and freezing procedures should be standardized. As an alternative to freezing, meat can be heated throughout to a temperature of at least 90 °C.

The availability of cesspools for the use of rural populations, as well as for campers and other tourists, would decrease the environmental infection.

This is a zoonosis which especially requires the collaboration of and liaison between public health and veterinary officials.

The series of meetings convened by FAO and WHO to plan and review research on the control of taeniasis have been useful in stimulating collaborative work and in generating new information. The Committee recommended that more meetings of this type should be held in the future.

### 6.3 Diphyllobothriasis

With the exception of *Diphyllobothrium latum* (syn. *Dibothriocephalus latus*) the exact classification of *Diphyllobothrium* species found in man is still open to discussion. Recently, several species could be clearly distinguished using as criteria differences of coracidial hooks and protein patterns of adult worms. This technique and possibly other methods of chemotaxonomy (e.g., isozyme patterns) may offer means of species identification.

#### 6.3.1 Epidemiology

In addition to man, a large number of fish-eating mammals can harbour the adult parasite, among them dogs, cats, pigs, bears, seals, sea-lions, and foxes. The adult worm inhabits the small intestine, and it has
been shown that it can survive from 10 to 30 years in man. After infection, the parasite grows quickly and already 25–30 days later eggs are excreted with the stools.

A large number of copepod crustaceans have been identified as first intermediate hosts of *D. latum* and several species of freshwater fish act as second intermediate hosts. Fish harbour the infective larva (plero-cercoid) in the muscle tissue, coelom, liver, gonads, and other organs, and man acquires the infection by ingestion of raw, infected fish.

*D. latum* biotopes are mostly shallow freshwater littorals with vegetation favourable to the development of copepods and fish. Lakes, water reservoirs, and river deltas provide better conditions for the life cycle than do rapidly flowing streams.

Foci of *D. latum* characteristically occur in temperate and subarctic areas, particularly in Asia and Europe. Important endemic zones include countries bordering the Baltic Sea (Scandinavia, Finland, and the relevant areas of the USSR), Alaska, and Siberia. *D. latum* is also known to occur in lake areas in North and South America, France, Ireland, Italy, Japan, Romania, and Switzerland, among other countries. The incidence of *D. latum* in man has rapidly decreased during the last few decades. In Finland, for example, the prevalence of worm carriers in the whole country decreased from 20% in the 1940s to 1.8% during the period 1969–1972. However, the total number of carriers was estimated in 1973 to be still around 9 000 000 people (5 000 000 in Europe, 4 000 000 in Asia, and 100 000 in North America).

Changes in ecological conditions—caused, for example, by the construction of dams and water reservoirs for power plants—may create new foci for the development of *D. latum* within periods of only 2–4 years (as noted in the Volga district and other locations in the USSR). In Chile and Peru *D. pacificum* uses marine fish as intermediate hosts and sea-lions and man as definitive hosts.

### 6.3.2 Clinical importance and diagnosis

In many cases the infection is asymptomatic, while in others mostly mild gastrointestinal symptoms occur. Statistical analysis has revealed that *Diphyllobothrium* carriers have significantly higher frequencies of fatigue, weakness, diarrhoea, and numbness of the extremities than non-infected persons. In a proportion of cases, apparently associated with the attachment of the parasite in the proximal parts of the small intestine, a megaloblastic anaemia develops ("pernicious" or "tapeworm anaemia"). This may lead to central nervous system disturbances and other clinical
manifestations. The anaemia is basically due to the uptake of vitamin B₁₂ by the tapeworm in competition with the host’s vitamin B₁₂ receptors. Infection is diagnosed by the detection of eggs in stools.

6.3.3 Treatment and control

For removal of the parasite, niclosamide and some other anthelmintics are used. Preventive measures include adequate inspection of fish markets, proper sewage disposal, health education, treatment of infected persons and animals, and the correct preparation of fish prior to consumption. Cooking is highly effective; plerocercoids are also killed by freezing.

6.4 Sparganosis

The term “sparganosis” is used for human infections caused by plerocercoid larvae of diphyllobothriid tapeworms, man being a paratenic host for the parasite. Evidence exists that larvae of *Spirometra* species—in the adult form inhabiting carnivores—are involved in human infections, but other species also may play a role. Man may acquire the infection by swallowing copepods containing procercoid larvae present in raw or inadequately cooked food prepared from second intermediate hosts, such as amphibians, reptiles, birds, or mammals infected with plerocercoids. In the case of *Diphyllobothrium thaliei* (central and eastern Africa), the meat of wild herbivorous mammals is involved. In some communities frog flesh is used for the treatment of wounds or of eye disease and plerocercoids present in the flesh may migrate into open wounds or into the periorbital tissue.

In man, plerocercoids have been found in the subcutaneous tissue, in lymph nodes, in the conjunctiva, and also in visceral organs, where they may produce pathological changes and corresponding symptoms.

Cases of sparganosis are mainly reported from countries of south-eastern Asia, but sporadic cases are also observed in Europe and other areas.

The main means of prevention are the boiling or filtering of drinking-water and the adequate cooking of fish capable of transmitting the infection.
7. TREMATODE INFECTIONS

7.1 Schistosomiasis (bilharziasis)

Schistosomiasis is one of the most widespread trematode infections. From the public health point of view the most important schistosomes are Schistosoma haematobium, S. intercalatum, S. mansoni, S. japonicum, and S. mekongi (27). The zoonotic aspects of these and related species are discussed below.

7.1.1 Schistosoma japonicum

It is generally agreed that both man and animals are maintenance hosts of S. japonicum, with the exception of the zoophilic strain, which is restricted to animals. Infection with this trematode is an important zoonosis, which, in the Philippines alone, affects some 600,000 persons. A wide range of domestic and wild animals have been found to be naturally infected. Some of them are important reservoir hosts—for example, in the Philippines, where schistosomiasis is a major public health problem and where 25% of the total transmission is attributed to animal reservoirs. Human infection with S. mekongi (a newly discovered species that resembles S. japonicum and occurs in the dog) has been recognized in the Lao People’s Democratic Republic and southern Thailand. Clinical cases of a similar parasite have recently been reported in Malaysia and they are suspected to be of sylvatic origin.

7.1.2 Schistosoma mansoni

As with S. haematobium, man is the most important natural host of S. mansoni. However, in recent years many animals have been found to be infected, especially in Africa and South America. Examples include gerbils and nile rats in Egypt, rodents in South Africa and Zaire, many species of rodents and other wild mammals, as well as cattle, in Brazil, and baboons, rodents, and dogs in East Africa. Rates of infection with S. mansoni are often high in these animals, many of which pass viable eggs in their faeces. It is not clear whether lower animals can maintain the infection in their own communities independent of reinfection from man. Although more than 50% of the baboons in some areas of East Africa have been found to be naturally infected with S. mansoni, they have always been encountered in areas where there were opportunities
of contact with man. However, more recent findings suggest that rodents in South America and the West Indies and baboons in Africa play an important role in maintaining the transmission of S. mansoni. For example, rats (Rattus rattus and R. norvegicus) were found to be heavily infected in some areas of Guadeloupe. The significance of murine infection in the epidemiology of the human disease merits further study.

7.1.3 Schistosoma haematobium

Present evidence suggests that man is the only significant maintenance host of this species. Although a few animals have been found to be naturally infected with S. haematobium (which is closely related to S. bovis and S. mattheei), the recorded infection rate has always been low. Examples of infected animals include baboons and monkeys in East Africa, rodents in Kenya and South Africa, pigs in Nigeria, and chimpanzees in West Africa. Further studies are needed in India, where a small focus of S. haematobium has been reported and where the snail host differs from that in Africa. In this area, schistosomes of the S. indicum group may be causing some confusion. There is no unequivocal evidence that such animal infections play a role in the human disease.

7.1.4 Schistosoma bovis and Schistosoma mattheei

Both these species are animal schistosomes but they have also been found in man, where they develop to maturity and eggs are passed in the faeces. S. bovis is less common than S. mattheei and occurs in cattle in East and West Africa, the Mediterranean littoral, and the Middle East. It is a serious pathogen of cattle in the Sudan but is a transient parasite of man. Cercariae of S. bovis may be associated with dermatitis in man and such sensitization may also lead to confusion in immunodiagnostic tests.

S. mattheei is widespread in ruminants, solipeds and baboons in central, southern and East Africa. Eggs of this parasite are frequently found in human faeces or urine, infection rates being as high as 40%. However, the infection usually occurs concomitantly in individuals infected with S. mansoni or S. haematobium and is generally light. It has been suggested that parthenogenetic egg production can occur in the females of S. mattheei when they are in association with males of S. mansoni or S. haematobium. It has also been suggested that this parasite is becoming better adapted to man, and that the relatively unimportant
zoonosis it causes may increase in significance with the development of a more intensive livestock industry in Africa.

7.1.5 Schistosoma intercalatum

This is morphologically indistinguishable from S. mattheei and though several workers consider it to be a strain of that species, hybridization studies suggest the two species are distinct. The zoonotic aspects of the infection have not been adequately studied. It is common in central Africa.

7.1.6 Other schistosomes occasionally seen in man

Some schistosomes, such as S. nasalis, Orientobilharzia turkistanicum, and S. indicum are of veterinary importance but have not been found in man.

Others, such as S. bovis and S. rodhaini, infect a wide range of hosts, including man, and although responsible for considerable morbidity in livestock are of very little public health importance. The cercarial stages of these and other species may enter the skin of man to cause a severe dermatitis (cercarial dermatitis), which may represent an occupational or recreational hazard.

S. indicum and S. margerebowie are parasites of either wild or domestic animals, and most of the human infections reported have been either abortive or, in some cases, spurious, as a result of eating infected livers.

7.1.7 Heterologous immunization by schistosomes infecting animals

(zooprrophylaxis)

In many of the endemic areas of human schistosomiasis in Africa cercariae of the schistosomes of cattle and wild antelopes occur in natural waters along with the cercariae of S. haematobium and S. mansoni. Man is continually exposed to infection with all these schistosomes.

The species probably involved include S. bovis, S. mattheei, S. leiperi, and S. margerebowie of domestic and wild ruminants, S. rodhaini of rodents, as well as, for example, S. hippopotami. These parasites are often transmitted by the same snail host that carries the parasite of human schistosomiasis. It has been suggested that previous exposure to heterologous species can confer a degree of resistance which reduces the severity of human infection and enhances resistance to reinfection.

Experimental studies confirm that heterologous immunization in animals results in a substantial level of protection. For example, parasites
infecting humans protect cattle and sheep to a varying degree against animal infections. Studies on the protection of nonhuman primates against human schistosomiasis using animal-infecting forms as immunizing agents show less immediate promise, but are encouraging enough for it to be recommended that this approach should be further investigated.

7.1.8 Cercarial dermatitis

Cercarial dermatitis—a worldwide problem—is caused by the cercariae of a number of schistosome species affecting mainly birds but also mammals. Exposure to the cercariae results in sensitization which, on renewed contact with cercariae and their penetration of the dermis, produces—according to the degree of sensitization—an initial burning sensation, then itching, followed by a papular or pustular eruption and later by a severe dermatitis which may persist for several days. The most severe forms result from sensitization with schistosomes which survive for short periods only in the skin of man. Avian-infecting forms (e.g., _Trichobilharzia_ and _Gigantobilharzia_) are important in this respect; however, the syndrome is also seen with schistosomes infecting man and other mammals.

The condition is commonly known as swimmers' itch, clam-diggers' itch, hunters' itch, etc., and may constitute a serious occupational disease and economic problem in areas where the work force comes into contact with water, as in paddy-fields, and a matter of public health concern in recreational areas, such as bathing beaches, and lakes frequented by wildfowl and used for hunting, sailing, and swimming.

7.2 Clonorchiasis and opisthorchiasis

Liver fluke disease, caused by _Clonorchis sinensis_, _Opisthorchis felineus_, and _Opisthorchis viverrini_, is widespread in parts of Asia and Europe. _C. sinensis_ is the most important liver fluke infecting man, and many millions of cases occur in China, Japan, the Republic of Korea, and countries of South-East Asia. _O. felineus_ is a trematode that infects man in central Siberia, other parts of Asia, and eastern Europe. _O. viverrini_ occurs frequently in man in South-East Asia and is especially important in the Mekong Valley area of the Lao People's Democratic Republic and in north-east Thailand.

7.2.1 Transmission

Infection is usually acquired through the consumption of raw fish, a common food in all the areas of heavy endemicity listed above. Infected
cats and dogs are usually found wherever the liver fluke is endemic in man, and these animals probably play an important role as reservoir hosts. Wild carnivores such as Korean and Japanese otters, martens, and badgers have also been found to be infected in nature and have been implicated in transmission.

The geographical distribution of infections with these liver flukes is considerably more limited in man than in the reservoir hosts. In endemic areas, people who live on the shores of small lakes or on river banks usually have a higher rate and intensity of infection than those living at a distance from such water bodies. Possibly the shoreline inhabitants regularly eat more uncooked fish than the others, and their fish may be obtained from directly polluted waters, since it is a common practice for people to defecate on lake shores and river banks and from their boats while fishing.

Although Clonorchis metacercariae have been found in fish throughout the year, the heaviest infections are encountered primarily in spring and autumn. General conditions of pisciculture in Asian countries favour infection, since fresh grass, straw, pig faeces, and human night-soil are dumped into fish-ponds as food for fish.

7.2.2 Clinical significance, diagnosis, and treatment

Light infections are asymptomatic, while those with hundreds of worms may be associated with mild, moderate, or severe symptoms, such as irregular episodes of flatulence, cholangitis, and obstructive jaundice. The worms induce adenomatous hyperplasia of the biliary epithelium, inflammation, fibrosis and thickening of the bile duct walls, formation of crypts, fibrosis of the portal areas, and other changes. In endemic areas an increased rate of cholangiocarcinoma has been associated with Opisthorchis or Clonorchis infection.

The diagnosis is based on the detection of eggs in stool samples. Drugs which have a partial effect include chloroquine and dehydroemetine, but treatment has to be prolonged for up to 2 months or more. Niclofolan has given promising results when administered at dose rates of 1–2 mg per kg of bodyweight for 2–3 days. Also, praziquantel has proved highly effective in a single oral dose of 50 mg per kg of bodyweight, as indicated by a 99% reduction in the egg count.

7.2.3 Prevention

Since the principal mode of infection is by ingestion of raw or improperly cooked freshwater fish, the prevention of liver fluke infection in
endemic areas can be accomplished most readily by health education recommending the thorough cooking of all such fish. Health education may be effective in urban areas, but may be much less so in the rural environment, where fish is the primary source of animal protein and where traditional culinary habits are not easily changed. Other control measures include better sanitation and improved methods for the storage and treatment of night-soil. The infection can probably be carried some distance from endemic areas through the practices of refrigeration and drying of fish, if such processes are insufficient to kill the metacercariae. This, in fact, can be achieved by freezing the fish at $-10 \, ^\circ C$ for at least 5 days, or salting in a 10% saline solution. Because of the widespread areas in which these liver fluke infections are present, the extermination of snails by engineering or chemical measures might be too expensive to be feasible. Unless effective biological control measures are discovered, any major effort directed against the snails will probably prove to be impracticable.

7.3 Paragonimiasis

The most important agent of paragonimiasis is *Paragonimus westermani*, the lung fluke of man. It is a significant public health problem in about 20 provinces of southern China, Japan, the Philippines, the Republic of Korea, and other countries of the Far East. Human infections with *P. westermani* are caused by the eating of raw or inadequately cooked freshwater crabs and crayfish or the contamination of other food items, hands, and cooking utensils with the metacercariae released from infected crabs during the food preparation process. In some areas, crab juice is used in certain dishes, and in Chekiang province of China ‘‘drunken crabs’’—crabs eaten alive after immersion in wine—are a source of infection.

Other mammalian reservoir hosts are cats, dogs, pigs, tigers, leopards, wolves, wildcats, and field rats. The wild boar, the rabbit, and the mouse have recently been considered to be paratenic hosts, and infection of man in Kyushu Island in Japan has ascribed to eating the raw flesh of the wild boar containing larval forms of the parasite. The significance of this finding has yet to be ascertained.

Other parasites of the genus *Paragonimus* of lesser overall importance than *P. westermani* and acquired by the consumption of raw crabs or crayfish are as follows:
(1) *P. pulmonalis* occurring in China (Province of Taiwan), Japan, and the Republic of Korea; it has a similar host distribution to that of *P. westermani* but in some areas it is more prevalent.

(2) *P. miyazakii* in man and wild canines and felines in Kyushu and Honshu, Japan.

(3) *P. skrjabini* (syn. *P. szechuanensis*) in man, dogs, and cats in Canton, China, and possibly Thailand; pulmonary involvement is less common with this species and it is usually found in subcutaneous nodules.

(4) *P. heterotrema* (syn. *P. tuanshanensis*) in rats, dogs, and cats in China, the Lao People’s Democratic Republic, and Thailand; human cases have been reported in the two latter countries.

(5) *P. africanus* of man, dog, mongoose, civet cat, and drill in the United Republic of Cameroon is similar to, and should be differentiated from, *P. utoerobilateralis*, which has a similar host range in Liberia, Nigeria, and the United Republic of Cameroon.

(6) *P. peruviana* in man, cat, and opossum in Peru and more recently in Costa Rica, Ecuador, and Panama; with this species, the rat is possibly a paratenic host.

Other species of the genus, such as *P. siamensis*, *P. macroorchis*, *P. kellicotti*, occur in various parts of the world but solely in animals. There is no evidence that they infect man.

Various diagnostic tests are available, including complement fixation, passive haemagglutination, precipitation, and flocculation. A highly purified antigen isolated by chromatographic techniques has been produced which does not cross-react with other parasites (e.g., schistosomes, ascarids, and trichurids) that are commonly found in endemic areas of paragonimiasis.

There is practically no danger of human infection if the second intermediate hosts (freshwater crabs and crayfish) are not consumed in the raw state. The possibility of infection by the drinking of contaminated water appears to be very slight. It has been shown in Japan that the infection rate of the second intermediate hosts decreases considerably when infected persons in the endemic areas are given mass treatment with bithionol, which is highly effective against the parasite. There are at present no practical measures that can be taken against the first intermediate host, the snail. The importance of paratenic hosts (e.g., wild boar) should be recognized.
7.4 Fascioliasis

Fascioliasis is an infection of herbivorous animals caused by liver-flukes of the genus Fasciola. Fasciola hepatica and F. gigantica cause death and disease, mainly in sheep and cattle, all over the world.

Human infection with F. hepatica has been reported from many countries and cases of F. gigantica infections in man have been recorded in the USSR, Hawaii (USA), and Viet Nam, as well as in several African countries. Infection is usually associated with the consumption of uncultivated raw watercress (Nasturtium officinale) and other plants, such as dandelions, growing in wet areas. In some instances water-borne infection is recognized where infected snails are present.

Most of the reports of human infection refer to single cases or to very small numbers of patients. However, under certain conditions the infection may occur in endemic-type foci afflicting larger groups of people. For example, 2.4% of about 3900 persons excreted Fasciola eggs in a specific area of Malawi, and a more recent report from Peru indicated that from 4.5% to 34% of children under 15 years old in some villages were infected.

The intensity of infection is usually low, and only single parasites or small numbers of them are to be found in the bile ducts of the human liver, but aberrant migrations can also occur and parasites have been found under the skin or elsewhere. The infection may be asymptomatic but symptoms of liver and general disturbances may occur.

Diagnosis is based on the patient's history and the examination of stools or duodenal fluid for Fasciola eggs. However, where the parasite does not reach maturity in man, or has migrated aberrantly, stool examination is not appropriate. Especially in these cases and during the pre-patent period of the infection immunodiagnostic tests are of value. The indirect immunofluorescent test, passive haemagglutination, gel precipitation and other methods have given reliable results. No specific drugs are available for the treatment of human cases of fascioliasis, but dehydroemetine and biathionol have been reported as being effective against the parasite.

The main preventive measure, besides the control of fascioliasis in animals, is to avoid consuming potentially infected plants and water.

7.5 Dicrocoeliosis

Dicrocoeliosis, caused by the lancet fluke, Dicrocoelium dendriticum, is very common in ruminants in all parts of the world, but confirmed
cases of human infections are rare. The infection is diagnosed by the
detection of the typical eggs in the stools, but it should be emphasized
that spurious infections due to the consumption of liver from sheep or
cattle infected with the adult flukes frequently lead to misdiagnosis. Also,
such eggs may be mistaken for Opisthorchis eggs.

7.6 Fasciolopsiasis

Fasciolopsiasis is an important intestinal infection of man and swine
caused by Fasciolopsis buski. Highly endemic foci are found in China,
India, and other parts of southern Asia. The intermediate hosts are
planorbid snails. The most important factor in the spread of human
fasciolopsiasis is a water caltrop (the water chestnut—Trapa natans), on
which the cercariae of the parasite encyst. The outer shell of this nut is
commonly peeled off with the teeth, particularly by children, in whom
the infection is usually heavier than in adults.

In some areas the prevalence in man does not parallel that in domestic
animals; this may be due to the custom, in these areas, of cooking water
nuts before they are eaten.

Control measures include health education to promote the cooking
of water nuts and the avoidance of drinking unfiltered water. Swine
should be protected from infection and treated if they are infected. Snail
control may not be practicable in many areas, especially where the water
nut is artificially cultivated in ponds and fertilized with human sewage.

7.7 Mesocercariasis

Some cases of mesocercariasis due to mesocercariae from dog strigeids
(principally Alaria alata) have been reported in man, causing sub-
cutaneous, ocular, and encephalic involvement. More investigation is
needed to assess the importance of this parasitic zoonosis.

8. NEMATODE INFECTIONS

8.1 Trichinellosis (trichinosis)

8.1.1 Species and strains

From the initial identification of Trichinella spiralis in 1835 until
recently, all trichinae were considered to be a single species. Strain dif-
fferences were recognized; the Arctic and tropical forms, although highly
infective to man, had exceptionally low infectivity for swine and rats. Because of these differences it was proposed in 1972 that *T. spiralis* should be subdivided into 3 species. The designation *T. spiralis* was to be retained for the synanthropic, zoonotic form of the infection which occurs in swine, rats, dogs, cats, and man, while the names *T. nativa* and *T. nelsoni* were to refer to the species found in sylvatic cycles involving wild carnivores.

*T. nelsoni* has been recorded in eastern and southern Africa, in Bulgaria, in southern parts of the USSR (Kazakh, Tadzhik, and Turkmen SSRs), and, more recently, in Switzerland. According to present knowledge, its area of distribution corresponds to the southern part of the Old World up to latitude 47° N. *T. nativa* has been identified in Canada and in parts of the USSR, mostly north of latitude 38° N. A proposed further new species, *T. pseudospiralis*, which was first isolated from a racoon in the northern Caucasus (USSR), is probably also present in India. This species is unique in that it does not produce a cyst in the musculature of the host and is capable of infecting birds as well as many mammals.

The validity of these new species, especially *T. nativa* and *T. nelsoni*, has been questioned by some authorities, who regard them as varieties or strains. Additional studies, using modern techniques—for example, scanning electronmicroscopy—may be necessary before a decision on validity can be made. All the species concerned are now maintained in laboratory animals.

Since most of the available isolates of *Trichinella* spp. have not been submitted to modern classification procedures, the homogeneity of the proposed species is not yet known.

### 8.1.2 Epidemiology

*Trichinella* are recognized to exist in most of the northern hemisphere, including the Arctic, and in parts of Africa, South America, and Asia. In some countries, the apparent absence of the parasite may be due to the lack of an intensive search for it rather than to its actual absence.

As reflected by the proposed new speciation, *Trichinella* is basically maintained in two types of cycle: the sylvatic and the synanthropic-zoonotic. The natural cycle, which would include *T. nativa*, *T. nelsoni*, and *T. pseudospiralis* (if these are valid species), primarily involves carnivores and is generally maintained by carnivorousness, including scavenging and cannibalism. Over 120 species of mammals have been found to
be naturally infected with *Trichinella*. Probably all mammalian species are susceptible in some degree to infection. The food habits of the potential host species, as well as climatic and environmental factors, control the spread of the parasite. The sylvatic cycle, which can exist in the absence of the zoonotic cycle, can nevertheless play an important role in human infection.

The zoonotic cycle, which basically involves the cycling of the parasite in swine with occasional offshoots to man, rats, cats, or dogs, is primarily man-related. Garbage that includes pork scraps, swine offal, or wild-animal carcasses is regarded as the prime vehicle.

Reports from the USA indicate that in herds of swine, even those not fed with garbage, the incidence of *Trichinella* may be high: in one case, for example, an infection rate of more than 50% was observed. In that and other instances, evidence was found of large rodent populations, and trapped rats and other feral animals had *T. spiralis* infection. It is suggested that the rat–swine–*Trichinella* association is probably a complicated one which has not yet been fully elucidated.

Recently, outbreaks of trichinellosis in man associated with the consumption of raw horseflesh have been reported; it was thought that the horses had probably acquired the infection from a special fattening food containing remnants of infected meat, such as pig, rat, and mouse. The susceptibility of horses to *Trichinella* has been confirmed experimentally.

Although the sylvatic and synanthropic-zoonotic cycles are distinct, interplay may occur. Infected wildlife may serve as a source of infection for swine, as has been evidenced by tracing back the origins of human outbreaks in eastern Europe and by epidemiological studies in the USA.

Wildlife can serve as a direct source of human infection. This is attested by infections in the Arctic traced to bear and walrus meat and in parts of Africa where bush pigs are the source of infection. Bear meat and wild boar constitute a source of human infection in the USA, northern Asia, and Europe.

8.1.3 *Diagnosis*

Muscle biopsy is the best diagnostic method for the detection of moderate and heavy infections in man. However, false negative results may be obtained with light or early infections. Several serological tests are available for diagnostic and epidemiological uses. The bentonite flocculation test is the most commonly used procedure. Others include the fluorescent antibody, latex flocculation, cholesterol-lecithin, complement
fixation and indirect haemagglutination tests. The ELISA test is highly specific and sensitive for detecting trichinellosis in swine but has not yet been fully evaluated as a technique for diagnosing the disease in man.

The trichinoscope has been routinely used in many countries of the world to detect Trichinella in the musculature of swine at slaughter. Although the procedure will detect moderate to heavy infections, light infections may be missed. It is also relatively expensive. Recently, attention has been directed to the development of alternative diagnostic methods which would be more secure and less costly. These include the pooled-sample-digestion method and the new serological methods—ELISA and fluorescent antibody tests. The pooled-sample-digestion method is a direct approach and such modifications as varying the number of muscle samples pooled, the size of individual samples and the procedures for digestion have been made by several laboratories. The ELISA test, as already mentioned, is highly sensitive and specific for detecting antibodies to Trichinella in the serum of swine. This test has been automated and is being used in certain countries under abattoir conditions or for epidemiological studies.

Serological tests have the inherent danger that an occasional heavily infected pig may be serologically negative.

8.1.4 Therapy

Human trichinellosis is usually diagnosed during the muscular phase of the disease. Although about 30 compounds show some degree of activity in controlling the enteric phase, only about half this number are active against the muscular phase. Only a few (e.g., thiabendazole) have been used clinically and results have been variable. Treatment in man generally includes corticosteroids to suppress allergic reactions.

Among the newer benzimidazole compounds, mebendazole may be of promise for the treatment of human trichinellosis. This drug is highly active against the intestinal and muscle stages of Trichinella in rodents and has not produced side-effects when given in high dose rates to patients with echinococcosis (see section 6.1.5). The efficacy of this and similar anthelmintics should be further evaluated in patients with trichinellosis.

8.1.5 Prevention and control

Trichinellosis in man can be controlled by eliminating the source of infection for swine and destruction of the parasite in pork. Prohibition of the feeding of raw garbage to swine can contribute significantly to
reducing swine trichinellosis. The cooking of garbage prior to feeding it to swine is useful as a method of control, but it is difficult to enforce, and ensuring that the cooking has been adequate is also a problem. Experience in the USA indicates that this measure is not always completely successful.

Any pork product from endemic areas should be cooked or deep-frozen prior to human consumption. The holding of pieces of pork up to 15 cm thick at a temperature of \(-25\) °C for 10 days will effectively destroying all Trichinella cysts. Thicker pieces should be frozen and kept at \(-25\) °C for 20 days.

The smoking, curing, and drying of meat are not reliable methods for the prevention of infection.

While regulations exist in some countries regarding the inspection of meat from wild animals, nevertheless people should be warned against the consumption of raw or undercooked meat of wild animals implicated in the sylvatic cycle in endemic areas.

8.2 Larva migrans

Cutaneous and visceral larva migrans are caused by invasion of the skin and internal organs by nematode larvae which migrate but do not normally mature in man. A wide range of species may be involved, but the most common are the hookworms (Ancylostomatidae) and the ascarids (Toxocara) of dogs and cats. Larval anisakines from fish are an important nondomestic source of infection.

(1) Cutaneous larva migrans (sometimes known as larva currens) is acquired by contact with soil containing infective larvae that can penetrate the skin. Although it occurs most frequently in areas where Ancylostoma brasiliense is common in cats and dogs, larvae of other species of hookworm (A. caninum, Bunostomum spp., and Strongyloides spp.) that penetrate the skin and develop in domestic and wild animals can cause the disease in man. Larvae are usually localized in the skin, where they cause a dermatitis of varying intensity; some cases may be severe enough to require hospitalization. Normally larvae are restricted to, and die in, the skin, but occasionally they migrate to the lungs; the skin lesions are then followed by pulmonary lesions of the form seen in Loeffler's syndrome. In such cases larvae may be found in the sputum. Thus, Ancylostoma larvae may produce both visceral and cutaneous
larva migrans. Evidence for this is provided by the findings that *Ancylostoma* larvae occur in association with corneal opacity and that larvae of *A. caninum* are sometimes excreted in the milk of paratenic hosts (sheep and goats). Diagnosis is made by clinical examination and control is effected by prohibiting dogs and cats from beaches, lawns, playgrounds, etc. Soil disinfection can be applied only in limited areas. Effective treatment has been achieved by oral and topical application of thiabendazole.

(2) *Visceral larva migrans* is defined here as a disease caused by the persistence or the migration of animal nematode larvae in the internal organs of man. Several nematodes have been associated with visceral larva migrans (see Annex 3), and of these *Toxocara, Anisakis*, and related genera are the most important.

8.2.1 *Toxocariasis (Toxocara larva migrans)*

Larvae of *Toxocara canis*, a dog ascarid, have been most commonly associated with this disease, but other *Toxocara* species may also be involved. Man acquires the infection by the ingestion of eggs containing the infective stage-2 larvae, and these larvae, which only rarely grow and develop in man, may be distributed in all parts of the body, including the brain and the eye.

Recent observations indicate that toxocariasis of man presents a growing health problem which requires attention.

8.2.1.1 *Prevalence in carnivores.* Prevalence rates of *T. canis* infection in carnivores are high throughout the world. For example, in Great Britain, 20.7% of 300 dogs were found to excrete *Toxocara* eggs (28). The rate of infection is highest in young animals owing to the prenatal and transmammary transmission of larvae. Egg excretion in infected young animals is commonly high and the finding of 10 000–15 000 eggs per gram of faeces is not unusual.

8.2.1.2 *Transmission.* *Toxocara* eggs are very resistant and can survive in soil for long periods—sometimes for a number of years. In view of the increasing numbers of dogs and cats in the urban areas of many countries, this factor creates a health risk. For example, recent studies in Great Britain have shown that 24.4% of soil samples of public parks were contaminated with *Toxocara* eggs (29). Similar results have been reported from other areas. It appears that environmental contamination with *Toxocara* eggs forms an important reservoir, from which man can be infected. This view is supported by the observation that many
patients with proved toxocariasis have not owned or had close contact with a dog or cat. Even though eggs are unlikely to mature on an animal’s coat, infective eggs from the soil may adhere to the hair so that contact with it can lead to infection. The possible role of food-and water-borne infections remains to be further investigated.

8.2.1.3 Prevalence in man. Human cases of toxocariasis have been reported from all parts of the world. Previous studies have indicated that about 2% of persons over 10 years of age in London and slightly more than 30% in various African cities exhibited a positive reaction to a *Toxocara* skin test. A recent serological survey gave evidence that approximately 2–3% of the apparently healthy population in Great Britain have experienced *Toxocara* infection (30). The common association of children with puppies tends to increase the likelihood of human infection.

8.2.1.4 Clinical importance in man. Visceral larva migrans is chiefly a condition of children between 18 months and 3 years of age. Continued reinfection may lead to severe infections with associated debilitating hepatic and pneumonic disorders. The lesions consist of focal or generalized eosinophilic granulomata, usually associated with a high blood eosinophilia. Other clinical symptoms include a cough and asthmatic manifestations. Another important effect is chorioretinitis, which sometimes leads to blindness. There is evidence that larvae may occasionally invade the brain, causing epileptiform symptoms or partial paralysis.

8.2.1.5 Diagnosis. Diagnosis of toxocariasis is based on the patient’s history, presence of hepatomegaly, radiographic examination, and the finding of leukocytosis, eosinophilia, and increased IgG, IgM, and sometimes IgE levels. Biopsies of liver or lung may help to identify tissue reactions indicative of toxocariasis but only occasionally can larvae be detected. Immunological methods are therefore of special value in diagnosis. A skin test with standardized *Toxocara* antigen was reported to be fairly sensitive and specific. At present, serological methods are more frequently employed. High sensitivity and specificity have been obtained with the indirect immunofluorescent test and the ELISA test using stage-2 *T. canis* larvae as antigen. Several reports indicate that the precipitation reaction with living larvae is highly specific. However, more comparative work is required on human and animal infection in order to determine the value of various serological tests and antigens.

8.2.1.6 Treatment. Several anthelmintics are available and are highly active against the intestinal stages of *Toxocara* in dogs. There is
an urgent need for anthelmintics which are active against larvae responsible for prenatal and transmammary infection. Evidence from isolated cases indicates that diethylcarbamazine had some effect in human toxocariasis; however, the results are difficult to interpret and more research is necessary in this field.

8.2.1 Prevention and control. Owing to the high prevalence of the infection among dogs, ownerless animals should be eliminated. The possible role in visceral larva migrans of other Toxocara species (for example, *T. vitulorum* of cattle and water-buffaloes) should be examined. Deworming of puppies aged 14-18 days, followed by periodic examination and, if necessary, repeated treatment, is recommended. Public open spaces to which dogs have access should be segregated from those used as children’s playgrounds, and practical measures should be taken to prevent contamination of the environment with *Toxocara* eggs.

8.2.2 *Anisakiasis (Anisakis larva migrans)*

Anisakiasis is caused by the larval stages of anisakine nematodes persisting in the alimentary canal or penetrating the tissues of human consumers of raw or semi-raw fish (see also section 3.4, page 18, and section 4.3, page 29). At least 30 genera of anisakines are recognized. Larvae from fish intermediate or transport hosts of those anisakine species that mature in warm-blooded definitive hosts are the ones likely to cause human infections. *Anisakis* (the so-called herring worms) and *Phocanema* (the so-called codfish worms, sometimes not distinguished from *Terranova*) are the two genera in which the majority of larvae recovered from human cases have been classified. Other species, belonging to the genera *Thynmuscaris* (*T. adunca*, from sardines) and *Contracaecum* (*C. osculatum*, from anchovy), have also been reported.

Symptoms are variable and nonspecific. Only a single larva has been recovered in the majority of human infections. Mild cases are associated with slight irritation of the alimentary canal, and the causative larva is detected only if it is vomited or noticed in the stools. Severe cases may be associated with irritation of the stomach or intestines and are frequently misdiagnosed as ulcers or inflammations due to other causes; anisakine larvae in the tissues of the stomach, intestines or other organs may elicit cellular reactions that are misdiagnosed as tumours. While anisakines may survive long enough in humans to cause the described symptoms and to moult (from stage-3 larvae to stage-4 larvae), they do not mature fully; eventually they die or are voided.
Sensitization may increase the severity of anisakiasis but epidemiological evidence and experimental infections indicate that previous exposure to anisakines is not necessary for the development of symptoms. In pigs experimentally fed *Anisakis* sp. or *Phocanema* sp. isolated from fresh fish, larvae attach to the stomach, producing oedema, haemorrhage, and inflammation. Nonexperimental anisakiasis has been reported in pigs fed waste from fish-processing plants.

Diagnosis is difficult unless the consumption of underprocessed fish is suspected. Since the 1950s, cases have been reported from the Americas, Europe, and Japan. Larvae recovered from patients are not easy to identify precisely. Larval anisakine nematodes have been mistaken for their superficially similar “terrestrial” ascarid relatives. However, morphological criteria now exist for identifying most stage-3 and stage-4 larval anisakines beyond type and ascribing them to genus and (in a few instances) even to species. Biochemical and immunological criteria of identification are being developed. In certain instances, morphological identification can be made from sectioned surgical biopsy specimens. A specific complement fixation test is available for diagnostic purposes.

Preventive measures include eviscerating fish as soon as possible after catch (to stop additional anisakines from moving into the edible musculature), and freezing at 0 °C for 60 hours those fish not intended for thorough cooking prior to consumption. Anisakine nematodes are found in freshwater fish, brackish-water fish and salt-water fish throughout the world, but the forms potentially pathogenic for humans occur primarily where species are cycled from aquatic mammals to aquatic invertebrates to fish. There is little host specificity of fish for anisakine species. The egg and the early larval stages found free in the environment or in invertebrates do not generally infect human beings.

8.2.3 *Angiostrongylia* (Angiostrongylus laevis migrans)*

The rat lungworm, *Angiostrongylus cantonensis*, is the cause of an eosinophilic meningoencephalitis and has been found in man in the spinal cord, brain, and anterior chamber of the eye. The disease is known to occur in southern Asia and the Pacific area.

Human infection results from the consumption of raw or undercooked intermediate hosts (snails and slugs) or paratenic hosts (e.g., freshwater prawns, crabs, and planarians).

Recently *A. costaricensis*, of which the definitive hosts are rats and coatimundi (*Nasua narica*), has been identified as the etiological agent.
of eosinophilic granulomata in the intestine of man in Central America. This form of angiostrongyliasis requires further study.

8.2.4 Other species concerned in larva migrans

Many other nematodes normally parasitic in lower animals cause ill health if they are accidentally acquired by man. Most of them are medical curiosities without public health significance, but a number are less rare and these include Physaloptera of monkeys, Gnathostoma of dogs and cats, Ascaris suum of swine and Lagochilascaris of leopards (of which the latter two may occasionally mature in man).

8.3 Filariasis

Brugia malayi is known to infect a wide range of animals, including cats, dogs, monkeys, insectivores, and pangolins; in addition, many species of lower animals have been infected in the laboratory. There are two strains of this parasite: the periodic form, which is widespread in India, in the more populated regions of Malaysia, and in other parts of southern Asia; and the subperiodic form, which is confined to swamp-forest areas. The latter form is definitely zoonotic, transmission occurring between man and forest animals through the agency of Mansonia mosquitoes, which show very little host preference. Control by chemotherapy has proved difficult because of suspected reinfection from animals.

There are no records of natural infection in animals of either the subperiodic or the periodic form of Wuchereria bancrofti. However, the natural periodic strain of W. bancrofti has been transmitted experimentally to the Taiwan macaque (Macaca cyclops) and to the crab-eating macaque (M. fascicularis). The fact that isolated foci of W. bancrofti occur in remote rural areas in parts of Africa and Asia suggests that further efforts should be made to look for possible animal hosts of this parasite.

Loa loa is found in man and in a variety of monkeys and baboons in the rainforest regions of Africa. At one time loiasis was assumed to be a zoonosis, but detailed studies of the transmission of the parasites from simian and human hosts have shown that they are ecologically quite distinct, with very little opportunity for overlap. There are also morphological and biological differences in the two forms of the parasite. Although laboratory studies have shown that fertile hybrids can be produced and monkeys can be infected with the form infecting human beings, there is no evidence that this occurs under natural conditions. Present evidence suggests that loiasis is not a zoonosis.
Only two confirmed cases of natural *Onchocerca volvulus* infection have been found in animals—in a gorilla in Zaire and an *Ateles* monkey in Mexico. Attempts have been made to infect a variety of animals in the laboratory, but only the chimpanzee has proved susceptible. Recent studies have shown that there are several races of *O. volvulus* infecting man. The African forest type differs from the more pathogenic savanna forms and both differ from the parasites seen in man in Central and South America. Further studies of the significance of onchocerciasis in nonhuman primates are needed, but present evidence indicates that in most areas the disease is maintained by interhuman transmission and is not a zoonosis.

Other species of filarial parasite found in man include the dipetalonematids *Dipetalonema perstans*, *D. streptocerca*, and *Mansonella ozzardi*. They may be prevalent locally, with infection rates exceeding 50%. Other species of dipetalonematids have been found in lower animals and they are transmitted by a variety of arthropods. It is not always easy to distinguish these species from the forms occurring in man because of the paucity of comparable material. Both *D. perstans* and *D. streptocerca* have been found in anthropoid apes in Africa, but not enough is known of their biology for their epidemiological significance to be assessed.

Several *Onchocerca*, *Parafilaria*, *Stephanofilaria*, and *Setaria* species occur in domestic livestock and wild ruminants in many parts of the world, but, despite the fact that humans must be exposed to their insect vectors, there is no proof that they become established in man or cause disease. It had previously been thought that tropical pulmonary eosinophilia might be produced by animal filariae, but recent studies suggest that the main cause of this syndrome in man is an allergic response to *W. bancrofti*.

However, parasites of the *Dirofilaria* genus, which occur in dogs, cats, and raccoons, cause aberrant infections in man associated with lesions in the lungs, subcutaneous tissues, and the eye. The dog heartworm, *Dirofilaria immitis*, has been associated with some 70 cases of pulmonary dirofilariasis which have occurred mainly in Australia, Japan, and the USA. The majority of the cases were symptomless and lesions were accidentally discovered during radiography or following pulmonary lobectomy on suspicion of malignancy. Sometimes chest pain, cough, and occasionally haemoptysis occur, and "coin lesions"—solitary circumscribed nodules 1–2cm in diameter—appear. Eosinophilia is usually absent, and since the parasites seldom reach the patent stage microfilariae are not detected. *D. tenuis* of raccoons has been observed in the subcutaneous tissues of man in North America. The lesions occur as a nodule in any
part of the body and are seen in individuals whose work or leisure brings them into contact with wildlife. *D. repens* of dogs in Africa, Asia, and Europe is associated with subcutaneous nodules, often in and around the eyes of man.

Serodiagnostic tests are being developed for the identification of these infections in man.

### 8.4 Dracunculiasis (dracantiasis)

This disease of man, which has been known since antiquity, is caused by the nematode parasite *Dracunculus medinensis*.

#### 8.4.1 Life cycle

The adult parasites inhabit the subcutaneous tissue mainly of the legs but also of other parts of the body, including the head and neck. The mature female forces its anterior end into the dermis, thus inducing oedematous swelling, inflammatory reaction, and blister formation. Upon contact with water the blister soon ruptures, and from the uterus of the female large numbers of larvae are released. After deposition of most of the larvae the female dies and is absorbed by the tissue.

The larvae may remain active in the water for 3–6 days. Further development to the infective third stage takes place in a suitable intermediate host within 2–6 weeks, depending on the external temperature. About 15 species of the crustacea *Cyclops* have been described as intermediate hosts of *D. medinensis*; these commonly inhabit such water-sources as ponds and wells. Infected *Cyclops* may survive for several months. Man acquires the infection by swallowing drinking-water containing infected intermediate hosts.

In the human body the parasites are released in the gut and penetrate the duodenal wall. Subsequently they migrate via the abdominal mesenteries to the subcutaneous tissue of various parts of the body. The mature female emerges 10–14 months after infection.

#### 8.4.2 Epidemiology and geographical distribution

Dracunculiasis is prevalent in rural communities in areas with a dry climate or with an extended dry season. Peak transmission occurs during the dry season, when the water levels in drinking-water sources are low and the density of infected intermediate hosts is therefore high.

Besides man, animals such as nonhuman primates, carnivores, cattle, and horses have been found to be infected with *D. medinensis* under
natural conditions. Dogs were involved in most of these reported instances. The presence of *D. medinensis* in animals living in areas where this disease in humans does not occur or has been eradicated indicates that dogs and possibly other animals may act as reservoir hosts. This view is supported, for example, by a report from the Kazakh SSR, where human dracunculiasis had been eradicated and where subsequently 11.7% of 213 dogs were found to be infected with *D. medinensis* (31).

On the other hand, there is some evidence that other *Dracunculus* species normally found in animals occasionally may infect man. Thus, sporadic cases of human dracunculiasis have been reported from the eastern USA, where infections of carnivores are usually attributed to *D. insignis*, which occurs in several parts of the USA and southern Canada.

Historically, the disease was associated with specific locations, as the terms "Guinea worm" or "Medina worm" imply. Today, human dracunculiasis is known to occur in circumscribed foci in the east, west, and north of Africa, in the Middle East, India, Iran, and Pakistan. It appears that the disease has died out spontaneously in Brazil and the West Indies, and has been eradicated in the USSR. The general incidence of dracunculiasis has declined in recent years, but exact figures on the number of people at risk are not available.

8.4.3 Clinical symptoms, diagnosis, and treatment

The infection is mostly asymptomatic for about 1 year, but clinical symptoms appear when the female migrates to the dermis. Prodromal symptoms may include fever, diarrhoea, vomiting, and urticaria. Specific signs of the disease are erythema, oedema, induration of the skin, as well as blister and ulcer formation at the site where the female penetrates to the surface. The severity of symptoms depends on the location of the worm. More severe symptoms are associated with the death of the worm, or secondary bacterial infection, or both.

Diagnosis is based on clinical symptoms, X-ray examination, and immunodiagnostic tests, such as the indirect immunofluorescent test. From antiquity until recent times mechanical extraction of the female worm by winding it out of the skin ulcer on a stick has been used as an effective method of treatment. Surgical removal after local anaesthesia and, more recently, chemotherapy are further possibilities. Niridazole, thiabendazole, and metronidazole have been found to be effective.

8.4.4 Prevention and control

The disease can be controlled by the improvement of water supplies—for example, by the introduction of piped water, by the substitution of
draw wells for step wells, or by the construction of bore and tube wells. In a large area of Iran, chlorination of drinking-water from cisterns, combined with measures designed to prevent water contamination with Dracunculus larvae, has led to an almost complete eradication of the disease. Boiling or filtering drinking-water provides personal protection.

8.5 Capillariasis

8.5.1 Intestinal capillariasis

Human intestinal capillariasis, caused by Capillaria philippinensis, was initially reported on the island of Luzon, in the Philippines, and was subsequently also observed in Thailand. Some 1700 cases, with 120 deaths, have been reported. The disease is characterized by diarrhoea, malabsorption, fluid imbalance, and a protein-losing enteropathy. The disease is twice as frequent in males and mostly occurs in the age group 20-49 years. Infection is associated with the ingestion of raw or undercooked infected freshwater fish but the definitive host in nature is unknown. Certain species of freshwater fish have been infected experimentally with embryonated eggs of C. philippinensis. When larvae, developed in the digestive tract of the fish during a 3-week period, were fed to monkeys (Macaca spp.) a patent infection resulted. The natural transmission of the parasite was demonstrated when freshwater fish (Hypsibotis bipartita) were fed to jirds (Meriones unguiculatus), which became infected. In these experiments evidence was obtained that autoinfection plays a role in the life cycle of the parasite, both initially and in maintaining the infection.

The recommended treatment is mebendazole administered at the rate of 400 mg per day for 15–20 days.

Control measures consist in the avoidance of eating raw fish, sanitary disposal of human excreta, and improved personal hygiene.

8.5.2 Hepatic capillariasis

Infection due to C. hepatica—rare in man—is associated with enlarged liver, marked ascites, and emaciation. In some cases death ensues. Adult worms occur in the liver of carnivores, rodents, pigs, monkeys, and other animals, and eggs are dispersed from the liver on the death of the host. Humans (mostly children) contract the infection through the ingestion of vegetables, fallen fruits, and water contaminated with embryonated eggs.
Human hepatic capillariasis has been reported from many countries of the world. Diagnosis can only be made by the demonstration of eggs in the liver either by biopsy or at autopsy. A serological test developed for experimental infections in animals should be evaluated in man. Preventive measures are the same as for other soil-borne infections.

8.6 Strongyloidiasis

Several species of *Strongyloides* are common intestinal parasites of ruminants, swine, equines, rabbits, primates, and other mammals. The infective stage-3 larvae of *Strongyloides* species from animals are able to invade the skin of man and to produce symptoms of cutaneous larvae migrans. Larvae of those species that are not adapted to man do not develop any further and die within several weeks after infection.

On the other hand, man is a host of *S. stercoralis*, which also occurs in monkeys, dogs, and cats. Man is susceptible to *S. fuelleborni*, which likewise infects monkeys. These epidemiological relationships have to be considered in research stations, zoological gardens, and other institutions dealing with monkeys.

*S. stercoralis* has a worldwide distribution, but it is more prevalent in tropical and subtropical areas, where infection rates in human populations with a low standard of living may be as high as 24%. Recent reports from Poland indicate that the parasite can spread in the temperate zone after importation.

Infection of man with *S. stercoralis* occurs by the percutaneous route, and the infective larvae rarely penetrate through the gastrointestinal tract. Recently the first case of transmammary transmission of *Strongyloides* larvae in man was described (22).

After skin penetration and body migration via the "tracheal" route, the adult parasites (only females) inhabit the intestinal tract. Stage-1 larvae hatch from eggs in the intestine and are excreted in the faeces. (In the case of *S. fuelleborni* the eggs are passed.) Owing to autoinfection, *S. stercoralis* can persist for many years in man.

Intestinal infection with *S. stercoralis* may be asymptomatic or associated with intestinal symptoms, such as diarrhoea, nausea, and malabsorption. A serious and sometimes fatal complication is hyperinfection, which occurs, for example, in malnutrition and during immunosuppressive therapy.

Diagnosis is based on the detection of larvae (*S. stercoralis*) or eggs (*S. fuelleborni*) in the faeces and also by culture techniques and duodenal lavage. However, improved diagnostic procedures are necessary to detect
latent infections, especially in patients for whom immunosuppressive therapy is contemplated. Thiabendazole is active against *Strongyloides* but patients with hyperinfection often respond inadequately.

Preventive measures should include the appropriate instruction of persons handling monkeys, regular examination of monkey faeces, and the treatment of carrier animals. Control of strongyloidiasis in monkey colonies can be achieved by an intensive, prolonged treatment programme with mebendazole.

8.7 *Trichostrongyliasis*

The genus *Trichostrongylus* is worldwide in distribution and inhabits the gastrointestinal tract of ruminants, equines, rodents, other animals, and man.

Human *Trichostrongylus* infections have been reported from some African countries, and from Australia, Chile, Egypt, Indonesia, Iran, Iraq, Japan, the Republic of Korea, Turkey, and the USSR.

At least 7 species of *Trichostrongylus* have been reported in man. *Trichostrongylus orientalis* can be regarded as a parasite that predominantly affects human beings, in a man-to-man transmission, and only occasionally occurs in ruminants. The use of night-soil as a fertilizer and the contamination of vegetables and soil with eggs and subsequently with infective larvae are regarded as important in transmission. In addition, *Trichostrongylus* species infecting ruminants, such as *T. colubriformis*, *T. vitrinus*, and *T. axei*, have been recorded in man. The spectrum of the species infecting man may differ from area to area. The reasons for the high prevalence in some areas of human infections with these species transmitted by animals are not fully understood. It is assumed that the close contact of people with their domestic animals and the use of animal faeces as fertilizer and fuel may play an important role in the transmission.

The intensity of infection in man is usually low; however, an instance of more than 4000 worms recovered from one person has been recorded. Most of the infections are asymptomatic, but in some cases gastrointestinal and general symptoms have been observed.

Diagnosis is based on the detection of eggs in faecal samples. In differential diagnosis hookworm infection has to be considered, since *Trichostrongylus* ova are often mistaken for hookworm ova. Specific treatment is possible with benzimidazoles (e.g., mebendazole, thiabendazole), pyrantel, and levamisole.
8.8 Mammonomonogamiasis

In some parts of the world (Australia, the Far East, Mexico, and the West Indies) *Mammonomonogamia* spp. from cattle and sheep may infect the larynx and pharynx of man. The mode of transmission is unknown. Even though the disease is not very severe, it should be taken into account, and the life cycle of the parasite requires further study.

9. INFECTIONS CAUSED BY PENTASTOMIDS AND ARTHROPODS

Some species of Arthropoda are endoparasitic or penetrate the body surface and cause infections which are transmitted from vertebrate animals to man. There is no doubt that these are true zoonoses. Other arthropods which do not penetrate the human body but are of public health importance are also considered below. Still others—though of public health importance—which approach man only to feed (e.g., mosquitoes and tsetse flies) will not be discussed here.

9.1 Pentastomid infections

Pentastomids (whose taxonomic status is unclear) have a complex cycle, which involves the presence of adults in snakes, canines, and humans, and of immature forms (nymphs) in domestic and wild herbivorous animals. Of public health importance are *Armillifer armillatus*, *A. moniliformis*, *A. grandis*, *Linguatula serrata*, and possibly *L. multiamulata*. Human and animal infections have been recorded in Africa, southern and western Asia, Jamaica, and the USSR. Human infection with *Armillifer* spp. arises as a result of drinking water contaminated with pentastomid eggs excreted by infected snakes, of handling infected snakes, or of eating the undercooked flesh of infected snakes.

Local conditions leading to the sharing of water-sources with snakes and susceptible mammals facilitate the life cycle of the parasites and increase the possibility of human infections.

In *Linguatula serrata* infection, the home slaughter of infected domestic herbivores and the hunting of infected wild herbivores may contribute to the infection of human beings and dogs. The symptoms in man are connected with the presence of immature stages of *L. serrata* in the pharynx. The disease is known as the *halzoum*, or *marrara*, syndrome.
Other forms in humans are connected with the presence of immature parasites in internal organs such as the lungs, liver, spleen, and mesenteric lymph nodes. Promising serological tests (e.g., complement fixation) are being developed. Control measures are based on water sanitation, the adequate cooking of food, and the appropriate instruction of people dealing with snakes and other animals in endemic areas.

9.2 Scabies

Man is subject to invasion not only by *Sarcoptes scabei* but also by *Sarcoptes* spp., affecting dogs, camels, goats, sheep, cattle, and horses, and by *Notoedres cati* from the cat.

Human scabies of animal origin is usually superficial and self-limiting, resolving itself in 4-6 weeks. Susceptibility is increased by the use of immunosuppressive drugs and by conditions that lead to immunosuppression.

There are indications that canine scabies in man has been on the increase in recent decades. The ears of dogs are commonly affected and there is a corresponding increase in the frequency of lesions on the hands and forearms of owners.

9.3 Pneumocarasis (pneumonyssiasis)

*Pneumonyssus similicola* is common in the lungs of rhesus monkeys, where it may be responsible for large numbers of focal lesions. In the 1950s pneumocarasis was considered an important disease in the tropics, with some cases occurring in temperate zones. Nowadays it seems of doubtful significance to man, despite possible exposure in, for example, laboratories housing primates. The incidence and prevalence of pneumocarasis in man, especially in tropical countries, needs further investigation.

9.4 Myiasis (33, 34)

Myiasis is a condition in which live human and other vertebrate animals are infested with dipterous larvae. Some of these are obligatory parasites of domesticated and free-living mammals, but they may attack human beings in the vicinity of their normal hosts. Others are facultative parasites of man and other vertebrates and develop normally in decaying organic matter such as carcasses, faeces, sewage, and decomposing vegetables.
The nasal bot-flies of sheep (*Oestrus ovis*) and of equines (*Rhin-oestrus pusorum*) sometimes drop their larvae in the natural orifices of the human body, thereby causing several kinds of damage. The disease occurs in shepherds and people living in pastoral areas. The larvae of horse bot-flies (*Gasterophilus spp.*) burrow in the human skin and cause a creeping cutaneous myiasis, which is, however, never serious.

The warble flies of cattle (*Hypoderma lineatum* and *H. bovis*) occasionally produce dermal or subdermal myiasis and (rarely) ophthalmomyiasis in man.

The bot-fly *Dermatobia hominis* is widespread in human beings and animals in Latin America. It causes cutaneous lesions in man, and its effects on domestic animals produce considerable economic losses. In Africa and southern Spain, the tumbu fly (*Cordylobia anthropophaga* and *C. rohdai*) causes a boil-like cutaneous myiasis in man and in a variety of domesticated and wild mammals. Rats and dogs form the main reservoir. Many other flies cause cutaneous and wound myiasis in man and animals. In the New World the species more commonly involved is the primary screw-worm, *Coelomyia hominivorax*, and in the Old World it is *Chrysomyia bezziana*. Many more species, of course, are implicated. They also invade the nasal cavity and other natural orifices.

Blood-sucking floor maggots (*Auchmeromyia luteola*) are widespread in human habitations in Africa, where they are an annoying and troublesome pest. Under certain conditions, pigs, wart-hogs, and ant-bears are attacked. Probably other burrow-inhabiting mammals are the sustaining hosts in areas away from human habitation.

Some 50 species of fly larvae, belonging mainly to the families Muscidae, Calliphoridae, and Sarcophagidae, have been recovered from the human alimentary tract, mostly passed out with the faeces. Their eggs or larvae are deposited on food and ingested with it. The flies may also lay their eggs near the anus and, on hatching, the larvae may enter the lower gut and sometimes the urinary tract and cause obstruction, pain, mucopurulent discharge, and a frequent desire to urinate.

The prevention of myiasis is mainly achieved by reducing the numbers of flies through the application of sanitary measures and the use of insecticides. The protection of animals, which is often necessary for economic reasons, leads to a reduction of myiasis in man also. The use of repellents, screening, and protective clothing is indicated in many situations.
9.5 Tungiasis

The chigoe (jigger) flea or sand-flea (*Tunga penetrans*), causative agent of tungiasis in man, attacks several species of hosts, including pigs, monkeys, and man. It is distributed in Africa south of the Sahara, and in a few tropical countries of South America. The presence of animal hosts contributes to its multiplication. The males are free-living; the female buries itself in the skin, eventually resulting in its complete encapsulation. Heavy infestation in man causes severe inflammation, usually of the feet. Control is difficult in temporary huts; the use of insecticides is recommended. As a means of prevention stout shoes should be worn in infected areas. Therapy includes surgical removal and topical application of insecticides.

10. OTHER PARASITIC AND ALLERGENIC ARTHROPODS

Many arthropod species exist in large numbers in the human environment because of the presence, in both urban and rural areas, of numerous vertebrate animals, domesticated, synanthropic, and wild. Some of these arthropod species are parasitic and others thrive in animal-related organic matter (e.g., faeces, hairs, feathers, skin, and other debris). From the point of view of injuries caused to human beings, they may be divided into the following categories: (1) ectoparasites—i.e., living temporarily on, or attached to, the human body, and (2) allergenic arthropods, principally mites.

10.1 Ectoparasites

10.1.1 Ticks

Ticks are common on domestic and wild animals, for which they have a fundamental importance as vectors of viral, bacterial, protozoan, and helminthic infections. Some 800 species are known. The presence of animals in an environment is fundamental to the multiplication of ticks, which may also be vectors of important pathogens of man.

Another significant effect of tick infection in man and animals is tick paralysis, a condition induced by more than 40 tick species, which inoculate their host with a toxin that causes various pathological changes.

The urban environment may provide conditions suitable for the perpetuation of ticks.
10.1.2 Nest-inhabiting mesostigmatic mites

Some mites of the order Mesostigmata, mostly associated with vertebrate hosts living in nests, may live on the human body several days and cause dermatoses. For example, the red mite of chickens, *Dermanyssus gallinae*, is a common parasite of wild birds, but can thrive in poultry houses, and so affect farm workers. Human beings may also be attacked when mites of the genus *Dermanyssus*, particularly from birds’ nests, migrate into bedrooms; this has been reported to have happened in hospitals. Other genera and species of mesostigmatic mites may be troublesome pests and vectors of viral, rickettsial, and other diseases.

10.1.3 Fur mites

Fur mites of the genus *Cheyletiella* occur on dogs (*Cheyletiella yasguri*), and cats and rabbits (*C. parasitivorax*). Persons owning these animals as pets may develop pruritus or dermatitis caused by migration of the mites, which are easily able to penetrate clothing. No lesions appear in the infested animals.

10.1.4 Trombiculid mites

Various species of chiggers, primarily of the genera *Eutrombicula* and *Neotrombicula*, cause dermatoses in man. The larvae attack many species of host, including man, transmitting trombiculosis. In the nymphal and adult stages they are completely free-living, but their numbers depend on the quantity of larvae that manage to survive by living on various vertebrate hosts. The best-known species causing dermatoses are *Neotrombicula autumnalis* in Central Europe and *Eutrombicula alfredii* in South America. Several other trombiculid species (primarily of the genus *Leptotrombidium*), including also vectors of rickettsioses, attack man but do not cause important dermatoses.

10.1.5 Fleas

Dog and cat fleas (*Ctenocephalides canis* and *C. felis*) are common in both rural and urban areas. They frequently attack man, and in some urban situations have replaced the common human flea, *Pulex irritans*. They may also transmit *Yersinia pestis* in man and, on rare occasions, the tapeworms *Hymenolepis diminuta* and *Dipylidium caninum*.

Fleas from other animals, of which the best known is the European chicken flea, *Ceratophyllus gallinae*, occasionally attack man, producing some skin reaction.
10.2 Allergic mites

Allergic mites are an important cause of respiratory and contact allergies and are almost worldwide in distribution. The presence of birds and other animals in the human environment creates conditions which are suitable for the multiplication of mites belonging to the families Pyroglyphidae, Tyroglyphidae, and Cheyletiellidae, for example. Birds' nests in human settlements, which provide an accumulation of feathers and skin scales, are especially suitable for the multiplication of mites of the family Pyroglyphidae. These mites and their excreta, debris, and dust constitute specific allergens, which sensitize man (so-called house dust-mite allergies) and cause bronchial asthma and rhinitis, mostly in children. More than 10 species of Pyroglyphidae—in particular, 3 species of the genus *Dermatophagoides*—have been found in human dwellings.

Various species of forage mites, mostly belonging to the families Tyroglyphidae and Glyciphagidae, usually live close to man, feeding on his stored products, on miscellaneous debris, and sometimes on other mites. Frequent exposure of the skin to these mites can lead to troublesome allergic dermatitis or to intestinal, urinary, and respiratory allergies.

Unfortunately, house dust allergy and other allergic dermatoses caused by mites are often misdiagnosed.

11. SUMMARY OF MAIN RECOMMENDATIONS

Recommendations directed to field and laboratory workers, parasitologists, veterinary and public health agencies, governments, and international agencies (FAO and WHO) are dispersed throughout this report. The following is a summary of the more important general recommendations. (With regard to those covering individual diseases, reference should be made to the appropriate sections in the body of the report.)

1) The simple definition of zoonoses contained in reports of the Joint FAO/WHO Expert Committee on Zoonoses (1, 4) should be retained but kept under review by FAO and WHO in the light of practical and scientific developments.

2) Socioeconomic evaluation should be an essential part of all programmes for the control of parasitic zoonoses, and more public health workers as well as veterinary personnel should be trained in the necessary epidemiological and economic methods. Moreover, FAO and WHO
should encourage and assist Member States to carry out surveys on the health and other socioeconomic consequences of food-borne zoonoses.

(3) National and international surveillance of zoonoses in man and animals in general should be intensified.

(4) FAO and WHO should expand the programme for the preparation of international standards and reference reagents for the diagnosis of the major parasitic zoonoses.

(5) A comprehensive study of food production processes and certain dietary practices which contribute to the endemicity of some of the important food-transmitted parasitic zoonoses should be carried out.

(6) Special guidelines are urgently needed to provide advice on simple preventive measures to ensure the protection of farm workers and other personnel against the occupational hazards presented by zoonoses.

(7) The following aspects are considered important in the implementation of resolution WHA31.48, adopted by the Thirty-first World Health Assembly, on the prevention and control of zoonoses and food-borne diseases due to animal products:

(a) In the proposed zoonoses centres, parasitology, especially its epidemiological and immunological aspects, should receive adequate attention.

(b) The existing network of FAO/WHO collaborating centres for research and training should be extended by designating further centres for particular parasitic zoonoses—e.g., echinococcosis (hydatidosis) and taeniasis (cystercerosis)—which are at present covered only in a general way. Centres concerned with food hygiene should be encouraged to strengthen their activities relating to food-borne parasites, as should the centres dealing with laboratory animals.

(c) With respect to the international collection and dissemination of information, the WHO Weekly Epidemiological Record could be used more extensively for transmitting information to all governments on public health and economic problems related to parasitic zoonoses. For improving the communication of such information to WHO, national epidemiological bulletins should be utilized, as well as surveillance systems implemented by the FAO/WHO collaborating centres.
(d) In order to assist Member States in their programmes in this field, manuals and laboratory guides on methods of surveillance, prevention, and control should be produced. These should give particular attention to such parasitoses as toxoplasmosis, trichinellosis, toxocariasis, cestode infections, liver fluke infections (clonorchiasis and opisthorchiasis), and paragonimiasis. It is also important that general guides covering such subjects as problems of urban living, hazards related to environmental change, and food-borne diseases should deal adequately with parasitic diseases.

(e) In many veterinary, medical, and public health schools the teaching of parasitology needs to be strengthened and special attention paid to epidemiology, surveillance, and control. FAO and WHO should cooperate in this endeavour, particularly in developing countries. The interrelationship between the medical and veterinary professions concerning parasitic zoonoses requires that veterinary teaching staff should participate in the education of medical students. Moreover, specialization training in zoonoses should be made available to physicians and veterinarians.

(f) The training of auxiliary veterinary and medical personnel should be an integral and essential part of national programmes for the prevention and control of parasitic zoonoses.

(g) International and national seminars, workshops, training courses, etc., for personnel at various levels should be organized in different regions, with special emphasis on simple modern techniques, methods of surveillance, and field control.

(h) At the community level health education should be emphasized and the importance of community participation should be stressed.

(i) Collaborative research in parasitic zoonoses should be encouraged, with special emphasis on methods of surveillance and control.

(j) In developing the programme, use should be made of national institutions and appropriate nongovernmental organizations that are in official relationship with FAO and WHO in order to carry out specific tasks.

(k) In view of the changes in ecological conditions generated by large development projects, adequate international technical cooperation should be made available for the prevention, surveillance, and control of parasitic zoonoses which might emerge, or have emerged, in the areas concerned.
The Committee considered that the foregoing proposals should be duly taken into account in the planning and implementation of collaborative field programmes of both FAO and WHO.

REFERENCES


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Annex I

A SYSTEM FOR THE CLASSIFICATION OF ZOONOSES

The zoonoses have been classified in terms of their reservoir hosts, whether these are man or lower vertebrate animals. Thus, the term anthro-
pozoonoses has been applied to infections transmitted to man from lower
vertebrate animals and the term zoonanthropozoonoses to infections trans-
mitted from man to lower vertebrate animals; however, these terms have
also been used interchangeably for all diseases found in both animals and
man. A third term, amphixenoses, has been used for infections maintained
in both man and lower vertebrate animals that may be transmitted in either
direction.

A classification that is based upon the type of life cycle of the infecting
organism and that divides the zoonoses into four categories, each with im-
portant shared epidemiologic features, has considerable teaching value.

The four categories are:

1. **Direct zoonoses** are transmitted from an infected vertebrate host to
a susceptible vertebrate host by direct contact, by contact with a fomite,
or by a mechanical vector. The agent itself undergoes little or no propa-
gative changes and no essential developmental change during transmission.
Examples are rabies, trichinosis, and brucellosis.

2. **Cyclo-zoonoses** require more than one vertebrate host species, but
no invertebrate host, in order to complete the developmental cycle of the
agent. Examples are the human taeniasis, echinococcosis, and pentastomid
infections.

3. **Meta-zoonoses** are transmitted biologically by invertebrate vectors.
In the invertebrate, the agent multiplies or develops, or both, and there is
always an extrinsic incubation (prepatent) period before transmission to
another vertebrate host is possible. Examples are numerous and include
arbovirus infections, plague, and schistosomiasis.

4. **Sapro-zoonoses** have both a vertebrate host and a non-animal
developmental site or reservoir. Organic matter (including food), soil, and
plants are considered to be non-animal. Examples include the various
forms of larva migrans and some of the mycoses.

Third report of the Joint FAO/WHO Expert Committee).


Williams & Wilkins, p. 516.
# Annex 2

**IMMUNODIAGNOSIS OF PARASITIC ZOONOSSES**

## Table 1. Antigens used for immunological tests

<table>
<thead>
<tr>
<th>Infection</th>
<th>Whole or particulate</th>
<th>Crude extract</th>
<th>Semi-purified</th>
<th>Purified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toxoplasmosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>African trypanosomiasis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Leishmaniasis</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chagas’ disease</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Echinococcosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cysticercosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Paragonimiasis</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Trichinelliosis</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Toxocariasis</td>
<td>+</td>
<td></td>
<td>+</td>
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</tr>
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</table>

## Table 2. Immunological tests for the detection of antibodies

<table>
<thead>
<tr>
<th>Infection</th>
<th>Indirect Immunofluorescence</th>
<th>Indirect Haemagglutination</th>
<th>Complement fixation</th>
<th>Bovine Scarlet</th>
<th>Lassa</th>
<th>Direct fluorescent</th>
<th>ELISA</th>
<th>Immunofluorescence</th>
<th>Dye test</th>
<th>Precipitation</th>
<th>Countercurrent Immmuno-electrophoresis</th>
<th>Radioimmunoassay</th>
<th>Skin Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toxoplasmosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>African trypanosomiasis</td>
<td>+</td>
<td>±</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Leishmaniasis</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>±</td>
<td>+</td>
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<td>±</td>
</tr>
<tr>
<td>Chagas’ disease</td>
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<td>+</td>
<td>±</td>
<td>+</td>
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<td>±</td>
</tr>
<tr>
<td>Echinococcosis</td>
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<td>+</td>
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<td>+</td>
<td>±</td>
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<td></td>
<td>+</td>
</tr>
<tr>
<td>Cysticercosis</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>±</td>
<td>±</td>
<td>±</td>
<td></td>
<td></td>
<td>±</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>+</td>
<td>±</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>±</td>
<td></td>
<td></td>
<td></td>
<td>±</td>
</tr>
<tr>
<td>Paragonimiasis</td>
<td>+</td>
<td>±</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>±</td>
<td></td>
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<td></td>
<td>±</td>
</tr>
<tr>
<td>Trichinelliosis</td>
<td>±</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>±</td>
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<td></td>
<td>±</td>
</tr>
<tr>
<td>Toxocariasis</td>
<td>±</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>±</td>
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<td>+</td>
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<td>±</td>
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<td></td>
<td>±</td>
</tr>
</tbody>
</table>

+ = Tests in use for screening, or as an aid to diagnosis, or both.
± = Tests under investigation.
Annex 3

PARTIAL LIST OF PARASITIC ZOONOSSES

This list is not comprehensive and is confined to those diseases in which the animal link in the chain of infection to man is considered to be important, although not always essential. Diseases or causative organisms of particular importance over large areas have been marked with an asterisk.

<table>
<thead>
<tr>
<th>Disease in man</th>
<th>Causative organism</th>
<th>Vertebrate animals principally involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PROTOZOAN INFECTIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amoebiasis</td>
<td>Entamoeba histolytica</td>
<td>Nonhuman primates, dogs</td>
</tr>
<tr>
<td>Babesiosis</td>
<td>Babesia divergens</td>
<td>Cattle</td>
</tr>
<tr>
<td>Balantidiasis</td>
<td>Balantidium coli</td>
<td>Voles, mice</td>
</tr>
<tr>
<td>Giardiasis *</td>
<td>Giardia species</td>
<td>Swine, rats, nonhuman primates</td>
</tr>
<tr>
<td>Leishmaniasis *</td>
<td>Leishmania donovani</td>
<td>Dogs, foxes, rodents</td>
</tr>
<tr>
<td>Visceral</td>
<td>Leishmania tropica</td>
<td>Dogs, rodents</td>
</tr>
<tr>
<td>Cutaneous</td>
<td>Leishmania species</td>
<td>Dogs, wild mammals</td>
</tr>
<tr>
<td>Malaria</td>
<td>Plasmodium knowlesi</td>
<td>Monkeys</td>
</tr>
<tr>
<td>Pneumocystis infection</td>
<td>Pneumocystis carinii</td>
<td>Monkeys</td>
</tr>
<tr>
<td>Intestinal</td>
<td>Sarcocystis mierhorstii (syn. S. suihominis; — Isospora hominis proparte)</td>
<td>Pigs</td>
</tr>
<tr>
<td>Toxoplasmosis *</td>
<td>Toxoplasma gondii</td>
<td>Cats, mammals, birds</td>
</tr>
<tr>
<td>Trypanosomiasis *</td>
<td>Trypanosoma rhodesiense</td>
<td>Game animals, cattle</td>
</tr>
<tr>
<td>American</td>
<td>Trypanosoma cruzi</td>
<td>Dogs, cats, pigs, other small mammals</td>
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2. HELMINTHIC INFECTIONS

<table>
<thead>
<tr>
<th>Trematode Infections</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphistomiasis</td>
<td>Gastrodiscoides hominis</td>
</tr>
<tr>
<td>Cercarial dermatitis</td>
<td>Schistosomatida</td>
</tr>
<tr>
<td>Clonorchiasis *</td>
<td>Clonorchis sinensis</td>
</tr>
</tbody>
</table>

Swine
Birds, mammals
Dogs, cats, swine, wild mammals, fish
<table>
<thead>
<tr>
<th>Disease in man</th>
<th>Causative organism</th>
<th>Vertebrate animals principally involved</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2. HELMINTHIC INFECTIONS (continued)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dicrocoiliasis</td>
<td><em>Dicrocoelium dendriticum</em> <em>Dicrocoelium hespes</em></td>
<td>Ruminants</td>
</tr>
<tr>
<td></td>
<td><em>Dicrocoelium species</em></td>
<td>Ruminants</td>
</tr>
<tr>
<td>Echinostomiasis</td>
<td>Echinostoma ilicarium and other Echinostoma species</td>
<td>Cats, dogs, rodents</td>
</tr>
<tr>
<td>Fascioliasis</td>
<td>Fasciola hepatica</td>
<td>Ruminants</td>
</tr>
<tr>
<td></td>
<td>Fasciola gigantica</td>
<td>Ruminants</td>
</tr>
<tr>
<td>Heterophisis</td>
<td>Heterophyes heterophyes and other heterophyes</td>
<td>Cats, dogs, fish</td>
</tr>
<tr>
<td>Metagonimiasis</td>
<td>Metagonimus yokogawai</td>
<td>Cats, dogs, fish</td>
</tr>
<tr>
<td>Opisthorchiasis*</td>
<td>Opisthorchis felineus and occasionally other Opisthorchis species</td>
<td>Cats, dogs</td>
</tr>
<tr>
<td></td>
<td>Opisthorchis viverini</td>
<td>Cats, wildlife, fish</td>
</tr>
<tr>
<td></td>
<td>Opisthorchis species</td>
<td>Cats, wildlife, fish</td>
</tr>
<tr>
<td>Paragonimiasis*</td>
<td>Paragonimus westermani and other Paragonimus species</td>
<td>Cats, dogs, wild felidae and suidae, rodents</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>Schistosoma japonicum* Schistosoma haematobium</td>
<td>Wild and domestic mammals</td>
</tr>
<tr>
<td></td>
<td>Schistosoma mansoni</td>
<td>Rodents</td>
</tr>
<tr>
<td></td>
<td>Schistosoma mekongi</td>
<td>Baboons, rodents</td>
</tr>
<tr>
<td></td>
<td>Schistosoma mattheei and occasionally other schistosomes</td>
<td>Cattle, sheep, antelopes</td>
</tr>
<tr>
<td>CESTODE INFECTIONS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berliliella infection</td>
<td>Berliliella stederi</td>
<td>Primates</td>
</tr>
<tr>
<td>Coenuriasis</td>
<td>Taenia multiceps</td>
<td>Sheep, ruminants, pigs</td>
</tr>
<tr>
<td></td>
<td>Taenia brauni</td>
<td>Dogs, rodents, wild carnivores</td>
</tr>
<tr>
<td>Diphyllodobothriasis*</td>
<td>Diphyllodobothrium latum</td>
<td>Fish, carnivores</td>
</tr>
<tr>
<td>Dipylidiasis</td>
<td>Dipylidium caninum</td>
<td>Dogs, cats</td>
</tr>
<tr>
<td>Echinococcosis*</td>
<td>Echinococcus granulosus</td>
<td>Dogs, wild carnivores, domestic and wild ungulates</td>
</tr>
<tr>
<td></td>
<td>Echinococcus multilocularis</td>
<td>Foxes, cats, dogs, rodents</td>
</tr>
<tr>
<td></td>
<td>Echinococcus vogeli</td>
<td>Dogs, bush dogs, pacas</td>
</tr>
<tr>
<td>Hymenoleplasia</td>
<td>Hymenolepis diminuta</td>
<td>Rats, mice</td>
</tr>
<tr>
<td></td>
<td>Hymenolepis nana</td>
<td>Rats, mice</td>
</tr>
<tr>
<td>Inermicapsillfer infection</td>
<td>Inermicapsilla madagascariensis</td>
<td>Rodents</td>
</tr>
<tr>
<td>Raillietina infection</td>
<td>Raillietina madagascariensis</td>
<td>Rodents</td>
</tr>
<tr>
<td>Sparagosisis</td>
<td>Pseudophylldine tapeworms</td>
<td>Cats, carnivores, mice, other vertebrates, amphibians</td>
</tr>
<tr>
<td>Taeniais*</td>
<td>Taenia saginata</td>
<td>Cattle</td>
</tr>
<tr>
<td>Taeniais*-cysticercosis*</td>
<td>Taenia solium</td>
<td>Swine</td>
</tr>
<tr>
<td>NEMATODE INFECTIONS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ancylostomiasis</td>
<td>Ancylostoma ceylanicum and other Ancylostoma species</td>
<td>Dogs</td>
</tr>
<tr>
<td>Ascarisasis</td>
<td>Ascaris suum</td>
<td>Swine</td>
</tr>
</tbody>
</table>
### Annex 3 (continued)

<table>
<thead>
<tr>
<th>Disease in man</th>
<th>Causative organism</th>
<th>Vertebrate animals principally involved</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capillariosis</strong></td>
<td>Capillaria hepatica</td>
<td>Rodents</td>
</tr>
<tr>
<td></td>
<td>Capillaria philippinensis</td>
<td>Fish</td>
</tr>
<tr>
<td><strong>Dioctophymiasis</strong></td>
<td>Dioctophyme renale</td>
<td>Fish, dogs, mustelids</td>
</tr>
<tr>
<td><strong>Dracunculiasis</strong></td>
<td>Dracunculus medinensis</td>
<td>Dogs, other carnivores</td>
</tr>
<tr>
<td><strong>Filariasis</strong></td>
<td>Brugia malayi (subperiodic strain)</td>
<td>Primates, cats, dogs, wild carnivores</td>
</tr>
<tr>
<td></td>
<td>Dirofilaria immitis</td>
<td>Dogs, cats, other mammals</td>
</tr>
<tr>
<td></td>
<td>Dirofilaria rossii</td>
<td>Dogs, cats, other mammals</td>
</tr>
<tr>
<td></td>
<td>Dirofilaria lusitania</td>
<td>Dogs, cats, other mammals</td>
</tr>
<tr>
<td><strong>Gongylonemiasis</strong></td>
<td>Gongylonema species</td>
<td>Ruminants, rats</td>
</tr>
<tr>
<td><strong>Lagochilascarisiasis</strong></td>
<td>Lagochilascarisis minor</td>
<td>Wild fowls</td>
</tr>
<tr>
<td><strong>Larva migrans, cutaneous</strong></td>
<td>Ankylostoma braziliense and other Ankylostoma species</td>
<td>Cats, dogs, sheep, swine, etc.</td>
</tr>
<tr>
<td><strong>Larva migrans, visceral</strong></td>
<td>Angiostrongylus caninensis</td>
<td>Cats, dogs sheep, swine, etc.</td>
</tr>
<tr>
<td><strong>Angiostrongyliasis</strong></td>
<td>Angiostrongylus costaricensis</td>
<td>Rates, coati, tayra</td>
</tr>
<tr>
<td><strong>Anisakiasis</strong></td>
<td>Anisakina species</td>
<td>Fish, marine mammals</td>
</tr>
<tr>
<td><strong>Gnathostomiasis</strong></td>
<td>Gnathostoma spinigerum</td>
<td>Cats, dogs, other vertebrates (fish)</td>
</tr>
<tr>
<td><strong>Toxocarasis</strong></td>
<td>Toxocara cati and other Toxocara species</td>
<td>Dogs, cats</td>
</tr>
<tr>
<td><strong>Mammonomonomiasis</strong></td>
<td>Mammonomonoporum laryngeus</td>
<td>Ruminants</td>
</tr>
<tr>
<td><strong>Oesophagostomiasis</strong></td>
<td>Oesophagostomum bronchiatum and other Oesophagostomum species</td>
<td>Primates</td>
</tr>
<tr>
<td><strong>Strongyloidiasis</strong></td>
<td>Strongyloides stercoralis</td>
<td>Dogs, monkeys</td>
</tr>
<tr>
<td></td>
<td>Strongyloides fuelleborni</td>
<td>Dogs, monkeys</td>
</tr>
<tr>
<td><strong>Tenuidens infection</strong></td>
<td>Tenuidens diminus</td>
<td>Primates</td>
</tr>
<tr>
<td><strong>Thelaziiasis</strong></td>
<td>Thelazia species</td>
<td>Dogs, ruminants</td>
</tr>
<tr>
<td><strong>Trichineliasis</strong></td>
<td>Trichinella spiralis and other Trichinella species</td>
<td>Swine, rodents, wild carnivores, marine mammals</td>
</tr>
<tr>
<td><strong>Trichostrongyliasis</strong></td>
<td>Trichostongylus colubriformis and other Trichostongylus species</td>
<td>Ruminants</td>
</tr>
</tbody>
</table>

### 3. Infections caused by arthropods and pentastomid parasites

**Myiasis**
- Calliphora, Cochliomyia, Cordylobia, Dermatobia, Gastrilus, *Chrysomyia, Hypoderma, Oestrus, Wohlfarthia*, other genera | Mammals |

**Pentastomid infections**
- Linguatula species | Annelid species | Dogs, snakes, other vertebrates |

**Pneumocercasis**
- Pneumocerca simica | Monkeys |

**Scabies**
- Sarcoptes species | Domestic animals |

**Tungiasis**
- Tunga penetrans | Domestic and wild mammals |
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