"*ANKYLOSTOMIASIS.*" No. II.

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In a previous paper (Volume III., p. 95 of this *Journal*) we gave an account of our observations on cases of ankylostomiasis in Cornish mines. The present paper will be devoted to a more general discussion of the disease from the point of view of its prevention, particularly in mines.

Distribution of Ankylostomiasis.

Ankylostomiasis is known to exist as an endemic disease in warm countries all over the world. The countries or districts within which it prevails to a serious extent appear to lie within about 35° north or south of the equator; but persons more or less infected with the worm, and occasional cases of the disease itself, are, in Europe at least, found among the agricultural population even north of latitude 45°, in Northern Italy, where the *Ankylostoma duodenale* was originally discovered, and in Hungary, where it has quite recently been found[1]. There are still, however, many countries or districts as to

[1] Iberer, *Münchener medizinische Wochenschrift*, June 9, 1903.

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which there is no definite information with regard to the presence or absence of a more or less widespread infection with the worm. It seems probable, for instance, that it may exist over the Spanish peninsula, and possibly in the south of France, as well as in the European countries to the south of Austria. It is certainly a very remarkable fact with regard to ankylostomiasis that though it has been known for 50 years, and its recognition is a matter of great practical importance, it is nevertheless so frequently not recognised. This was the case with the Cornish outbreak, for instance; and a still more striking instance is that of its prevalence among the agricultural population in many parts of the Southern States of America, from North Carolina to Texas. Although Hirsch[1] pointed out more than 20 years ago that judging from the descriptions in medical literature ankylostomiasis is common in the Southern States, yet it appears that the disease remained unrecognised locally, and consequently untreated, till about a year ago, when its identity and wide prevalence were established by Stiles[2].

In the course of his investigation of ankylostomiasis in the United States, Stiles discovered that the worm commonly found there is of a different species from that described in European cases. He also found that worms from cases in Porto Rico and Cuba were of the American species. It thus appears probable that the ankylostomiasis which is so prevalent in British and other West Indian Islands, and possibly that in Brazil and other South American countries, may be partly at least due to the American species. Schneider identified worms obtained by Wucherer in Brazil about 1866 as *A. duodenale*, and Capps[3] has recently observed the same species in a case from Panama, but Pieri

[1] *Handbuch der historisch-geographischen Pathologie*, 1881.

[2] "Report upon the Prevalence and Distribution of Hook-worm Disease in the United States." *Bulletin No.* 10, *Hyg. Lab. U.S. Pub. Health and Mar. Hosp. Service*, 1903. The American species has only one median tooth, in place of the two dorsal teeth and four ventral hooks which surround the mouth of the *A. duodenale*. The bursa of the male worm is also different in the two species, and the eggs of the American worm measure, according to Stiles, about 64 to 76 μ by 36 to 40 μ instead of a mean of about 59 by 37 μ as in the case of the Old World species. Stiles adopts the names *Uncinaria duodenalis* and *Uncinaria americana* for the two worms, and calls the disease Uncinariasis or Hook-worm disease. The zoological grounds for this change of nomenclature, which is certainly very confusing, are criticised by Looss (*Centralblatt f. Bakt.* XXXI. p. 422, 1902). The American species has no hooks of any kind, and the disease has been generally known as ankylostomiasis or anchylostomiasis for 25 years.

[3] *Journ. of American Med. Assoc.* Vol. XL. p. 28, 1903.

has observed *A. americanum* in a case from Brazil[1]. Von Linstow[2] reports that he has found the same species in the intestine of the West African Chimpanzee, and suggests that the American infection has originated from slaves brought over from Africa. It does not seem to be definitely ascertained as yet to which species the ankylostomiasis met with in various parts of Africa outside Egypt, and elsewhere throughout the world, is due. *A. duodenale* was identified by Stiles in a case from the Philippines. The worms examined by us in Cornwall were *A. duodenale.*

In warm countries ankylostomiasis occurs among the agricultural population, and seems to be nearly always associated with gross faecal pollution of the soil round dwellings. The disease does not originate in towns, where there are always arrangements of some kind for the disposal of excreta; but it has been repeatedly observed among men employed in brick-making, even as far north as Cologne. Faecal pollution of the wet clay in the clay pits during warm summer weather doubtless accounts for the infection. By far the most serious trouble from ankylostomiasis in temperate climates has, however, arisen in connection with deep mines and tunnels under mountains; and we propose, therefore, to devote special attention to this subject.

Serious attention was first drawn to ankylostomiasis in Europe by the discovery that a great outbreak of anaemia among the men engaged in making the St Gothard Tunnel was in reality ankylostomiasis. The worms were first discovered at post-mortem examinations on tunnel workers who had died in hospital. Owing, however, to the prevalent belief in "miners' anaemia" due to bad air or other causes it was some time before, through the work chiefly of Perroncito[3], proofs were afforded that the tunnel disease was simply ankylostomiasis, and that it was easily curable by large doses of certain vermifuge remedies, of which the most suitable were found to be extract of male fern and thymol. Perroncito found that the same disease existed among miners at Kremnitz in Hungary, and it was soon afterwards found among colliers at St Étienne in France, Liége in Belgium, Brennberg in Hungary, Aachen and Westphalia in Germany. Recently the disease has spread greatly in Belgian and German collieries, and in some of the Hungarian collieries it has also been extremely troublesome.

From old medical records it appears probable that ankylostomiasis existed in many European mines previously to the St Gothard

[1] *Centralbl. f. Bakteriol.* Vol. xxxiv. p. 533, 1903.

[2] *Centralbl. f. Bakteriol.* (1) Vol. xxxiv. p. 527, 1903.

[3] See Perroncito, *Archives Italiennes de Biologie*, Vol. II. p. 315 (1882) and III. p. 7.

outbreak. It is difficult, for instance, to conclude that the epidemic of anaemia at Anzin near the Belgian frontier of France about 1802 was anything else but ankylostomiasis. "Brickmakers' Anaemia," which was definitely shown in 1882 to be ankylostomiasis, is known to have existed near Cologne since 1872 and near Bonn since 1878. The anaemia in Hungarian mines appears also to have existed before the St Gothard Tunnel was made. Undoubtedly, the dispersal over Europe of the St Gothard workers must have spread the disease, and the Belgian collieries may well have been infected from this source. Owing, however, to the readiness with which the existence of ankylostomiasis escapes diagnosis it is very difficult to trace definitely the sources of infection. About 1893 cases began to be noticed by Loebker at the deep collieries of the great Westphalian Colliery district. The infection was probably brought by miners from Hungary. About the same time a number of cases began to be noticed at deep Belgian coal-mines. The numbers of cases of definite anaemia observed at Westphalian collieries by the Medical Officers of the Knappschafts-Verein (a compulsory insurance association for miners) were as follows since 1896:

1896	107	1900	275
1897	113	1901	1030
1898	99	1902	1355
1899	94		

The great increase in the number of cases, from 1900, was coincident with the introduction of a compulsory system of watering every working part of the collieries in order to prevent coal-dust explosions. In the Belgian deep collieries the disease has spread greatly during the last ten years, though definite figures as to the number of cases of illness are not available. The French collieries seem to have suffered very slightly. As already mentioned in our previous paper, the recent outbreak of ankylostomiasis in Cornish mines seems to have begun about 1894, though it was not recognised till the end of 1902. Judging from statements made to us by old miners, however, it seems possible that there may have been a previous outbreak at Dolcoath Mine. Dr J. B. Montgomery of Penzance has communicated to us the interesting fact that about 50 years ago he observed a group of cases of persistent anaemia among miners who had returned from Chili, and that their symptoms seemed to correspond to ankylostomiasis. Dr Jago of St Just has also observed similar cases much more recently among returned miners. It thus seems not improbable that the infection may

have been brought to Cornish mines long ago. As many Cornish miners have gone to collieries in various parts of England they have presumably carried the infection with them. Infection may also have been easily brought to England by Italian or other foreign miners, or by men returning from tropical countries. Thus a case of ankylostomiasis in a collier was recently recorded by Stockman[1]. The patient had recently returned from military service in India, and was sent from a Scotch colliery to the Glasgow Royal Infirmary, where he was found to be suffering from ankylostomiasis. As yet, however, no outbreak of ankylostomiasis has been discovered in any colliery in Great Britain. In the collieries of the United States and Canada there is likewise no recorded outbreak, though Stiles records cases among miners in the infected Southern States. Many Hungarians are reported to be employed in coal-mines in the United States.

It may be taken for granted that ankylostomiasis exists among the miners in nearly all tropical and warm countries; but information on the subject is very scanty. Cases have been recorded at the Kimberley diamond mines: also in Queensland, so that the disease may perhaps exist in Australian mines. We ourselves observed that a white miner just returned from Mysore was infected. The disease has not been observed in the gold-mines of the Transvaal, although presumably hundreds of infected natives are employed in the mines. Possibly the Transvaal mines, which are very dry, do not permit of its spread. It would, however, be rash to assume that ankylostomiasis is absent in mines in any country, unless it has been definitely looked for and found to be absent.

Life-History of the Ankylostoma.

The successful prevention of the spread of ankylostomiasis depends mainly on a knowledge of the conditions under which the *Ankylostoma* propagates itself. We propose therefore to discuss the life-history of the worm from this point of view.

The records of post-mortem examinations show that the adult worms, male and female, live in the upper part of the small intestine, mostly about the upper part of the jejunum. During life they are probably nearly always firmly adherent to the mucous membrane, though they can apparently change their positions.

[1] *Brit. Med. Journ.* Vol. II. p. 189, 1903.

The adult worms may live in the human bowel for several years. This is a point which it was almost impossible to settle satisfactorily in regions such as Egypt and India where there is an infection of the general population; but in Cornwall, where the miners are alone infected, and in the United States, where infection is confined to the Southern States, several clear cases lasting for about five years have been recorded. C. W. Stiles[1] has found cases in children who were inmates of an institution (where reinfection seems to have been satisfactorily excluded) to which they had been removed from an infected area between six and seven years previously. In Cornwall we met with a youth (R. S., case xvi.[2]) who gave up underground work in consequence of anaemic symptoms which developed shortly after he began working in Dolcoath. Rather more than four years afterwards we found that his stools still contained a few eggs. During this time he had been engaged in driving a butcher's cart and had never even been to a mine. In this case there does not seem to have been the slightest chance that he could have become infected in any way since leaving Dolcoath. In another case a miner from Dolcoath (case xxxviii. p. 133) had been confined to his home (six miles from the mine) by miners' phthisis, and 20 months after his last contact with the mine we obtained numerous worms after thymol treatment. In Westphalia it has been repeatedly observed that miners returning from two years' military service are still infected. The butcher's boy whom we have mentioned had entirely recovered from his anaemia when we saw him (Hb 99 %), and he was to all appearances in good health. Such cases illustrate the insidious way in which *Ankylostoma* might gain entry to a mine, and the dangerous character of apparently harmless individuals.

Though it is thus clear that the worm may live a long time, we have evidence that in many cases they soon die out. C. F. Fearnside[3] examined prisoners when they were first admitted to an Indian gaol, and also those who had been inmates for more than six months. With proper sanitary arrangements, it is extremely unlikely that anyone would become infected while under detention. He found that 68 % of the fresh cases were infected with *Ankylostoma*, but only 58 % of the older inmates. In the U.S. Government Hospital for the Insane it has been found by P. E. Garrison and others that the frequency of infection with all intestinal parasites diminishes with the length of residence[4].

[1] *Loc. cit.* p. 58.
[2] *Journal of Hygiene*, Vol. III. p. 130.
[3] *Brit. Med. Journ.* 1900, II. p. 541.
[4] *Treasury Dept. U.S. Hygiene Lab. Bulletin* 13, 1903.

In Cornwall we met with at least one case in whom the worms appear to have completely died out without any specific treatment (J. W., case xxii., Vol. III. p. 131). He had suffered severely from pallor and dyspnoea six years before and had in consequence given up underground work for employment on the surface in a machine shop. His faeces contained no eggs and have been examined on several occasions.

It seems then that the adult worms are capable of such longevity that one can only be sure that an individual, who in the past has had contact with an infected place, is not infected by showing that his stools are free from eggs. For this purpose it is necessary that the examinations should be made very thoroughly and on more than one occasion. No importance at all should be attached to the fact that such a case has recovered from symptoms of anaemia. We have seen numerous cases of complete or partial recovery subsequent to an exchange of underground for surface employment, but eggs were found in nearly every instance.

It is thus quite evident that a person who has once been even slightly infected may, if the conditions be favourable, as in a warm and damp mine, spread the disease many years after he has himself acquired the infection—perhaps in some other country.

Although the *Ankylostoma* ova must often remain for several days in the intestine they are apparently never very far advanced in development when passed. In fresh or nearly fresh faeces we have usually found the eggs at the 4-cell to 16-cell stages. The 2-cell stage is not infrequently seen, but we have never observed unsegmented ova, or ova which had passed the morula stage. They will hatch in a few hours if the faeces are kept moist and warm, or in a few days at the temperature of a fairly warm room. All authorities are agreed that the eggs require free oxygen for their development. The reason why they do not develop further in the intestine is presumably, therefore, that free oxygen is lacking. If the adult *Ankylostoma* is also, unlike some other intestinal worms, aerobic, we can better understand why it fixes itself to the intestinal wall, since it will there obtain free oxygen as well as nutriment.

The ova appear to be as a rule pretty evenly distributed in a given sample of faeces; but it would seem that they may be absent for a short time although living worms are still present in the intestine. It has been repeatedly stated, for instance, that when ova have disappeared from the faeces shortly after the administration of extract of male fern or thymol, they have been found again a few days later. In

any case it seems hardly probable that any very definite relationship can exist between the number of ova present in a given weight of faeces and the number of worms in the intestine.

When the faeces are exposed to air outside the body, and kept from drying, the ova will develope and hatch within a wide range of temperature. After the cell-mass in the ovum has reached the morula stage it bends round within the shell, assuming a comma form. As the body elongates further it begins to show very active writhing movements, and finally assumes a figure of eight form, when the movements cease. This period of quiescence seems always, so far as we have been able to observe, to precede rupture of the shell and emergence of the larva.

The accurate investigation of the conditions under which eggs and larvae develope is a matter of no small difficulty. Artificial cultivations seldom seem to realise the optimum conditions for the development of the eggs and the growth of the larvae, and one lot of faeces will give very different results from those obtained from another. In some faeces the eggs hatch out quickly and the larvae live and grow well, while in another the young larvae die as soon as they are hatched. In some samples even we have failed to get the eggs to hatch at all under precisely the same conditions which were favourable in other cases. Possibly these ova were not impregnated, but we can offer no certain explanation of the differences which we have observed. They do not seem to depend on variations in the reaction of the faeces (which has always been acid in samples more than a day or two old). In several instances we have noticed that the eggs will not hatch or only hatch very slowly in fluid stools, while in more solid samples from the same individual they have grown well. On the other hand, variations almost as great have been noted in different samples of about the same consistency from the same patient.

Under the circumstances we propose to give a short account of the more important facts which have been ascertained in this connection without attempting to traverse the whole of the extensive literature on the subject, and with reservations which the apparently inconsequential irregularity of the experimental results renders necessary.

A. Temperature. The eggs are killed in about 24 hours by exposure to a temperature of about 40° C. (104° F.) or to a nearly freezing temperature. They will not hatch in 6 weeks under the variations of outdoor temperature found in London in November and December (0·5° to 12·5° C., 33° to 54° F.), nor in 5 weeks at the

temperature of the laboratory at Dolcoath in November, where the thermometer during the day-time generally rose to between 11° and 13° C. (52° to 55° F.). The eggs may hatch at any temperature from 16° C. (61° F.) to 38° C. (100° F.). In an ordinary hot incubator (37° C. = 98·5° F.) the eggs often die before hatching, but a few larvae sometimes hatch out in about 24 hours and then rapidly die away, seldom reaching the "encapsuled" stage.

In a series of cultures watched for five days we found that at a temperature of about 32° C. some of the ova were hatched within 24 hours. At 37° development was less rapid, and usually arrested before the stage of hatching. Even at 32°, in one experiment, development was completely arrested just before the hatching stage, and no further changes were observed after the first 24 hours. At 30° we observed a retardation of hatching in most of the ova, though development up to the hatching stage was about as rapid as at 32°, and after three days about two-thirds of the eggs were hatched. At 27° most of the eggs were hatched within 2 days, and nearly all in 3 days, but none within 1 day. At 24° only about a third had hatched after 2 days, but nearly all in 3 days. At 21° none had hatched in 2 days, about half in 3 days, and nearly all in 4 days. At 18° about a fifth were hatched after 3 days, and nearly all after 4 days. At 16° about a fifth were hatched after 4 days, and nearly all after 5 days. At 13° none were hatched after 5 days, but about a third seemed just ready to hatch. In this series of cultures, which were in covered Petri-dishes on moist sand, none of the free larvae continued to grow, possibly because the faeces were too dry. It will be seen, however, that at temperatures from 30° to 16° nearly all the eggs hatched within 5 days.

After hatching, the larvae, under suitable conditions, continue to grow, and after moulting once at least, reach a stage at which they are about 0·6 mm. in length and actively motile. The chitinous sheath is now very prominent, and can usually be seen to be more or less separated from the contained larva, the head and tail of which are often retracted from the ends of the sheath. There are no sexual differences, or signs of any mode of reproduction, and outside the body the larvae never pass beyond this the so-called "encapsuled" stage which, as will be seen below, is the infective one[1].

[1] The further stages of development within the body have been investigated by Looss, *Centralbl. f. Bakt.* (1), 1897, p. 913. A short and copiously illustrated summary of what is known as to the structure and stages of development of *Ankylostoma* is given by Stiles, *loc. cit.*

We have observed these full-grown larvae in samples of faeces left in bottles at the ordinary room temperature of about 15° or 16°. They appear, however, to develope much more readily when the faeces are placed in a covered dish with a very shallow layer of water in the bottom, and they are found swimming about in enormous numbers in the water.

Practically it is of course very important to find the minimum temperature at which "encapsuled" larvae can be grown: the limit has been placed at 20° C. (68° F.) by Bruns, who has studied the matter very carefully[1]. This is far above the mean annual temperature of any part of England and also higher than the temperature in many mines. We have however on two occasions and with two different lots of faeces succeeded in hatching the eggs and growing the larvae to the infective stage at a temperature which at no time exceeded 17° C. (62·5°) and was nearly always 15·9° C. (60·6°). The larvae seemed to be very vigorous, as did also a culture grown at 19° (66°). The critical point seems then to lie somewhere between 13° and 16° C. (55° and 60° F.). Below this temperature the eggs will not hatch, while above it they may do so and the larvae may grow to the "encapsuled" stage. It is not however to be assumed that all samples of infected faeces will produce larvae at 17° C.: the optimum temperature seems to be about 24° C. (75° F.). Samples of infected faeces placed in jars in Dolcoath Mine (temp. 25° C.=77° F.) showed numerous larvae at the end of five and seven days, but none in 48 hours.

We have hardly any information as to the influence of variations of temperature on the development of the eggs. This is the condition under which eggs would be in the open air in England, and it would be of importance in cases where the daily maximum is above, while the minimum is below, the critical limit which we have endeavoured to define. There seems to be no reason why the eggs should not hatch at 60° F., a temperature which is often found in the open air in this country. We are, however, ignorant of the influence which a daily reduction of temperature to below 60° may have. The daily minimum in England is rarely more than 60°[2]. The time during which they are

[1] Quoted by Haldane, Report to the Home Secretary on Ankylostomiasis in Westphalian Collieries, *Parliamentary Paper* [Cd. 1843], 1903.

[2] The following data (extracted from the Greenwich Records for the fifty years 1841 to 1890) may be of interest. Mean daily temperature more than 15·5° C. (60° F.) on 71, and less than 4·4° C. (40° F.) on 56 days per annum. The mean maximum temperature is more than 15·5° C. (60° F.) on 162 days, and more than 21° C. (70° F.) on 86 days, while the mean minimum is below 1·7° C. (35° F.) on 87 days. The average number of days per

exposed to the necessary warmth is also no doubt of great importance: in our laboratory experiments four to eight days were taken to hatch the eggs at 16° C. (61° F.), and another three or four weeks for the larvae to reach the "encapsuled" stage. This time is necessarily prolonged if at intervals the culture is exposed to lower temperatures. It cannot however be denied that there is a possibility that eggs left in the open in England might hatch and the larvae grow to an infective stage during the hotter months of a favourable year (June to August). In almost every part of this country however the spread of *Ankylostoma* is practically checked by the proper use of sanitary arrangements, and it is extremely improbable that any eggs would come to maturity in face of the temperature combined with systematic sewage disposal.

As far as we know the spread and prevalence of the disease depends on the development of the larvae to the infective stage, and there is no better illustration extant of the effects of temperature than the following table, compiled from figures quoted by Dr Tenholt with regard to collieries in Westphalia[1].

Temperatures about working face	Number of collieries 1901	Number of men employed underground 1901	Cases of anaemia per 1000 men employed underground
Below 17° (63° F.)	67	36033	0·6
17° to 20° (63° to 68° F.)	84	68604	0·4
20° to 22° (68° to 72° F.)	45	43710	2·5
22° to 25° (72° to 77° F.)	33	39836	11·7
Over 25° (77° F.)	12	9853	39·9

Dr Tenholt further found that the cases found in the mines with a temperature of less than about 22° C. appeared to be among men who had come from mines with a higher temperature, where they were doubtless infected.

annum on which the temperature rises above 21° C. (70° F.) is 77, and on nearly 4 days per annum does the minimum fail to fall below 15·5° C. (60° F.). The average number of days on which the temperature falls below freezing-point is 56, on nearly 5 of which it remains continually below 0° for 24 hours.

These figures must not be applied too closely to the *Ankylostoma* problem. Other factors have to be taken into consideration, such as exposure to direct sunshine in sheltered places such as quarries, cooling of the faecal mass by evaporation, &c. If, as appears to be the case, small variations of temperature about 16° C. are important, different parts of England must be considered separately. The mean annual temperature at Greenwich for the years 1841—1890 was 9·7° C. (49·46° F.), while that of Penzance is 11·5° C. (52° F.). These figures are misleading in the sense that they tell us nothing of the prevalence of hot spells in the summer and of spells of cold in the winter of sufficient severity to kill *Ankylostoma* eggs and larvae.

[1] See Haldane, *loc. cit.*

B. Moisture. All observers agree that thorough drying will kill both eggs and young and old larvae, and with this our own experience agrees. On the other hand, immersion in water prevents the eggs from developing and in a few days kills them. The larvae on the contrary do well in water. The degree of drying necessary to kill the eggs and larvae is a high one, and is only attained slowly in the interior of a large mass of faeces, but in many instances probably suffices to render deposits harmless. The great importance of adequate moisture is shown by the history of the Westphalian collieries, where the introduction of compulsory watering of the roads to prevent dust explosions in dry collieries was at once followed by the blazing up of what had previously been but a smouldering infection.

C. Oxygen. A fairly free supply of oxygen is necessary for the development of the eggs and for the growth of the larvae. This is shown by the absolute failure of eggs to develope at any temperature when sealed up, or even when covered with a thick layer of water. Absence of oxygen is not quickly fatal however: in one of our experiments eggs were sealed up and kept at about 30° for nine days. At the end of this period none had advanced at all, but 48 hours after air had been freely admitted to the culture nearly all the eggs contained young embryos. Lambinet estimates that it takes about 10 days' immersion in water to *kill* the eggs.

D. Light. It has been found by several observers that exposure to direct or even diffuse sunlight is sufficient to prevent development and to kill within about 48 hours.

E. Disinfectants. The eggshell of *Ankylostoma* is probably composed of chitin, an insoluble and impenetrable substance which also forms the sheath of the "encapsuled" larvae[1]. It is presumably the possession of this coat which confers on them the high powers of resistance which they exhibit towards the ordinary disinfectants, etc. Perroncito[2] observed this many years ago, and it has been constantly confirmed by other writers. Thus J. Lambinet[3] found that immersion of the eggs in such powerful solutions as 2 p.c. corrosive sublimate or 3 p.c. lysol for one hour will not prevent their subsequent development when removed to a medium free from the reagent: while glycerine or strong salt solution rapidly destroys the eggs, acting of course as dehydrating

[1] This has never, so far as we are aware, been definitely shown for *Ankylostoma*, but a chitinous coating is certainly present in most Nematodes.

[2] *Arch. Ital. de Biol.* III. 1882, p. 7.

[3] *Bull. Acad. Roy. de Médecine de Belgique* (4) XV. 1901, p. 397.

agents. The same observer found that in one hour eau de Labarraque or eau de Javelle (sodium and potassium hypochlorite) will not effectively penetrate the shell: this is of considerable interest since, with the exception of strong mineral acids, hypochlorite will alone dissolve chitin. We have found that hot solutions of eau de Javelle dissolve the egg-shell of *Ankylostoma* in a few minutes; the action of these solutions on chitin in the cold does not advance beyond softening in a reasonable time.

When the action of reagents upon the larvae is considered, it is necessary to distinguish carefully the stage of growth of the larvae in question. On first emerging from the egg they have no special chitinous coat and are very easily killed by 0·1 p.c. sublimate or any other germicide. It is a common observation that at high temperatures (37° C.) the eggs often hatch very quickly, but that the young larvae die almost immediately. It is very possible in these cases that they are killed by some substances in the decomposing faeces. When the larvae have become "encapsuled," they show great resistance. Thus Lambinet found that 2 p.c. sublimate does not kill in six hours, while in 25 p.c. sulphuric acid they live for $\frac{3}{4}$ hour. Other observers have obtained similar, though perhaps not such exaggerated, results. We have noticed ourselves that large larvae will live for more than half-an-hour in $2\frac{1}{2}$ p.c. sublimate in 1 p.c. acetic acid.

But when viewed as a practical question, the matter assumes rather a different light. It is quite true that both eggs and large larvae will withstand for a time very powerfully toxic reagents, and will develope and live when removed from such solutions to blander surroundings. In practice however disinfectants are applied to stools and allowed to remain in contact with them for a considerable time: it is then of no moment if the eggs do develope since the newly-hatched larvae will soon be killed by the disinfectant[1]. Even when "encapsuled" larvae are concerned, a moderate extension of the time limit during which they are exposed to the solution will experimentally give results which encourage the practical use of disinfectants. We have found, and have confirmed the experiments several times, that comparatively

[1] This is true of course only with some dry system of dealing with faeces. With a water-borne system there is no danger from infected stools except possibly on sewage farms. In some places underground it is true that the water will wash any disinfectant away from the faeces: but under such circumstances the abundance of water will of itself be a great hindrance to the development of the eggs.

weak solutions will in about 24 hours destroy vigorous "encapsuled" larvae. The following data were obtained from a culture six weeks old; a small number of larvae were immersed in about ½ in. depth of the solutions:—

	16 hours	48 hours	36 days
London tap-water	lively	lively	lively
+1·8 p.c. NaCl	lively	lively	lively
+0·2 p.c. corrosive sublimate	dead		
+0·1 p.c. corrosive sublimate	dead		
+1 p.c. izal	dead		
+0·4 p.c. izal	most dead	all dead	
+0·2 p.c. izal	most dead	all dead	

It is probable that a shorter time is sufficient, but one cannot accurately judge of the death of these large larvae until structural changes are perceptible. Cessation of movement (which occurs after about 1 hour in 0·1 p.c. sublimate) does not necessarily indicate death. With the exception of plain tap-water, the solutions mentioned were very soon fatal to young larvae.

In the same way the eggs are killed if the disinfectant is allowed to remain in contact with them for some time. A few drops of formalin, for instance, added to a two ounce bottle half full of faeces, will effectually prevent the development of the eggs.

Longevity of Eggs and Larvae. The question of how long eggs and larvae will live without coming into relation with human beings, is one of great practical importance, and it is to be regretted that the information on these points which is at our disposal is far from complete.

If faeces containing ova are left in the open air during an average English autumn with no frost, drying being prevented, many soon die, but a fair number remain capable of developing into larvae at a suitable temperature for at least six weeks, and at the end of that time there is no indication that the number of live eggs is materially diminishing, though their capacity to hatch quickly is seriously diminished. Frost kills the eggs, but apart from this there seems to be no reason for supposing that infected faeces will become innocuous if left alone for several months.

Our information with regard to the longevity of the larvae is little more precise. In some cultures the larvae die off rapidly as soon as they are hatched: in others they grow to the so-called "encapsuled" stage and then die quickly. In other instances again they will live for months

at this stage with a very small mortality. Dr Bruns in Westphalia has thus maintained cultures actively virulent for at least six months[1], and Leichtenstern for seven months. The longevity of the larvae seems then to be considerable under favourable circumstances; but it also depends to a large extent on small details of the surroundings (nature of faeces, temperature, moisture, etc.), which are at present not at all fully understood.

It is not improbable that conditions in the soil, apart from moisture and temperature, influence the development of the larvae. Stiles reports, for instance, that ankylostomiasis in the Southern States of America is chiefly confined to the dwellers on sandy soil, and that those living on clay are almost immune.

Infective Stage. Although it was pointed out by Grassi and Parona in 1879 that the infective stage of the *Ankylostoma* is probably the developed larval worm, definite experimental evidence of this fact was first furnished by Leichtenstern[2]. The latter observer showed that if either the ova or the freshly hatched larvae are swallowed by men, the adult worm does not develope in the intestine, since no ova appear in the faeces. On the other hand, if the fully developed, "encapsuled" larvae be swallowed, ova begin to appear in the faeces after about a month. The latter observation has recently been confirmed by Pieri[3], with a culture of larvae from the American variety of *Ankylostoma*, the ova appearing in the faeces after 30 days.

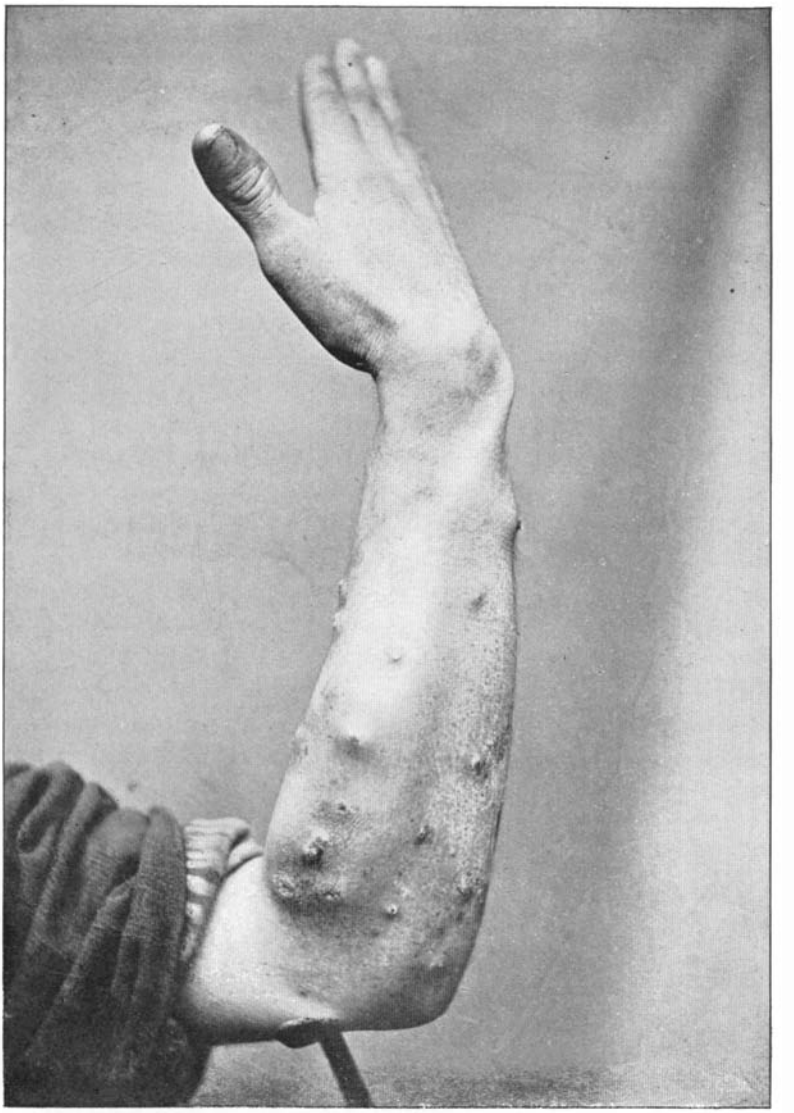
Paths of Infection. It is quite evident from these experiments that one source of infection by *Ankylostoma* is through the mouth; and till recently it was assumed that this is the sole source of infection. In 1898 Looss[4] made the observation that after a few drops of a culture of ripe *Ankylostoma* larvae had accidentally dropped on his hand, the skin at the place became inflamed; and some time afterwards he found that he was suffering from ankylostomiasis. As it appeared to him very improbable that he had been infected through the mouth, and as the disease is not endemic in Cairo, where he was working, he concluded that he had probably been infected through the skin. Some time later he made the further experiment of smearing a few drops of a culture on the skin of the leg of a hospital patient shortly before the leg had to be amputated. On excising the skin and cutting sections he

[1] Haldane, *loc. cit.* p. 5.
[2] *Centralbl. f. klin. Med.* 1886, p. 675.
[3] *Centralbl. f. Bakteriol.* Vol. 34, p. 533, 1903.
[4] *Centralbl. f. Bakteriol.* Vol. 24, p. 486, 1898; Vol. 29, p. 733, 1901.

found larvae in the subcutaneous tissue, into which they had apparently penetrated through the hair follicles. He also found that the larvae disappear very rapidly when placed on the skin, and that after a short time only empty sheaths are to be found, while a localised dermatitis is quickly produced. The disappearance of the larvae, and dermatitis, have also been recently observed by Pieri[1] in two experiments. In 1902 Bentley[2], who had seen the first paper by Looss, observing that the skin-disease known in Assam as "pani-ghao," "water-itch," or "ground-itch," was associated with the prevalence of ankylostomiasis, made a series of experiments on the subject. Water-itch occurs in the wet season, and affects the feet of coolies who work barefooted in polluted earth. A few hours after exposure of the feet to the polluted ground intense itching and burning at the affected place is felt. A vesicular eruption follows in about a day, and the vesicles commonly become pustules. In bad cases the skin may slough. The disease appears also to exist in the sugar plantations of the West Indies. Bentley found that he could produce a similar eruption on the skin of the arm by applying moist earth which had been contaminated with faeces containing *Ankylostoma* ova and incubated for a week, and that the same earth when incubated with faeces free from *Ankylostoma* eggs, or after the larvae had been killed by drying for a few hours at the air-temperature, produced no effect. He concluded that the eruption is primarily due to invasion of the skin by the larvae, though a secondary bacterial infection is doubtless usually also present. The fact that the disease occurs only in the wet season is easily explicable on this hypothesis, since the *Ankylostoma* larvae can only develope on wet ground. It appears that affections similar to or identical with the coolies' water-itch in Assam also occur elsewhere in tropical countries, though they may of course be due to other causes.

We have already given an account of the very troublesome skin-eruptions which have been associated with the prevalence of ankylostomiasis among the miners at Dolcoath mine in Cornwall, and which had come to be known as "New Sump bunches," the "New Sump" or Engine shaft at Dolcoath being the one in which the men were far most frequently affected by both anaemia and the skin eruptions. The eruptions did not specially affect the feet of the miners, and were usually on other parts of the body; but the miners wear thick boots, and often work stripped to the waist on account of the heat, or very lightly clad. They

[1] *Arch. Italiennes de Biologie*, Vol. 37, p. 269, 1902.
[2] *Brit. Med. Journ.* 1902, Vol. 1, p. 190.



A severe case of "bunches" on the arm of a Cornish miner. See pp. 88—89.

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are thus more exposed to mud and dirt on other parts of the body than on the feet. Plate IX is from a photograph of a bad case of "bunches"; we are indebted for it to Dr Blackwood of Camborne. The patient was a Dolcoath miner who had come to him for treatment. The men described intense itching, followed by papular, vesicular, and pustular eruptions, just as in the case of "water-itch."

Skin symptoms have not, so far as we know, been described in connection with outbreaks of ankylostomiasis in mines elsewhere. Enquiries made recently by one of us among medical men engaged in dealing with ankylostomiasis in the Westphalian mines failed to elicit any information as to skin eruptions specially associated with ankylostomiasis. Some of the miners referred, it is true, to skin eruptions due to their work underground, but there was no evidence to connect these with ankylostomiasis. The infection of the Westphalian mines was, however, so far as could be judged, in no case nearly so intense as in the New Sump shaft at Dolcoath, and skin affections to the same extent could therefore hardly be expected.

In November 1902 one of us made numerous attempts to produce a skin infection on his own person by smearing cultures of larvae on the arm, where they were allowed to remain (bandaged up in a moist condition) for as long as twelve hours. Artificial cultures of all ages were used, including some which contained abundant active "encapsuled" larvae: faecal material containing larvae from Dolcoath Mine was also tried. In no case was any local reaction obtained; this is remarkable if the generally filthy nature of the applications is alone considered. From November 1902 till June 1903 both the faeces and blood were repeatedly examined and no evidence was found of the presence of eggs or of anaemia or eosinophilia. From June till October 1903 these examinations were repeated occasionally but always with negative results.

Quite recently Looss[1] has published a further most important paper on skin infection. Two puppies, which had previously by examination of the faeces been ascertained to be free from infection, were smeared over about 20 square centimetres of the back with a culture of the larvae of *A. caninum* (an intestinal worm closely allied to the *Ankylostoma* of man). The culture was kept applied for two hours by means of a bandage, and scrupulous precautions were taken to disinfect the place afterwards, and prevent the animals from by any means swallowing any of the larvae. Both animals died after nine days.

[1] *Centralbl. f. Bakt.* Vol. 33, p. 338, 1903.

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The organs were very pale[1], and in the small intestine were found enormous numbers of the worms in an early stage of development. An experiment was also made on a man who was at the time free from infection. A small quantity of a culture of *Ankylostoma* larvae was smeared on his arm. The usual inflammatory reaction appeared at the time, and 71 days later ova began to appear in the faeces. These increased in numbers for several weeks, until they became fairly abundant. So far as could be ascertained the man had not been otherwise exposed to infection in any way.

These experiments seem to render it all but certain that infection with *Ankylostoma* may occur quite readily through the skin. Previously to the paper by Looss just referred to experiments had been published by Pieri[2] on infection through the skin. The latter observer obtained apparently negative results. He experimented with a culture of ripe larvae of *A. americanum* on three persons, including himself and Prof. Grassi, in whose laboratory he was working. After 40 days no ova could be found in the faeces of any of the persons experimented on, and the results appeared to be clearly negative, as it was assumed that, as in the case of infection through the mouth, the ova would appear within this period if at all. After 71 days, however, ova were found in the faeces of Pieri, who had been most strongly infected. Up to six months from the date of infection no ova were found in the faeces of the other subjects of the experiment. Pieri considers it probable that his infection was accidental, as he was working with cultures in the laboratory; but at any rate these experiments seem to partly confirm the theory of Looss, though they indicate that infection occurs much less readily through the skin than through the mouth in man.

Assuming the correctness of the theory of Looss it seems very probable that in the case of work such as mining or brick-making, and even agricultural employment, the chief path of infection is through the skin rather than through the mouth. If this be so it cannot be expected that precautions, however perfect, against infection through the mouth will avail in preventing infection with *Ankylostoma* during such work.

[1] In one of the animals there were some small haemorrhages in the mucous membrane, and in the other no haemorrhages. The young worms contained no blood. As, however, the signs of anaemia seem to have been very marked this experiment seems to confirm the conclusion which we put forward in our previous paper that the anaemia cannot be explained by loss of blood caused by the bites of the worms.

[2] *Arch. Italiennes de Biologie*, Vol. 37, p. 271, 1902.

There are evidently many points with regard to infection through the skin that remain to be cleared up. Why, for instance, was the period between the skin infection and the appearance of ova in the faeces so long (71 days) in the case of Looss's and Pieri's experiments on man, as compared with the much shorter period (about 30 days) in infection by the mouth, and the very short time required for the worms to reach the intestine in the experiments on dogs?

Van Durme[1] has recently found that the larvae of *Angwillula intestinalis* (*Strongyloides intestinalis*) are also capable of penetrating the skin of animals, and producing dermatitis with a pustular eruption.

Our knowledge is scanty as to the symptoms produced during the period which elapses between infection with the *Ankylostoma* and the complete development of the adult worm. The experiment of Looss, quoted above, shows that fatal effects may be produced in animals; but no definite symptoms have been observed in cases of artificial infection in man; and in natural infection in man the larvae are usually introduced so gradually that observations can hardly be made as to the early effects of infection. It is not yet even known whether the eosinophilia and anaemia begin to develope before the worms have reached their adult stage, though it is perfectly clear that the presence of the adult worms in the intestine maintains the anaemia, at any rate in some individuals. Men coming fresh to the work in the infected Cornish mines seem most apt to suffer from anaemia; and this might at first sight seem to suggest that the worm in its early stages causes most harm. Fresh infection must, however, be occurring, and the facts are most easily explained on the theory that in the majority of individuals some form of immunity is gradually established to the presence of the worms. Nearly all the men working in the mine appear to be infected with the worm, and a great many of these suffered at first from anaemia, but gradually recovered completely without giving up their employment and without treatment; on the other hand there were some individuals who continued to be ill for long periods even after giving up work underground, and in whom, therefore, the immunity did not become established, though they recovered when treated with thymol. The immunity theory seems also to be strengthened by the fact that in many tropical districts nearly all the inhabitants may be infected with the worm, while cases of actual anaemia are not common. Stiles mentions that the anaemia of ankylostomiasis seems to be less common

[1] *Thompson-Yates Laboratory Reports, Liverpool*, 1902, p. 471.

among negroes than among white persons. Possibly there is some degree of hereditary immunity in natives of tropical countries, though all races are certainly more or less subject to the disease.

Diagnosis of Ankylostomiasis and Ankylostoma Infection.

As only a certain proportion of the persons infected with the *Ankylostoma* show any symptoms of illness, a distinction must be drawn between persons actually suffering from ankylostomiasis and those who are simply infected with the worm, though from the standpoint of Preventive Medicine the diagnosis of *Ankylostoma* infection is usually much more important than that of the disease itself.

The symptoms which are suggestive of ankylostomiasis fall under two general heads:—(1) those belonging to the anaemia such as pallor, shortness of breath on exertion, and palpitations of the heart; (2) gastro-intestinal symptoms, including dyspepsia of various kinds, epigastric pain, and irregularity of the bowels. This second group of symptoms includes nothing which might not be due to any anaemic condition, but there is little doubt that patients suffer from these troubles before (or without) becoming at all seriously anaemic. The skin eruptions which we have previously described (III, p. 107) may not be due to *Ankylostoma*, but there are, we think, sufficient reasons for looking upon them as, in part at least, specific, so that their presence should rouse suspicion. It may not be out of place if we here repeat the common warning—not to judge of anaemia by the colour of the patient's cheeks. Ruddy cheeks are often found with the pale lips and conjunctivae which are almost always trustworthy guides to the haemoglobin content of the blood. Definite anaemia in adult males without any obvious cause is such an uncommon affection that its occurrence should at once suggest Ankylostomiasis, especially in those whose occupation is suspicious (miners, &c.), and who have been exposed to infection in the tropics. We have found the haemoglobinometer of the utmost service in establishing the existence and degree of the anaemia, and in following the effects of treatment. An accurate determination of the haemoglobin can be made in three or four minutes with the Gowers-Haldane haemoglobinometer. This instrument requires, however, a supply of lighting gas for saturating the blood-solution with carbonic oxide; and as gas is not always available it is well to have, along with the instrument, one of the old Gowers picro-carmine standard

colouring tubes, the indications given by which may be checked from time to time against the CO-haemoglobin permanent standard of the Gowers-Haldane apparatus.

Assuming that ova have been found in the stools, and that the patient is more or less anaemic, there will nevertheless often arise doubts as to whether the symptoms presented by a patient are wholly, or even partly, due to ankylostomiasis; and this difficulty is much greater in tropical countries, where, perhaps, nearly every native of the country may be more or less infected. Such causes of secondary anaemia as malaria and other fevers, scurvy, chronic starvation, &c., must thus all be considered. In certain mines the possibility of lead-poisoning must also be taken into account. In Cornwall the chief source of difficulty in diagnosis was "miner's phthisis" or silicosis in its various forms. It was often impossible to judge whether respiratory and cardiac symptoms were due to ankylostomiasis alone, or partly to silicosis; but in cases of pure ankylostomiasis there was seldom if ever any wasting.

A positive diagnosis of *Ankylostoma* infection rests on the discovery of the eggs in the stools. In the majority of instances they occur in very large numbers, and owing to the fact that they are deposited when the contents of the gut are still fluid, they are uniformly distributed throughout the faecal mass. It is, in consequence, unnecessary to search more than one portion of a stool, and as a rule the eggs are very easily found. A small portion of the faeces should be thoroughly mixed with two or three drops of water in a watch-glass, and the fluid part removed to a slide and spread out into a thin layer by means of a cover-glass. Fluid stools may be examined direct, but in the end the quickest plan is to dilute the faeces and examine several preparations rather than to attempt to search in the thicker mixture. A thin, watery film can be examined very quickly and with a low power, and there is no chance of eggs being hidden by *débris*. In a thick preparation the search has to be made very slowly and carefully. The most convenient objective to use is one of about 8 mm. ($\frac{1}{2}$ or $\frac{1}{3}$ in.), though, using thin preparations and with some practice, the eggs can easily be found with a $\frac{2}{3}$ or 1 in. As in all similar manipulations, time is on the whole saved if every preparation is examined systematically on a mechanical stage.

It is fortunate that the eggs present an appearance which is highly characteristic, and there is really nothing else found in *fresh* faeces which can be easily mistaken for them. The important and diagnostic points of the egg as seen in fresh faeces are:—

(1) the egg is regularly oval in outline and has a regular contour

(not circular as in *Taenia* or flattened on one side as in *Oxyuris* or with projections as in *Trichocephalus* or *Bilharzia*).

(2) the egg-shell is very thin and appears as a single line (not as two concentric lines as in *Oxyuris*, &c.).

(3) the egg-shell is smooth (not mamillated as in *Ascaris*). *Ascaris* eggs, stripped of their mamillated outer covering, have sometimes been mistaken for *Ankylostoma* eggs: the shell is, however, far thicker.

(4) the egg-shell is transparent and perfectly clear (it is not stained brown or yellow as in *Trichocephalus* or *Ascaris* with the outer covering not stripped off).

(5) the contents are grey (not yellow) in colour, are very readily seen through the pellucid shell, are divided into distinct roundish masses (*i.e.* cells), usually 4 to 16 in number, and do not completely fill the shell.

In any case of doubt the eggs should be carefully measured. Different authorities give varying figures[1]; the average of all the measurements given by Scheube is about $59\mu \times 37\mu$, and unless the figures obtained are somewhere near these suspicion should be aroused that the objects in question are not *Ankylostoma* eggs. When the egg has been seen once or twice it seems almost impossible that any mistakes should be made: but W. R. Stone[2] has recorded that the seeds of the strawberry have been carefully collected from faeces and placed in a museum series as *Ankylostoma* ova.

A positive diagnosis is usually reached very quickly; but it is necessary to search several preparations before one is justified in saying that no eggs are present. When the eggs are very few Giles[3] has suggested that the faeces should be mixed with a dilute solution of magenta, when the eggs stand out as unstained objects. We have not found this procedure of any particular advantage, but our experience of Stiles'[4] sedimenting process is not unfavourable.

Even if no eggs can be found by prolonged and repeated searches, it does not necessarily follow that the patient does not harbour the worm (see above, Vol. III. p. 126). Other points must then be taken

[1] See the table in B. Scheube (*Diseases of Warm Countries*, Eng. Trans. 1903, p. 420). The extremes given here are: length 44 to 70, breadth 23 to 43. Our own measurements give 56 to 70×37 to 50, with an average of $62 \times 42\,\mu$. According to C. W. Stiles (*Treasury Dept. U.S. Hygienic Lab. Bull.* 10, 1903) the eggs of the American species (*Uncinaria americana*) are a good deal longer (64 to $76\,\mu \times 36$ to $40\,\mu$).

[2] *Medical News*, Vol. 82, 1903, p. 682.

[3] *Report on Kála-Azár*, Shillong 1890, p. 109.

[4] *loc. cit.*

into consideration: exposure to infection, symptoms (if present), and the condition of the blood. We have already detailed the results of the blood examinations made at Dolcoath, and purpose to deal with the use of the stained film in the practical diagnosis of *Ankylostoma* infection in a future paper. In this place we would only say that (1) the absence of an increase of eosinophile leucocytes does not render the presence of worms impossible, and (2) the failure of an eosinophilia to disappear after specific treatment is not an indication that the worm is still present.

From the point of view of public health, the important point is to diagnose the presence of the worm irrespective of the presence of any of those gastro-intestinal and anaemic symptoms which constitute the disease ankylostomiasis. If any such symptoms are present they may suggest the examination of the stools, or, among an infected population, may make the diagnosis of *Ankylostoma* a probable inference, but one which will require definite proof before any drastic treatment is undertaken.

It has been shown by several observers that thymol will sometimes produce specimens of the adult worms in cases where no eggs have been found in the stool. Except in exceptional instances it is hardly justifiable to administer an adequate anthelmintic dose of thymol as a purely diagnostic procedure. It may, however, be necessary sometimes to treat a patient on presumption. To find the worms easily, it is necessary to bring about an early and copious evacuation of the bowels in order that the worms may not be digested after being killed. A large amount of faeces should then be mixed and thoroughly agitated with five or ten times its bulk of water in some deep vessel (a large coffee-tin answers very well) and the mixture allowed to settle for a couple of minutes. The liquid is then poured off, fresh water added and the process repeated. After the second washing the sediment (which is now practically free from any objectionable odour) is emptied out on to a dish or plate and carefully searched. The worms are opaque white, sometimes with a reddish tinge, the females being about half-an-inch long and the males a little shorter; they are positively identified by the two pairs of pointed "hooks" on the ventral surface of their mouth[1]. The characteristic bursa at the tail end of the male is visible to the naked eye, and its details can be made out under a low power. With the exception of the other varieties of *Ankylostoma* there are no parasitic

[1] The American species differs in some particulars: *vide supra* p. 74.

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worms which possess anything at all like the copulatory bursa of the male. Permanent preparations of the worms are best made by mounting them in Farrant's medium or glycerine without any fixation.

We have repeatedly observed that in cases where, to judge from the abundance of the ova in the faeces, a large number of worms must have been present, only a very few whole worms, and numerous fragments, could be found in the faeces when there had not been an evacuation of the bowels very soon after the administration of thymol. The worms are readily digested by the pancreatic ferment, and in these cases nearly all seem to have been digested, as the faeces afterwards remained free from ova.

It sometimes happens that one meets with lively young larval worms while searching for eggs. If the faeces are quite fresh these may generally be taken to be *Anguillula stercoralis* without any very serious chance of error. The same assumption may be made in older specimens if these have carefully been kept cool since deposition and have not been in such a position that extraneous worms could have crawled into them from without.

It will, however, be necessary sometimes to search for evidence of *Ankylostoma* in faeces which have been passed for a considerable and often indeterminate time. Such occasions arise when examining faecal deposits collected from a mine or some such place. The eggs can easily be found in deposits which from their general appearance, loss of odour, &c., may be judged to be at least several weeks old. They only differ from fresh eggs in the appearance of their contents, which are agglomerated into a granular mass on the death of the embryo: the shell retains its contour and appearance for a long time. Even if the temperature has been such that larvae have hatched out, a certain number of eggs can generally (we fancy always) be found, since some of the eggs die in the early stages. The empty egg-shells are very difficult to find. If, however, the sample contains small worms and no eggs, a number of possibilities arise. The small worms may be (1) *Ankylostoma* larvae, (2) larvae or adults of some other parasitic worm, (3) larvae of some free-living nematode which have entered the faecal deposit since it was deposited, (4) the adult form of some small nematode worm[1]. The last are probably easily separated by the fact that they will show sexual

[1] We are assuming that the larvae found bear some superficial resemblance to those of *Ankylostoma*. Dipterous and coleopterous larvae can and do occur in these faecal deposits; they are easily separated by their segmentation, the presence of hairs, eyes, the elaborate mouth, &c. Unless the worm is unsegmented it cannot be a Nematode.

characters, the females containing ova, and the males having some penile apparatus, commonly (according to our own observations) two equal spicules. But their presence in a sample introduces a possible fallacy which it is necessary to guard against: the eggs of some of these free-living nematodes are not at all unlike *Ankylostoma* eggs, and when such are found in an old faecal deposit which has been exposed to possible contamination from the soil it is necessary to see that the eggs correspond in all respects with those of *Ankylostoma* before pronouncing that they belong to that worm[1]. The adult worms and the eggs found may be *Anguillula*, but it is not possible to say with certainty that this is the case, unless one can find similar living larvae in fresh stools. It is generally possible to see readily if the eggs present have been laid by the worms which are found: if so, they cannot be *Ankylostoma* eggs. A case might easily occur where free-living nematodes had entered faeces which also contained *Ankylostoma* eggs: under such circumstances difficulty might be expected, but we believe that it is possible to make a certain diagnosis in most cases if due care is exercised. In the absence of both *Ankylostoma* eggs and of any adult worms, the satisfactory diagnosis of any larvae which may be found does not seem to be a practical possibility. The larvae of many nematode worms so closely resemble one another, and the published information with regard to the non-parasitic forms seems to be so scanty, that it is not worth while to enter into any material discussion of the subject. There are, however, three points which have come under our own notice and which may be helpful: (1) the larvae may easily be reared, and if they belong to non-parasitic worms from the earth sexual forms can be obtained, (2) the larvae of both *Ankylostoma* and *Anguillula* have regularly tapering tails, those of some other allied worms are rather abruptly truncated, and terminate in a filament, (3) *Ankylostoma* larvae are relatively more slender than many others, and (when developed) the external sheath is very much more conspicuous. The collection of a number of samples

[1] Some samples collected in a Shropshire mine by Mr John Cadman, H.M. Inspector of Mines (who kindly sent them to us for examination), were full of some Nematode belonging to the family *Anguillulidae*. The eggs were very similar to those of *Ankylostoma*, but were rather smaller (41 to 60 × 28 to 34; average 53 × 32 μ), the sides were somewhat flattened by pressure within the mother's body, the contents filled the shell more completely; and the young larvae which were present in some of them were larger. Similar eggs were to be seen within the bodies of the adult females which were present. There is every reason for supposing that these were free-living Nematodes which had entered the faeces subsequent to their deposition in the mine. The larvae which were present showed that they were not *Anguillula*.

of faeces underground is very much easier than to obtain fresh specimens directly from the men, and, if *Ankylostoma* is prevalent, evidence of its presence can, we believe, generally be derived from such material. But it is quite clear that nothing found in these deposits can be taken as positive evidence except undoubted eggs of *Ankylostoma*.

In several cases we have found young active larvae in fresh stools (cases IV, VI, XIV, XXI). These resembled the larvae of the parasitic nematode *Anguillula* (*Strongyloides*) *stercoralis* (*intestinalis*)[1] and probably belonged to that worm, which is so frequently found in association with *Ankylostoma*. In none of the cases however were they at all abundant. It is very rarely that the eggs of *Ankylostoma* hatch within the alimentary canal, and on the whole it seems practically certain that they were *Anguillula*. It is to be regretted that a more careful examination of them was not made at the time. How far *Anguillula* is definitely pathogenic is not known: gastro-intestinal symptoms (especially a chronic diarrhoea) and anaemia have been attributed to it, but other writers regard it as harmless. Bücklers[2] has recorded an eosinophilia of 13·5 p.c. in a case of pure *Anguillula* infection; P. K. Brown[3] 6 p.c., and Pappenheim[4] 0·8 p.c. It is however clear that neither the symptoms nor the blood changes in our cases could have been due to *Anguillula*, since this worm was present in so few instances.

Anguillula eggs are similar to those of *Ankylostoma*, but practically never occur as such in the stools: they hatch within the alimentary canal and appear as larvae.

Treatment.

The procedure adopted in Cornwall was to give a purgative of calomel in the afternoon, and next morning (usually a Sunday morning if the man was at work) to give three successive doses of 30 grains each (2 grammes) of thymol as emulsion or in capsules at intervals of two hours. The patient was kept in bed and instructed to take no food except tea or coffee and no alcohol. After the last dose another purgative was given, castor-oil being, however, avoided. No unpleasant effects

[1] Good summaries of our knowledge of the life-history of this worm are given by W. S. Thayer (*Journ. Exp. Med.* VI. 1901, p. 75), and R. P. Strong (*Johns Hopkins Hosp. Reports*, X. 1902, p. 94). Strong's case had 0·1 to 0·3 p.c. eosinophiles but had some leucocytosis from an abscess at the time.

[2] *München. med. Wochenschr.* 1894, p. 22.

[3] *Boston Med. and Surg. Journ.* CXLVIII. 1903, p. 583.

[4] *Centralbl. für Bakteriol.* XXVI. 1899, p. 608.

were observed. The patients were all treated at home, so that the results could not be so well observed as if they had been in hospital. All the men treated were anaemic and more or less ill, and in most cases the improvement following the treatment was very striking, although in one case which is quoted below, the improvement was only slow, in spite of the fact that ova had completely disappeared from the faeces.

This treatment is substantially what has been adopted by English medical officers in tropical countries all over the world. Thymol treatment seems to have first been successfully tried by Bozzolo during the St Gothard epidemic. The particular method followed is practically that recommended by Lutz, who has discussed the treatment very fully[1], and it was adopted in Cornwall on the advice of Sir Patrick Manson.

The following cases illustrate the effects of treatment:—

R. C., age 25. Miner at East Pool Mine. When seen in Nov. 1902 had been ill with pallor and dyspnoea for 12 months. During this period he had been vigorously treated with iron, arsenic and other drugs, including β naphthol and bone-marrow, but had grown steadily and progressively worse. He had been so ill that he had been at home for 7 months and for a fortnight had been unable to leave his bed. He was intensely pale and very weak: there was no oedema. Hb. 17 p.c. Eggs very abundant. He received thymol treatment on Nov. 21, Nov. 28 and on Dec. 19, as up to the latter dates his stools still contained eggs. On Dec. 10 Hb. = 25 %, and on Dec. 16 he was well enough to go for a walk. On Dec. 18 Hb. was 36 p.c. On Feb. 2, 1903 Hb. = 60 p.c., and on March 10 he was returning to work with 84 p.c. Hb. He was now in excellent health, and shortly afterwards left England for the S. African mines.

J. S., age 51, was overman for shaft-work. Illness began in 1899 with general weakness, palpitation and dyspnoea. Gave up underground work, stopped at home for 6 months, and then, somewhat better, did light overman's work on the surface. He had marked general oedema in 1901. In Nov. 1902 he was still seriously ill and for some time past had made no further improvement. Hb. 48 %. Eggs abundant. On Nov. 14, 264 worms were obtained after thymol; patient said he felt better after this but on Dec. 1 his Hb. was only 43 % and plenty of eggs were still present. During the winter patient made no great improvement though he felt distinctly better and his gastric symptoms were relieved. In the early part of 1903 he received two further dosings with thymol and during the spring and summer made good but slow progress. In the summer his faeces were twice examined by one of us with negative results, and in Dec. 1903 a very thorough search failed to reveal any eggs. His Hb. in July was 64 %, and on Dec. 3, 92 %.

P. P., age 43. Worked formerly as an ordinary miner at Dolcoath mine. Illness began 4 years ago with palpitation and dyspnoea, also had "bunches" badly. At home 5 months, when he improved considerably, but has only been able for light employment on the surface. Is pale, weak, more or less emaciated, and very

[1] Volkmann's *Sammlung klinischer Vorträge*, No. 265, 1885, p. 2478.

depressed. Has some of the appearances of commencing miner's phthisis. Hb. 35 % on Oct. 31, ova fairly abundant in faeces. On Dec. 8 came to the Radcliffe Infirmary, Oxford, where he was under the care of Dr Ritchie. Very careful examination of lungs, heart, and other organs disclosed no abnormality. On Dec. 16, and again on Dec. 26, Hb. = 44 %. On Dec. 26 three 30-grain doses of thymol after a purgative. No faeces till Dec. 28, when only about 11 half-digested worms could be found. Jan. 5, Hb. = 51 %. Very few ova present in the faeces. Jan. 10, thymol treatment repeated. About 17 worms or parts of them found in the faeces. Jan. 13, Hb. = 62 %. Jan. 19, repeated search shows no more ova in the faeces. Feb. 7, Hb. = 71 %. Feb. 10, Hb. = 73 %. Patient went home very greatly improved, and was now quite bright and cheerful. He had, however, only gained 5 lbs. in weight in spite of careful feeding, and he still looked very thin. Dyspnoea and palpitations much less, but still distinctly present. He found himself unable for hard underground work; and although he continued well for the next few months we hear that he has recently developed a bad cough and other symptoms of lung trouble.

The medicine which is universally used at the Westphalian collieries for treating ankylostomiasis is ethereal extract of male fern. As the doctors engaged in treating the disease are nearly all under the direction of Dr Tenholt, the Chief Medical Officer of the Knappschafts-Verein, the procedure employed is fairly uniform. Dr Tenholt informed one of us that as a general rule the following plan is adopted:—

On the first day, the patient, who is kept within the hospital, receives in the evening a purgative, consisting of 0·3 gramme (5 grains) of calomel. Next morning he takes no food, and is given 8 to 10 or 12 grammes (2 to 3 drachms) of extract of male fern, the taste being usually concealed by the addition of syrup of senna and a little chloroform. In the afternoon a further dose of 0·3 gramme of calomel is given. The patient is only kept in bed if he is weak. On the third day no medicine is given, except a further dose of calomel in the evening if required. On the fourth day the dose of male fern is repeated in the morning and the calomel in the afternoon. On the 5th, 6th, and 7th days the faeces are examined for ova, and if on three successive days no ova are found the patient is discharged. If ova are found the whole course is repeated from the beginning, and at the end of another five days the examination is repeated. If the result is again positive there is another week of treatment and examination. If at the end of this time ova are still present the patient is discharged for the time, as further treatment would be unwise. He cannot, however, return to work underground.

Such energetic treatment is, of course, not without its risks; but although several thousand men have been treated no deaths are known to have been caused by the treatment. There have, however, been two cases of permanent blindness, several cases of temporary affection of

vision, and a few cases of alarming collapse. Dr Tenholt remarks that some of the cases in which very few ova were present in the faeces have been most resistant to the medicine.

The opinion of both Dr Tenholt and Prof. Loebker is that extract of male fern is preferable to thymol, provided that care is taken that the extract employed is fairly fresh. Experience with thymol did not seem, however, to have been very extended in Westphalia.

It is clear enough that both extract of male fern and thymol are very effective remedies, and there is little doubt that one or the other will continue to be preferred by different doctors. Thymol, has, however, the advantage that it can always be obtained in good condition. It has been used very extensively by English medical officers in Egypt, India, the West Indies, West Africa, &c., and seems to have given very satisfactory results.

To obtain the desired result it is necessary that the drug should be well powdered and administered in sufficiently large doses. Doses of two or three grains are quite useless. The doses necessary are so large that their administration would be attended with no inconsiderable risk if any material proportion were absorbed from the bowel. An amount sufficient to turn the urine dark brown or black is often absorbed when 90 grains in all are given. To prevent this reaching a dangerous quantity one must be careful to avoid giving anything to the patient in which thymol is soluble. It is for this reason that alcohol, oils, and fats should be withheld; above all the drug itself must not be given dissolved in alcohol. Sandwith has found that brandy does no harm, and is of use with very reduced patients, but it is better not to run any risk of occasionally meeting with someone who shows an idiosyncrasy towards thymol. The experiments of Stiles and Pfender[1] show that the administration of alcohol with thymol reduces the minimum fatal dose for dogs.

Whatever anthelmintic is used, it is of great importance that the results of treatment should be properly gauged by microscopical examination of the faeces. Thymol is sometimes without effect, and, though a partial clearance of the worms will nearly always benefit the patient, a complete cure cannot be looked for unless all the worms have been killed. As an infected individual, a partially cured patient is more dangerous than one who is manifestly anaemic and incapacitated from work. To secure this complete destruction of the worms it is frequently necessary to repeat the thymol or other treatment more than

[1] Stiles, *loc. cit.* p. 87.

once. In Cornwall the very few cases which are known to have been treated to a cure (*i.e.* till no more ova could be found in the stools) have all required more than one dose. Of the 184 cases recorded by Sandwith[1] only 23 % were cured by one dosage with thymol, and 23 % required more than three dosages. The largest number necessary was eight, and the average number 2·6.

In some instances thymol fails to kill the worms at all. C. F. Fearnside[2] gives some examples where daily doses of 20 or 30 grains continued over long periods left many eggs still in the stool; we have had one case where after 40 grains no worms could be found in the faeces: subsequently 60 grains produced large numbers.

Thymol, again, may kill all the worms, but may yet fail to save the patient's life. Cases where the severity of the disease has so destroyed the patient's constitution that the process of reparation fails despite removal of the cause will be chiefly found among those who are subjected to the concurrent ravages of some other chronic disease, or chronic starvation.

Sandwith had eight cases which died after thymol treatment, and T. A. Claytor[3] has recorded a case which proved fatal, although the condition of the blood had much improved under an extremely vigorous and apparently successful course of thymol.

In estimating the efficacy of treatment, it is necessary to wait a few days before examining the stools. Some worms may still be present, but may not be laying eggs freely immediately after having been subjected to the action of an anthelmintic. That this may actually occur has been shown by Bücklers[4].

We cannot too strongly emphasize the fact that it is most undesirable to undertake the treatment of a case unless one is prepared to give adequate doses, and to repeat such doses at intervals until the faeces are found (on thorough examination) to be free from ova.

Prevention of Ankylostomiasis.

It is evident that the problem of preventing the spread of ankylostomiasis differs greatly in warm climates where the disease is endemic among the general population, and in temperate climates where it is

[1] *Lancet*, 1894, I. p. 1365.
[2] *Brit. Med. Journ.* 1900, II. p. 541.
[3] *American Journ. Med. Sciences*, CXXIII. 1902, p. 28.
[4] *loc. cit.*

only met with under special circumstances, as in underground work. In the latter case the task of prevention is much less difficult.

It follows from the account given above of the life-history of the *Ankylostoma* that to prevent the spread of ankylostomiasis it is necessary to prevent the ripe larvae from entering the body. This end might be attained either by personal precautions against ingestion of larvae by the mouth and skin infection, or by preventing the development of larvae. We may first discuss what may be obtained by the former means.

There is no evidence, and very little probability, that larvae may be present in water which to naked eye examination is perfectly transparent. If larvae are brought into water they rapidly sink to the bottom, and are therefore very unlikely to be present in clean water, since the finer sediment with which they are abundantly mixed in the polluted mud or dirt where they develope settles more slowly than the larvae themselves. We believe that there is practically no risk of infection if care be taken that only clear water is drunk. Among the native populations in some warm countries even this elementary precaution is not, however, taken, muddy water being sometimes drunk, so that as a matter of fact ankylostomiasis is probably spread to a considerable extent by water. So far as we have been able to ascertain the underground water in mines is very seldom drunk by miners in European countries, the almost universal custom being for miners to take sufficient water, tea, or coffee with them from the surface, unless water from the surface is supplied by special pipes, or there are springs unconnected with workings above. The water which drains from a mine is evidently liable to pollution of all kinds, both organic and inorganic, and ought never to be drunk.

Ankylostoma larvae may also be ingested with dirty food, and absence of ordinary precautions in this respect is doubtless often responsible for infection. In mining work it is often difficult for the miners to properly clean their hands before taking their underground meals. The food can, however, be kept wrapped up in paper when handled, and by this means kept from contamination. This simple and effective precaution, which is very commonly adopted by miners, ought to be always taken when food has to be eaten with unwashed hands.

Infection is probably often carried by introducing dirty hands into the mouth, by dirty pipes, &c., and this would be prevented by more cleanly habits.

Air-borne infection seems to be very improbable. In the first place

living *Ankylostoma* larvae are naturally found only in damp material, which cannot be suspended as dust. If this material is dried and thus becomes capable of suspension in air, the larvae are killed by the drying. In any case they are so bulky that if by any means they were temporarily suspended in the air they would rapidly fall to the ground.

In mining and other similar work it appears to be probable that the most serious risk of infection is through the skin, and the nature of the work makes it quite impossible to avoid this. European miners wear thick boots, so that their feet are but little exposed; but the high temperatures often make it impossible for them to work unless they are lightly clad, and often they have to work stripped to the waist. Temperatures of from 80° to 95° are, for instance, common in Cornish mines. In any case their thin clothing is probably very little protection against *Ankylostoma* larvae, as their clothes are very often wet with mine water or perspiration, so that the larvae will easily penetrate to the skin. Practically the only precaution that can be taken is to avoid unnecessary contact with mud, dirty water, or damp surfaces which are likely to be contaminated with larvae; and doubtless much may be done in this way. The contaminated soil is, however, liable to be carried all over a mine, including the ladders used in metalliferous mines and in coal-mines where, as is common in Westphalia, the strata run almost vertically up and down. The larvae may find their way on to damp wood, and the Dolcoath miners often attribute their "bunches" to contact with damp wood.

This brings us to the consideration of measures designed to prevent the development of larvae in places where they might give rise to infection. One method of attaining this object is to establish a rigid system of excluding persons infected with the worm from the places where the development of larvae would entail risk. To exclude such persons it is necessary to institute a medical examination of everyone admitted, and exclude all those whose faeces contain ova. To exclude only those who are evidently anaemic would clearly be of little use from the point of view of prevention, since for one person who is actually anaemic there will usually be a large number who are infected though not evidently suffering in health. In the most infected Cornish mine, for instance, it appeared from our observations that practically speaking all the men were infected, while comparatively few were markedly anaemic. Many of the infected men had a completely normal percentage of haemoglobin. The same observation was made on a much larger scale in the Westphalian colliery district, where complete

statistical information was obtained with regard to many of the mines[1]. It was found that while in nine of the most seriously affected collieries only 958 men had been noticed at the periodical medical inspections during 1902 to be visibly anaemic, yet ova were present in the faeces of 6,190 men at the end of the year. In consequence of the general alarm produced by the spread of infection among the miners it was enacted in 1903 that in addition to sanitary precautions underground the faeces of 20 % of the miners working in each colliery should be examined, and that when as a result of this examination a mine was found to be, in the opinion of the Chief Inspector, infected, the faeces of all those employed in it should be periodically examined, and the infected men excluded from work until they had been completely freed by treatment from the worms, and satisfactory evidence from a specially qualified physician was forthcoming that no ova were present in their faeces. Special doctors were attached to each infected mine, with the sole duty of conducting the microscopic examinations and treatment. Barrack hospitals were also provided for the treatment of those infected, and the certificate of freedom from infection was only given after examination of the faeces on three different days, as it was found that a negative examination on one day did not afford sufficient evidence.

The effects of these regulations, which were very thoroughly carried out, have been most marked, as might be expected. In every colliery where they were applied the percentage of infected men has greatly diminished. Thus in six large collieries for which complete figures were recently available the average percentage of infected men had diminished from 30 % at the first round of examination and treatment to 8·7 % at the third; and cases of anaemia had apparently disappeared entirely. At another colliery the percentage of infected men was 20 % at the first examination, 13 % at the second, 8 % at the third, 3·6 % at the fourth, and about the same at the fifth, sixth, and seventh examinations. The latter observations seem to indicate that it is difficult to completely eradicate the infection. Official statistics which have just been published show that out of 188,730 men employed in the mines of the district 17,101, or 9·1 %, were infected. In the collieries declared to be infected

[1] For recent detailed information with regard to the Westphalian outbreak see the Report by Dr Haldane to the Home Secretary on Ankylostomiasis in Westphalian Mines, *Parliamentary Paper* [Cd. 1843], 1903: also special supplement to the *Colliery Guardian*, November, 1903.

out of 63,000 men 12,157 were found to be infected, or 19·3 %. By December 1903 this number was reduced to 4,819, or 7·6 %, although in most of these collieries only one round of examination and treatment had been completed. Considering that at the time when the measures just referred to were initiated the disease was rapidly spreading, this is a most striking result.

The inconvenience and expense of carrying out such regulations is of course very considerable. In Germany however the matter is greatly facilitated by the fact that there is established by law a very complete medical and insurance organisation for the miners, with ample funds, which are obtained by deducting a certain amount weekly from the miner's wages and the mine-owner's profits. The yearly income of this association in Westphalia is about £1,500,000, the number of members being about 200,000. This organisation has provided doctors and hospitals, and its certificates must be produced by men applying for work, so that infected men can easily be traced. A great deal of the expense falls however directly on the colliery-owners, who have paid part, at least, of their wages to the men confined to hospital for treatment, besides other heavy expenses. The treatment and subsequent examinations occupy at least a week, but often much longer, as repeated doses of vermifuge remedies are commonly needed in order to completely expel the worms. The men not unnaturally object to the treatment and confinement to hospital, particularly as they themselves seldom feel in the least out of health, and the treatment is far from pleasant and occasionally causes symptoms of collapse and impairment of vision. Several cases of permanent blindness or impaired vision have been observed in Westphalia as a result of large doses of male fern.

The difficulty of carrying out this system would certainly be greater in England and elsewhere than in the Westphalian mines; and the question arises whether it is not possible to obtain almost equally good results for practical purposes by easier and less expensive means. The Westphalian system of inspection and treatment has been combined with very thorough sanitary precautions underground, which seem to be necessary in any case, and which must now be discussed.

It is clear that if contamination of the ground by human faeces can be altogether prevented there is no possibility of ankylostomiasis spreading, as ripe larvae cannot then reach those who would otherwise be exposed to infection. Ankylostomiasis seems to be entirely absent as an endemic disease in towns with any moderately good system of

removal of excreta. This is the case even in countries such as Egypt and the tropical parts of the South American Continent, where the disease is very prevalent in the agricultural districts. There may be great difficulties in carrying out efficient measures for the safe disposal of human faeces among the native populations in tropical countries; but in European and North American countries at any rate such measures ought not to present much difficulty. The state of matters disclosed by Stiles in the case of country districts in the Southern States of America might, for instance, well be remedied by suitable sanitary administrative measures. The same remark applies to the case of mines and brick-fields in North European countries.

So far as we have been able to ascertain it is a very general custom among miners in England to deposit their faeces at any convenient place in the mine. Some miners, it is true, very seldom make use of the mine for this purpose, but others do so regularly. We are informed that in some collieries the men usually bury the faecal deposits in coal-dust in the "goaf" (worked-out part of the mine); but it is quite common to find these deposits at the sides of haulage roads in wet places, and elsewhere in positions where they might easily be trodden on and thus carried about the mine. In England there are no legal regulations of any kind with regard to pollution of mines by faeces.

Some mines must be much more liable to become infected than others. It follows from what has been said above that when a mine is naturally, or on account of very free ventilation, dry, the larvae can hardly develope to the infective stage. In all mines, however, wet parts can be found; and pumping is always needed to keep the workings from being flooded.

In some mines, again, the temperature may be so low that development of the larvae only occurs very slowly, if at all. There are, however, very few mines of any size in England where a temperature of over 16° C. (61° F.) is not met with in many parts of the workings; and it has been shown above that the infective larvae can develope at this temperature. Experience hitherto in Westphalia seems to indicate that there is much less likelihood of a mine becoming seriously infected if a temperature of over 21° (70° F.) is not reached at the working face; but both laboratory experiments and the data obtained in the course of the Belgian Government Enquiry on ankylostomiasis show that mines with a much lower temperature may become infected. Out of 41 infected mines in the Liége District the temperature at the working face is

stated as under 20° (from 15° to 20°) in 16 cases[1]. The percentage of infected men varied from 4·4 to 5·2.

In Levant Mine near St Just in Cornwall the temperature is very high, ranging from 23° (71° F.) at the bottom of the down-cast shaft to 34·5° (93°) in the deep workings. The workings are also very wet. Yet there are no symptoms of ankylostomiasis among the miners, though it seems almost certain that infection has been repeatedly introduced. The workings are under the sea, and the mine-water is salt. A sample was found to contain 1·8% of sodium chloride. In this water we found that newly hatched larvae (though not the ripe "encapsulated" larvae) were killed; and probably the freedom of the miners from ankylostomiasis is due to the salt water. In some other mines similar causes may prevent the growth of the larvae.

In spite of the fact that some mines may doubtless be practically immune from infection with *Ankylostoma* larvae we think there is urgent necessity for measures to prevent pollution of the workings of any mine by human faeces. Even if there be no risk of ankylostomiasis through the absence of such regulations, there is certainly risk of the spread of other infective diseases such as enteric fever. For this reason, and because in practice it is evidently very difficult to say whether or not any particular mine would be immune to ankylostomiasis, we think that the regulations should be made legally compulsory. A further reason in favour of making no exceptions is that when only certain mines come under regulations of this kind difficulties are more apt to arise with the miners, who are accustomed to move freely from one mine to another.

To carry out the object of preventing pollution of a mine by human faeces it is necessary to prohibit such pollution under a sufficiently deterrent penalty; we have no doubt that the great majority of miners would support the regulations, but there are always some, particularly among the younger and thoughtless men, who could only be restrained by the fear of punishment in some form.

As a rule there is no reason why any miner should require to relieve his bowels underground except very occasionally, and the habit which some miners have of doing so should be put a stop to. The necessity will, however, sometimes arise; and arrangements must be made to provide for this. In the Westphalian mines galvanised iron receptacles,

[1] Barbier. Paper read before the International Congress of Hygiene, Brussels, 1903, Section IV. The figures are given in the Table at the end of the paper.

furnished with a seat and air-tight cover, are placed in convenient positions along the roads and in the workings of each mine, the duty of providing and keeping them in order being thrown on the mine-owners. At Dolcoath Mine in Cornwall galvanised iron pails of a convenient height are now provided, but without seats, since the latter are apt to become soiled. In Westphalia milk of lime, which kills the larvae with certainty, is generally used as a disinfectant. It has, however, the disadvantage that it does not act as a deodorant; and the smell from the receptacles is very unpleasant. At Dolcoath dry disinfectants have hitherto been used for the pails; but information as to the best practical disinfectants has not yet been obtained. Many substances are probably available. The experiments quoted above show, for instance, that ·5 % izal emulsion will kill even the "encapsuled" larvae. Strong-smelling disinfectants are scarcely available in a mine.

Any legal restriction as regards pollution of the ground by miners would require to be accompanied by provisions requiring mine-owners to provide and keep in order a sufficient number of underground receptacles for the reasonable requirements of the miners. It is also desirable that a sufficient number of good privies or water-closets should be provided on the surface, though the need for this is not so great at English collieries as in many Continental mines, where the men change their clothes and wash in a building provided at the pit-head. We can see no reasons why the regulations just recommended should not be successfully carried out in all mines; and where they were carried out the infection of a mine with ankylostomiasis and other similar filth diseases would be practically impossible.

In the case of mines which have already become thoroughly infected there is much to be said in favour of the Westphalian plan of continuing for some time to examine and treat every man in the mine for infection with the *Ankylostoma*, and at the same time introducing strict sanitary regulations and endeavouring by every means to destroy the larvae already present. The practical difficulties of carrying out such a plan in any mine in Great Britain are, however, very considerable, and would require to be carefully taken into account beforehand. One of the first results of introducing such a plan might probably be to disperse the miners to other mines and to prevent other men from applying for work. On the other hand, when a mine is once thoroughly infected, the men employed in it will continue for many years to be a source of danger to other mines; and the infection will be got rid of very slowly by sanitary

measures, however perfect, since the adult worms, and possibly even the larvae, may continue to live for some years.

Men who are suffering from symptoms of ankylostomiasis ought never to be allowed to work underground unless they submit to efficient medical treatment. They are not only an evident source of danger to other miners, but they may easily become so ill as to be incapable of providing for themselves and their families, even if they are not in actual danger.

In the case of mines which are not infected, mine-owners would do well to exclude as far as possible infected men. Any new men coming from infected countries or districts might well be examined medically before being allowed to work underground. By this means the risks of infection would be considerably diminished, though by no means abolished. Local arrangements might easily be made for the examination of samples of faeces from suspected men.

In some cases it may be possible by increased ventilation to so dry a mine or reduce the temperature that the development of ripe larvae is impossible; and doubtless the excellent ventilation in most English collieries greatly reduces the risk of ankylostomiasis. In such cases, however, not merely expense but also other factors have to be taken into account. For instance, in metalliferous mines the dangers from inhalation of stone-dust completely dwarf those from ankylostomiasis; and a dry mine, which would probably be more dusty, might be far more dangerous to health than a wet one. In coal-mines the risk of coal-dust explosions has also to be considered; and to guard against these the Westphalian Board of Mine-inspectors, supported by the Mine-managers, have deliberately continued the system of keeping every working part of the mines damp, although they are well aware that by doing so they greatly increase the chances of the mines becoming infected with ankylostomiasis.

Addendum. We have just received an important paper (*Klinisches Jahrbuch*, Vol. XII. 1904) by Dr H. Bruns, Director of the Bacteriological Laboratory, Gelsenkirchen, on "The Influence of Physical and Chemical Agents on the Ova and Larvae of *Ankylostoma*." This paper not only contains a description of experiments referred to above, the results of which were kindly communicated to one of us by Dr Bruns, but many additional data of much interest. Bruns found, for instance, that after 5 days at 5° to 7° C. all ova and larvae were destroyed; that larvae were killed by 3 days, and ova by more than 16 days, of deprivation of

oxygen ; that larvae died after 20 days in clean tap-water ; that dilution of faeces up to from 10 to 100 times favoured the development of ova, while dilution to 1000 times or more prevented their development ; that while average faeces contain about 80 % of water, in faeces dried till only about 60—70 % of water was left ova would not develope ; and that ova were killed when only 40—45 % of water was left. He also describes a large number of experiments with various disinfectants, and mentions that many attempts at practical disinfection underground by spraying disinfectant solutions had been unsuccessful. These trials were made by himself and Mr G. A. Meyer, the well-known Manager of Shamrock Colliery in Westphalia.