AN OUTBREAK OF ANKYLOSTOMIASIS IN ENGLAND. No. I.

(Plates I—V. and One Figure.)

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CONTENTS.

The outbreak which is the subject of the present paper was discovered in the course of an enquiry which is at present being made on the request of the Home Secretary by Mr J. S. Martin, Inspector of Mines, and one of us, into the ventilation of Cornish mines. A number of cases of anaemia had occurred among the miners employed at Dolcoath Mine, Cornwall; and as the anaemia was generally attributed to some defect in the ventilation, this mine was among the first visited. On examination into the state of the mine, the symptoms of the affected men, and the history of the outbreak, it appeared that the anaemia was almost certainly caused by ankylostomiasis. A more detailed enquiry, in which we have both been engaged, established beyond all doubt the nature of the disease, and has furnished the opportunity of investigating a number of points bearing on the nature and method of spread of ankylostomiasis. A short report on the outbreak has already appeared[1]. We are indebted to Dr S. G. Scott,

[1] Haldane, "Report to the Home Secretary on an Outbreak of Ankylostomiasis in a Cornish Mine," *Parliamentary Paper*, 1903.

who has also been engaged in the Home Office Enquiry, for a number of valuable notes as to blood-examinations, and many other details.

As is well known, ankylostomiasis is one of the commonest diseases in tropical and sub-tropical countries. Its main symptoms are those of anaemia; and it is due to the presence in the upper part of the small intestine of numerous small worms of the species most commonly known as *Ankylostoma duodenale*. The worm itself was first described in Italy by Dubini[1] in 1838, but its definite association with anaemia was discovered by Griesinger[2], who showed that the disease known as Egyptian Chlorosis is due to its presence. A few years later Wucherer showed that the anaemia common in Brazil is ankylostomiasis; and ankylostomiasis has since been identified in many other tropical and sub-tropical countries as a common, wide-spread, and very troublesome disease. About twenty years ago there occurred a very serious outbreak of anaemia among the men engaged in the construction of the St Gothard tunnel. This was shown by Perroncito and others to be ankylostomiasis. The disease was more fully studied, and the present methods of treatment by large doses of extract of male fern or thymol were introduced. In recent years the disease has spread in French, Belgian, German, and Austrian collieries, causing much trouble.

The worm does not reproduce itself within the intestine, but the female produces an enormous number of ova, which pass out in the faeces, and under suitable conditions of temperature etc. develope into larval worms. According to some observations there is a free sexual form of the worm outside the body, but it is most generally believed that this is not the case, and that infection is conveyed by swallowing the larval worms. It has recently been shown by Looss[3] that the young worms are capable of penetrating into the hair-follicles and producing a local dermatitis. The same observer believes that the young worms may reach the intestine by passing onwards from the hair-follicles.

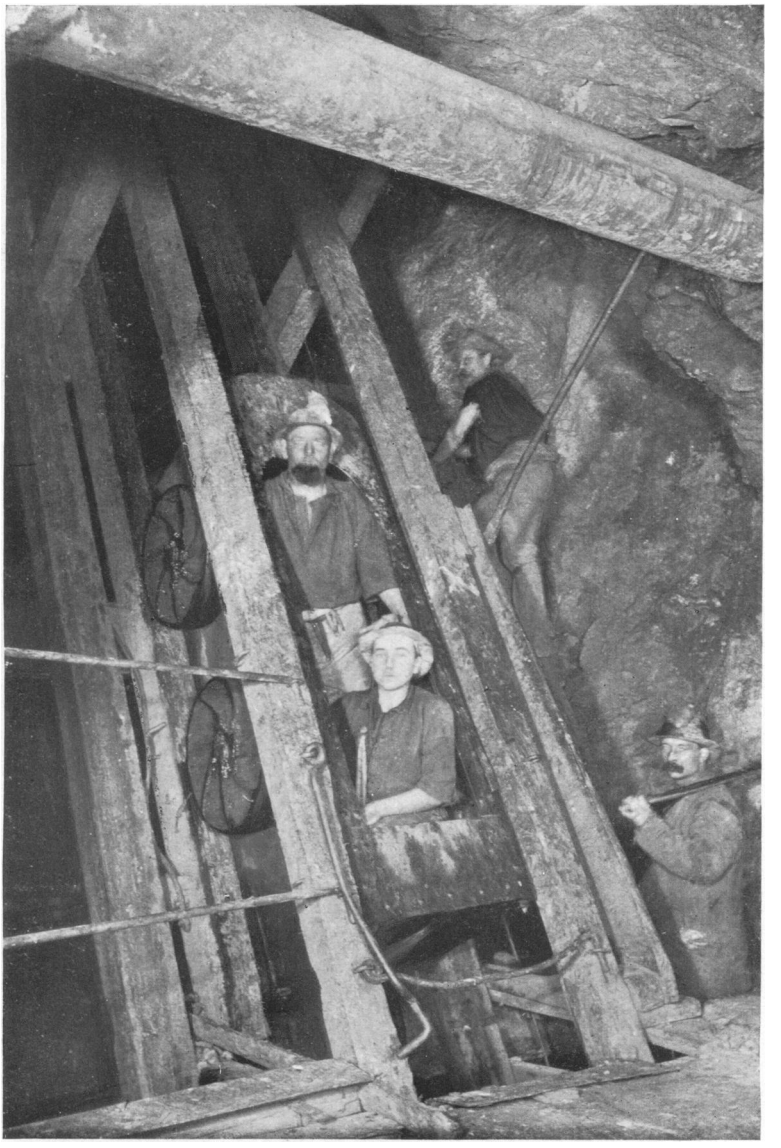
The Conditions met with in Dolcoath Mine.

As the occurrence of ankylostomiasis in an English mine evidently depends upon the special conditions underground, some account must be given here of these conditions as they exist at Dolcoath and in other similar mines.

[1] *Annali Univ. di Medicina*, 1843.

[2] *Archiv f. physiol. Heilkunde*, Vol. XIII., 1854, p. 555.

[3] *Centralbl. f. Bakt. u. Parasitol.* 1898, Vol. XXIV., pp. 483—488; 1901, Vol. XXIX., pp. 733—739.



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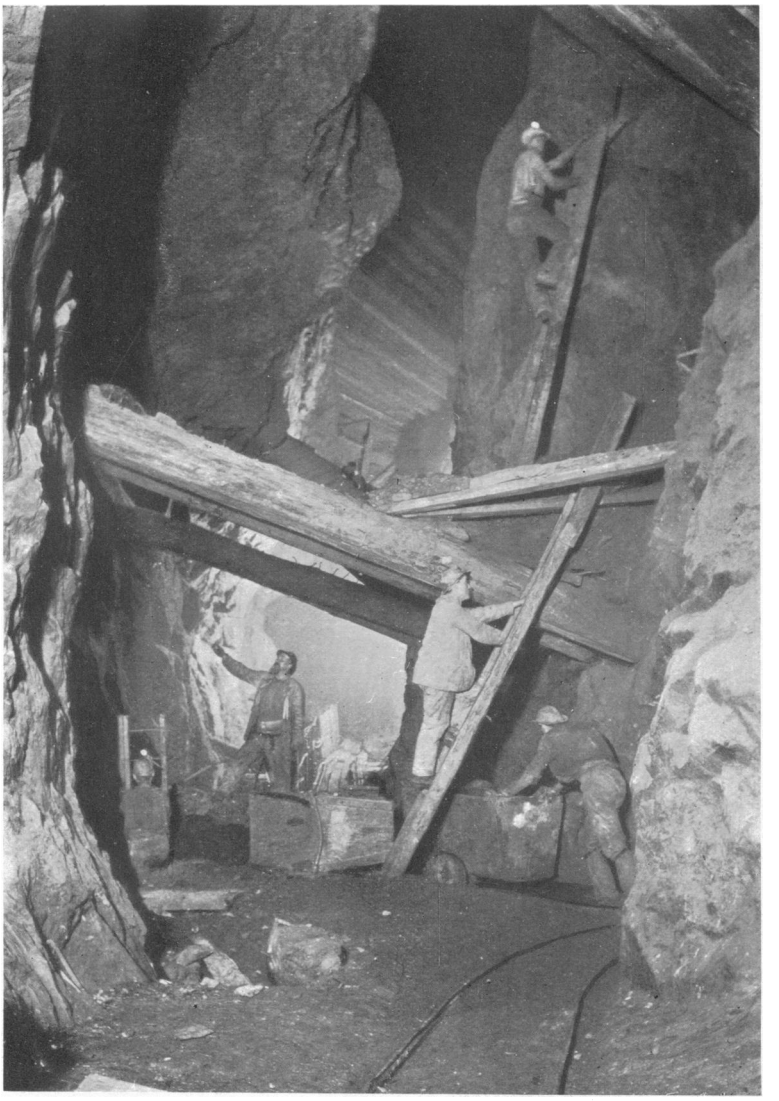
Gig at 302-Fathom Level, Dolcoath.



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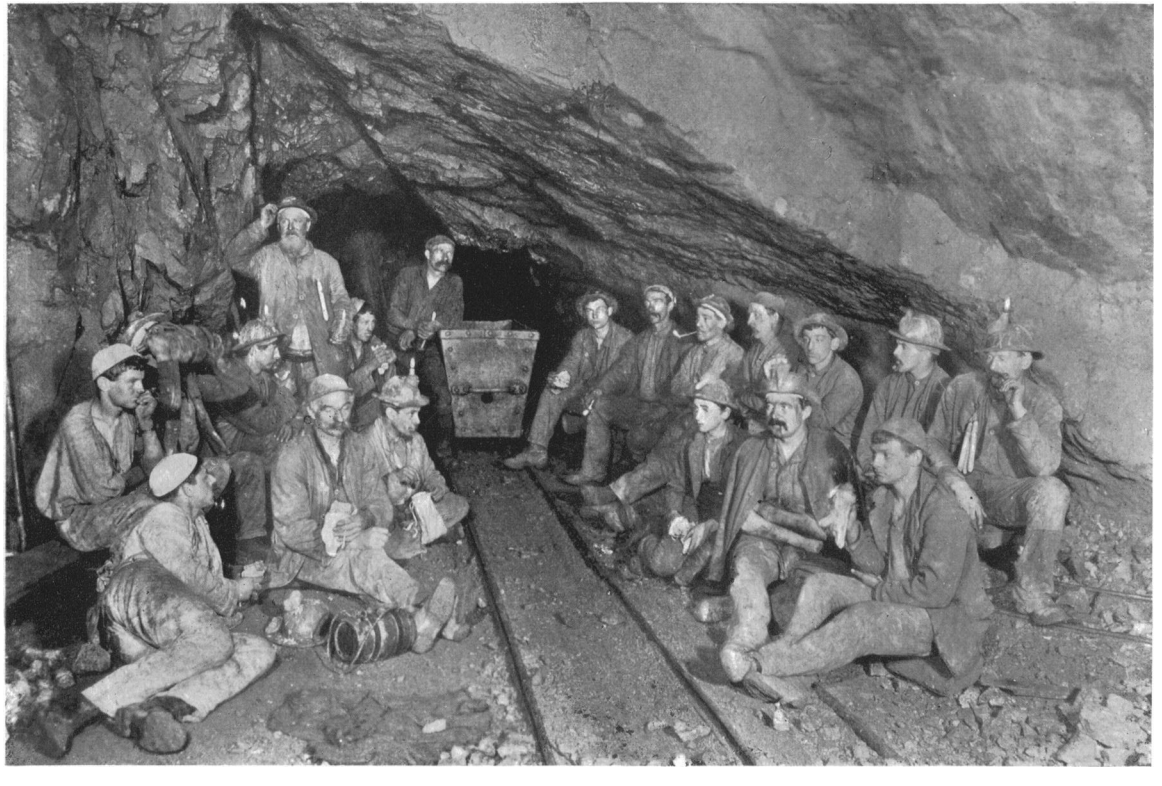
In 170-Fathom Level, East Pool Mine.



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Croust-time in a Cornish Mine.

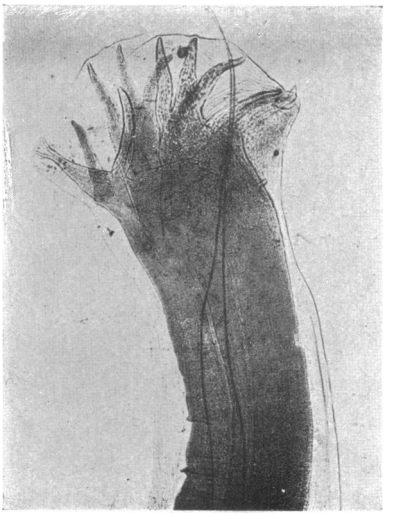

Fig. 1. Posterior end of adult male Ankylostoma, × 40.

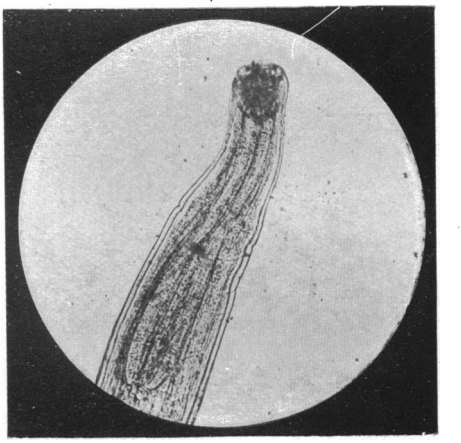

Fig. 2. Head of adult Ankylostoma, × 30.

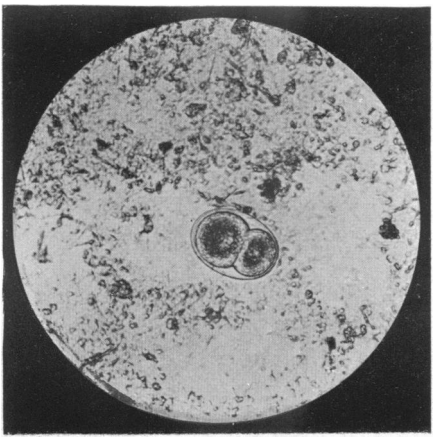

Fig. 3. Two-cell stage of developing ovum, × 200.

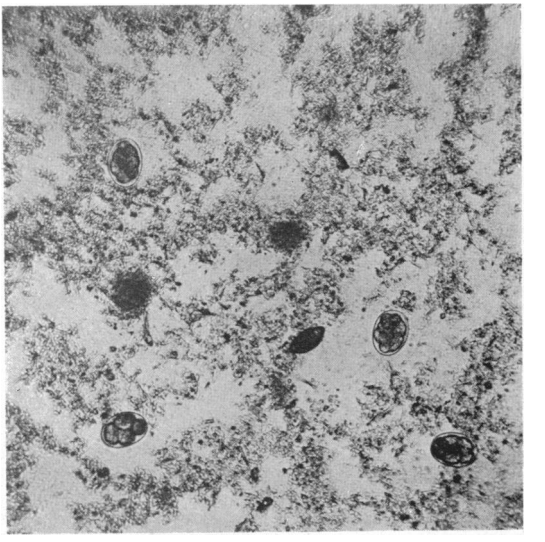

Fig. 4. Ova at different stages. Near centre an ovum of *Trichocephalus dispar*, × 50.

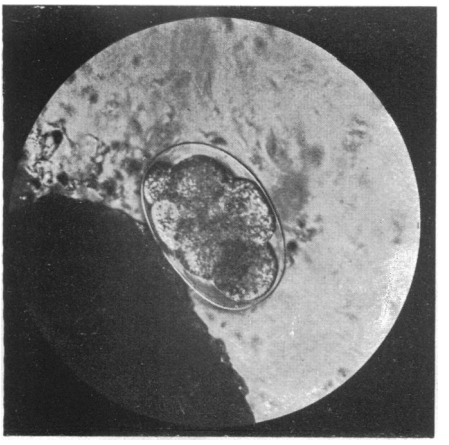

Fig. 5. Eight-cell stage of ovum, × 400.

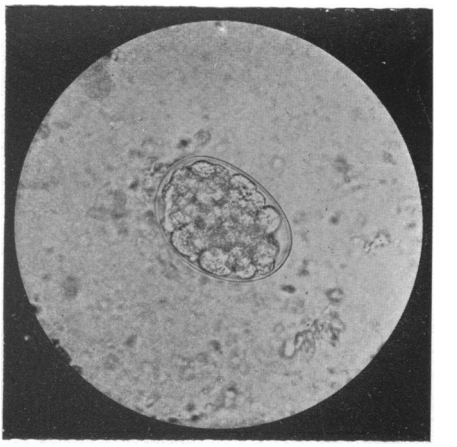

Fig. 6. Morula stage of ovum, × 400.

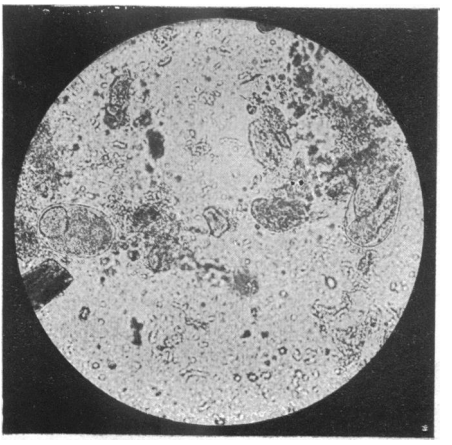

Fig. 7. Ova showing larval worm coiled up inside, × 160.

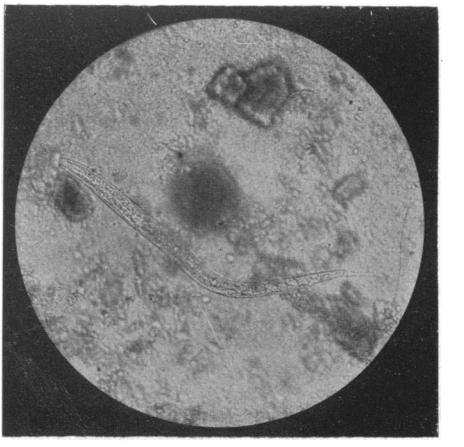

Fig. 8. Recently hatched larval worm

The Cornish mines, including Dolcoath, are all metalliferous, by far the most important metal extracted being tin. The ore occurs in lodes, which run downwards through the "killas" (an argillaceous schist) and granite. The workings follow the lodes downwards, the lode being extracted wherever it is rich enough to repay the expense, and left where this is not the case. Fig. 1 (p. 136) shows a vertical section of the Dolcoath Main lode, which runs down nearly vertically through the killas and granite. The depths are indicated in fathoms (1 fathom = 6 feet or 1·83 metres). It will be seen that copper ore occurred in the upper part of the lode, and was formerly mined. The present workings are mostly at a depth of over 2000 feet and have reached nearly 3000 feet. Only tin ore is now obtained.

The ore is wound up through several shafts in iron boxes known as "skips," which run on wheels wherever the shaft is not vertical. Somewhat similar iron boxes known as "gigs" are used for the conveyance of men to and from their work (see Plate I.)[1]. There are also ladder-ways at the sides of the shafts, and at many points throughout the workings (Plates I. and II.), to enable the men to pass from level to level. In working the lode the shaft is first sunk, and levels driven horizontally outwards from it (see Figure 1). The latter are then connected at intervals with the level above by "winzes" driven upwards or downwards through the lode, by which means adequate ventilation of the levels is secured. The portions of the lode, or "stopes," thus blocked out are then gradually removed, the ore being shot down into the level below and removed to the shaft on small wagons running on rails and pushed by hand. In driving the levels and "rises" passing upwards from them, rock-drills driven by compressed air are commonly used for boring the holes which receive the explosive (usually dynamite). On the stopes hand-drills are used. The space left after the lode has been extracted is known as a "gunnis," and may extend upwards or downwards for hundreds of feet. When a level crosses a "gunnis" the roadway is supported on timber.

The general ventilation of a Cornish mine is produced, almost invariably, by "natural" means only. Large fans or furnaces, as in coal-mines, are not employed, nor would it be possible to employ them unless the shafts were closed laterally so as to prevent short-circuiting between downcast and upcast shafts. The air-currents down the downcast, and up the upcast shafts depend on the fact that the

[1] Plates I. II. and III. are from photographs taken by magnesium light by Mr I. S. Burrow, photographer, Camborne, and reproduced by his permission.

temperature below is usually much higher than on the surface, and that even when, in warm weather, the difference of temperature would not by itself suffice to produce a current, the temperature in any shaft which has been previously acting as a downcast will always be lower, at the same levels, than in the corresponding upcast shaft. The general course of the air-currents in Dolcoath mine is indicated by the arrows on the section. It will be seen that roughly speaking the air passes down by the shafts at each end of the section of lode worked, and passes up by the shafts in the middle. The temperature is consequently a good deal lower in the Eastern and Western (Stray Parks) shafts than in the middle shafts—a fact which, as will be seen below, was probably of considerable significance in relation to the spread of ankylostomiasis among the miners.

To ascertain the amount of impurity in the air of the mine samples were taken at the points marked A to H on the section. These samples were collected on October 16th 1902 in stoppered bottles by the method described in this *Journal*, Vol. II. p. 416. The analyses were made by the method described by one of us in the *Journal of Physiology*, Vol. XXII. p. 465, 1898, the gas-burette being that shown at Fig. 5 of the same paper. The results are given in Table I.

TABLE I.

Air Analyses at Dolcoath Mine.

	Oxygen per cent.	CO_2 per cent.	Oxygen diminished per cent.	CO_2 increase per cent.
Outside air (was perfectly pure).	20·94	·03	0·00	0·00
A. 302 fathoms level in Eastern (downcast) Shaft.	20·94	·03	0·00	0·00
B. 302 fathoms level at end, cross-cut in granite, air blown in.	20·82	·08	0·12	0·05
C. 375 level, North Lode, at stoping in open place.	20·79	·110 / ·115	0·15	0·08
D. 412 level, large open gunnis (dry 77°, wet 76°).	20·85	·095	0·09	0·065
E. 440 level, at New Bridge (dry 77°, wet 76°).	20·83	·09	0·11	0·06
F. 470 level, rise in crosscut north of lode, drill idle.	20·67 / 20·66	·22 / ·23	0·275	0·225
G. 455 level, bottom of Engine (upcast) Shaft (dry 79°, wet 78°).	20·85	·095	0·09	0·065
H. 375 level, taken from gig in Engine Shaft.	20·79	·110 / ·115	0·14	0·082

Samples B and H were examined with an incandescent platinum spiral for CH_4, CO, etc., but no traces were found.

It will be seen that the air in the shafts, open levels, and stopes was on the whole surprisingly pure, chemically speaking. The anaemia among the miners could evidently have nothing to do with impurities in the air. On the day when the samples were taken it was found that about 14000 cubic feet (400 cubic metres) of air per minute were passing down the Eastern shaft at A.

The impurities found in the air have several sources—(1) human respiration, (2) combustion of candles, (3) combustion of dynamite, (4) decay of timber, and (5) chemical changes occurring in the lode and surrounding strata. The number of men employed, and the weight of candles and dynamite burnt, between the Eastern (downcast) and Engine (upcast) shafts, would scarcely account for more than about a third of the impurity found in the upcast air; and probably the greater part of it is due to chemical change in the lode and surrounding strata. In certain unventilated levels, where work had been suspended, we obtained clear evidence of the influence of chemical changes in the lode on the purity of the air. Thus in one such level, at the point marked K on the section, which was very hot and dry, the air at the point where a sample was collected caused panting (due to the carbonic acid), and a tallow candle would only burn when held horizontally, with the wick well spread out. The sample consisted of:

Oxygen	18·00.
Carbonic Acid	3·18.
Nitrogen	78·82.

On examining the roof numerous crystals of calcium sulphate were found, along with hydrated oxide of iron. As iron pyrites (FeS_2) was also present in the lode, and water containing carbonate of lime in solution, it was evident that a chemical process represented probably by the following equations was occurring:

$$4FeS_2 + 15O_2 + 8H_2O = 2Fe_2O_3 + 8H_2SO_4, \text{ and}$$
$$8H_2SO_4 + 8CaO,\ H_2O,\ (CO_2)_2 = 8CaSO_4 + 16H_2O + 16CO_2.$$

This process would yield air similar to that found, with a slightly greater quantity of carbonic acid than corresponded to the oxygen which had disappeared. It would seem from some of the analyses in Table I that at other parts of the mine carbonic acid may be reabsorbed by carbonate of lime to form bicarbonate, or to form carbonate of potash from the silicate contained in the granite, as often the increase in carbonic acid (at Dolcoath and other Cornish mines) is considerably less

than the diminution in oxygen. Similar oxidation processes often occur on a much larger scale in coal-mines[1].

The temperatures observed in the Eastern (downcast) and Engine (upcast) shafts, and at various points in the adjoining workings, are shown on the section. The highest temperature indicated (at the bottom of the upcast shaft) is 79° F. (26° C.), but in driving levels and rises from them to levels above, higher temperatures are experienced. A temperature of nearly 90° F. (32° C.) is not unusual at such places in Cornish mines.

There are several causes for the high underground temperature—(1) the heating of the air by compression as it descends the downcast shaft; (2) the higher natural temperature of the strata as depth increases; (3) the presence of men, and the combustion of candles and explosives; (4) heat-production due to oxidation in and about the lode. As the propagation of ankylostomiasis in mines depends to a large extent on temperature, a brief discussion of these various causes is desirable.

Heating of the air by increase of atmospheric pressure as it descends the downcast shaft is observed in all mines. This heating amounts to about 5½° F. (3° C.) for every 1000 feet. As, however, the temperature of the air in descending is affected by the temperature of the shaft-walls, and by the amount of moisture taken up from the walls, the actual difference in temperature between the air at the top and the bottom will seldom correspond exactly to the difference stated. The actual temperature at the bottom seems to correspond approximately to the excess due to compression over the *mean* annual temperature on the surface. At Dolcoath the temperature at the 412 fathom level below adit (= 2500 feet below surface) was 68·5° F. (20·3° C.). As the mean annual temperature at Camborne is about 53° F. (11·7° C.) a temperature of 67° F. (19·5° C.) at this depth would be expected according to the above rule. A somewhat higher temperature is, however, to be expected in summer and autumn than in winter and spring. In an upcast shaft the air is always cooled by decompression. As, however, the air is nearly saturated with moisture at the bottom, mist is formed in the air on its way upwards, and a corresponding amount of latent heat liberated, so that the actual cooling of the air on its way upwards is not so great as the heating on the way downwards. The heating in the downcast shaft, with corresponding cooling and

[1] Haldane and Meachem, *Trans. Inst. of Mining Engineers*, Vol. xvi. 1899.

deposition of moisture in the upcast, is the converse of the phenomena observed when wind blows over a range of high mountains (*e.g.* the Alps). The dangerous drying effect produced by the air in the intake roads of a deep colliery may be compared with the corresponding effects of the "Föhn" wind in Switzerland, while the mist and deposition of moisture always observed in an upcast shaft may be compared with the rain and snow deposited by wind in passing over a chain of mountains.

It will be seen from the section that the temperature in the workings at Dolcoath, as in other mines, is considerably higher than can be explained by the rise due to compression of the air. The difference is certainly due in part to the increased natural temperature of the strata, but there is no doubt that the influence of this factor has been greatly exaggerated, and that the limit of depth at which mining can, with intelligent precautions, be carried on without serious inconvenience from the heat, is very far from having been reached. A series of temperature observations was, for instance, made at Dolcoath for the Royal Commission on the Health of Metalliferous Miners, which reported in 1864[1]. Although at that time the depth reached by the workings was less by 1200 feet than at present, yet the temperatures observed (76° to 84° F.) near the bottom of the Engine Shaft were quite as high as those now met with at corresponding positions 1200 feet lower on the same shaft. According to the most reliable observations in bore-holes the average increase in the natural temperature of the strata is about 1° F. for every 70 feet, or 1° C. for every 126 feet, but the amount varies considerably at different places, and the workings of a mine may be either above or below the natural temperature of the strata, according as the ventilation varies in relation to the heat-production by oxidation[2]. Assuming that the temperature in Dolcoath mine away from the downcast shaft depended on the natural temperature of the strata, and that there was an increase of 1° F. for every 70 feet of depth, we should expect to find a temperature of 94° F. at the bottom level, which is 2850 feet below the surface, whereas the actual temperature is only about 79° F. (26° C.).

The difference may be partly due to a less rate of temperature-increase in the strata at Dolcoath than at most other places, but it is not necessary to assume this. In the paper just referred to it was shown that the heat-production from oxidation in the coal at Hamstead Colliery (as in many other collieries) was greatly in excess of the heat

[1] See Section of Dolcoath Mine at page 14 of Appendix A; also Appendix B, p. 298.

[2] Haldane and Meachem, *loc. cit.*

carried away by the ventilation-current. In consequence of this the temperature of the mine was rising progressively, and spontaneous fires in the coal were becoming more and more troublesome[1]. The heat-production, as compared with the heat carried away by the ventilation current, was calculated from the deficiency of oxygen in the upcast shaft as compared with the readings of dry and wet-bulb thermometers at the bottoms of the downcast and upcast shafts respectively. A similar calculation made for Dolcoath mine shows that the heat carried away by the ventilation-current is considerably in excess of the heat formed in the mine. The workings are therefore being on the whole progressively *cooled* by the ventilation-current, and their comparatively low temperature is thus easily explained. In headings &c. a high temperature must, however, be met with unless the local ventilation is sufficient to carry off the heat formed by oxidation &c., and to cool down the rock as it is opened out.

About 700 men are employed at Dolcoath. They work in three shifts. The mine is almost everywhere damp, so that much mud adheres to their boots, clothes, and hands. This mud is carried about, particularly upon the boots, and is necessarily deposited upon the rungs of the ladders, from which it is conveyed to the hands of the next man who ascends or descends (see Plates I. and II.). Thus if the mud is contaminated with infective material it becomes almost impossible for the men to avoid infection. The clothes used in the mine are changed in a building on the surface provided with drying accommodation and lavatories, and known as the "dry." The men can thus come to and go from the mine dry and clean. The clothes become wet during work, partly from water and mud in the mine, and partly from perspiration caused by working in a warm and saturated atmosphere. In the warmer places the men work stripped to the waist, as in collieries.

Plate III. shows an underground meal, or "croust." The food, consisting of "pasties," is commonly carried in a small bag, which greatly contributes to cleanliness. The water is carried in a wooden keg (seen in the foreground), from which the men drink directly. The mine water is not drunk by the men. The kegs are certainly liable to contamination with mud unless great care be exercised, since the bung is constantly in contact with muddy hands and clothes, not to speak of mud from the ground and from the faces of miners. The pipes of men who smoke are also contaminated with mud.

[1] Just after the paper was written the whole of the main roads had to be abandoned on account of a great fire due to spontaneous combustion.

In English mines there is, so far as we are aware, no privy accommodation underground, and Dolcoath has been no exception to this rule, although ample accommodation is provided on the surface. Owing to the thoughtless habits of a number of the men the ground has been polluted by faecal deposits at many parts. In the imperfect light it is impossible to avoid treading on these deposits, so that the ankylostome ova and the larvae which have developed from them in the warm and moist atmosphere, must be carried on the boots of the men to the roadways, ladders, skips, &c. Both in Dolcoath and in a neighbouring mine we have repeatedly found ova in the faecal deposits, together with very numerous larval worms apparently identical with those of *Ankylostoma*. Samples brought from various parts of Dolcoath were in every case infected with these ova or larval worms. The openings of disused levels are specially contaminated by excrement, but other parts are also made use of by the men. At intervals in the shaft there are large cisterns, from which the water is pumped by the shaft pumps to cisterns above, and thence to the surface. These are to a certain extent used by the men for receiving their evacuations; and this plan seems much less open to objection, as the faeces are pumped to the surface, where they can probably do no harm; and running water is said to prevent in any case the development of the ova.

Origin and Progress of the Outbreak in Dolcoath Mine.

At what time and by what means ankylostomiasis was first introduced into Cornwall it is now impossible to determine accurately; but it seems probable that the disease was brought, not by men from infected mines on the Continent, but directly from some tropical country. Cornish miners in charge of machine drills, or various departments of mining work, are now constantly going and coming from various parts of Asia, Africa, North and South America, and Australia; and the manufacture of mining machinery is a very important Cornish industry. As ankylostomiasis is endemic in many of the places from which these miners return, there is every likelihood that a good many of them will return infected, although possibly with so few ankylostomes that they are not anaemic. In examining blood-films from a number of men who had not worked in Dolcoath, or so far as we could ascertain been in any way exposed to ankylostomiasis infection in Cornwall, we found one sample of blood in which the eosinophile leucocytes were increased to 24 %. See Appendix, case LX. As shown below, this is one important

symptom of infection. Although the miner had no definite symptoms of illness we obtained a sample of his faeces, and found that ankylostome ova were present, though in small numbers. On enquiry we found that he had returned from Mysore several months previously, where he had doubtless been infected, though only slightly. There have doubtless been many such cases in recent years; and from this example it may easily be seen how the infection has reached Cornwall.

The outbreak at Dolcoath appears to have begun about eight years ago. Some of the affected men sought treatment in the West Cornwall Miners' Hospital at Redruth, about three miles away; and the following record of cases admitted for anaemia since 1893 affords some idea of the course of the outbreak. Of the cases recorded in the table 61 % were of miners directly from Dolcoath. Only one death occurred.

TABLE II.

Year	Cases admitted
1893	1
1894	3
1895	9
1896	13
1897	29
1898	23
1899	12
1900	11
1901	7
1902 (till December) ...	8

The anaemia first began to attract attention at the mine about six years ago. The cases appear to have occurred almost entirely among men working in and around the Engine Shaft, where a large number of the men are employed. Practically everyone in this part of the mine seems to have been more or less affected, including the Manager and nearly all the officials employed underground. The position of this shaft, with the temperatures observed in it, is shown on the section (Figure 1). It will be seen that it is an upcast, and considerably warmer than the downcast shafts.

About the end of 1898, when the numerous cases of anaemia were causing much trouble, the Manager, Mr R. Arthur Thomas, was led to suspect that the occurrence of what the miners called "bunches" (a skin affection which will be described below) was connected with contamination of the mine by faeces. He accordingly provided additional privy accommodation on the surface, and requested the

men to avoid polluting the mine. He also ordered a large quantity of chloride of lime and permanganate of potash to be used at polluted spots in the mine and shafts. At the same time the ventilation was improved by various means; and finally, at the beginning of 1900, four centrifugal fans were placed on levels close to the Eastern Shaft at the places shown on the section, so that fresh air was blown through doors towards the Engine Shaft. By this means the temperature of the Engine Shaft and adjoining workings was apparently lowered distinctly, the improvement in ventilation being evident to Mr Martin when he re-visited the mine. The number of cases of anaemia has diminished greatly during the last two or three years, probably owing to these measures, although the possibility must also be borne in mind that some form of immunity to the effects produced by the presence of the worms in the intestine may have developed among the miners.

Fortunately there is surface employment for a large number of men at Dolcoath, and many of the men have been transferred to this or to work in the downcast shafts, as soon as they began to be seriously anaemic. Others have gone into Hospital or been sent to a Convalescent Home for a time, while others have obtained employment elsewhere. In the great majority of these cases the tendency has been towards more or less complete recovery. When the opportunity for renewed infection is prevented the worms existing in the intestine evidently tend to die out, as they cannot multiply within the body; and the anaemia correspondingly diminishes. Some of the worms may, however, remain in the intestine for years, as will be shown later. Of the cases which we have seen only one was extremely grave and it improved rapidly after treatment with thymol. Some idea of the number of men at present affected will be afforded by the particulars of cases in the Appendix.

In spite of many enquiries we have been unable to obtain any evidence of spread of the disease above-ground: but there is little doubt that the mines in the neighbourhood are more or less infected. We have examined a number of the men working in mines at some distance, but except in men who had been previously working in Dolcoath, or lately returned from abroad, we could see, or hear of, no evidence of definite anaemia. This is the more remarkable as probably nearly all the men working in Dolcoath have been, or are, more or less infected. It must be borne in mind, however, that many mines are much shallower and cooler than Dolcoath, and that the men may, perhaps, be cleaner in their habits.

Symptoms observed.

With certain possible exceptions mentioned below, the most important symptoms which the infected miners exhibit depend on the anaemia which is, in many instances, produced. Pallor, particularly of the lips and conjunctivae, together with palpitations and dyspnoea on exertion are the three chief signs which ankylostomiasis produces in common with any other anaemia. Underground work in Cornish mines always involves a good deal of climbing up almost vertical ladders. This is a form of exertion which soon brings into prominence any tendency to dyspnoea, and provides the basis for a very useful test question. A good many of the milder cases complain of palpitations only, though in some the dyspnoea is recognised without any excessive cardiac action being noticed. It is interesting to notice that the degree of dyspnoea does not altogether vary with diminution in the percentage of haemoglobin. It is a little surprising that hard manual labour can in some instances be done without difficulty with a haemoglobin percentage of 36—38 of the normal (cases XXXIX. III. IV., Appendix), and several further examples will be found in the table of cases of regular pit work being done with less than 50 p.c.[1] On the other hand there were examples such as case I, where with 48 p.c. there was marked dyspnoea on walking on the flat. Dizziness and faintness on exertion were complained of only occasionally.

The dyspnoea and palpitations are undoubtedly due to the deficient percentage of haemoglobin and red corpuscles, but do not appear to be caused simply by the deficient oxygen-carrying power of the blood. Where the symptoms are due solely to deficient oxygen-carrying power (as in carbonic oxide poisoning[2]), dizziness, loss of power, and fainting are by far the most prominent symptoms. Palpitations are also present, but dyspnoea is hardly noticed. In anaemia, on the other hand, dyspnoea is very prominent, and is probably due to rise in the carbonic acid tension of the blood. It is well known that the ease with which blood gives off its carbonic acid depends upon the presence of the red corpuscles. Any deficiency in the latter will thus diminish the difference in carbonic acid percentage between venous and arterial blood, and thus tend to produce carbonic acid dyspnoea.

[1] B. K. Ashford (in Cabot's *Clin. Exam. of Blood*, 4th ed., 1901, p. 430) has also drawn attention to this peculiarity.

[2] Haldane, *Journ. of Physiol.*, Vol. XVIII., pp. 201, 430.

Oedema has not been a marked feature of the Cornish cases: indeed only one of our cases has a history of obvious general oedema; and swollen feet were curiously absent from the general histories. No traces have been found of petechiae, retinal haemorrhages, &c.

Gastrointestinal disturbances have been present in most of the cases of definite anaemia. The loss of appetite, dyspepsia, and occasional vomiting, which were frequent though never very prominent symptoms, may reasonably be ascribed to the anaemia. On the other hand many cases had nothing except a certain amount of epigastric pain, in some instances amounting to nothing more than epigastric uneasiness. This was not associated particularly with the taking of food. In one case a moderate degree of tenderness was elicited by the pressure over the region of the duodenum. Irregularity of the bowels was present in most cases, alternating diarrhoea and constipation being perhaps the commonest condition. Some complained of either diarrhoea or constipation: others seemed to be normal in this respect. In no case could any history of melaena be obtained, and in none of the samples of faeces examined was the colour suggestive of bleeding into the alimentary canal. It is probable that these symptoms as well as the pains are, in part at least, due to the presence of the intestinal parasite, though any of them might be due to the anaemia alone. The most anaemic case which came under our notice (XI.) was singularly free from any disturbances of the intestinal tract.

In one case (I.) absence of knee-jerks with an indefinite dulling of tactile sensibility over the legs was observed. Systematic examinations into these nervous affections were not made. Fever seems to be absent both at the onset and later, except in cases of marked anaemia which may show a low irregular pyrexia.

The miners complained a great deal of certain skin affections, and among themselves associate these eruptions very definitely and emphatically with the anaemia. It has already been stated that the worse degrees of "Dolcoath anaemia" are popularly associated with the "New Sump," or Engine Shaft. Our enquiry has shown that this association, though less absolute than the miners would have one believe, is actually borne out by facts. In the same way the skin affections are described as "New Sump bunches" or "botches." They appear very rapidly, are extremely irritable, and sometimes do and sometimes do not come to a head. They are very commonly attributed to sitting upon or leaning against the rock, and more especially the timber, underground. There are a number of men who only go down

the New Sump shaft on Saturdays, when they are engaged in repairing the pumping machinery: it seems to be almost a cause of surprise with them if by the same evening, or at latest the next morning, some "bunches" have not made their appearance. They are specially liable to appear on the buttocks, knees, and forearms. In several cases the "bunches" have been described as definitely preceding by a short interval the onset of anaemic symptoms. With the decline in the number of cases of anaemia which has taken place in the last three years, these "bunches" have also become much less frequent. It has therefore not been possible to see a great number of cases. From those we have been able to examine it would appear that the cutaneous affections may be described under three headings:—

(1) *Furuncles* of varying size, some being no more than pin-head pyodermias, others containing as much as a drachm of pus. Even the smaller ones have a great deal of hard thickening round the actual purulent focus. In some cases, at any rate, their origin from infections of hair follicles seemed clear, the follicle being filled with a plug of inspissated pus leading to a larger quantity of pus situated beneath. In many instances these furuncles gradually disappear without any pus making its appearance on the surface. To the naked eye the pus presents no unusual appearance.

In view of the recently published evidence[1] that *Ankylostoma* larvae may penetrate the hair follicles, the examination of the contents of these furuncles was of considerable interest. Nothing in the way of larvae or any other phase in the life-history of *Ankylostoma* could be identified in the pus. If these furuncles are specific it is probable that histological examination of the pus would reveal an excess of eosinophile cells similar to that found in the blood, while if they are due to ordinary pyogenic infection of the skin of persons infected with *Ankylostoma* and showing an eosinophilia in the blood, it is to be expected that the pus would consist of the ordinary polymorphonuclear neutrophile cells. If, again, the infection is primarily specific and becomes secondarily infected, an excess of eosinophiles in the pus might be either mixed with or obliterated by an excess of neutrophile cells. On microscopical examination of films of pus from these furuncles abundant groups of *Staphylococci* were found. Nearly all the cells were the ordinary neutrophile leucocytes in various stages of degeneration. An occasional eosinophile cell could, on prolonged examination, be detected

[1] Looss (1901), *Centralbl. f. Bakteriol.*, Bd. xxix. pp. 735—739.

in all the cases examined, but in no case under similar circumstances did we fail to find a certain number of red blood corpuscles. The possibility also that some of the smaller boils arose from scratched wheals of urticaria (see below) must be considered. In no instance was anything found which even approached eosinophile pus. On the other hand, the presence of the cocci renders possible the explanation that a specific eosinophile reaction on the part of the leucocytes towards an ankylostoma infection had been overwhelmed by a neutrophile reaction induced by a secondary infection with pyogenic organisms. It should perhaps be mentioned that among those cases from which some pus was obtained was the lad (case XII.) whose blood showed an extreme instance of eosinophilia.

(2) *Urticaria.* This seems to be common, though hardly so frequent as the furuncular affection. It is difficult to ascertain exactly what the relative frequency is, for the wheals are often infected by scratching, and so fail to entirely disappear in a few days. There is, however, no doubt that true urticaria often occurs, and the extremely irritable variety of "bunch" which spreads rapidly about the body and may disappear again in a few hours may be taken as being urticarial in nature. Urticaria is more commonly due to general dissemination of toxic substances in the body than to local external applications, and it seems not unlikely that it is in the present instance due to the presence of *Ankylostoma* in the gut. There is no doubt that urticaria is very much more frequent among infected miners than it is among the general population. Unfortunately there seem to be few if any underground workers at Dolcoath who do not harbour the worm, so that the influence of the hot, moist atmosphere and the profuse sweating cannot be excluded. At St Agnes the miners do not seem to be generally infected (see Appendix), and urticaria is not more frequent than among a normal population. Here, however, the mine is shallow and relatively cool, so that the two cases are not parallel. The majority of cases at Dolcoath, since leaving the shaft or pit and working on the surface, have never had any "bunches" at all, either furuncular or urticarial, though they were having constant attacks while underground. But in the case of James W. (XXXVIII.), who has kept the house for the past 20 months, six miles from Dolcoath, attacks of urticaria have been frequent since giving up work; so long as he worked underground he suffered almost constantly from small boils which he has never had since he left the mine. Such a case as this renders it not improbable that the urticaria is comparable to that which is sometimes associated with hydatids.

In two cases differential counts of the leucocytes have been made, (α) in blood and serum squeezed from the fresh, uninflamed wheals of an urticaria in the leg, (β) in blood from the finger. The results are as follows:

		Lympho-cytes	Inter-mediate	Large hyaline	Neutro-phile	Eosino-phile	Mast-cells
P. W. J.	urticaria	28·7	6·6	1·0	36·7	27·0	0
	finger	12·3	2·0	3·3	51·7	30·0	0·7
W. J. J.	urticaria	40·0	7·3	4·3	35·0	13·3	0
	finger	29·7	3·3	2·0	55·3	9·3	0·3

These figures yield evidence of an uncertain character. The marked excess of lymphocytes in the wheals suggests that it might be more proper to compare the eosinophiles to the neutrophiles rather than to the total leucocytes. If this is done the proportion of eosinophiles in the finger blood to those in the wheal becomes 100 : 126 and 100 : 237 in the two cases respectively.

(3) *General pruritus.* A few of the cases find a general pruritus without any objective signs, and especially marked over the trunk, a very troublesome complaint. As usual, it is most marked at night, though it is interesting to note that in one instance this feature still held although the individual was working all night and slept during the day. In the same case, the expulsion of more than 200 worms by thymol resulted in a complete cessation of the irritation for about a week; it then returned, though in less degree, and at the same time it was found that ova were still present in the faeces in some numbers. This pruritus is not a common symptom (if it be really a symptom of ankylostoma infection). It occurs equally in the old and young; thus cases I. aged 51 and VI. aged 20 presented the worst degrees, and neither was exposed to fresh infection.

Attention may finally be called to the fact that in some cases, among which is the most anaemic of all (XI.), there is no history of any skin affection whatever to be obtained.

The definite diagnosis of ankylostomiasis depends, of course, on the recognition of the ova in the faeces. As a rule there is no difficulty in finding the ova. All that is necessary is to mix a small fragment of the faeces with a drop of water spread out on a slide, and search with a low power. Plates IV. and V., which are from micro-photographs kindly made for us by Dr C. A. Coventon at the Pathological Laboratory, Oxford, show the appearances presented by the ova at different stages of development, and by the larval and adult worms. Figures 3 to 6 show the ova as seen in fresh faeces.

Changes in the Volume of the Blood.

The essential symptoms of ankylostomiasis are those of what is commonly known as anaemia; and for practical purposes the word "anaemia" has now lost its etymological significance, and denotes simply any condition in which the percentage of haemoglobin in the blood is abnormally low. Indeed, no case in which there was definite evidence of anaemia in the etymological sense has ever been recorded. It is evident that anaemia may be produced, either by a diminution in the total haemoglobin in the vascular system, without a corresponding diminution in the total volume of the blood, or by an increase in the total volume of the blood, without a corresponding increase in the haemoglobin. It has recently been shown by Lorrain Smith[1] that pernicious anaemia and anaemia from haemorrhage are of the former, and chlorosis of the latter type. It was evidently of importance to ascertain to what type the anaemia of ankylostomiasis belongs; and we have therefore determined the total volume of the blood in several cases.

The method used was that of Haldane and Lorrain Smith[2]. The principle of this method is as follows: (1) The percentage of haemoglobin is determined colorimetrically, and from the result the percentage capacity (by volume) of the blood for absorbing oxygen or CO in combination with the haemoglobin is calculated. (2) A known volume of CO is administered to the patient. (3) The percentage to which his haemoglobin is saturated with CO is determined colorimetrically immediately after the absorption of the gas. It is evident that from the percentage saturation actually observed, as compared with the volume of CO absorbed, it is possible to calculate the CO (or O_2) capacity of the whole of the blood—*i.e.* the volume of CO or O_2 required to saturate the whole of the haemoglobin in the blood. As, however, the percentage O_2 or CO capacity of the blood is also known, the total volume of the blood can easily be calculated. Thus if the corrected volume of CO absorbed was 75 c.c., the percentage saturation of the haemoglobin with CO 15, and the percentage O_2 capacity of the blood 18·5, the O_2 or CO capacity of the whole blood would be $75 \times \frac{100}{15} = 500$ c.c., and the total volume of the blood $500 \times \frac{100}{18{\cdot}5} = 2700$ c.c. If the body-weight (without

[1] *Trans. of the Pathological Society*, Vol. LI. p. 311.
[2] *Journ. of Physiology*, Vol. XXV. p. 33, 1900.

clothes) were 60 kilos the oxygen capacity in c.c. would be ·83, and the blood-volume 4·5 c.c. per 100 grammes of body-weight.

The haemoglobin was determined by an accurately graduated and standardised Gowers-Haldane haemoglobinometer[1], the reading of 100% by which corresponds to an oxygen capacity of 18·5 c.c. per 100 c.c. of blood. The carbonic oxide used was analysed after each experiment; and the volume administered was measured from a burette instead of the measuring cylinder originally described. The standard blood solution employed in the titrations was made from fresh human blood, and was found to give exactly the same tint at corresponding dilutions as the patients' blood.

Our first two experiments were made under the belief that the anaemia of ankylostomiasis is probably due simply to loss of blood through intestinal haemorrhage caused by the presence of the worms, and to a subsequent more rapid reproduction of the plasma than of the haemoglobin[2]. If this were the case the total haemoglobin in the vascular system would be greatly diminished, and consequently only a small volume of CO could be administered without saturating the haemoglobin to such an extent as to produce symptoms. We therefore only gave small amounts of CO. Somewhat to our astonishment the saturation of the haemoglobin was in each of the two cases so low that very accurate titrations could not be made. It was evident that the blood-volume was greatly increased, and we therefore gave more CO in the subsequent experiments. The following table gives the results.

Case-number in Appendix	c.c. of CO absorbed at 0° and 760 mm.	% saturation of haemoglobin with CO	Oxygen capacity of total blood	% of haemoglobin normal = 100 %[3]	Percentage oxygen capacity of blood	Total volume of blood in c.c.	Body-weight in kilos	c.c. of blood per 100 grms. body-weight	c.c. of oxygen capacity per 100 grms. of body-weight
I	41	8·2	500	44	8·1	6170	72	8·6	·70
VI	41	8·5	480	47	8·7	5520	60	9·2	·80
VI	72	15·9, 16·5 } 16·2	445	41	7·6	5860	60	9·8	·74
X	72	19·4, 19·7 } 19·5	375	49	9·1	4070	53	7·7	·70
Average	—	—	—	45	8·4	—	—	8·8	·735
Average for 12 healthy men	—	—	—	100	18·5	—	—	4·5	·83

[1] *Journ. of Physiology*, Vol. xxvi. p. 497, 1901.

[2] See *Cohnheim's Allgemeine Pathologie*, Vol. i. Chap. vii. (2nd edition).

[3] These values differ from those given in the Appendix: they were determined on other days.

It will be seen by reference to the Appendix that cases I. and VI. were of old standing in men of 51 and 20, while case X. was very recent, in a lad of 17. In each case the volume of the blood was increased far beyond the normal limits recorded by Haldane and Lorrain Smith in the paper just quoted. The average increase amounted to 94 %. The total oxygen capacity (which is a measure of the total haemoglobin in the blood) was only slightly diminished (by 11 %). It is thus evident that the condition of the men examined was essentially one of hydraemic plethora. If the blood had been concentrated to its normal volume the haemoglobin percentage would have risen from 45 % to 89 % of the normal. The slight remaining deficiency may perhaps be set down to the haemorrhages which, from post-mortem records, seem undoubtedly to occur in cases of ankylostomiasis.

In cases I. VI. X. the colour indices of the red corpuscles were ·74, ·79, and ·58 (see Appendix). It follows from this that the total number of red corpuscles in the blood was in each case a good deal above the normal—in case No. VI. by as much as 42 %.

For comparison's sake we add the following table, showing Lorrain Smith's average results for anaemias of other type.

	% of haemoglobin (normal = 100 %)	Red corpuscles in millions per cubic mm.	c.c. of blood per 100 grms. of body-weight	c.c. of oxygen capacity per 100 grms. of body-weight
Six cases of anaemia from haemorrhage	33	3·067	6·5	·39
Seven cases of pernicious anaemia	26·5	·940	8·6	·40
Twenty-one cases of chlorosis	39·9	3·222	10·8	·79
Four cases of chlorosis after iron treatment	74·0	5·399	6·2	·84
Six healthy young women	93·0	4·952	5·3	·92

It will be seen at once on comparing this with the previous table that the anaemia of ankylostomiasis differs greatly from anaemia of haemorrhage or pernicious anaemia, but closely resembles the anaemia of chlorosis. It is true that the volume of the blood is usually increased, and that the colour index of the red corpuscles is low in anaemia from haemorrhage, but the difference in the total oxygen capacity of the blood sharply differentiates the two conditions. In the cure of ankylostomiasis anaemia by vermifuge remedies the same rapid concentration of the blood doubtless occurs as Lorrain Smith has demonstrated in the cure of chlorosis.

In the absence of further experimental data there is little use in discussing the means by which the anaemia of ankylostomiasis is brought about. The most commonly accepted explanation, that the anaemia is directly due to loss of blood from the punctures of the worms, is however, evidently incorrect.

Changes in the Constituents of the Blood.

The changes in the constituents of the blood have been examined in a number of cases. It has been impracticable to enumerate the cells in all instances, but in each case the haemoglobin has been estimated and stained films examined. It is from these examinations perhaps that the most reliable and useful information is to be gained. The haemoglobin was estimated by Haldane's modification of Gowers' haemoglobinometer, an accurately graduated and standardised instrument being employed. Where gas was not available an original Gowers standard of known error was used. The cells were counted with the Thoma apparatus, using Toisson's diluting fluid and a Zappert counting-chamber, and counting 100 small squares for the red cells and 9 sq. mm. for the leucocytes. In the differential leucocyte count 500 leucocytes were counted except in one or two instances. Though other stains were occasionally used, as a routine the films were stained with different varieties of Jenner's solution[1].

It is important in considering the results of the blood examinations to appreciate the errors which may be present, arising either from the method of experiment used or from the circumstances under which the different examinations have been made. The error of the haemoglobinometer has been shown (Haldane, *loc. cit.*) to be very small (less than 1 p.c.). In counting the red cells by the method here used the error is commonly said to be about 3 per cent., but this is probably far too optimistic a view to take of the accuracy of the method in general practice. That there is a considerable error in counting the leucocytes by the Thoma method is generally admitted, but to what dimensions this error may rise is not known. The differential count would appear at first sight to be liable to but a very small error; but successive counts of 500 or 1000 cells in the same film show that the successive results may vary a good deal in cases where there is no question of any error of judgment in assigning each cell to its appropriate class.

[1] We have to thank Dr Gustav Mann for a supply of a particularly admirable sample of eosinate of methylene blue in methyl alcohol, which gave excellent results.

Thus in two cases the figures for the neutrophiles in each of four successive thousands of white cells were;

59·2	55·5	55·2	53·6	per cent.
35·8	32·7	38·7	34·8	„ „

In view of a tendency to lay too much stress on small differences in blood-counts it seems well to call attention to the fact that an error of method is present and that it is not altogether negligible in magnitude.

A further source of error in comparing the different cases which we have collected arises from the fact that it has been found utterly impracticable in dealing with an active body of working men to ensure that all the estimations should be done at the same time of day and in the same relation to the taking of food. As a matter of fact however the present estimations were almost all made at a time after the last considerable meal, when digestion leucocytosis has become practically negligible, and which was in a large number of instances roughly the same. The fluctuations which take place from week to week in normal persons who show no signs of illness must also be considered in comparing the results of single examinations in a series of individuals[1]. The possibility of the presence of other diseases which might influence the condition of the blood was carefully considered; the few cases where such was found are mentioned under the appropriate heading. We might however state definitely here that in none of our cases did we find any history or indication of asthma, skin affections, etc. which might account for the increase in the eosinophile leucocytes.

The classification of the different varieties of leucocytes is not quite the same as that commonly adopted. The term "lymphocyte" is confined to small cells with very little cytoplasm and a deeply staining nucleus. "Large hyaline" includes the well-known cell of large size with a (usually) indented nucleus which does not stain deeply, and fairly abundant cytoplasm containing abundant basophile granulations. Between these two well-marked classes are a considerable number of cells which in size and other characters lie in an intermediate position. The relative number of these "intermediate" cells varies a good deal in different films, and the cells which are classed together under this heading are an exceedingly mixed collection. So little is known of these non-granular leucocytes that further subdivisions would in the present instance serve no useful purpose. To obtain figures

[1] See for example the differential counts in cases II. and XL. and contrast those in case XII.

comparable to other differential counts the "lymphocytes" and the "intermediates" should be taken together to represent the lymphocytes of the ordinary classification.

Literature. Without attempting an exhaustive survey of the literature it seems proper to give some account of the results which have been obtained by others in examining the blood in cases of ankylostomiasis. With really only one exception the published observations are rather fragmentary. A few cases are described, chiefly with reference to the increase in eosinophile leucocytes, by Zappert and others[1]. The figures of Leonard Rogers[2] have been republished more than once and constitute perhaps the best known work on the subject. They deal with the total red cells, haemoglobin, total leucocytes and specific gravity of about a dozen cases among the natives in Assam. His average figures are: Hb 15·2 p.c., red cells 2,145,000, leucocytes 5338, sp. gr. 1·034, and colour index 0·35. The haemoglobin estimations were made with the original instrument of Gowers, and are on that account to be regarded with great suspicion in the absence of definite standardisation of the apparatus, particularly for low percentages. There are indeed data which lead one to suppose that Rogers' standard was too low: he states[3] that the average haemoglobin percentage for healthy Europeans resident in Assam is about 80 in the healthier season, and 71 p.c. in the rainy season, the average for healthy Assamese being 62. On the contrary, other workers, in investigations conducted with a considerable degree of thoroughness, appear to have established the fact that the haemoglobin and red cells of healthy persons, both

[1] J. Zappert, *Wiener klin. Wochenschr.* 1892, p. 347, and *Zeitschr. f. klin. Med.* XXIII. 1893, p. 257; Bucklers, *Münchener med. Wochenschr.* XLI. 1894, p. 22; Müller and Rieder, *Deutsches Archiv f. klin. Med.* XLVIII. 1891, p. 114; Leichtenstern, *Wiener klin. Rundschau*, 1898, pp. 413 and 429. Some other references are given by B. K. Ashford (*loc. cit.*), and in Scheube, *Krankheiten der warmen Länder*, 1900.

[2] The original table (*Report on Kala-Azar*, Shillong, 1897, p. 95) is as follows:— Hb % 15·2; Reds 1,145,000; Whites 5,338; Whites : Reds 1 : 524; sp. gr. 1·034; Hb value 0·31. It is at once obvious that this is not correct, for the colour index calculated from the Hb and reds as given is 0·65. From the ratio whites to reds and from calculating the reds from the colour index and the Hb it appears that the correct number for the reds is the figure (2,145,000) given by Rogers in the *Journ. of Pathol. and Bacteriol.* v. 1898, p. 399. The original table appears in the *Brit. Med. Journal*, 1900, II. p. 544, and is reproduced by R. C. Cabot, *Clinical Examination of the Blood*, ed. 4, 1901, p. 428, though the data for detecting the error accompany it. If the different columns in the table apply to the same series of cases, the colour index and proportion of whites to reds are also wrongly stated; the former (0·31) gives with 15·2 per cent. Hb about 2·45, the latter about 2·8 million reds.

[3] *Journ. of Pathol. and Bacteriol.* v. 1898, p. 399.

Europeans and natives, resident in the tropics are not reduced[1]. It is therefore not improbable that the haemoglobin percentages given by Rogers are all some 20–30 per cent. at least lower than they should be, and, if that is so, it follows that the very low colour index, on which the author lays so much stress, is also too low. The results with the original Gowers instrument in cases of extreme anaemia are particularly unreliable, as the method of graduating the instrument was quite unsound, and tended to make the results much too low even when the standard picro-carmine tube was of the correct tint.

F. M. Sandwith[2] records the results of the examination of the blood in 173 cases in hospital in Cairo. The haemoglobin (estimated by the original Gowers method) varied from 10 to 54, with an average of 26 p.c. One of the most interesting points which this author brings out is that during the process of cure the number of leucocytes per cub. mm. increases[3] (average on admission 10,360 and on discharge 15,730 per cub. mm., the average gain in red corpuscles being 1,290,000, and in haemoglobin about 27 p.c. in the same cases).

The most careful and complete account which we have seen is one by B. K. Ashford[4] dealing with 19 cases at Puerto Rico. The blood-counts were done in duplicate and the Hb estimations (with a Fleischl apparatus) in triplicate. His averages are: Hb 21, red cells 1,776,000; leucocytes 7000; colour index 0·6. In the differential count, the average percentage of eosinophiles is 10·3, six of the nineteen cases being under 5 p.c. Poikilocytosis was present in most cases, with abundant megalocytes and microcytes; polychromasia was only marked in four instances. Normoblasts were present in fourteen cases and in six were accompanied by megaloblasts; in no case however did the latter predominate. Two of his cases had a colour index of more than unity—1·43 and 1·09. Good examples are given of the extremely rapid changes, both backwards and forwards, which may take place in a short

[1] C. Eijkman (*Virchow's Archiv*, CXXVI. 1891, p. 113), using a Fleischl haemoglobinometer and a Thoma-Zeiss counting apparatus, found about 5·2 million reds and 96·5 to 100 per cent. Hb. Similar results (reds and sp. gr.) were obtained by Max Glogner (*ibid.* p. 109).

[2] *Lancet*, 1894, I. p. 1365. Some determinations of the volume of the red cells by Kaufmann are given here (15—43, av. 25 p.c.), but the numbers of cells in the same cases are not recorded.

[3] In the single case (XI.) which we have had an opportunity of observing, the leucocytes *fell* 40 per cent. while the Hb increased 20 per cent.

[4] *New York Med. Journ.* LXXI. 1900, p. 552: a rather more convenient account has been contributed by the author to R. C. Cabot, *op. cit.* p. 429.

time: thus one case in 20 days gained three p.c. Hb and nearly two million red cells, reducing the colour index from 1·43 to 0·43. Ashford states that there is probably no true leucocytosis in ankylostomiasis[1], and endeavours to account for the leucocytoses which have been observed as being due to intercurrent diseases. Among his cases are three in which there is some increase in the white cells—11,000, 12,700, and 18,000. The second of these has 6 p.c. of eosinophile cells and no intercurrent disease; the first has 31 p.c. and an abscess of liver, while the third has 40 p.c. eosinophiles and is "believed" to have had pneumonia at the time of examination. Among the other 16 cases in no instance does the percentage of eosinophiles rise above 17. So far from demonstrating by these figures that there is no leucocytosis, the author would seem to have advanced evidence of some weight in favour of the opposite view. It is going out of the way to suggest that pneumonia may cause a leucocytosis of 18,000 of which 7,200 are eosinophiles. Such a condition is contrary not only to all observations and theory on both pneumonia and conditions which favour eosinophilia, but is the reverse of what has been actually observed in ankylostomiasis. Leichtenstern has put on record[2] the observation that the incidence of a croupous pneumonia reduced the percentage of eosinophiles in the blood of a patient suffering from ankylostomiasis from 72 to 6–7, recovery from the pneumonia raising the number again to 54 p.c. That the percentage of eosinophiles was as much as 40 in Ashford's case is to be rather taken as evidence that the belief that the patient had pneumonia was without very much foundation. In our five cases (X. XII. XIII. XXIX. XXXII.) with a leucocytosis of more than 15,000 special enquiries were made for any other malady which might induce such a result: none were found.

There is a widespread idea that the changes in the blood produced by ankylostomiasis are either sometimes or frequently indistinguishable from those associated with progressive idiopathic pernicious anaemia[3].

[1] If, as is perhaps best, we confine the term ankylostomiasis to a condition of anaemia produced by *Ankylostoma*, there is probably more truth in this statement than if we include all cases of infection by *Ankylostoma*. J. B. Greene (*New York Med. Journ.* LXXV. 1902, p. 460) records a leucocytosis of 45,000.

[2] In P. Ehrlich and A. Lazarus, *Die Anaemie*, Part I. p. 113. It is hardly necessary to acknowledge the debt which we owe to the brilliant chapter on specific leucocytoses in this book when any question, such as the present one, requires discussion.

[3] R. C. Cabot, article in Hektoen and Riesman's *Pathology*, I. 1901, p. 458; J. Ewing, *Clinical Pathology of the Blood*, 1901, p. 420. On the other hand J. C. da

Such modern examinations as have been made (and they are few in number) hardly bear out this view, though of course the difficulty of the definition of what constitutes "pernicious" anaemia introduces a complication. Poikilocytosis, polychromasia, normoblasts, and megaloblasts have been described: on the other hand the colour index is nearly always very low, and the megaloblasts less numerous than the normoblasts. No investigations into the condition of the marrow appear to have been made. Ashford mentions a single example with a colour index of 1·4, and this seems to be the case nearest a "pernicious" type, except that there were more normoblasts than megaloblasts. With one somewhat doubtful exception, our own cases show nothing more than may be met with in severe chlorotic anaemias, though the total blood volume is not unlike that of pernicious anaemia.

Taking a somewhat elastic view of what constitutes pernicious anaemia, it cannot be said that it is other than an extreme rarity in ankylostomiasis.

A detailed account of the changes which we have found in a series of cases is given in the Appendix. The essential alterations consist in an anaemia of severe chlorotic type with a large increase in the total volume of the blood, a varying increase in the leucocytes, and a marked relative and absolute increase in the eosinophile cells.

The haemoglobin is diminished in very varying degrees in different cases. The extremes which we have observed in infected persons are 17 (case XI.) and 104 per cent. (case XXXVII.). The reduction in the number of red cells per cubic millimetre shows equally wide variations (1·5 to 5·4 millions), but is proportionately less than the diminution in the Hb percentage. The colour index is thus low. In a series of cases of such varying severity it is not possible to arrive at satisfactory average figures, but in those cases—16 in number—where full blood examinations were made and in which the Hb falls below 60 per cent. the figures are as follows. The maximum and minimum of red cells occur in the two cases giving the maximum and minimum of haemoglobin.

Costa, *Clinical Hematology*, 1902, p. 357, points out that it differs from *Bothriocephalus* anaemia in not simulating idiopathic pernicious anaemia, and Ewing, *op. cit.* p. 177, agrees that the similarity has never been properly demonstrated. Among other authors, H. Sahli (*Deutsches Arch. f. klin. Med.* xxxii. 1883, p. 421) and J. P. Maxwell (*Journ. of Tropical Medicine*, iv. 1901, p. 317) definitely state that, in cases which had reached a grave degree of anaemia, the red cells did not show the poikilocytosis, etc., of pernicious anaemia.

		Max.	Min.	Average
Haemoglobin per cent.		58	17	43·1
Red cells	per cent.	81	30·5	64
	millions per mm.^{3}	4·072	1·533	3·188
Colour index		0·71	0·56	0·67
Leucocytes per mm.^{3}		44,000	3,800	13,300

The actual highest and lowest colour indices occurring among these cases are 0·81 and 0·53. The lower indices appear to be associated with the lower percentages of haemoglobin; thus the average index for those cases (five) with from 30–39 per cent. Hb is 0·64, from 40–49 per cent. (six) is 0·68, and from 50–59 per cent. (four) is 0·75. Thus the more profound the degree of anaemia the less does it tend to show the high colour index characteristic of the pernicious type. In four instances (XIV. XVI. XXII. XXIX.) the colour index was found to be definitely above unity (1·11 to 1·38). Beyond the fact that the Hb percentages were high (89–98) no other peculiarity could be found in these cases, either clinically or in the blood.

Microscopically the red cells in the majority of cases exhibited nothing more than a deficiency in haemoglobin. In the single really severe case which we found (XI.), where but 1·5 million red cells were counted, a more than usually prolonged and careful search was made for the so-called "degenerative" signs of pernicious anaemia: a small degree of poikilocytosis and a more extensive amount of Gabritschewsky's polychromasia (only however in normocytes) were found; five normoblasts, four with polychromatic cytoplasm, and two doubtful megaloblasts were seen: megalocytes were present in very small numbers. In one other case a single, and in another (XVIII.) two normoblasts were seen; the latter case also showed two examples of punctate basophilia which occurred in single cells in two (III. and XXXIX.) other cases. A small amount of polychromasia was present in many cases, but seldom to a degree much greater than is sometimes found in bloods which cannot be regarded as other than normal. Poikilocytosis was only found in one instance (XI.), and there not to any extent. In several cases (*e.g.* X. XXIV.) a good deal of variation in size was present (diam. 4·5—10·5 μ). Our cases are not so severe as those which have been studied by others, most of the men having advanced a good way towards recovery by the time they were examined. This may be the reason why we have not found more morphological changes in the red cells.

The total leucocytes per cubic millimetre varied from 3,800 to 56,000, the average of the 16 distinctly anaemic cases being 13,300. It may be well to state at once that the reaction of the leucocytes to

Ankylostoma infection is independent of the reaction of the red cells and plasma-volume: by the time that a condition of marked anaemia has been produced the leucocytic reaction seems to have generally to a large extent passed away. The condition of the white cells, in short, in the anaemic disease called ankylostomiasis does not represent in full their response to the presence of the worm in the intestine. The four highest counts are all in youths with but a short history of illness and are cases which may well be recent infections:—

Case	Age	Total leucocytes per mm.^{3}	History of illness	Hb p.c.
XXXII	23	56,000	a few weeks	80
XII	17	44,000	6 months	50
X	17	24,400	2 ,,	40
XXIX	18	20,600	6 ,,	98

These high figures are not necessarily associated with severe symptoms of any kind: case X. was severely anaemic, but case XII. was mild, and the other two had hardly any symptoms at all. If with these cases we contrast the four which show the lowest counts of white cells we find that they are old-standing cases:—

Case	Age	Total leucocytes per mm.^{3}	History of illness	Hb p.c.
II	43	3,800	4 years	35
XVI	21	6,200	4 ,,	99
XXXIII	18	6,700	2 ,,	38
III	32 circ.	6,800	4 ,,	38

In the differential count of the leucocytes the outstanding feature is the absolute and relative increase in the number of eosinophile cells[1]. For the 16 cases already referred to with a distinct reduction in the Hb percentage, the average percentage of eosinophiles is 23 (11·4 to 72·7) as compared with a normal percentage of about 2·5 and the average absolute number 3,000 per cubic mm. (676 to 32,000) as compared with a normal of about 225. Among the series of 46 cases which are recorded in Section I. of the Appendix, two showed only a high normal percentage (XXXVI. 3·6 per cent.; XVII. 3·7 per cent.; and 459 absolute), and four others (VII. IX. XL. and XLIII.) failed to reach 10 per cent. at the first examination[2]. The following table shows the

[1] The eosinophiles, probably chiefly on account of their size, are destroyed more than the other varieties in making films; hence the figures are a trifle too low.

[2] In case XL. a second count gave 16 p.c.: on the other hand case II. on a second examination only gave 9 p.c.

relation to the total number of leucocytes and to the percentage of haemoglobin :—

No. of cases	Total leucocytes per mm.^{3}	Average p.c. of eosinophiles		Average p.c. of haemoglobin	
5	> 14,000		47·7		63·0
4	13,000 to 14,000	23·2		71·5	
5	12,000 to 13,000	17·5	19·1	57·4	62·4
2	11,000 to 12,000	14·6		62·0	
4	10,000 to 11,000	14·2		69·5	
2	9,000 to 10,000	11·3	14·7	66·0	65·4
4	8,000 to 9,000	16·8		61·0	
2	7,000 to 8,000	15·3		72·5	
4	6,000 to 7,000	14·45	15·2	68·7	65·0
1	< 6,000	17·8		35·0	

This table shows that the proportion of eosinophiles bears no precise relation to the degree of anaemia as indicated by the haemoglobin percentage, but that it corresponds in a general way to the degree of leucocytosis which is present[1]. From this it follows that the higher percentages of eosinophiles are found in those cases which have the higher absolute numbers per cubic millimetre—in short, that the condition is one of eosinophile leucocytosis. Thus, using the figures already given, we find that with a leucocyte count of 13,285 and a percentage of eosinophiles of 22·9, the total eosinophiles per cubic mm. number 3,053; this deducted from the total leucocytes leaves a number (10,232), which is not in great excess of a variable normal. The next table shows the absolute figures of the differential counts of 12 cases. The last column gives the total leucocytes per cubic mm. after deducting the absolute number of eosinophiles: the results indicate that the leucocytes other than eosinophiles take a variable share in the high leucocytosis. Thus in case XXIX. deduction of the eosinophiles reduces a leucocytosis of 20,600 to a normal 9,000. On the other hand, cases X. and XXXII. show that the neutrophiles and non-granular cells may be about doubled when the leucocytes are increased about three- and seven-fold. We would emphasize the fact that the subjects of these

[1] As was the case in *e.g.* T. R. Brown's classical case of trichinosis (*Journ. Exper. Med.* III. 1898, p. 315).

Case	Total leucocytes	Lymphocytes	Intermediate	Large hyalines	Neutrophiles	Eosinophiles		Mast-cells	Total leucocytes less eosinophiles
						Absolute	Per cent.		
"Normal"	8,000	1,880		240	5,600	240	3	40	7,760
II	3,800	631	312	220	1,938	676	17·8	23	3,124
I	8,800	1,179	651	546	4,946	1,408	16·0	70	7,392
XVIII	10,700	1,873	696	303	4,548	3,231	30·1	0	7,469
XXIV	12,300	1,304	1,107	664	5,264	3,936	32·0	25	8,364
XI	12,960	1,840	311	467	8,139	2,048	15·8	155	10,912
VI	13,100	865	1,755	2,044	5,633	2,698	20·6	105	10,502
XV	13,500	1,242	1,080	1,080	7,020	2,970	22·0	108	10,530
XIII	16,200	2,722	583	486	9,979	2,365	14·6	65	13,835
XXIX	20,600	4,326	865	247	3,420	11,577	56·2	165	9,023
X	24,400	2,440	1,854	1,025	11,810	7,076	29·0	195	17,324
XII	44,000	2,772	220	308	8,580	31,988	72·7	132	12,012
XXXII	56,000	3,024		1,568	14,336	37,072	66·2	0	18,928

high leucocytoses presented no morbid condition other than *Ankylostoma* infection which could account for the state of the blood[1].

With regard to the proportions and absolute numbers of the other varieties of leucocytes present little can be said. The figures indicate wide variations and the changes are irregular. For the 16 anaemic cases the average is:

Lymphocytes	14·4 per cent.	= 1,915	absolute
Intermediates	7·4 „	= 984	„
Large hyalines	5·9 „	= 785	„
Neutrophiles	48·7 „	= 6,477	„
Eosinophiles	23·0 „	= 3,059	„
Mast-cells	0·6 „	= 80	„

In view, however, of the independence of the anaemic and leucocytic reactions it would be more proper to study the question in those cases which show a marked leucocytosis. In the next table the total eosinophiles are deducted and omitted and the other varieties are given as percentages of the total leucocytes left after deduction of the eosinophiles. Only the five highest leucocytoses are thus dealt with.

Case	Total leucocytes	Total leucocytes less total eosinophiles	Lympho-cytes	Percentages of leucocytes other than eosinophiles formed by			
				Inter-mediate	Large hyaline	Neutro-philes	Mast-cells
XIII	16,200	13,835	19·7	4·2	3·5	72·1	0·4
XXIX	20,600	9,023	47·9	9·6	2·7	37·9	1·8
X	24,400	17,324	14·0	10·7	5·9	68·2	1·1
XII	44,000	12,012	23·1	1·8	2·6	71·4	1·1
XXXII	56,000	18,928	15·9		8·3	75·7	0

With one marked exception these figures show an almost normal condition. Case XXIX. has a large excess of lymphocytes, and on looking through the cases in the Appendix other examples of a similar condition will be found. The large hyalines in the same way are somewhat increased in a good many cases. In view of the possible

[1] Case XIII. had four fair-sized furuncles which were beginning to heal; XXIX. and XII. had remains of one and two small pyodermias respectively; while X. and XXXII. were free from skin troubles. None of them had urticaria.

association of mast-cells and eosinophiles the figures for the former are of interest: the average is distinctly higher than that which is usually regarded as normal[1], and in one case (LVI.) the high figure of 2·5 per cent. is reached. The higher percentage of mast-cells is not however associated with the higher percentage of eosinophiles, and in 6 cases (including XXXII.) out of 58 examples of infected persons none were seen. On the other hand none were recorded in the short counts of 4 out of 11 non-infected Cornish miners. It may therefore be concluded that *Ankylostoma* produces some increase in the mast-cells which is proportionately much less than, and is not parallel with, the increase in eosinophiles.

Of the six cases where the eosinophiles fall below 10 per cent. three (VII. IX. XVII.) show a diminution of neutrophiles with an increase in the lymphocytes, while the other three (XXXVI. XL. XLIII.) may be called normal counts. None of these cases were at the time of examination suffering from symptoms of anaemia in any but the slightest degree, though the haemoglobin was in two instances under 60 per cent., and there is no reason for thinking that any of them were recent infections.

The discovery of a few neutrophile myelocytes in one severe case (XI.) is of interest in view of their frequent association with pernicious anaemia. They have been previously recorded in ankylostomiasis[2].

No abnormal histological changes were found in the leucocytes. The eosinophile cells were large (average about 14μ) and well-formed, with abundance of granules; they seemed to be always rather larger than the neutrophiles. The nucleus was of the shape which is so characteristic of normal eosinophile cells, *i.e.* formed of two oval approximately equal parts, joined by a fine filament, the latter lying generally in fixed films toward the periphery of the cells[3]. No eosinophile myelocytes could be found. The curious irregular granules in the

[1] We are inclined to think that the numbers of this variety of leucocyte which are present in normal blood are commonly somewhat underestimated. The reason may possibly lie in the fact that Ehrlich's triacid stain does not bring them out very clearly; Jenner's stain renders them one of the most prominent and unmistakable features in the film. The statement that in health they never exceed 0·5 per cent. is certainly not true.

[2] B. K. Ashford, *loc. cit.* W. L. Blickhalm (*Medical News*, Philadelphia, LXIII. 1893, p. 662) found an excess of eosinophiles and mast-cells (α and γ granulations of Ehrlich), but he does not mention any cell which can be identified as a myelocyte.

[3] Ehrlich and Lazarus (Myers' translation, p. 76) state that, except for tinctorial differences, it is "completely similar" to the neutrophile nucleus. Such a condition is very exceptional. Ehrlich has in another place quoted from Jolly a correct description (*Rapport sur la leucocytose, XIII^e Congrès internat. Méd.*, Paris, 1900, p. 4).

cytoplasm of some of the smaller of the intermediate non-granular cells which stain a metachromatic red with Jenner's stain seemed perhaps rather more numerous in these cases than they do in normal blood.

In spite of the fact that an eosinophilia is occasionally absent, there is no doubt that it may be frequently of service in suggesting the diagnosis of a case of anaemia of doubtful origin. It is a test which can often be easily made when a sample of the faeces cannot be obtained, and the examination of a blood film is a procedure which should always be undertaken in any doubtful case of anaemia. In the present instance it would have cleared up the mystery of "Dolcoath anaemia" years ago. As to its value in diagnosis, where it stands almost by itself, it is not easy to make a definite statement. We have come across four cases (XXII. XXIII. XXX. XLIV.) where the count gave 13·8, 11·2, 22·6, and 13·8 per cent. eosinophiles respectively (for which no other reason could be found) and where very thorough examinations of the faeces failed to reveal the presence of any ankylostoma ova. Two cases gave a history of pit work and illness six years ago which corresponded to those obtained in clear cases of *Ankylostoma* infection at Dolcoath, while the others had been exposed to possible infection, one for several years, the other only recently. It has been shown[1] by the test of autopsies that a few worms may be present in the gut in cases where during life the examinations of the faeces has proved negative. Taking this fact into consideration, there seems to be little doubt that, among a community exposed to infection, a positive blood examination may be regarded as overriding a negative search for ova in the faeces. We have accordingly regarded these four instances as being examples of infection, as well as five other miners (XXVI.—XXIX. and XXXI.) the faeces of whom were not examined, and in whose blood the percentage of eosinophiles varied from 12·6 to 56·2. On the grounds of exposure to infection and an eosinophilia (9·2 to 48·0 per cent.) we also regard the eleven cases given in Section II. of the Appendix as being in all probability infected. Among the pitmen at St Agnes (where the mine is shallow and cool) no history of anything like ankylostomiasis could be obtained except in one case (LXI.): in this instance infection by *Ankylostoma* as a

[1] Leonard Rogers, *Indian Med. Gazette*, xxxv. 1900, p. 129. Bucklers (*Münch. med. Wochenschr.* XLI. 1894, p. 21) records an interesting case where no eggs could be found after 227 worms had been expelled with male fern: a further dose however produced 9 more *Ankylostoma*. As P. Sonsino (Davidson's *Hygiene and Diseases of Warm Climates*, 1893, p. 896) points out, eggs can only be found if the intestine contains adult females engaged in oviposition.

cause of the severe anaemia was excluded by the blood-count (3·5 per cent. eosinophiles) and no ova could be found in the faeces. Inspection of one of the shifts as they came up from underground failed to reveal any examples of unusual pallor or of dyspnoea on climbing the ladders, the general healthy appearance of the miners here contrasting strongly with the pallor which is so common at Dolcoath. Blood films were taken from eleven of the least ruddy men who could be found; on examination eight of them showed from 1 to 4·75 per cent. eosins, and two others which were not counted showed no excess of eosins on inspection. The tenth case (LX.) however, who had lately returned from India, gave 23·8 per cent. eosins in the differential count, and a moderate number of *Ankylostoma* eggs were found in his faeces.

It is possible that such cases as XXII. and XLIV. were not infected at the time of examination and that their eosinophilia was a remainder of a previous infection which had died out. We have at present no data by which this question can be settled[1]. The death of a large number of worms is certainly not necessarily followed by an immediate fall in the eosinophiles; indeed in some of our cases the percentage actually rose[2] (see cases I. IV. XI. XL.).

The possibility of the changes which we have described being due in some instances to some other intestinal parasite must of course be considered. The only one of which we obtained evidence was *Trichocephalus*. The characteristic eggs of this worm were found in a good many cases; unfortunately the fact was not noted in all instances but most are recorded in the table in the Appendix. We are not aware that an eosinophilia has at present been established for *Trichocephalus* as it has been for most of the intestinal worms, though a fatal anaemia has been attributed to it.

[1] Ehrlich (*Rapport sur la leucocytose*, p. 11) cites a case which Leichtenstern (*Die Anaemie*, p. 113) has put on record as showing that "after removal of the worm" an eosinophilia (8 per cent.) persists for a long time owing to hypertrophy of the eosinophile part of the bone-marrow. It is however distinctly stated by Leichtenstern that in the following year this same case still harboured a few worms (eosins 8 per cent.), so that there appears to be no ground for assuming either that all the worms were expelled the year before or that a habit of eosinophilia persists after their complete expulsion. In this case, on killing (most of) the worms, the eosins fell at once from 54 to 11 per cent.; from which it might be argued that on killing them all the eosins would have reached a normal figure. The difficulty of being quite sure that any individual is quite free from *Ankylostomata* by any means short of autopsy seems an almost insuperable one. We are inclined to regard the blood-count as the finest test which we at present possess. Thus case IV. is probably still infected, though no ova can be found in the faeces.

[2] The partial digestion and presumable absorption of a number of dead worms might well increase the eosinophiles for a time.

APPENDIX.

TABLE OF CASES.

SECTION I.

	Name and age	History, symptoms, occupation, etc.	Present condition	Ova in faeces	Red cells per cub. mm. in millions	Hb p.c.	Colour-index	Total leucocytes per cub. mm.	Lymphocytes	Intermediate	Large hyaline	Neutrophile	Eosinophile	Mast-cells
I	J. S., 51	In charge of four shafts (including Engine Shaft) for 18 years. Illness began 3 years ago with general weakness, palpitation and dyspnoea. At home 6 months. On surface 2 years. Some epigastric pain and dyspepsia. Had urticarial bunches often, but not since leaving shaft. Marked general oedema 18 months ago. Has had continual general pruritus for 2 years	Dyspnoea on slight exertion, no oedema, general pruritus	Oct. 31 abundant. *Trichocephalus* present Nov. 14 thymol 264 worms, females 55 p.c. Nov. 15 Nov. 22 ova numerous Dec. 1	3·216	48 43 43	0·74	8,800	13·4 10·8	7·4 5·6	6·2 3·4	56·2 61·0	16·0 18·0	0·8 1·2
II	J. P., 43	Worked in Engine Shaft. Illness began 4 years ago with palpitation and dyspnoea. At home 5 months, since on surface: has not improved at all. Bowels loose when in shaft, but not since. Had bunches badly, but little pruritus	Dyspnoea on slight exertion, general health bad	abundant Oct. 31. *Trichocephalus* present also worms obtained	2·192	35 Nov. 7	0·81	3,800 11·8	16·6 4·4	8·2 2·2	5·8 72·0	51·0 8·8	17·8 0·8	0·6 0·8
III	M. B., 32 circ.	Machine work. Dyspnoea, palpitation and pruritus 4 years ago. Has worked on surface at stamps for last 4 years; condition has much improved. Bunches preceded illness	Can do work easily	moderate	3·024	38	0·63	6,800	16·2	11·0	10·4	50·0	11·4	1·0
IV	W. F. A., 27	Pitman off Engine Shaft. Ill 4 years ago with dyspnoea, palpitation and cramps in legs. For last 3 years on surface. Had bunches in pit but not since. Has much improved.	A little dyspnoea on exertion, at work regularly	Oct. 31 few. *Trichocephalus* also Nov. 1 thymol 7 worms Nov. 15 no ova Nov. 20 Nov. 25	3·328	37 36 45	0·56	8,200	16·6 21·0	5·2 3·0	5·2 1·5	53·0 39·5	19·4 33·5	0·6 1·5

V	G. P., 50	In Engine Shaft 21 years. Anaemia and palpitation in 1897. "Pimples all over" 4—6 weeks before palpitations. Has improved greatly	Well except for slight dyspnoea, works underground	moderate. *Trichocephalus* present	3·968	56	0·71	7,500	16·6	11·8	7·8	47·0	16·8	0
VI	B. R., 20	Eastern Shaft. 3 years ago went down Engine Shaft and immediately had rash on back, shortly afterwards began to be pale; has not improved since. Palpitations, little dyspnoea, intermittent diarrhoea	Too ill to work but can get about, has general pruritus	abundant	3·376	54	0·79	13,100	6·6	13·4	15·6	43·0	20·6	0·8
VII	W. P., 28	Machine man. 2 years ago pale and short of breath. At home 4 months, never ill till in Engine Shaft. Bunches appeared before anaemia	Slight dyspnoea but feels quite well, pale	moderate	4·424	74	0·83	10,750	26·0	6·2	7·0	54·4	6·0	0·4
VIII	J. P., 34	Has never had any symptoms at all. Machine man, has worked all over the mine exactly as Case VII.	Has exceptionally healthy appearance	few	4·712	94	1·00	12,700	31·8	9·6	5·0	36·0	17·2	0·4
IX	A. T., 36	Pale and palpitations in 1896, ill till 1901. Has gone underground about 2 days a week throughout, and (except when too ill) up to the present time. Botches several times	No symptoms now present	very few	4·936	102	1·04	10,000	31·4	4·0	3·6	55·2	5·6	0·2
X	N. S., 17	12 months underground at Tincroft, at Dolcoath 12 months. 7 months ago was in Engine Shaft for 4 months. Ill for last 2 months with dyspnoea, some epigastric pain, botches	Dyspnoea on exertion, very pale, cannot work	moderate	3·432	40	0·58	Nov. 15 24,400 Nov. 19 31,400	10·0	7·6	4·2	48·4	29·0	0·8
XI	R. C., 25	Came from E. Pool to Dolcoath for 4 days 18 months ago (not to Engine Shaft); since at E. Pool. Ill 12 months with pallor and dyspnoea; at home 7 months, and confined to bed 14 days. No skin affections	In bed, very weak and intensely pale, no oedema	Nov. 16	1·533	17	0·56	12,960	14·2	2·4	3·6	62·8	15·8	1·2
			Ova abundant, thymol Nov. 21, 28, and Dec. 19, many worms; ova still numerous on Dec. 10	Dec. 10	2·192	25	0·57	12,200	7·4	2·6	3·2	74·4	11·0	0·4
									neutrophile myelocytes 1 p.c.					
			Able to go for a walk on Dec. 16	Dec. 18		36		7,690	18·4		5·2	58·0	17·0	1·4
									neutrophile myelocytes 0·2 p.c.					
			Trichocephalus ova also present	Dec. 20				7,850	11·0	1·8	5·2	67·0	13·6	1·4

SECTION I. (*continued*).

	Name and age	History, symptoms, occupation, etc.	Present condition	Ova in faeces	Red cells per cub. mm. in millions	Hb p.c.	Colour-index	Total leucocytes per cub. mm.	Lymphocytes	Intermediate	Large hyaline	Neutrophile	Eosinophile	Mast-cells
XII	J. C., 17	Between New East and Valley 3 months, previous in Harriet for 18 months, pale and short of breath 6 months	At work underground, does not look very pale	moderate Nov. 20 Nov. 21 Nov. 24	3·192	50	0·78	44,000	6·3 8·9 9·0	0·5 3·6 3·1	0·7 0·5 0·5	19·5 20·7 20·7	72·7 65·8 66·2	0·3 0·5 0·5
XIII	T. T., 32	4 years in Engine Shaft. Has suffered from bunches ever since he came to mine (has furuncles now on both ankles and left elbow). No dyspnoea or palpitation	Looks pale but feels quite well	moderate	3·768	47	0·63	16,200	16·8	3·6	3·0	61·6	14·6	0·4
XIV	J. C., 22	Works at E. Pool. Has been to Dolcoath with machines several times, last 8 months ago. No botches. No dyspnoea or palpitation	General health not very good	very few. *Trichocephalus* present	3·330	92	1·38	13,500	20·6	3·4	1·6	45·8	27·6	1·0
XV	J. M., 25	Engine Shaft 8 years. A little dyspnoea. Not pale. Botches frequent	At work, slight dyspnoea	moderate	4·072	58	0·71	13,500	9·2	8·0	8·0	52·0	22·0	0·8
XVI	R. S., 21	Worked in S. Lode 4 years ago. Became pale and short of breath and gave up mining. Has been in butcher's trade since. Much better but not quite well. Never in Engine Shaft. No botches	Working, does not look anaemic	very few. *Trichocephalus* ova also found	4·488	99	1·11	6,200	36·6	6·6	3·2	40·2	12·0	1·4
XVII	J. R., 27	In Engine Shaft till 2½ years ago, since in Eastern. Pale, etc. 3 years ago; in hospital for a month	At work underground	moderate	4·128	74	0·90	12,400	27·6	18·0 (300)	6·6	43·6	3·7	0·3
XVIII	J. M., 18	Began in Engine Shaft 2 years ago. Ill for 9 months and off work for 2 months with palpitation and dyspnoea. Bunches preceded paleness. Almost constant diarrhoea	Cannot work	moderate	3·352	36	0·53	10,700	17·5	6·5	2·8	42·5	30·1	0
XIX	J. R., 25	Engine Shaft 12 months, previously all over mine. Ill 12 months with dyspepsia. No dyspnoea. Not paler. Bunches occasionally	At work, does not look anaemic	few	3·456	70	1·01	9,250	25·0	6·4	4·4	53·0	10·4	0·8

XX	R. W., 29	Engine Shaft 2 years. Ill 18 months with epigastric pain and vomiting. Has had botches	A good deal of dyspnoea on exertion	few	5·384	62	0·58	9,000	37·8	7·4	2·8	38·6	12·2	1·2
XXI	F. N., 36	At Dolcoath 3 years, previously at Tincroft and abroad. Has been off work 5 months with general weakness. Sometimes short of breath. Very few botches	Cannot work, possibly has tubercular peritonitis	moderate	5·280	70	0·66	8,650	19·5	15·8 (6 00)	6·8	37·3	20·6	0·16
XXII	J. W., 49	Pale and dyspnoeic 6 years ago. Has not been underground for 6 years, but has worked as a fitter. Does not handle anything from mine	Pale, general health bad	none found on 2 separate occasions	3·272	89	1·37	7,600	31·0	3·8	2·8	48·2	13·8	0·4
XXIII	A. R., 22	Carpenter. Has worked in upper part of Eastern Shaft for last 9 months only. A little paler lately. No dyspnoea. Marked constipation with colicky attacks for last 3 months	Looks very well	none found	4·848	88	0·91	8,100	33·0	4·2	3·8	47·6	11·2	0·2
XXIV	S. J., 24	Underground, not in Engine Shaft. A little palpitation, no dyspnoea. Has become a little paler. Has had bunches (urticarial) several times, first attack 9 months ago	Feels quite well	fairly numerous	3·144	46	0·74	12,300	10·6	9·0	5·4	42·8	32·0	0·2
XXV	W. J. S., 29	In Engine Shaft 7 years. Pallor and dyspnoea for 5 years. A good deal of epigastric pain. Had no bunches till 3 or 4 years ago	At work, a little dyspnoeic, very pale	moderate : 4 worms+	3·216	46	0·72	12,000	13·2	4·8	4·6	57·6	19·0	0·8
XXVI	J. M., 22	New East underground. No dyspnoea. A little paler lately. Small bunches occasionally	Feels quite well		4·080	80	0·98	11,100	20·2	4·2	6·8	55·6	12·6	0·6
XXVII	M. T., 50	At Dolcoath 2 years in Engine Shaft. No dyspnoea or palpitations. Diarrhoea for last 5 weeks	Looks very pale but feels fairly well		3·296	44	0·67	11,600	19·0	4·2	3·8	55·6	16·6	0·8
XXVIII	J. S., 24	Pitman. A little dyspnoea and palpitation, and rather paler. No botches	Looks very well		5·112	100	0·98	6,900	23·8	4·4	3·8	47·0	20·4	0·6
XXIX	E. J. T., 18	Underground 12 months stoping. For last 6 months has had epigastric pains and is a little paler and slightly dyspnoeic. Botches sometimes	At work, looks quite well		4·208	98	1·16	20,600	21·0	4·2	1·2	16·6	56·2	0·8

SECTION I. (*continued*).

	Name and age	History, symptoms, occupation, etc.	Present condition	Ova in faeces	Red cells per cub. mm. in millions	Hb p.c.	Colour-index	Total leucocytes per cub. mm.	Lymphocytes	Intermediate	Large hyaline	Neutrophile	Eosinophile	Mast-cells
XXX	J. C., 22	Engine Shaft 5 months. Stoping previously in New East for 8 years. A little dyspnoeic for 3 years. Not paler. Bunches sometimes	At work, does not look anaemic	no ova found	4·176	82	1·00	13,600	14·8	7·0	3·6	51·8	22·6	0·2
XXXI	P. C., 29	Underground in Engine Shaft till dyspnoea and palpitations made him come on surface 4 years ago. Constant diarrhoea for about 5 years (no melaena)	At work		4·706	66	0·70	10,500	14·2	5·5	4·0	60·25	15·25	0·75
XXXII	S. C., 23	Stoper in Eastern Shaft. Never worked in New Sump. Weak and sick for last few weeks. Abdominal discomfort. No dyspnoea. Poor appetite. Has had bunches all over	At work	moderately abundant	5·350	80	0·75	56,000	5·4		2·8	25·6	66·2	0
XXXIII	J. H. S., 18	Underground at Dolcoath 4 years. Pallor and dyspnoea on exertion 2 years ago, now better. Considerable epigastric pain. Had bunches when working in Engine Shaft		moderate	2·900	38	0·65	6,700	27·0	15·0	7·0	36·5	14·0	0·5
XXXIV	J. M., 34	Machine man 6 years. Pale and dyspnoeic for last 12 months		moderate		88		7,200	12·8	11·2	4·0	52·0	20·0	0
XXXV	C. M., 36	Engine Shaft. Pale and dyspnoeic in 1897. At home 12 months, on surface since. Botches began just before palpitation. Intermittent diarrhoea	Can work, is indefinitely ill	very few		70			15·6	6·4	3·4	47·4	26·4	0·9
XXXVI	T. S., 52	Underground 30 years. Pale and a little short of breath 6 years ago, is now better. Not in Engine Shaft	Can work without difficulty	moderate		58			21·6	3·0	1·4	69·8	3·6	0·6
XXXVII	W. J.	Underground superintendent. Constantly in Engine Shaft. Became very pale 2 years ago but had no palpitation or dyspnoea	Appears to be in perfect health and feels very well	moderate		104			41·2	4·6	2·4	34·2	17·0	0·6

XXXVIII	J. W., 50	Underground. Pale and short of breath 2 years ago. Has kept the house since March 1901, 6 miles from Dolcoath. Had many (furuncular) bunches when in mine	Has fibrosis of left lung, short of breath on exertion, often has attacks of urticaria	moderate : 111 worms, females 75 p.c.		34		15·6	3·0	1·4	55·6	24·4	0
XXXIX	T. W., 19	Underground New East. Paler and a little dyspnoeic for 18 months. Botches frequently, but not lately	Works underground without difficulty, looks very pale	many		36		19·0	5·2	1·6	54·0	20·2	0
XL	F. C., 22	Underground Engine Shaft 3 years. A good deal of dyspnoea. Not paler. Bunches sometimes	Does not look anaemic	rather abundant Dec. 12 thymol		52		14·2	5·2	1·8	69·0	9·4	0·4
				Dec. 19		62		15·6	4·0	5·2	58·0	16·4	0·8
XLI	T. U., 49	Underground machine man. Came to Dolcoath 6 years ago, and soon after had shortness of breath and became pale. Had bad attacks of haematemesis 6 years and 9 months ago	Pale, a little dyspnoeic on exertion	moderate		50		15·6	6·4	3·0	58·4	15·6	1·0
XLII	J. W., 47	Underground in Harriet 10 years. Pale and short of breath 2 years ago, better now. Bunches frequently	Works easily, but general health indifferent	moderate : a few worms		61		12·8	7·6	3·8	64·8	10·2	0·8
XLIII	A. B., 21	Harriet 6 months, previously in Engine Shaft. No dyspnoea or palpitation. Is rather paler than formerly. Has furuncles on knee now	At work, no symptoms of anaemia	many		66		13·6	10·2	5·8	62·4	7·0	1·0
XLIV	C. T., 37	Underground in South Lode. Very pale in 1894. At home 2½ years and on surface since. No history of "botches." Frequent diarrhoea	Does not look anaemic. Epileptic	none found				27·0	9·0	1·8	48·0	13·8	0·4
XLV	W. C., 48	At Dolcoath 24 years, except 1894–1900 in India. Some dyspnoea on exertion for last 5 months	Has early fibroid changes in lungs	few		100		8·0	7·0	4·75	67·25	11·5	1·5
XLVI	R. B., 44	30 years underground at Dolcoath. Three attacks of pleurisy recently	Pale, at work underground	moderate				20·0		5·5	61·0	13·0	0·5

Section II.

Containing eleven cases of underground workers at Dolcoath whose faeces were not examined but whose occupation raises a strong presumption that they are infected though they shew little or no symptoms. The blood examinations are incomplete but the differential count greatly strengthens this presumption.

	Name and age	History, occupation, etc.	Present condition	Hb p.c.	Lymphocytes	Intermediate	Large hyaline	Neutrophile	Eosinophile	Mast cells
XLVII	A. G., 19	Underground at Dolcoath. Considerable epigastric pain. Palpitation on exertion. Not paler: bunches occasionally	Works easily underground	80	15·8	6·8	3·6	50·0	23·0	0·8
XLVIII	J. C., 22	Engine Shaft 2 years. Palpitation 5 months. Not paler. Epigastric pain. Botches sometimes	,,	92	19·0	5·4	2·6	56·2	15·2	1·6
XLIX	R. H., 36	21 years underground. Engine Shaft 6 months. No symptoms. A few botches	,,	99	19·3	8·3	3·7 (300)	50·0	17·3	1·3
L	A. M., 22	Underground 7 years. At Dolcoath in Engine Shaft 7 weeks. No symptoms	,,	98	21·75	7·25	3·75 (400)	54·5	12·5	0·25
LI	H. R., 35	Underground in Engine Shaft 2 years. No symptoms	,,	86	15·6	6·8	0·8	44·8	31·0	1·0
LII	R. E. C., 22	Underground in Engine Shaft 18 months. A little dyspnoea. Botches sometimes	,,	71	12·4	7·0	4·4	28·0	48·0	0·2
LIII	C. T., 52	Underground for many years. Has been to India, etc. Has never had any anaemic symptoms. Has always been very subject to attacks of urticarial botches at Dolcoath	,,	90	16·0	13·75	8·25 (400)	43·25	18·0	0·75
LIV	E. I., 29	Machine man. Has miner's phthisis	,,	59	6·0		5·8	73·4	11·4	0·8
LV	H. V. T., circ. 25	Surveyor underground at Dolcoath 5 years. No history of anaemic symptoms	Feels quite well	85	16·0		5·5	59·0	19·5	0·5
LVI	S. H., 21	Works in Engine Shaft. Bunches and paler lately	Works easily underground		19·5		5·0	56·0	17·0	2·5
LVII	J. R., 59	Underground at Dolcoath till palpitations and dyspnoea made him leave 3 years ago. Improved and worked at South Condurrow till recently	Shoemaking now		16·6		5·6	67·8	9·2	0·8

Section III.

Surface workers at Dolcoath in whom there is no suspicion of infection.

	Name and age	History, occupation, etc.	Present condition	Hb p.c.	Lymphocytes	Intermediate	Large hyaline	Neutrophile	Eosinophile	Mast cells
LVIII	R. P., 54	Carpenter. Does not handle anything from underground and has not been down mine for 30 years. Always been very well	In excellent health	105	33·6	3·6	3·4	54·4	4·8	0·2
LIX	R. G., 60	Underground till 9 years ago. No history of any symptoms. Works at tin-dressing	Enlarged prostate and cystitis		7·0	4·4	5·4	81·6	1·2	0·4

Section IV.

Underground workers at West Kitty Mine, St Agnes (see p. 103).

LX	J. J.	No history or symptoms of anaemia. Has lately returned from 4 years in the Mysore Gold Mines. In faeces a moderate number of Ankylostoma and abundant Trichocephalus ova found			14·6	6·0	3·6	50·8	23·8	1·2
LXI	G. C., 58	Very weak and anaemic 8 months, in bed 4 months. No fever or local symptoms. Possibly malignant. No ova found in faeces. Blood does not shew any blood disease		35	8·0	4·5	2·0	81·5	3·5	0·5
LXII to LXIX	G. R.	Eight pitmen. No history or symptoms of anaemia in any case. All in good health. Differential counts of 200—300 only			39	8·5	3·5	46	1	2
	J. C.				26	4·3	3·3	65·3	1	0
	W. F. P.				18	11·5	5·5	61	3·5	0·5
	W. W.				15	8·5	6	69·5	1	0
	W. M.				38·7	12·7	3·3	42·3	3	0
	W. R.				18·0	16·5	7·5	56	2	0
	J. H.				31·5	5	2	56·5	4	1
	W. T.				27	4·75	2·75	60·0 (2 normoblasts in counting 400)	4·75	0·75

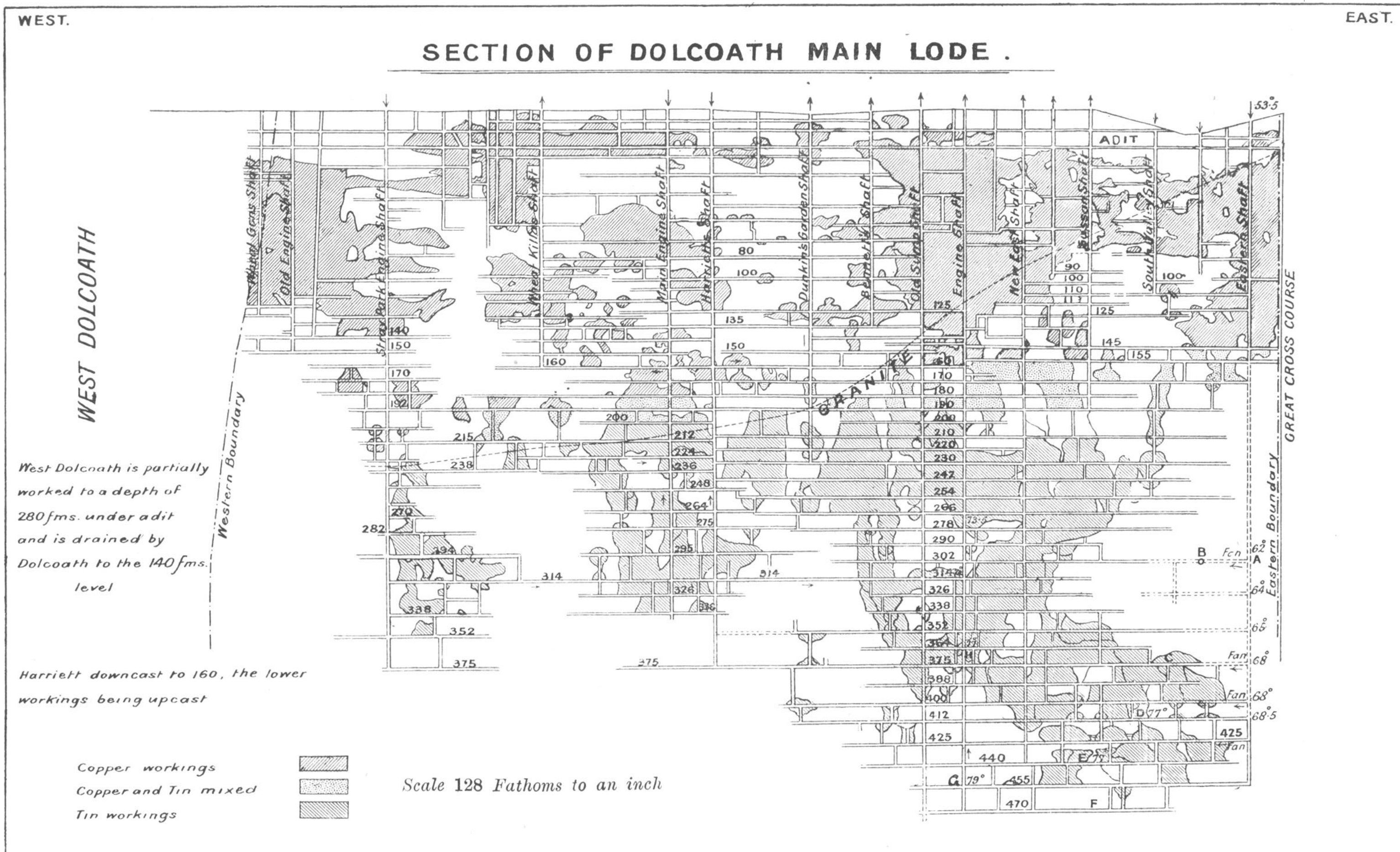
WEST.
EAST.
SECTION OF DOLCOATH MAIN LODE.
WEST DOLCOATH
West Dolcoath is partially worked to a depth of 280 fms. under adit and is drained by Dolcoath to the 140 fms. level
Harriett downcast to 160, the lower workings being upcast
Copper workings
Copper and Tin mixed
Tin workings
Scale 128 Fathoms to an inch
Western Boundary
Eastern Boundary
GREAT CROSS COURSE
GRANITE
ADIT
Old Engine Shaft
Stray Park Engine Shaft
Main Engine Shaft
Harriett's Shaft
Dunkin's Garden Shaft
Bennetts Shaft
Old Sump Shaft
Engine Shaft
New East Shaft
Bussons Shaft
Eastern Shaft

Fig. 1 (see p. 97).