

## Update Le point

Articles in the *Update* series give a concise, authoritative, and up-to-date survey of the present position in the selected fields, covering many different aspects of the biomedical sciences and public health. Most of the articles are written by acknowledged experts on the subject.

Les articles de la rubrique *Le point* fournissent un bilan concis et fiable de la situation actuelle dans les domaines considérés, couvrant de nombreux aspects des sciences biomédicales et de la santé publique. La plupart de ces articles auront donc été rédigés par les spécialistes les plus autorisés.

# Public health significance of intestinal parasitic infections\*

WHO EXPERT COMMITTEE<sup>1</sup>

*Intestinal parasitic infections are distributed virtually throughout the world, with high prevalence rates in many regions. Amoebiasis, ascariasis, hookworm infection and trichuriasis are among the ten most common infections in the world. Other parasitic infections such as abdominal angiostrongyliasis, intestinal capillaritis, and strongyloidiasis are of local or regional public health concern. The prevention and control of these infections are now more feasible than ever before owing to the discovery of safe and efficacious drugs, the improvement and simplification of some diagnostic procedures, and advances in parasite population biology.*

## METHODS OF ASSESSMENT

The amount of harm caused by intestinal parasitic infections to the health and welfare of individuals and communities depends on: (a) the parasite species; (b) the intensity and course of the infection; (c) the nature of the interactions between the parasite species and concurrent infections; (d) the nutritional and immunological status of the population; and (e) numerous socioeconomic factors. All the above factors may in turn be modulated by seasonal and climatic conditions. Thus, while it is generally extremely difficult to measure the suffering caused by infectious diseases, in the case of intestinal parasitic infections this is even more true because so many cases of the diseases are asymptomatic and therefore remain undetected.

\* This article is based on extracts from WHO Technical Report Series, No. 749 1987 (*Prevention and control of intestinal parasitic infections*, report of a WHO Expert Committee), Geneva. World Health Organization Price: Sw. fr. 12.— A French translation of this article will appear in a later issue of the *Bulletin*.

<sup>1</sup> The WHO Expert Committee on Prevention and Control of Intestinal Parasitic Infections met in Geneva, Switzerland, on 3-7 March 1986. Members: D. Bunnag, B. D. Cabrera, D. W. T. Crompton, Z. Farid (absent), H. M. Gilles, O. O. Kale, S. P. Kan-Chua, W. L. Kilama, P. D. Marsden, A. Martinez-Palomo, N. Ozeretskovskaya, and M. G. Schultz. *WHO Secretariat*: D. Barua, P. C. Beaver, A. Davis, and Z. S. Pawlowski

The public health significance of intestinal parasitic disease would be best assured if the available quantitative techniques could be adopted to evaluate morbidity (1). The willingness of societies to pay for the elimination or the control of disease might be readily harnessed if government policy-makers and health planners could be given the chance to compare cost-benefit or cost-effectiveness analyses of the various courses of action with estimates of the predicted economic losses due to morbidity.

For a given intestinal parasitic infection quantitative information might be sought about years of potential life lost, number of healthy days lost, incidence rates of the disease, and prevalence and case fatality rates by using quantitative methods now being used for other diseases (e.g., cancer and cardiovascular diseases). However, great care should be taken in selecting the indicators for assessing the public health significance of intestinal parasitic infections because of regional variations in their importance. Although calculations of years of potential life lost are valuable in the measurement of the public health consequences of malignant and cardiovascular diseases, both of which are killing diseases, such data have but limited application in the assessment of the public health significance of intestinal parasitic diseases because they are usually characterized by low mortality (1, 2). However, in the case of intestinal parasitic diseases the cost to the health care system and services as well as to individuals and the community, in terms of lost nutrients and reduced productivity, can be easily estimated and measured.

The information required for this purpose can be obtained if efforts are made to collect accurate epidemiological, parasitological, and pathological data. Such data are essential for every aspect of prevention and control programmes, from policy decisions about implementation to the routine monitoring of progress. They also provide the basis for reviewing the public health significance of these diseases in terms of the advantages to communities of controlling intestinal parasitic infections.

Current experience suggests that intestinal parasite control programmes are appropriate and socially advantageous because people can (a) actually see the effects of primary health care interventions (in terms of expelled worms, etc.), and (b) start to learn some simple facts about health care (simple health education) by watching their village or community become healthier as a result of the control measures. Control programmes against intestinal parasitic infections also have public health significance because they serve to bring together different sectors of the primary health care services.

Attempts to measure the morbidity of individual intestinal parasitic infections must be continued in different regions and among different societies. The study of morbidity will be made easier and results will become comparable if certain definitions of cases and levels of intensity are agreed. A summary of recommended terms for cases of intestinal parasitic infections is presented in Table 1.

The difficulties in assessing the public health significance of intestinal parasitic diseases can be appreciated by understanding the debate about the magnitude of the role of ascariasis in the complex etiology of protein-energy malnutrition in children (3, 4). The investigation of this problem relies upon field research in communities where the prevalences of ascariasis and protein-energy malnutrition are high and where sufficient time is allowed for growth improvement to occur and be detected in some participants receiving anthelmintic treatment. The study design should rely on double-blind procedures using infected and uninfected subjects randomly allocated to either treatment or placebo groups. The use of a placebo should be approved by an independent ethical committee. The sample size for the study should be calculated in advance according to the level of significance sought when the results are analysed, and the statistical analysis must accommodate confounding variables including polyparasitism.

Secure evidence for the existence of a causal relationship between ascariasis and impaired growth will have been obtained when two statistically supported effects are detected (3).

Table 1. A summary of terms used to describe cases of intestinal parasitic infections, their definitions, and suitable diagnostic methods

Term	Definition	Diagnosis <sup>a</sup>	International Classification of Diseases code no.
Ascariasis	Any infection by <i>Ascaris</i>	<b>Faecal examination</b> Expulsion of worms	127.0
Light ascariasis <sup>b</sup>	Infection with less than 5000 EPG <sup>c</sup>	<b>Egg count</b>	
Heavy ascariasis	Infection with over 50 000 EPG <sup>c</sup>	<b>Egg count</b>	
Fatal ascariasis	Death attributed directly to <i>Ascaris</i> (intestinal obstruction, biliary ascariasis, etc.)	<b>Hospital records</b> Postmortem examination records	(560.9) (576.2)
Ancylostomiasis	Any infection with <i>Ancylostoma duodenale</i> ; if <i>A. ceylanicum</i> is involved, <i>A. ceylanicum</i> infection is the preferred term	<b>Examination</b> of expelled adult worms or of <b>cultured 3rd-stage larvae</b>	126.0
Necatoriasis	Any infection with <i>Necator americanus</i>	As above	126.1
Hookworm infection	Any infection with <i>Ancylostoma</i> or <i>Necator</i> (species not specified)	<b>Faecal examination</b>	126.9
Mixed hookworm infections	Any infection caused by more than one hookworm species	<b>Examination</b> (at least in subsamples) of expelled adult worms or of <b>cultured 3rd-stage larvae</b>	
Hookworm anaemia	Iron-deficiency anaemia in heavily infected individuals	<b>Signs of anaemia, measurement of haemoglobin level, egg count</b>	(280)
Heavy hookworm infections	Hookworm infection intensive enough to cause anaemia (critical worm load differs locally depending on age, sex, iron intake, and species of hookworm)	<b>Egg count plus haemoglobin level</b>	
Trichuriasis	Any infection with <i>Trichuris</i>	<b>Faecal examination</b>	127.3
Light trichuriasis	Infection with 1000 EPG or less <sup>c</sup>	<b>Egg count</b>	
Heavy trichuriasis	Infection with over 10 000 EPG <sup>c</sup>	<b>Egg count</b> Demonstration of <i>Trichuris</i> by proctoscopy	
Strongyloidiasis	Any infection caused by <i>Strongyloides stercoralis</i> ; if other species are involved: <i>S. fuelleborni</i> infection or " <i>S. cf fuelleborni</i> " infection are preferred terms	<b>Faecal examination</b> (special techniques) Duodenal content examination <b>Faecal examination</b> As above	127.2
Disseminated strongyloidiasis	Any infection with <i>S. stercoralis</i> with involvement of other organs (lungs, central nervous system)	As above, plus <b>clinical examination</b>	
Heavy strongyloidiasis	Any infection with <i>S. stercoralis</i> , usually symptomatic and easily diagnosed, occurring mainly in immunosuppressed patients	<b>Faecal examination</b> (not necessarily by concentration or special techniques) Examination of duodenal contents and demonstration of a high number of larvae	
Mixed intestinal helminthiasis (nematodiasis)	Any infection caused by more than one common species of nematode worms ( <i>Ascaris</i> , <i>Trichuris</i> , <i>Ancylostoma</i> or <i>Necator</i> , <i>Strongyloides</i> )	<b>Faecal examination</b>	127.8

<sup>a</sup> Methods most suitable for public health purposes are given in bold type

<sup>b</sup> A proportion of light infections can also be expressed as the U-rate, i.e., the percentage of *Ascaris*-positive faecal examinations in which only unfertilized *Ascaris* eggs were found

<sup>c</sup> Definition is arbitrary. EPG = eggs per gram of stool

Table 1: *continued*

Term	Definition	Diagnosis <sup>a</sup>	International Classification of Diseases code no.
<i>Taenia solium</i> taeniasis	Any infection with <i>T. solium</i> tapeworm	<b>Examination of scolex or proglottid</b>	123.0
<i>T. solium</i> cysticercosis	Any infection with larval form of <i>T. solium</i>	<b>Clinical examination</b>	123.1
<i>T. saginata</i> taeniasis	Any infection with <i>T. saginata</i> tapeworm	<b>Examination of scolex or proglottid</b>	123.2
Taeniasis	Any infection with unspecified <i>Taenia</i>	<b>Faecal and/or anal swab examination</b>	123.3
Giardiasis	Any infection with <i>Giardia intestinalis</i> (asymptomatic or symptomatic)	<b>Faecal examination</b> Duodenal content examination	007.1
Symptomatic giardiasis	Infection with <i>G. intestinalis</i> with symptoms such as diarrhoea, abdominal pain, or discomfort which disappear after specific treatment	As above plus <b>clinical examinations before and after treatment</b>	
Amoebiasis	Any infection of the large intestine with <i>Entamoeba histolytica</i> (for other species the preferred terms are, e.g., <i>E. hartmanni</i> infection)	<b>Faecal examination</b> (it is necessary to show that infection is not due to <i>E. hartmanni</i> , <i>E. coli</i> , or other amoebae) <b>Faecal antigen examination</b>	006
Asymptomatic carrier/ Luminal amoebiasis (acceptable alternative term)	Any infection of the large intestine with <i>E. histolytica</i> without symptoms or signs; "cyst passer" is not a correct term	<b>Faecal examination</b> <b>Clinical examination</b> Serological tests and negative rectosigmoidoscopy examination <b>Faecal antigen examination positive</b>	
Invasive amoebiasis	Any tissue infection with <i>E. histolytica</i> (intestinal or extraintestinal)	<b>Faecal and clinical examination</b> <b>Serological examination</b> (demonstration of specific antibodies)	
Amoebic dysentery	Dysentery (diarrhoea with blood, mucus, and tenesmus) caused by pathogenic <i>E. histolytica</i>	<b>Erythrophagous <i>E. histolytica</i> trophozoites in fresh stool;</b> <b>clinical examination</b>	006.0
Amoebic abscess	Focal necrosis of liver caused by pathogenic <i>E. histolytica</i>	<b>Clinical examination;</b> serological examination (demonstration of specific antibodies)	006.3

<sup>a</sup> Methods most suitable for public health purposes are given in bold type

First, the severity of the aspect of ascariasis under study should be shown to increase with increasing intensity of infection. Secondly, in the infected group of subjects, morbidity should decrease after treatment or should not change after the use of the placebo. Conversely, there should be no demonstrable change in the subjects of the uninfected group in response to the administration of either drug or placebo.

Finally, it cannot be stressed too strongly that the use of the collective term "intestinal parasitic infections" is arbitrary and for convenience only. Even the seemingly closely related species have differences in their biology and in the form and severity of the disease they cause. Thus, each parasitic infection must be evaluated at the regional or local level according to its prevalence, the morbidity it causes, and its relative importance with regard to other health problems—an approach which should be borne in mind when considering tactics for prevention and control. Experience has shown that many of those infected with intestinal helminths remain asymptomatic, while a few become ill and even fewer die. It must be remembered, however, that intestinal helminthiasis affect an enormous number of people and a few in this context can be a million.

## HELMINTHIC INFECTIONS

Intestinal helminths are so named because their life history includes a period of obligatory residence in the human alimentary tract or because they induce pathological changes in that site. Not surprisingly, nutritional impairment is often associated with chronic intestinal helminthiases, with those infected suffering from protein-energy malnutrition, iron-deficiency anaemia, and vitamin A deficiency. Although malnutrition is now recognized as having many causes, closely related to socioeconomic factors, available evidence indicates that several of the intestinal helminthiases contribute to the generation and persistence of malnutrition in developing countries.

Estimates of the global prevalence of the intestinal nematode infections transmitted through soil are as follows: 1000 million cases for *Ascaris lumbricoides*; 900 million for hookworms (*Ancylostoma duodenale* and *Necator americanus*); and 500 million for *Trichuris trichiura* (2).<sup>a</sup> It should be noted, however, that, since many people are likely to be infected by more than one species concurrently, the total prevalence of all nematode infections may be lower than the sum of the above figures. Another perspective of the high prevalences of these infections can be gained by noting that an average prevalence figure for *A. lumbricoides* infection for the population of Africa, extracted from some 300 published studies during roughly the last decade, is 32%, with children ( $\leq 17$  years old) showing a higher prevalence rate than adults ( $\geq 18$  years old). These figures do not take into account such factors as climate and population density. Some countries have overall average prevalences ranging from 16 to 48%, and within a country the prevalence rate may range from 0 to over 70%.

In Brazil, the laboratories of the Ministry of Health carried out 2.5 million examinations of stool samples and found the prevalence of *A. lumbricoides* to be 59.5%; the prevalence rates in the different states of Brazil ranged from 26.7 to 97.6%. According to the same source, in 1969 the national prevalence of hookworm infection (mainly *N. americanus*) was 26.5%. In another extensive survey, of 25 000 children and adults in Malaysia (from birth to over 60 years of age), the overall prevalence of intestinal parasitic infections was found to be 39.6%, with as much as 89% in a subsample of children between the ages of 6 and 12 years.

There are other helminth infections associated with the intestinal tract that are less widespread in man than the intestinal nematodes transmitted through soil, but which must be mentioned because they already do or may have local or regional public health significance. These include infections caused by *Hymenolepis nana*, *Taenia saginata*, *T. solium*, *Fasciolopsis buski*, *Angiostrongylus costaricensis*, and *Capillaria philippinensis* (2, 5).

**Ascariasis**

*Ascaris lumbricoides* occurs throughout the world. It is transmitted through the ingestion of infective eggs from contaminated food, hands or water (3, 5, 6). An adult female worm living inside an infected person produces on average about 240 000 eggs per day for about a year, which are passed in the faeces. The eggs develop in the soil within 2–3 weeks, given optimal temperatures, presence of oxygen, and moisture. On being swallowed, each egg develops into a larval worm in the small intestine. The larvae migrate through the body via the hepatic portal system to the liver and lungs where they develop further for 1–2 weeks. Then, they return to the small intestine and attain sexual maturity. The release of eggs by

<sup>a</sup> These estimates of the global prevalences of intestinal parasitic infections have been made on the basis of meagre data. The purpose of presenting these tentative figures is to draw attention to the probable scale of parasitic infections in relation to other diseases.

the female worms begins about 2 months after ingestion of infective eggs. Adult worms are large, with the male worms measuring up to 20 cm and females up to 45 cm in length. *A. lumbricoides* is highly specific for man and the infection does not produce a strong protective immunity. For its survival the parasite depends greatly on a high reservoir of infective eggs in an environment and thrives in areas where there is a lack of sanitation, particularly where people defecate indiscriminately around human settlements and where human excrement (night-soil) is used as a fertilizer in agriculture. The eggs are able to survive in adverse environmental conditions (owing to their protective shell), and this further helps the parasite to persist.

Several types of complication are associated with ascariasis. Intestinal obstruction may be produced by a bolus of worms, or adult worms may migrate from the small intestine into the bile and pancreatic ducts, respiratory passages, and peritoneum. These conditions may cause medical or surgical emergencies. *Ascaris* pneumonitis due to larval migration is probably quite common although it is rarely detected clinically. *A. lumbricoides* releases powerful allergens which may induce hypersensitivity (3).

Statistics for hospital admissions due to ascariasis are scarce, but recent data from Burma show that 1185 of the 2057 patients admitted to the surgical wards of the Rangoon Children's Hospital with acute abdominal problems during 1981–83 were, in fact, suffering from ascariasis (3). A series of investigations is needed to estimate the mortality rate associated with ascariasis in areas where the prevalence is known to be high.

Chronic ascariasis is the most common form of *Ascaris* infection since people tend to be reinfected repeatedly for much of their lives. Preschool children are the group at greatest risk to actual or potential deleterious effects. Controlled experiments with pigs infected with *A. suum* have shown that the infection causes a significant reduction in food intake and rate of body weight gain, with impaired nitrogen balance and fat absorption and some degree of malabsorption including lactose intolerance. These unequivocal findings, which are not seen in pigs kept free from the intestinal stages of *A. suum*, suggest that the nutritional status of children may be adversely affected during ascariasis, particularly if their food intake is marginal in quantity or quality.

Some clinical studies with small numbers of children have shown increased losses of nitrogen in faeces, decreased absorption of fat and nitrogen, malabsorption and accompanying villous atrophy, and impaired absorption of vitamin A; however, certain other similar studies have shown no such effects. Recent larger-scale studies in Panama have demonstrated lactose maldigestion or intolerance during ascariasis in preschool children and have detected a decreased intestinal transit time. Some epidemiological data from Panama indicate that the presence of the intestinal stages of the parasite can explain why *Ascaris*-infected children have significantly lower plasma vitamin A concentrations than similar uninfected children.

Community studies of children in their normal home environments, carried out with minimum interference from the observers, have shown that differing degrees of growth retardation (as assessed by standard anthropometric methods) can occur during ascariasis. On the other hand, chemotherapeutic expulsion of *A. lumbricoides* is accompanied by small, but significant improvements in the rate of weight gain, as has been shown in: Deoria district, Uttar Pradesh, India; Lushoto, Tanzania; Machakos district, Kenya; Bali, Indonesia; and Kuala Lumpur, Malaysia. In Bali, the improvement in the rate of weight gain was most marked in undernourished children (3). Findings of several other studies fit this pattern, although because of confounding variables such as intestinal polyparasitism, it is often difficult to attribute malnutrition in cases of parasitic infections to ascariasis alone. Not every investigation has found an improvement in the growth rate following treatment for ascariasis (4), but this is not surprising since communities vary in cultural practices, economic and nutritional status, availability of health care, climate, and other factors.

Furthermore, *A. lumbricoides* may vary in pathogenicity in different regions of the world.

In September 1984, a conference on Ascariasis and its Public Health Significance was held in Banff, Canada. The delegates reviewed present knowledge concerning the relationship between *A. lumbricoides* infection and childhood malnutrition and concluded that ascariasis contributed to poor nutritional status in children. The conference stressed that the extent of the contribution could not be fully determined at present and that further studies were needed to assess it more fully and to determine its public health significance (3, 7).

### Hookworm infections

The adult stages of the blood-sucking nematodes *Ancylostoma duodenale* and *Necator americanus* are found attached to the mucosa of the small intestine, particularly of the jejunum, in many people living in tropical and subtropical countries (5). These intestinal parasites are known as hookworms and their pathogenicity is closely related to their mode of feeding. They may occur as single or mixed infections in the same person. There is no direct evidence that man develops protective immunity to hookworm infection, but epidemiological studies predict that some degree of immunity probably develops with time.

The hookworm life-cycle is direct and begins with the eggs being released by the female worms into the lumen of the small intestine and being passed in the faeces. The embryos within the eggs develop rapidly, given moisture, warmth, and oxygen, and skin-penetrating, third-stage infective larvae are formed within 5–10 days after the deposition of the eggs. Infection occurs when the larvae enter the body through the skin, most commonly through the feet. Larvae of *A. duodenale* are also infective by mouth.

In an endemic area, contaminated soil may continually or seasonally bear large numbers of infective larvae, which are found at the surface of the ground when the soil is damp. Lack of sanitation, indiscriminate defecation, and high egg production ensure constant exposure to infection, as do the practices of using the same places for defecation and going barefoot. The skin-penetrating larvae probably do not survive for more than a month under tropical conditions, but adult *A. duodenale* and *N. americanus* are believed to be capable of surviving for on average about 1 and 4 years, respectively. In light infection *N. americanus* may live for up to 15 years. Following infection, the prepatent period for *N. americanus* is 7 weeks, while that for *A. duodenale* is unpredictable, ranging from 5 weeks to 9 months; reasons for this extreme variation are not fully understood, but arrested development of the larvae in the tissues is a possibility.

Hookworm infection causes chronic blood loss and depletion of the body's iron stores, leading to iron-deficiency anaemia. The blood haemoglobin concentration below which anaemia is considered to be present varies with age, sex (and whether a woman is pregnant), and altitude. Moreover, the blood haemoglobin concentration gives no indication of the state of the body's iron stores, which may be seriously depleted before anaemia becomes apparent.

The body's iron stores are maintained by the daily absorption of iron from the small intestine. The availability of dietary iron for absorption depends on the quantity and type of iron in the food (vegetable or animal sources), the ratio of vegetable to animal iron, dietary factors that promote or inhibit iron absorption, the absorptive capacity of the intestinal mucosa, and the body's iron reserves. The most serious cause of iron loss from the body is chronic haemorrhage; estimates show that a blood loss of 15–20 ml per day into the lumen of the small intestine will produce a state of negative iron balance. This is because the normal absorption of iron from the diet and reabsorption of some of the iron lost from intestinal bleeding together do not result in absorption of enough iron to make up the daily loss of iron in 15–20 ml of blood. Thus, the body is forced to use up its iron stores (about

1 g) to maintain the blood haemoglobin concentration. *Ancylostoma duodenale* and *N. americanus* have been estimated to cause a daily loss into the small intestine of 0.14–0.26 ml and 0.02–0.07 ml per worm, respectively. When several hundred hookworms are present in the small intestine, the daily blood loss is sufficient to cause anaemia, even in well-nourished children or adults.

Hookworm infection must be considered an important factor in the etiology of tropical iron-deficiency anaemia, and this has implications for young children, pregnant women, and the health and productivity of adults whose livelihood and contribution to the economy depend on hard physical work (2). Anaemia is always associated with a diminished capacity for sustained hard work and exercise. Hookworm infection also causes a loss of blood plasma into the small intestine, which can lead to hypoalbuminaemia in some subjects. It has been suggested that a sudden loss of plasma albumin due to hookworm might be enough to precipitate an episode of kwashiorkor in a susceptible malnourished child. A severe impairment of the nitrogen balance in heavily infected hookworm patients has been detected, but it is not clear whether the imbalance results from some degree of malabsorption or from enteropathy leading to protein loss. Reduced food intake has been reported in anaemic hookworm patients, and a survey in Papua New Guinea revealed an association between the intensity of hookworm infection and poor nutritional status. The contribution of hookworm infection to malnutrition is in general not as well established as its role in iron-deficiency anaemia.

### Trichuriasis

Considering its worldwide distribution and high prevalence, trichuriasis has been neglected more than most of the other intestinal parasitic diseases (2). The nematode *Trichuris trichiura* has a simple life-cycle, with eggs serving as the infective stage. The adult worms survive for as long as 5 years, firmly attached to the epithelial lining of the large intestine, with the caecum being the most commonly affected region. Each female worm has been estimated to produce from about 2000 to 14 000 eggs per day and these leave the host in the stools and contaminate the human environment, as do the eggs of *A. lumbricoides* and the hookworms. Under suitable conditions, infective larvae develop inside the eggs in about 3 weeks and some may retain their viability for months. About 70–90 days after infective eggs are swallowed, the host begins to pass *T. trichiura* eggs, indicating that adult worms are present in the large intestine.

The morbidity associated with trichuriasis is due to the worms' unique mode of attachment to the wall of the large intestine. Each worm is about 50 mm long and has a thin anterior part with which it burrows into the intestinal wall where it feeds on the intestinal tissues. The degree of morbidity is related to the intensity of the infection. Chronic impairment of the host's nutritional status should be suspected when diarrhoea, hypoalbuminaemia, and iron-deficiency anaemia are observed in association with the presence of the parasite. *T. trichiura* is likely to cause anaemia less frequently than do hookworms; when anaemia does occur, it is due to the ulceration of the intestine resulting from a very heavy worm burden (6).

### Strongyloidiasis

Strongyloidiasis occurs in various forms, depending on the species (*Strongyloides stercoralis* or *Strongyloides fuelleborni*), geographical location, and age of the host (2, 5). *Strongyloides stercoralis* is widely distributed in the tropics and subtropics in areas of poor



sanitation. Infection occurs when third-stage larvae, which have developed in soil contaminated by human defecation, penetrate the skin. The larvae migrate first through the tissues and then via the lungs to gain access to the small intestine where parthenogenetic adult females develop and live in the epithelium of the jejunal mucosa. The females penetrate deep into the mucosal glands and begin to release eggs from which larvae emerge while still in the intestine. Larvae reach the external environment in the stools and some develop into infective, skin-penetrating, third-stage larvae, while some others grow into free-living adult male and female worms.

Sometimes, the larvae become infective before they are passed out. This leads to auto-infection, and explains how some people have remained infected with *S. stercoralis* for more than 30 years after leaving an endemic area.

*Strongyloides fuelleborni* occurs in tropical Africa and parts of Asia and a form of this species, or a very close relative, identified for the present as "*S. cf fuelleborni*", is found in Papua New Guinea. One biological difference between the life-cycles of *S. fuelleborni* and *S. stercoralis* is that in the former, eggs rather than larvae are passed in the stools of the host. Experience of health workers in endemic areas is that infections with *Strongyloides* spp. are not easily diagnosed.

Strongyloidiasis occurs in several forms: (a) an acute, usually symptomatic *S. stercoralis* infection; (b) a chronic infection, usually in adults who have been away from an endemic area for some time; (c) an overwhelming or disseminated form of *S. stercoralis* infection (now recognized as a danger to immunocompromised patients); and (d) the swollen belly (or baby) syndrome due to "*S. cf fuelleborni*" in infants in Papua New Guinea. In the chronic form of strongyloidiasis, symptoms of hypersensitivity, such as urticaria, coughing and eosinophilia, may develop, presumably in response to the production and migration of new larvae.

Clinical studies and case histories of adults with strongyloidiasis due to *S. stercoralis* show that concomitant diarrhoea, weight loss, malabsorption, and associated lesions in the mucosa of the small intestine may occur (5). This pattern of the disease has been described frequently in members of armed forces who have served in an endemic area but have developed symptoms years after leaving that area. Many infected people appear to be asymptomatic, but if their immune status is compromised, each is potentially at risk of developing disseminated strongyloidiasis in which the larvae of *S. stercoralis* massively invade the tissues and organs (particularly the lungs), usually with fatal results. Thus, in endemic areas, patients who are to receive immunosuppressive therapy should be screened beforehand for the presence of *Strongyloides* infections. Much more work is needed at the community level to determine the public health significance not only of *S. stercoralis* but also of *S. fuelleborni*, about which little is known.

"*Strongyloides cf fuelleborni*" is now known to cause a serious and life-threatening disease called swollen belly (or baby) syndrome in infants in Papua New Guinea. The symptoms of this disease include diarrhoea and oedema, the latter perhaps developing as a result of a decline in plasma albumin owing to the effect of an enteropathy causing protein loss. It has been suggested that infants may acquire the parasite from their mothers during breast-feeding.

### Other nematode infections

*Angiostrongylus costaricensis*, *Anisakis marina*, *Capillaria philippinensis*, *Enterobius vermicularis*, and *Trichinella spiralis* are species of nematodes that become established in the human gastrointestinal tract in different ways and are often associated with localized but nevertheless acute and sometimes life-threatening diseases (2, 5).

*Angiostrongyliasis.* *Angiostrongylus costaricensis* has an indirect life-cycle and people acquire the infection by ingesting infective third-stage larvae contained in either the tissues or extruded mucus of the intermediate host, which is usually a slug. The infection is a zoonosis and the cotton rat (*Sigmodon hispidus*) and other rodents are the natural definitive hosts in Latin American countries.

After ingestion, the infective larvae develop into adult worms, which remain mainly in the ileo-caeco-colic branches of the anterior mesenteric artery. In man, as in cotton rats, the adult worms release eggs, many of which become trapped in the alimentary tract tissues causing inflammatory reactions and granuloma formation. Thrombosis and necrosis may result from the presence of adult worms in the blood vessels. Abdominal palpation may indicate the presence of a tumour-like mass. The liver and testicles may also be invaded. Until recently, the diagnosis of abdominal angiostrongyliasis was difficult and many cases may have been overlooked. In many cases, owing to the difficulties in diagnosis and often late detection of abdominal angiostrongyliasis, the disease had to be treated by extensive surgery. Thus, more research is needed to develop a simple and accurate diagnostic test so that the prevalence and distribution of this disease can be determined and monitored, and medical rather than surgical treatment used.

*Anisakiasis.* Occasionally, outbreaks of anisakiasis have occurred in countries where partially cooked or pickled marine fish form a substantial part of the diet. The life-cycle of *Anisakis marina* is indirect and complex, with fish serving as the intermediate hosts, and predatory whales, dolphins, and sometimes seals forming the natural definitive hosts. Infection occurs when a person swallows the live infective larvae of *A. marina*, or of other closely related species. Following ingestion, the larvae penetrate into the walls of the stomach or of the small intestine, and inflammation, oedema, and tumour-like granulomas develop. Later in the course of the disease, intestinal obstruction or perforation and peritonitis may occur, for which surgical treatment is necessary. Anisakiasis is common in Japan.

*Capillariasis.* This intestinal disease, caused by *Capillaria philippinensis*, was characterized as a result of an outbreak in the Philippines in which there were about 1400 cases and more than 100 deaths. The disease occurred mainly in adults, with males appearing to be more susceptible than females.

The life-cycle of *C. philippinensis* in man is still not fully understood, but it is indirect and involves a freshwater fish as the intermediate host. Eggs passed in human stools later develop into infective larvae; these become established in fish which, if eaten raw or undercooked, can pass the parasite to man. The adult worms are small and lodge in the jejunal mucosa, where a self-perpetuating, auto-infection process occurs, sometimes causing a massive worm burden to build up.

The disease causes diarrhoea, malabsorption, weight loss, enteropathy with protein loss, weakness and, in some cases, a gradual progression to death. Many cases of *C. philippinensis* infection appear to be asymptomatic, but the history of the disease shows it to have a potentially high mortality rate.

*Enterobiasis.* *Enterobius vermicularis* is a small nematode with a direct life-cycle that normally involves only the alimentary tract; it has a high degree of specificity for man. The adult worms live in the large intestine and the mature female worms crawl out of the anus, usually at night, and deposit or burst to release sticky eggs in the peri-anal region. An infective larva develops in each egg about 4 hours after deposition and when these are swallowed the cycle is completed.

Children throughout the world appear to be most susceptible to *E. vermicularis*. However, the disease is probably more common in the temperate regions and developed countries than in the tropics and subtropics. *E. vermicularis* is the only parasitic worm

commonly encountered in developed countries. To become infected with it still carries a sense of shame and some degree of social stigma in the more affluent and sophisticated societies. The prevalence of enterobiasis may be underestimated because population surveys to detect it are uncommon, especially in developing countries.

The commonest symptoms of enterobiasis are anal pruritus accompanied by scratching which can lead to eczematous dermatitis, bleeding, and secondary bacterial infections. In some children, restlessness and insomnia are associated with enterobiasis, and these may interfere with performance at school and learning ability. *E. vermicularis* may cause appendicitis if the worms become localized in the appendix. Invasion of the female reproductive tract by migrating worms is not uncommon.

*Trichinellosis.* *Trichinella spiralis* infection is a zoonosis of worldwide occurrence. It is acquired by ingesting inadequately cooked meat, especially pork. Upon entry into the body, the encysted larvae in the meat become activated and develop into adult worms which live in the epithelium of the mucosa of the small intestine. Full details of the biology of *T. spiralis* and the health hazards of trichinellosis are available in guidelines prepared by WHO (8). The parasite is mentioned here because diarrhoea, constipation, and abdominal pain have been observed to coincide with intestinal invasion by adult worms.

### Taeniasis

In man, the adult *Taenia saginata* and *Taenia solium* live in the small intestine. These infections are acquired through the ingestion of infective cysticerci in undercooked beef (*T. saginata*) or pork (*T. solium*). The adults of both species of tapeworm are large and produce a variety of gastrointestinal symptoms. The most serious form of *T. solium* infection is a condition called cysticercosis (9) in which cysticerci develop in the human body. *Taenia saginata* infection seldom causes clinical problems, but in routine diagnostic procedures, it may easily be confused with the much more serious *T. solium* infection.

*Taenia solium* infection is endemic in many countries of Latin America, Africa, and Asia as well as in some parts of Europe and the USSR. When a person ingests infective eggs of *T. solium*, the larval stages leave the intestine via the hepatic portal system and are dispersed throughout the body where some develop to form cysticerci. Cysticerci that develop in the central nervous system (neurocysticercosis) represent a serious threat to the individual and even to the community if this condition is prevalent. For this reason, intestinal taeniasis in man cannot be ignored (9).<sup>b</sup>

### Hymenolepiasis

The adult *Hymenolepis nana* attains a length of about 40 mm and lives attached to the mucosa of the small intestine. This tapeworm has a wide distribution and is found commonly in children in the arid countries of the tropics and subtropics, mostly in Asia. The life-cycle is direct and involves an internal auto-infection process. Person-to-person transmission may also occur, which may cause epidemics: indirect transmission is also possible, in which the infective cysticercoid stages are acquired by swallowing flour beetles. During auto-infection, the eggs discharged by the adult tapeworm hatch in the intestine to release larvae which penetrate the villi and develop there to form cysticercoid stages. The cysticercoids are liberated from the villi and, after activation, develop into adult tapeworms. Thus, the parasite population can increase within the body without the need for transmission across an unfavourable environment (5).

<sup>b</sup> Guidelines for surveillance, prevention and control of taeniasis cysticercosis. Unpublished WHO document, No VPH/83.49. 1983

Intensive *H. nana* infection may be found in undernourished or immunocompromised children. The cysticercoid stages damage the intestinal mucosa, which might explain the observation that infected persons show signs of protein loss. Diarrhoea, abdominal pain, weakness, and weight loss have been associated with hymenolepiasis.

### Intestinal trematode infections

Schistosomiasis, clonorchiasis, and opisthorchiasis are not dealt with in this report. Current knowledge on schistosomiasis was reviewed recently by a WHO Expert Committee (10) and a similar review of clonorchiasis and opisthorchiasis is planned.

The other trematode infections that present a health hazard to man include those due to *Fasciolopsis buski*, *Heterophyes heterophyes*, and *Metagonimus yokogawai*. These are almost exclusively found in people living in south-east Asia. The life-cycles of the parasites are indirect and generally similar, with man becoming infected on swallowing encysted metacercariae. The metacercariae, which develop after the parasites have undergone a phase of asexual multiplication in the tissues of snails, are found encysted on aquatic vegetation or on or in freshwater fish, crustaceans, and molluscs. All these vehicles for the transmission of trematode metacercariae are important food items for many people.

Fasciolopsiasis, caused by the adult stages of *F. buski* in the small intestine, is considered to be an important disease for man. The infection is both endemic and zoonotic and is prevalent where people raise pigs and grow edible water plants. The adult flukes become attached to the intestinal mucosa, and heavy infections cause inflammation, ulceration, haemorrhage, persistent diarrhoea, nausea, vomiting, and abdominal pain. Malabsorption and an enteropathy causing protein loss have also been suspected.

## PROTOZOAN INFECTIONS

Infections of the human intestinal tract with the pathogenic protozoa *Entamoeba histolytica*, *Giardia intestinalis*, and *Cryptosporidium* spp. are a common cause of diarrhoea and have a worldwide distribution (11, 12). The complications of invasive amoebiasis are potentially fatal and giardiasis may cause malabsorption in children.

In view of the high prevalence of protozoan intestinal infections and the morbidity they cause, measures aimed at their prevention and control should be strengthened. Although adequate treatment for amoebiasis and giardiasis is available, the diagnosis of these infections presents difficulties, particularly in epidemiological surveys, because the microscopical techniques used require highly skilled personnel seldom available where these infections are most prevalent.

### Amoebiasis

Invasive amoebiasis is a major health and social problem in western and south-eastern Africa, south-east Asia, China, and Latin America, especially in Mexico. Inadequate sanitary conditions in these regions and the presence of highly virulent strains of *Entamoeba histolytica* may combine to sustain a high incidence of both intestinal amoebiasis and amoebic liver abscess. At present, on a global scale this infection represents one of the most common causes of death from parasitic intestinal diseases. It has been estimated (2) that, in 1981, probably 480 million people carried *E. histolytica* in their intestinal tracts and 36 million developed invasive forms of amoebiasis. A thorough review of the literature revealed that at least 40 000 died as a consequence of this infection; fatal amoebiasis is mainly due to fulminating colitis or liver abscess. The mortality from fulminating colitis is almost 70%, and that from liver abscess is up to 10%. Amoebic dysentery and amoebic appendicitis have a fatality rate of 0.5–27%, if not diagnosed properly and treated early.

For full recovery, patients with amoebic colitis, amoeboma, and amoebic abscess usually require a few weeks of hospitalization and 2–3 months of convalescence (12).

In many regions, amoebiasis is an important cause of diarrhoea and dysentery. In Mexico City, up to 15% of cases of acute diarrhoea and dysentery in children requiring hospitalization were found to be associated with *E. histolytica*. Amoebiasis may be more severe during pregnancy and lactation, and in persons with immunodeficiency; homosexuals, immigrants from certain tropical countries, and travellers are also specially liable to infection. Urban migration, the deterioration of the economies of certain developing countries, and the increasing size of urban slums with crowded, unhygienic conditions may accelerate the spread of amoebiasis and so result in even greater morbidity and mortality from this infection in the future.

### Giardiasis

*Giardia intestinalis* (*G. lamblia*) infection is endemic throughout the world and epidemics of it occur sporadically. Reported prevalence rates range from less than 1% to more than 50%, depending on the geographic location of the population and the prevailing type of *Giardia* transmission (i.e., indirectly through faecally contaminated hands, water, or food or even by the direct faecal–oral route). It has been estimated (2) that about 200 million infections occur per year in Africa, Asia, and Latin America.<sup>c</sup> Surveys of giardiasis may give underestimates of prevalence or misleading results because the irregular release of cysts (the detection of which in stool is the basic test for giardiasis) may result in their not being detected when only one stool sample is examined.

In the United States of America and the United Kingdom, giardiasis is the most commonly reported intestinal parasitic infection of man. In 1983, in the USA, *Giardia* was identified as the cause of 68% of waterborne outbreaks of diarrhoea in which an etiologic agent was known. In 1984, more than 250 000 people in Pennsylvania were advised to boil drinking-water because the routine chlorination process was not effective against *Giardia* contamination. In temperate climates, giardiasis can be heavy and persistent in people with some form of immunodeficiency; in some areas even drug resistance has been suspected.

Various factors influence rates of morbidity due to *G. intestinalis* infections: primary versus secondary exposure, age, concurrent infections, nutritional and immunological status, the infecting dose of *Giardia* and, possibly, differences in *Giardia* strains. Although a substantial proportion of infections may pass unnoticed, probably about 500 000 people suffer from symptomatic giardiasis every year.<sup>c</sup> Giardiasis is one of the common causes of acute or persisting diarrhoea in children in developing countries. There is some evidence from population studies that giardiasis interferes with intestinal absorption of nutrients and the growth rate of children.

### Cryptosporidiosis

Since the first case of human cryptosporidiosis was reported in 1976, this infection has been frequently diagnosed in patients with the acquired immunodeficiency syndrome (AIDS). In AIDS victims it causes profuse watery diarrhoea, and is considered a serious complication. In patients with normal immune function, diarrhoea associated with cryptosporidiosis may be acute, but is usually self-limiting. There are sporadic reports of *Cryptosporidium* spp. infection among the general population and particularly in those suffering from diarrhoea. In the latter group, it has been identified in 4.3% of Costa Rican children and in 10.8% of Venezuelan children. In the United Kingdom, *Cryptosporidium* spp. were the second most common enteric pathogens identified. Outbreaks of crypto-

<sup>c</sup> See footnote *a* on page 579

sporidiosis in tourist groups and children's institutions have already been reported. It will probably take another decade or so to understand better the public health importance of this infection.

### Other protozoan intestinal infections

Other protozoan intestinal infections either have a restricted geographical distribution (for example, balantidiasis, *Isospora belli* infections) or are widely distributed, but seldom pathogenic (for example, *Sarcocystis* spp., *Dientamoeba fragilis*, *Trichomonas hominis* infections) (5).

Balantidiasis occurs in populations that live in close contact with infected pigs. Water-borne epidemics of balantidiasis in man have been reported. Many human infections are self-limiting and asymptomatic but, in some cases, balantidiasis may cause an ulcerative colitis and even a fulminating dysentery with intestinal perforation and haemorrhage.

*Isospora belli* infections occur in the subtropical and tropical regions and the prevalence is usually low. The clinical picture varies from asymptomatic infection to persistent severe diarrhoea with a malabsorption syndrome.

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The time is now appropriate for taking action to control the intestinal parasitic infections. This is feasible at reasonable cost as a result of the development of primary health care, based on community support and intersectoral collaboration. The wider use of modern methods has led to a deeper understanding of the public health significance of intestinal parasitic disease, and new epidemiological insight has been gained. More effective drugs are also available and there is every chance of improving diagnostic methods through the application of molecular biological techniques.

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