HOOKWORM IN CALIFORNIA GOLD MINES

RALPH W. NAUSS, M. D., DR. P. H.*

Read before Section on Industrial Hygiene, American Public Health Association, at San Francisco, Cal., September 17, 1920.

HISTORICAL—EUROPE

As far back as 1847[1] it was believed that "Egyptian Chlorosis" was due to ankylostoma found in the small intestine at autopsy. Subsequent to that time, there have been many reports of the finding of ankylostoma in anemic individuals and their presence has been believed to have some relation to the causation of the anemia. However, it was not until after work was begun on the St. Gothard Tunnel[2] that the significance of this parasite in the etiology of both endemic and epidemic anemias was generally appreciated. Several years before the appearance of a very severe and fatal anemia among workmen engaged in this tunnel in 1880, Prof Grassi[3] made known his discovery of diagnosis of hookworm infection by microscopic examination of the feces. This made possible a thorough clinical study of the St. Gothard epidemic. Since that time hookworm anemia has been found to be a serious menace, not only in the tropics and subtropics generally but also in mines situated in various countries of the temperate zone.

Perroncito,[4] to whom the principal credit is due for establishing the true etiology of the anemia among workmen engaged in the St. Gothard Tunnel, also showed hookworm infection to be prevalent among men employed in various mines of Hungary, Sardinia and South Central France. About this time hookworm infection was likewise found to be quite common among brickworkers in Germany. The origin of soil infestment in and around brickfields[5] was traced to immigrants (Walloons) who worked in the mines of Belgium during the winter months and migrated to Germany to labor in the brickfields during the spring, summer and early fall. In 1896[6] it was discovered that hookworm-infected workmen from certain Austrian mines were carrying the infestation into German mines. Whether or not this was the occasion of the first appearance of the infestment in German mines is not definitely known. It seems, however, very probable that hookworm disease has existed among miners in Hungary, France, Belgium and possibly Germany, for several centuries at least, the belief being that former epidemics of anemia among miners in these countries were caused by hookworm infection.

In Germany,[7] after the discovery above mentioned, steps were taken to control the anemia developing among miners by the provision of sanitary conveniences and the treatment of the sick, incapacitated and anemic. The disease, however, continued to spread, and as a consequence, a complete hygienic program was adopted in 1903, including the discovery and cure of all infected miners whether sick, anemic, incapacitated or merely carriers. This, though expensive and time-consuming, has proven to be the best policy. In Austria, where incomplete measures only were attempted, anemia is said to have continued to exist among 20 to 90% of the workmen. In Belgium the results achieved have been in ratio to the thoroughness of the control campaigns. Circumstances and conditions in French and English mines seem to have been more favorable for the control of mine infestment, and as a result the application of more or less incomplete measures have given gratifying results in control of ankylostomiasis among miners.

CALIFORNIA

The specific cause of the anemia,

*The author was engaged as Asst. Epidemiologist by the California State Board of Health when the material for this paper was collected.

known for years to have been exceedingly prevalent among miners employed along the "Mother Lode," California, was first recognized in 1906 by Dr. F. F. Sprague of Jackson, who had previously seen service in the Philippine Islands It was he also who first treated this condition successfully at Jackson and endeavored to convince his colleagues of its specific nature and curability. Dr. E. E. Endicott,[8] health officer at the time of Amador County, Calif., and attending surgeon for men employed in two of the largest gold mines situated near Jackson, the county seat, followed the lead of Dr. Sprague in the correct diagnosis of these anemias and achieved most gratifying results in the proper treatment of the same.

In 1909, Dr. Herbert Gunn,[9] representing the California State Board of Health, made an investigation to determine the extent of infection among "Mother Lode" miners. In certain groups of miners, he found a high percentage showing an abnormal Eosionophilia, the cause of which was revealed by confirmatory stool examinations. His conclusions were as follows:

(1) Hookworm disease is endemic in certain mines of California.

(2) From 50% to 80% of those working in these mines are infected.

(3) The infection undoubtedly is present in practically all the gold mines of California and in those of Nevada, just over the border.

No further attempts at investigation or control of ankylostomiasis among California miners were made until 1916, when the California State Board of Health in coöperation with the Federal Bureau of Mines and the Industrial Accident Commission of California agreed upon the following program:

1. To encourage the superintendents of the various mines to coöperate in the campaign.

2. To examine fecal specimens from the miners and determine the percentage of infected miners.

3. To reach an agreement with superintendents, that all infected men must be treated.

4. To make re-examination of all treated men.

5. To issue "Hookworm Certificates."

6. To re-examine eventually all California miners.

The results of work conducted along these lines by Cumming and White, representing respectively the California State Board of Health and the Federal Bureau of Mines, were published in 1917 by the U. S. Bureau of Mines (Dept. of the Interior) in Bulletin 139, entitled "Control of Hookworm Infection at the Deep Gold Mines of the Mother Lode, California." This report is most interesting statistically, but not very convincing regarding endemicity and the actual control of the infection among workmen.

In October, 1916 (the work of Cumming and White having been conducted during the Spring and early Summer of this year), the work of investigation and attempts at control of hookworm disease among miners were continued by the California State Board of Health under the direction of Dr. Cumming. However, owing to labor conditions, it seemed impractical immediately to resume activities along the "Mother Lode." It was, therefore, decided first to make a survey of the Grass Valley Gold Mining District, which is similarly situated in the Western foothills of the Sierra Nevada, some 60 or 70 miles northwest of Amador County, in which the deepest "Mother Lode" mines occur. This survey was completed during the latter part of November, 1916, and resulted in the finding of but two infected miners out of a total of some 1,400 workmen examined (one of these men was known to have formerly worked in "Mother Lode" mines).

In December, 1916, the labor situation had improved sufficiently to justify the resumption of our work among "Mother Lode" miners. The remainder of this paper is concerned with a discussion of factors influencing endemicity of hookworm disease in mines and the results of

related observations and experiments made by me during the winter and spring of 1916-17. Statistics as to the incidence of infection among men engaged in the various "Mother Lode" mines surveyed in 1916 and 1917 are shown on the tables here displayed. The significant reductions in percentages that appear so striking in some instances are not due primarily to the effects of treatment but rather to the marked turnovers in labor resulting from the general strike which occurred in the fall of 1916. A re-examination of some 40 men found to be infected before the strike and treated one or more times showed a much less reduction in percentage of infection than is indicated for Mine "A," given at the head of the table.

FACTORS INFLUENCING ENDEMICITY OF HOOKWORM INFECTION IN MINES

The time allowed for the reading of papers in section meetings is such that only a brief résumé of my original discussion on these points can be attempted. In this article, which has not yet been published, factors influencing endemicity which depends on infestment of mine soil and water with hookworm larvæ are considered under four headings as follows:

1. Temperature, relative humidity and ventilation.
2. Mine drainage and methods of collection and removal of mine water.
3. Chemical composition of mine water.

TABLE I

Detailed Results of Diagnostic Surveys for Hookworm—Cumming and White,[10] 1916, and the Author, 1917

		Underground Workers				Surface Workers		
Mine	Year	Number Examined	Number Found Infected	Per Cent Infected	Mine	Number Examined	Number Found Infected	Per Cent Infected
A	1916	158	95	60	A	37	3	8
	1917	303	35	11		53	2	4
B	1916	292	47	16	B	..	..	..
	1917	370	30	8		94	2	2
C	1916	171	114	67	C	28	1	4
	1917	101	28	28		8	0	0
I	1916	....	..	..	I	..	..	..
	1917	58	8	14		..	..	..
D	1916	57	22	39	D	13	3	23
	1917	52	44	46		..	..	..
J	1916	..	..	..	J	..	..	..
	1917	57	9	16		14	0	0
E	1916	56	13	23	E	..	..	..
	1917	46	1	2		..	..	..
F	1916	29	6	21	F	18	2	11
	1917	31	3	10		12	0	0
G	1916	121	40	33	G	27	4	15
	1917	114	8	7		24	1	4
K	1916	..	..	..	K	..	..	..
	1917	42	2	5		17	1	6
H	1916	85	26	31	H	14	1	7
	1917	76	11	14.5		19	0	0
L	1916	..	..	..	L	..	..	..
	1917	125	16	13		15	1	6.5
M	1916	..	..	..	M	..	..	..
	1917	32	0	0		13	0	0
N	1916	..	..	..	N	..	..	..
	1917	85	6	8		27	0	0
O	1916	..	..	..	O	..	..	..
	1917	103	5	5		9	0	0
P	1916	..	..	..	P	..	..	..
	1917	113	0	0		60	0	0
Q	1916	..	..	..	Q	..	..	..
	1917	28	0	0		12	1	8
R	1916	..	..	..	R	..	..	..
	1917	34	9	26.5		..	..	..
Total,	1916	969	363	36.2	Total,	1916 137	14	11.3
	(Average per cent for 8 mines)					(Average per cent for 6 mines)		
Total,	1917	1770	195	11.9	Total,	1917 377	8	2.1
	(Average per cent for 18 mines)					(Average per cent for 14 mines)		

4. Mine sanitation with particular reference to feces and disposal.

Temperature, Relative Humidity and Ventilation.—Under natural conditions, the most suitable temperatures for growth and saprophytic development of hookworm embryos to the infective larval stage are between 65° and 85° F. (18° and 30° C.). Below this range of temperature growth and development are slow; above this range growth and development are rapid but the eggs, embryos and larvæ are very apt to die. In the laboratory under artificial conditions, good results can be achieved if temperatures from 25° to 30° C. are maintained. The average temperatures of only a few of the mines, included within the scope of my observations and studies of hookworm infection among California miners, fell below a temperature generally considered necessary for normal growth and development of hookworm embryos and larvæ. Similarly it may be said regarding both limits of temperature above mentioned that there was no mine in some parts of which conditions of both temperature and relative humidity were not favorable for the establishment of endemic foci, assuming all other necessary favorable conditions to have been present. As to relative humidity, it may further be said in general that the humidity in all these mines was uniformly high.

Without going into more detail under this heading it must suffice to state that effective ventilation tended, as would be expected, to reduce materially both the underground temperatures and relative humidities. However, good ventilation was the exception and not the rule in "Mother Lode" mines. Where ventilation was effective comparatively low degrees of infection among the men appeared to be the case.

Methods of Collection and Removal of Mine Water.—A study of mine drainage and methods of collection and removal of mine water proved to be most interesting and instructive. In addition to drainage along the floor levels of mines, it is necessary also to consider leakage from one level to another through fills and connections such as shafts, winzes and raises. These are all very important factors in the possible dissemination of larvæ from infested localities. Whether the infective larvæ are caught up and transported by water as it is drained off from infested areas or whether the collected drain water is supplied more directly with larvæ hatched from ova-laden feces through the use of water collecting devices for toilet conveniences, seemed to make little difference in the ultimate dissemination of larvæ. Attempts to intercept hookworm larvæ while being carried by mine drain water proved unsuccessful. However, periodic observations on the dissemination of larvæ hatched from infested stools deposited along a mine drain gutter as shown in Illustration I indicate the important role which mine drain water may play in the distribution of infective larvæ.

Boycott and Haldane,[11] who investigated ankylostomiasis among Cornish miners in 1903-1904, mention the use of the pump-cisterns by the men for receiving their evacuations and think "their use for this purpose less open to objection, since the feces are pumped to the surface where they can probably do no harm." They state further that "running water is said to prevent, in any case, the development of ova." These statements are, however, contrary to my observations and experience. In mines where the sumps were so used, the highest degrees of infection were found to exist among the underground workmen. Likewise the clinical histories of cases pointed quite clearly to the infested sumps as the most probable sources of high degrees of infection among the workmen. Running water did not appear in any way to prevent the development of larvæ from the ova. Furthermore, as already intimated, in addition to not preventing development of the larvæ, running water undoubtedly serves

both to distribute and collect larvæ from points of origin. Evidence on this point will be presented a little later.

In case of one mine (mine B in Table II) situated in the very center of the endemic area, a comparatively low degree of infection was upon examination found to exist among the underground workmen engaged therein. Without a careful survey of past and present methods of feces disposal in conjunction with the particular method of collection and removal of the mine drain water, a satisfactory explanation of this apparent anomaly would have been difficult if not impossible. In brief, it was found that the men defecated into wooden tanks or exit-pipes leading from the same, which were completely emptied at least once a day. The use of special water hoisting skips in a vertical shaft favored the removal of the water containing ova-laden feces with a minimum amount of shaft contamination. With these exceptions the circumstances incident to the operation of and conditions existing in this mine were quite similar to those found in neighboring mines where a high degree of hookworm infection existed among the underground workmen.

Chemical Composition of Mine Water.—The relation of the chemical composition of mine water to the prevalence of hookworm infection among the workmen presented another interesting problem in my investigations. In case of two neighboring gold mines and a nearby copper mine which was also included within the sphere of our activities, surprisingly low percentages of infection were found among workmen engaged therein. Average samples of drain water from the two gold mines in question showed about 1% chlorine and a representative sample secured at the copper mine showed 1.6% chlorine as sodium chloride and a correspondingly high percent of the sulphate radicle iron and copper. See Mines N and O in Table II.

During the course of their investiga-

TABLE II.

REARRANGEMENT OF PERCENTAGES OF INFECTION GIVEN IN TABLE I TOGETHER WITH OTHER DATA.

Orientation Along Lode	Mine	Percent Workmen Infected Underground 1916	1917	Surface 1916	1917	Average Temperature of Working Levels (Winter)	Depth of Working Levels (In feet)	Underground Toilet Facilities	Remarks
	L	....	13	....	6½	82° F.	1200–1800	Fair	
	H	31	14½	7	0	69° F.	1900–2000	Poor	
	K	....	5	....	6	69° F.	1600–2000	None	
	G	33	7	15	4	78° F.	2000–2800	Conditions very bad. Poor	
	F	21	10	11	0	62° F.	400–850	None	
	E	23	2	....	....	71° F.	1400–1800	None. Men go to surface.	
	J	....	16	....	0	.....	.....	None	Old mine just being reopened.
North—West	D	39	46	23	....	77° F.	2700–3200	Very bad. Sumps used	
	I	....	14	....	....	78° F.	.....	None	Mine recently reopened
	C	67	28	4	0	75° F.	1800–2850	Poor. Sumps formerly used	Drain water from mine "D" removed through shaft of this mine.
	B	16	8	....	2	73° F.	2400–3450	Fair	
	A	60	11	8	4	85° F.	3900–4300	Fair. Sump said to have formerly been used.	
South—East						DEEP RIVER GORGE			
	M	....	0	....	0	.....	400–600	None	Mine water contains: 1% Na Cl. Copper Mine 1.6% Chlorine high in SO_4, Fe. and Al.
	N	....	8	....	0	73° F.	1900–2750	Poor	
	O	....	5	....	0	75–80° F.	1400–2700	None	
	P	....	0	....	0	73° F.	1100–2750	Poor	1% Na Cl.
	Q	....	0	....	8	Similar to P.	.....	.....	Mine reopened recently Water saline
						DEEP RIVER GORGE			
	R	....	26½	....	....	76° F.	1300–1900	Poor Sump used.	

tions in Cornish mines, Boycott and Haldane also found hookworm infection rare among the workmen engaged in one mine the workings of which extended beneath the sea and into which sea water percolated. Frequently specimens of drain water from this mine showed less than 1% of chlorine as sodium chloride. In discussing the action of disinfectants on hookworm larvæ, these investigators[12] point out the necessity of carefully distinguishing the stages of growth of the larvæ in question. Upon emergence from the egg, they are readily killed by comparatively weak germicides, but if given favorable conditions of temperature, moisture, abundant food supply and freedom from contact with deleterious substances until encapsulated in the second moult skins, then these so called "encysted larvæ" manifest greatly increased powers of resistance to adverse conditions and substances.

According to both Manouvriez[13] and Calmette,[14] mine water, containing as low as 2% sodium chloride appeared to have been effective in preventing the infestment of the soil in French mines. These authors differ, however, as to the practicability of artificially salting mines in order to prevent infestment of the soil. I am inclined to agree with Calmette regarding the impracticability of this procedure as an effective control measure on a large scale for the reasons: (1) That the rapid dilution of the sodium chloride by the mine drain water will not permit of the maintenance of a sufficient degree of concentration and (2) in view of the great total length of drifts and cross-cuts such practice would entail an expense out of all proportions to the object desired to attain. However, on a small scale, salting applied to limited localities will undoubtedly prove more or less effective. In order to secure more light if possible on the effects of the chemical environment on the hatching of hookworm ova and development of the larvæ resulting therefrom, experiments were devised, approximating in so far as possible actual mine conditions. Accordingly, typical specimens of mine earth were collected which seemed to represent the variations in geological formation and mineral composition of ore and rock that it was thought might have a bearing on this problem. These earths, after being dried, were thoroughly sterilized by heat and employed in two sets of parallel culture experiments. In the one series suitable quantities of ova-laden feces and mine earths were intimately mixed and cultured in a moist condition at 28.5° C.; in the other series the feces mixed with bone black (Loos method) were superimposed upon wafers of mine earth, the whole thoroughly moistened and cultured in a similar manner. The results of these two series of parallel experiments seemed to justify two conclusions: 1. That chemical mine soil environment as indicated by the chemical constitution of mine drain water exerts a marked influence on hatching, growth and development of hookworm larvæ. 2. That where deleterious substances are present in no great quantity the attainment of maturity (second moult or so-called encysted stage) is insured only when this state is reached before contact with harmful substances. It is quite well known that hookworm ova and larvæ in the encysted stage are quite resistant to adverse conditions as to chemical composition of the surrounding medium. The experiment is, however, too limited in scope to form the basis of any sweeping deductions, but it does appear to indicate at least that when the formations are of such a nature as seriously to load the drain waters with acid radicles such as chlorine or sulphate in combination with sodium, iron, copper, etc., hookworm larvæ will with difficulty be able to reach maturity under natural conditions and the small percent which may arrive at the infective resistant stage will have less opportunity of surviving long.

Mine Sanitation with Particular Reference to Feces Disposal.—It is an

unfortunate fact that the great majority of responsible persons engaged in the mining industry, have failed until very recently to recognize the importance of underground sanitation. Only comparatively few companies can boast of having given this matter the attention which it deserves until faced by an increasing prevalence of anemias due to hookworm infection. Even on the surface, the supply of toilets has frequently been most inadequate and crude. Consequently, although miners were in many instances expected to return to the surface to defecate when necessary, the usual result was that the men for sake of convenience and to avoid discomfort, especially in cold weather, would almost invariably resort to abandoned or unfrequented parts of the workings.

Such conditions and practice were far from the exception in "Mother Lode" and adjacent mines previous to 1916. In some instances, somewhat prior and in most cases subsequent to this time, very important improvements in the disposal of feces had been introduced into many of these mines. However, there still remains much to be desired in the way of more careful attention to details and the enforcement of sanitary rules. There are nevertheless notable exceptions to this statement and the general tendency seems to be in the desired direction. The greatest difficulty, encountered on the part of mine superintendents and foremen desirous of doing all possible to minimize fecal contamination of mine soil, is the periodic collection and removal of accumulated excreta by transport to the surface. Most men are unwilling to do such service even when inducements such as extra pay or shortening of time on duty are offered.

In England,[15] it was thought that simple prophylactic measures sufficed to eliminate ankylostomiasis as an "industrial inconvenience" among miners. The scare, it is said, accomplished the greatest good in bringing much needed improvements in mine sanitation and thereby safeguarding the future. It is furthermore believed that the outbreak in Cornwall proved the general immunity of most mines in England since there had been free and frequent interchange of men between the infested mines and mines located elsewhere in England. It is also contended that "As far as the infested mine itself is concerned, it does not seem that the benefits which have been gained in Westphalia (Germany) are greater than those in Cornwall to a degree at all commensurate with the enormous sums of money which have been spent on medical examination and treatment and the payment of wages to men under treatment." It is admitted, however, that the German system has the great advantage within a few years of largely reducing the number of men capable of carrying the infection to fresh places.

PLATE I

Ova-infested stools scattered at intervals along a mine-drawn gutter.

Circumstances and conditions regarding ankylostomiasis among California

miners are in many respects similar to those reported from England. The description of Cornish mines as given by Boycott and Haldane in writing of their investigations, would with slight alterations serve quite well as a general account of "Mother Lode" mines. Likewise, the limited prevalence of the disease and the ease of reduction of incidence by the application of sanitary measures afford striking parallels. Regarding the freedom of other groups of mines in California, we have not full information, but sufficient data have already been collected to justify the statement that the disease had probably only secured an endemic foothold in some of the deep "Mother Lode" mines. No evidence of endemicity elsewhere in the state, either in mines or on the surface, has been found. State officials who are familiar with mines throughout the state, report conditions more or less unfavorable except in "Mother Lode" mines. Likewise, the examination of selected groups of workmen in a number of instances lends further support to this statement.

RESULTS OF OBSERVATIONS AND EXPERIMENTS IN MINE "A"

1. **Dissemination of Larvæ in Mine.** Notwithstanding the rigid discipline regarding the use of underground commodes in this mine, it was found that men occasionally resorted, for toilet purposes, to unfrequented parts of the mine when convenient and detection seemed unlikely. (Plate II is typical of such conditions.) In one particular cross-cut stools were on several occasions found deposited at intervals along one edge of the drain gutter (as depicted in Plate I already referred to). Upon microscopic examination, several of these were found to contain an abundance of hookworm ova. At regular intervals subsequently, samples were taken from these stools, from the surrounding earth and sediment deposited along the edges and bottom of the drain gutter both above and below the sites of excrement. The nematode larvæ obtained therefrom were observed from time to time and compared with those derived by culture from the stools as originally found, i. e., before larvæ had been hatched from the ova.

The method employed for the separating of hookworm larvæ from mine earth, consisted in placing the earth to be examined upon a medium ribbed paper filter and leaching with warm water from time to time permitting slight drying during the intervals. This seemed to be a fairly satisfactory method of securing the desired segregation of hookworm larvæ. As to just how effective this method may be, I cannot state since no attempt was made to determine this point. However this may be, I had no difficulty in obtaining hookworm larvæ from mine earths by persistent leaching with warm water. Several common earth nematode larval forms also came through the filters quite readily but little difficulty was experienced in identifying the hookworm larvæ.

These observations showed that under the most favorable conditions which was the case in this cross-cut, the larvæ are hatched out from hookworm ova in a few days and soon leave the stool, being found in the moist parts of adjacent surroundings, particularly close to the edges of the drainage gutter and frequently in the fine sediment accumulated on the bottom of the same. In all instances such larvæ had apparently already reached the end of the second moult stage. They were sometimes quiescent and at other times they were quite active in their movements. Concentrated light and heat appear to stimulate active movement.

As time goes on, one may demonstrate the presence of hookworm larvæ at increasing distances down stream from the point of origin. Thus it can readily be understood how in a comparatively short time, thousands of hookworm larvæ originating from a single stool may be scattered along drain gutters and eventually reach the shaft where they may accumulate in the water catchment and storage devices or be scattered still fur-

ther following the water in its course to lower levels in the mine. It can also be easily appreciated that transport of such infested drain waters to the surface in open "skips" may soon result in serious infestment of the entire shaft where sufficient dampness exists, which is the rule. These being the possibilities of mine soil infestment, resulting from one limited focus of infestment in the mine, what must be the sum-total resulting from promiscuous defection in a large mine with its many ramifications of drift, cross-cut, raise and stops? Such conditions previously existed in "Mother Lode" gold mines. Owing to circumstances and conditions highly favorable to the establishment and maintenance of endemic foci in some of these mines, hookworm infestment of the soil early became established. These facts enable us to account for the reputation which mention of the "Mother Lode" mining district seems in general to have carried among miners and also to understand why the rank and file of men employed therein were drawn more largely from classes of foreign mine workers who are not at all careful about their personal habits.

2. Infection of Puppy Dogs.—As an ultimate means of determining the presence, identity and infective nature of hookworm larvæ obtained from earth collected in infested mines, an attempt was made to infect very young puppy-dogs in the abandoned cross-cut in Mine "A" where the observations just described were made. These animals which were of the fox terrier breed, were upon several occasions adequately exposed to mine soil thought to be infested with hookworm larvæ.

Shortly after the arrival of the half dozen puppy-dogs secured for the conduct of this and several other experiments, distemper unfortunately manifested itself among them. The two fox terriers appearing to be in the best condition were selected for this crucial experiment. The one lived but 12 days after the last exposure in the mine, while the other survived 29 days. At autopsy in case of the former, a small immature nematode worm was found in the upper half of the small intestine. This specimen showed clearly the two pairs of teeth characteristic of *A. duodenale*. The latter animal gave the following post-mortem findings.

PLATE II

Typical of abandoned cross cuts in some of the mines frequented by men for toilet purposes.

"Rigor mortis not yet set in. Slight sub-acute inflammation of stomach and duodenum. Both lungs consolidated. All other organs in apparently normal condition. In the middle one-third of the small intestine, there were found five hookworms (one male and four females), which are but one-half the usual size. However, microscopic examination shows mouth parts of all and the bursa in case of the one male to be well developed." (These five specimens have been identified by Dr. W. W. Cort, formerly Consulting Helminthologist to the California State Board of Health, and sub-

sequently by Dr. Allen J. Smith, Professor of Pathology in the Medical School of the University of Pennsylvania, as *Ankylostoma duodenale*. However, the females lack evidence of sexual maturity as shown by absence of identifiable mature ova in the uterus.)

Judging from the length of time elapsing between infection and death in case of the second animal (approximately four weeks), it seems most probable that infection was by mouth. It is generally accepted that 6 to 9 or 10 weeks is required for complete development when larvæ enter exclusivey by way of the skin, while two or three weeks less time is required when they enter by way of the mouth. Furthermore, the stage of growth in case of the one specimen secured from the first experimental animal after 12 days can only be accounted for on the assumption that entrance of the original mature saprophytic larva was direct through the mouth of this animal.

The above experimental infection of puppies with *A. duodenale* proves conclusively that hookworm larvæ, capable of infecting selected young puppies and beyond a reasonable doubt underground workmen also, were present in this crosscut. Moreover the similarity of general underground conditions and sanitation in other parts of this mine ("A") and contiguous mines justifies the further conclusion, based on analogy, that hookworm infection could be even more easily acquired by the underground workers (the natural habitat of the adult *A. duodenale*) as long as infected men continued unrestricted to commit nuisances in these mines or were permitted to defecate into the water catchment storage devices.

INFECTION AMONG SURFACE WORKERS

The existence of hookworm infection among brickmakers in Germany has already been referred to. Owing to the low temperatures existing during the winter months, reinfection of the brickfields was probably necessary at the beginning of each warm season. As a consequence of this and other circumstances, connected with brickmaking, the earth infestment appears to have been a localized one, affecting principally those employed in the brickfields or others whose occupations necessitated tramping over the same areas as was the case with shepherds at times according to Leichtenstern.

At mines, infection among surface workers has been found to be relatively low both in Germany and along the "Mother Lode." European investigations state that not over 1% of infection has been found among surface mine employees at any time. During the period of my work, only one infection was discovered, the origin of which could not be traced to infested mines or known infested surface localities. As was the case in Germany, no instances of infection were found among the wives and children of miners in California.

The variable temperature, generally low humidity, abundant sunlight and comparative sparseness of shade throughout the gold mining districts in the Sierra Nevada foothills, are all factors operating against the establishment of endemic foci on the surface in the neighborhood of mines. There was not lacking, however, a supply of infective larvæ discharged with drain waters from infested mines during 1916 and 1917 and previous years. In some cases, such mine drain waters had been used for irrigating gardens, and it seemed that under such circumstances some infestments of the soil might reasonably have been expected. However, such practice was the exception and not the rule. If, on the other hand, such infested mine drain waters had been used extensively for irrigation, some infections would have most probably developed among others than miners during the growing season. As a matter of fact, mine drain waters were almost invariably discharged into the small streams, together with the stamp mill "tailings," which are heavily laden with pulverized rock. The latter accumulates along the banks of the streams in firm

deposits which are quickly dried by sun and wind, thus making very difficult the existence of hookworm larvæ carried down with this heavy sediment and firmly incorporated in the drying and hardening deposits of the same.

IDENTITY OF SPECIES

Owing to the lack of control over the patient during the course of treatment, it was found very difficult to secure specimens of the adult worms being passed. However, during the re-survey in 1917, an attempt was made to collect adult worms from selected men employed in some of the mines. When given the series of doses of medicine with directions as to when and how to take them, the patient was also supplied with a gauze net (medium mesh) about 14 inches square which was provided with a string of about the same length, attached to each corner. These strings were secured to opposite ends of two small sticks, each about ten inches long, which were intended to serve as handles with which to lift the net and contents from the bowl of the toilet and wash the bulk of the feces collected through the meshes with water by alternately elevating and lowering the handles over the bowl of the toilet. In case of one mine where there was a dispensary situated near the "collar" of the main shaft, the placing of the net in the bowl of the toilet and manipulating of the same with water afterwards was done by an attendant, the vermifuge having been administered by the mine physician. Where the treatment was taken by the individual at home, he was instructed how to use the net and told to wrap it (wet) securely in heavy paper after washing as directed and return it the following morning to a place designated at the mine.

In this way, during the winter and spring of 1917, 70 adult specimens were secured from 14 different miners. One of these men was a Castilian, who had left Spain only four months previously. He showed a very marked anemia and his first stool after treatment contained considerably more specimens of *A. duodenale* than were separated. Only one specimen of *Necator americana* (female) was secured, and this came from a patient showing a number of male specimens of *A. duodenale*. This would seem to indicate quite clearly that the prevailing species was *A. duodenale* and that *N. americana* only occurred in an occasional case. Out of the 63 identificable specimens, 39 were found to be males and 24 females, thus giving a decided predominance of males. The largest number of specimens secured from one individual was 20, which indicates the comparative low degree of infection existing among the men at this time. During the course, however, of the first diagnostic survey made by Cumming and White in 1916 and previously according to the testimony of local mine physicians and others, the infection must frequently have been much more severe, judging both by the accompanying anemias and number of adult worms, said to have been found in the stools passed after the administration of the vermifuge, which was thymol in practically all cases treated at those times.

RESULTS OF TREATMENT

The marked reduction in both the total percentages of men infected and the severity of individual infections already alluded to which occurred during the interval of six months elapsing between the diagnostic surveys of 1916 and 1917, may be attributed largely to changes in and instability of labor brought about by the general strike which occurred during the fall of 1916. Treatment of infected men could have had comparatively little influence as a factor in bringing about this reduction, since only a small percent of infected men submitted to treatment which could not be controlled owing to the lack of authority and dispensary facilities. The rapid turnover in the personnel resulting from the voluntary and involuntary exodus of old, highly infected employees, and the importation of new blood (largely free of infection)

does, however, in my opinion, constitute the most important factor, which will supply an adequate explanation of these quantitative differences in diagnostic results and apparent therapeutic success, otherwise most difficult to account for. The method of diagnosis, namely centrifugation as described by Cumming,[16] was followed in all cases. This is by no means faultless as shown by frequent comparisons with the direct slide and the Loos cultural methods. However, the possible discrepancies are not serious when large numbers of examinations are being made as has been shown by contrasting the results of the 1916 and 1917 surveys with those of subsequent surveys made in both the "Grass Valley" and "Mother Lode" mining districts. In the latter diagnostic surveys the culture method was used but actual statistics are not available to the author.

Regarding treatment following the resurvey made by me in 1917, nothing of an encouraging nature can be said since it was conducted as before but with less apparent success. Later ankylostomiasis occurring among miners of California was made a compensable disease by the State Industrial Accident Commission and the management of the State Insurance Fund agreed to treat all discovered cases under supervision until cured of the infection.

SUMMARY AND CONCLUSIONS

1. Anemia formerly so common among "Mother Lode" miners in California has been shown to be due almost exclusively to hookworm infection.

2. The California State Board of Health, in coöperation with the Federal Bureau of Mines, undertook a systematic survey of "Mother Lode" miners in 1916, which resulted in demonstrating the seriousness of ankylostomiasis among underground workers in this locality.

3. The Bureau of Communicable Diseases of the California State Board of Health began in the winter of 1916-17 a more comprehensive survey and detailed investigation of hookworm infection among miners and soil infestment in various mines of California with a view to the control and ultimate eradication of the same.

4. The above mentioned survey and investigation in 1916-17 was conducted by the author, his purpose in the latter being not only to throw more light on the extent, topography and "demic" character of the disease but also to show how infection may be disseminated through mines, how and where the disease is usually contracted and to establish the apparent fact of endemicity in some instances and its absence in others.

5. The results of the author's observations and investigation were as follows:

(a) Endemicity of hookworm infection in mines is dependent not only on favorable conditions of temperature, relative humidity, mine drainage and chemical character of mine drain water but also on the particular circumstances and conditions existing relative to mine pollution with ova-laden feces.

(b) The use of mine water catchment devices and storage tanks, reservoirs, etc., to receive the evacuations of men while underground, may be responsible for a high incidence of ankylostomiasis among workers.

6. Nematode larvæ, resembling hookworm larvæ morphologically, were isolated from mine soil in a certain crosscut in mine "A," and it was proved subsequently by infection of puppy-dogs in this same locality that hookworm larvæ capable of development into adult *A. duodenale* were actually present in the mine soil.

7. Ankylostomiasis among California miners has centered largely in a few of the deepest gold mines situated along one section of the "Mother Lode" in Amador County.

8. Surface infection did not exist in the vicinity of "Mother Lode" mines since practically all cases of ankylostomiasis discovered among surface workers were traceable to contact in mines with infested mine soil or drain water.

REFERENCES

1. Pruner-Bey. Krankheiten des orients, 1847, p. 244.
2. Bugnion, (Ed). L'Ankylostome duodenal et l'anémie du Saint Gothard. Revue Médicale de la Suisse romande, Nos. 5 and 7. Geneve, 1881, pp. 13-20 (in reprint).
3. Grassi. Intorno all' anchilostomiasi. Annali universali di medica, 1878.
4. Perroncito. Communication à l'académie des sciences de Paris, du 7 juin, 1880.
5. Leichtenstern, O. Über ankylostona duodenale bei den ziegelarbeitern in der umgebung Kölns, Deutsche med. wchnschr. Berl. & Leipz., July 9-23, 1885, vol. 11, pp. 484-486, 501-503, 523-526.
6. Löbker, Dr. & Dr. Hayo Bruss. Über das Wesen und die verbreitung der wurmkrankheit (Ankylostomiasis) mit besonderer beruchsichtigung ihres auftretens in deutschen bergwerken. Berlin, Springer, 1906, pp. 10-11.
7. Ibid. Pp. 61-68.
8. Endicott, E. C. My experience with hookworm infection in the deep gold mines of California. Jour. A. M. A., Chicago, 1911, LVII, 1106-1107.
9. Gunn, Herbert. Hookworm disease in mines of California. Monthly Bulletin, State Board of Health, Vol. 6, Dec., 1910, pp. 408-415. Abstracted in Jour. A. M. A., Vol. 56, Jan. 28, 1911, pp. 258-260. Editorial comment, pp. 272-273.
10. Cumming, Jas. G., and White, Jos. H. Control of hookworm infection at the deep gold mines of the Mother Lode, Cal. Bull. 139, Dept. of Interior, Bureau of Mines, Govt. printing office, Washington, D. C., p. 9.
11. Boycott, A. C., and Haldane, J. S.
    (1) An outbreak of Ankylostomiasis in England, Jour. of Hyg., vol. III, pp. 95-137 (5 plates and 1 fig.).
    (2) Ankylostomiasis, Jour. of Hyg., Vol. IV—2, 1904, pp. 73-111.
12. Ibid. (2), p. 85.
13. Manouvriez, Anatole (fils). Eaux salées de filtration rendant certaines mines de houille refractaires a l'infestation par les larves d'ankylostome. Bull. Acad. de Méd., Paris. 3 serie, vol. 53, pp. 514-531.
14. Calmette, M. Bulletin de l'académie de médicin, Séance du 25 juillet, 1905.
15. Boycott, A. C., and Haldane, J. S. Ankylostomiasis, Jour. of Hyg., IV, —2, 1904, pp. 88-89.
16. Cumming, Jas. G., and White, Jos. H. Control of hookworm infection at the deep gold mines of the Mother Lode, Cal. Bull. 139, Dept. of Interior, Bureau of Mines, Govt. printing office, Washington, D. C., pp. 37-38.

Score Cards in Three Colors.—The value of score cards for improving the conditions of food establishments is generally recognized; perhaps, in some cases, over-rated. To obtain full value from their use it is necessary for the general public to understand their purpose and to be able to see them easily. As few people would have the courage to go inside of a store or restaurant, look at a card and turn around and leave if the score were unfavorable, cards should be posted so that people can see them before entering.

In order to meet this condition the County Board of Health of Morgan County, Ala., passed, on request, a regulation requiring that all score cards be posted in the show windows of places scored. The cards used are of three colors—white for good scores, blue for fair and red for poor. As a result of the passage of the regulation and the use of the colored cards, it is possible for people to see from across the street in what condition an establishment has been found by the inspector. A scramble on the part of proprietors to put their places in order and what appears to be a real effort to keep them in good condition has followed the introduction of this plan.

F. W. DERSHIMER,
Director of Rural Sanitation, Alabama State Board of Health.