ENVIRONMENTAL STUDIES OF FAMILIES IN TENNESSEE INFESTED WITH ASCARIS, TRICHURIS AND HOOKWORM.

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Introduction.

Recent studies have emphasized that the factors influencing the spread of *Ascaris lumbricoides* and *Trichuris trichiura* and to a somewhat lesser extent hookworm are very largely centered in the family. This has been found to be true not only for isolated rural families but also for those living in villages, mining camps and even in some cases in towns of considerable size (Cort, Otto and Spindler, 1930; Cort, Stoll, Riley and Sweet, 1929). This suggests that one of the best ways to study the methods of spread of these intestinal worms in any region is to apply to the family as a unit the methods available for such investigations. It is of course necessary first to pick out families for study which represent different types of infestations and environmental conditions. To do this fecal examinations by the dilution egg counting method (Stoll, 1923, and Stoll and Hausheer, 1926) are made of the general population involved. An analysis of the results of these examinations by families makes it possible to locate those that show the different types of infestation, the different combinations of the parasites and the different kinds of environments to be found in the particular areas being studied. A considerable number of negative or lightly infested families as economically and socially similar as possible to those carrying infestations should be included as controls. The larger the series of egg count examinations and the more complete the analysis, the better will be the chance of selecting families for study that are truly representative.

* This paper is a joint contribution from the Department of Helminthology of the School of Hygiene and Public Health of The Johns Hopkins University, the Department of Preventive Medicine of the Vanderbilt University School of Medicine and the State Department of Health of Tennessee. It represents the results of researches carried on as part of the program for the study of ascariasis in the United States under the auspices of the Division of Medical Sciences of the National Research Council with the aid of a grant from the American Child Health Association. A part of the funds were furnished by the State Health Department of Tennessee.

The environmental studies of individual families should include a consideration of every possible factor that might be involved in the spread of intestinal helminths. Attention must be given to such general things as climate, soil, vegetation and gardens near the houses, water supply, economic status and occupation, as well as to food habits, household sanitation, personal hygiene and the play habits of the children. A central feature must be an attempt to locate the sources of infection with the different worms. This involves particularly an investigation of the soil pollution habits, the attempt to determine the distribution of the infective eggs or larvae of the worms in the immediate environment and a consideration of the habits of the people that would expose them to infection. Most important in the consideration of soil pollution habits is the attempt to find the places where stools are deposited on the ground. Associated with this should be a consideration of whether these places are favorable or unfavorable for the development of the eggs or larvae to the infective stage. Added to this should be a study of the factors such as domesticated animals or drainage that would serve to scatter the eggs in the family environment. Methods for the isolation of the eggs and larvae from the soil (i.e. the Baermann isolation method and the Caldwell egg isolation technic [see Cort, Ackert, Augustine and Payne, 1922, and Spindler, 1929 a]) are available and are of critical importance in determining the presence and distribution of such infective stages in the vicinity of the houses. Finally attention must be directed to the habits of the members of the household that would bring them in contact with sources of infection.

We are presenting in this paper the results of the application of the methods mentioned above to the study of the three common intestinal worms of man in a large series of families in Tennessee. Later reports will give an account of the distribution of the intestinal helminths in Tennessee as determined by an analysis of the egg counts of over 25,000 individuals from all parts of the state. While the discussion in the present paper is centered in ascaris, which was by far the commonest parasite found, both trichuris and hookworm are also given consideration.

Certain points in regard to the life cycles of these three parasites must be kept in mind to make the discussion which follows clear. In all three the eggs are not infective when they pass out of the human body. In ascaris and trichuris all the free life is passed within the egg, which becomes embryonated or infective in about three weeks or more when moisture and temperature conditions are favorable.

While the eggs of both these parasites are very resistant to environmental conditions recent investigations have shown that there are critical differences, the eggs of trichuris being less resistant to desiccation and requiring more moisture for development than those of ascaris. To these differences has been attributed the more restricted distribution of trichuris in certain areas in the mountain regions of the southeastern United States (Spindler, 1929 b). Infection with both these parasites appears to come about chiefly, if not entirely, by way of the mouth. It has been shown that ascaris eggs will under certain conditions hatch outside the body (Swellengrebel, 1913; Asada, 1921; Kondo, 1922; Hirasawa, 1927) and it has even been suggested that human infection by the penetration of such larvae through the skin may be a common occurrence (Maplestone, 1928). A comparison of the ascaris larvae which have hatched outside the body with infective hookworm larvae shows how poorly adapted they are for free life and skin penetration. It certainly seems to us that the burden of proof rests upon those who advocate this method of infection as important in ascaris dissemination. The relation of the pig ascaris to human infection is still a matter of dispute. Since no differences can be found (Bakker, 1921) the pig and the human forms seem to belong to the same species in so far as the usual methods of distinguishing species are concerned. Recently a Japanese investigator has reported the infection of pigs on a deficient diet with eggs of human origin (Hiraishi, 1927 a and b and 1928). Undoubted proof of human infection from pig sources is apparently not available and certain recent epidemiologic studies argue against the view that such infection does occur (Caldwell and Caldwell, 1926; Payne, Ackert and Hartman, 1925). In a recent summary on this subject Hall (1930) has lent the weight of his opinion to the view that the pig ascaris is a separate strain derived from the human ascaris.

Turning to the hookworm it hardly needs to be emphasized that the hatching of the eggs in the open, the period required for development to the infective stage and the common method of infection by penetration through the skin, introduce a series of factors that makes the process of dissemination of this parasite quite different from that of ascaris and trichuris. This is clearly brought out by the very great differences between the distribution of hookworm in the southern United States and that of ascaris and trichuris, although the fact must not be left out of consideration that all three do occur together over wide areas of the world.

There are other differences between these three parasites which must profoundly affect their dissemination, such as differences in egg

production, length of life and resistance of the host to infection. In the present state of our knowledge it is impossible to evaluate such differences, and they cannot, therefore, be given much consideration in the comparisons made from family environmental studies. The points, therefore, that are stressed in the discussion that follows are the relation of human habits to the spread of these parasites under the limitations produced by climate, soil and other general environmental factors.

There were in all 531 families from all parts of Tennessee on which environmental studies were made. These families fall naturally into two groups, those from the mountainous sections including eastern Tennessee and the Cumberland Plateau and those from the more open country, especially the central basin and the Mississippi lowlands. The family studies from the mountain areas will be discussed first in an attempt to evaluate the factors that are involved in the spread of the worms. The studies on the lowland families will be considered in a separate section in which the discussion will be centered on the reasons for the low incidence of worms in these areas.

Studies on the large round worm, Ascaris lumbricoides, in the mountain sections.

Of the 329 families visited in the mountain areas of Tennessee 265 harbored some combination of ascaris, trichuris and hookworm; the remainder served as controls. Of the positive families 254 had ascaris and 113 harbored only this worm. The families visited were but a small part of those actually given stool examinations. While a complete analysis of these examinations cannot be given here it is of interest to note that the ascaris incidence varies from a fraction of a per cent in many communities in the central and western part of the state to about 90 per cent in some communities in the mountainous areas. Of the 25,192 examinations compiled at this time from all parts of the state 26.3 per cent show ascaris, which is approximately the same incidence as reported at the time of the early work of the Rockefeller Sanitary Commission over 15 years ago. The trichuris incidence is 7.8 per cent and the hookworm 7.4 per cent, this latter parasite showing a marked reduction in the past 15 years.

Before going further with the family environmental studies from the mountain areas it will be worth while to consider the type of people they represent. Except for a small number from mining camps the families in our series are all rural. They represent in almost all cases the indigenous descendants of the early Scotch-Irish settlers of

the region. In the rougher parts of the mountain areas and in the infertile more isolated sections of the Cumberland Plateau, the people are still very primitive and ignorant and live on a very low economic level. The development of roads and the introduction of schools are, however, having an effect. The more fortunate people living in the broader, more accessible valleys and on the more fertile lands of the Cumberland Plateau are more advanced and make a much better living. Many of these people have large cattle or dairy farms or a sufficient amount of good land to have become fairly prosperous so that they can hardly be classed with their more backward neighbors from the hills. In some parts of the mountain areas there are mining camps in which people from every grade are collected. In these camps the companies have usually made provision for better living conditions than are found in the poorer mountain homes. The houses are in most cases of better construction and the sanitary facilities provided are more or less satisfactory. The extent to which these provisions are utilized will be mentioned later.

In the more isolated sections of the poorer mountain and plateau counties are found the most backward conditions. In such areas one finds the mountaineers' cabins scattered in the "hollows," at the base of the mountain ridges and in "coves" far back in the mountains. These people obtain their livelihood almost entirely from whatever limited amount of produce they can raise on small, almost untillable patches of soil, often less than an acre in extent. Children for generations have settled near their parents until the population is much greater than the land can reasonably support. Many of these counties have no organized county health work because the per capita wealth is not sufficient to support a full time health department and the state health department has not yet been able to reach them. In other counties organized health work has but recently been initiated with the cooperation and assistance of the state health department. Some of the wealthier, more accessible mountain counties, however, have had well organized and active health departments for many years. Even in such counties the sanitary work is just beginning to reach out into the more isolated sections. On account of the variety of conditions described above we have been able to study families of various grades of wealth, in all degrees of contact with the outside world and from areas in all stages of sanitary development. This makes it possible to compare the conditions of the most backward, isolated, uninstructed people with those in various stages of economic, social and sanitary advance.

In considering the families of our series with regard to the factors influencing the spread of ascaris we will take up first the more general environmental relations. In the first place we obtained no evidence that climate is of any significance in producing differences in the ascaris infestations in the different families in our series since temperature and rainfall are fairly uniform over all the areas studied. It is evident of course that regions of warmer temperature and heavier rainfall such as the tropics are in general more favorable for the building up of the heaviest type of a general ascaris infestation, since optimum conditions for the development of the eggs and for contact with the sources of infection extend over a longer period of the year. The fact remains, however, that very heavy infestations are built up under the climatic conditions of the Tennessee mountains wherever the human habits are favorable. Nor could we obtain any evidence that the type of soil was of significance, since heavily infested families appeared to be as common in the sandy areas of the Cumberland Plateau as where the soil was a clay or a clay sand mixture. The findings in Panama by Brown (1927 b) that ascaris eggs were all killed on sandy soil when exposed to direct sunlight apparently do not apply to the same extent at least to Tennessee where the sun temperatures even on the hottest days are much lower. Undoubtedly a considerable part of the eggs are killed under these conditions, especially during a hot dry season such as the summer of 1930, but apparently the situation in Tennessee is the same as in the mountains of Virginia where it was demonstrated (Otto, 1929) that ascaris eggs developed and remained viable for a considerable period on the surface of both sandy and clay soil unprotected by shade or vegetation. Here it was only when the top soil was largely composed of cinders that the sun's rays were lethal to the eggs. In our Tennessee studies we repeatedly isolated viable embryonated ascaris eggs from the bare unshaded surface of both sandy and clay soils in the dooryards of ascaris families. This finding also suggests that in this area the presence or absence of trees, gardens or other vegetation in the yards makes no significant difference in the dissemination of ascaris. In fact ascaris families of the heaviest type were found both in houses where the yard was entirely bare and unshaded and also where there was a considerable amount of vegetation. Further there was no evidence that the drainage or slope of the yards was of any particular significance. In fact a consideration of the data obtained from this long series of family environmental studies has convinced us that the factors which determine the presence or absence of ascaris in the mountain regions

of Tennessee are directly related to the habits of the people, and that the general environment either physical or social is of significance only in so far as it is of influence on these habits.

In the study of each family observations were made on the source of water supply. Just as in the Virginia investigations (Cort, Otto and Spindler, 1930) no evidence was obtained that people were infected from their drinking water. Water was usually obtained from springs at some distance from the houses or from wells. No correlation seemed to exist between the type of water supply and the degree of infestation and both the most heavily infested families and those entirely negative were found with springs, with wells or with piped water. Of course it would not be possible to state that infection was never derived from drinking water but we have no evidence that infection from this source is of any importance in this region.

Of all the human habits related to the spread of ascaris those that have to do with the disposal of human excrement are by far the most important. As primitive rural families with heavy ascaris infestation move into towns with sewage systems or into well sanitated mining camps, their infestations gradually disappear as they become influenced by the standards of living of those around them and as they adapt themselves to life under the more sanitary conditions of their new environment. On the other hand examples of ascaris families in our Tennessee records in towns or mining camps with good sanitation living under conditions of soil pollution are not at all unusual. Such families are either of the very poorest type or are primitive mountain people who have only recently moved into the new situations. It is evident that education and the weight of public opinion will gradually bring the great majority of such families up to the sanitary level of the communities in which they live.

In the rural families and smaller communities of the mountain regions of Tennessee disposal of human excrement is either a matter of general soil pollution or the use of some type of privy. In their attitude toward the disposal of human excrement these people are in general surprisingly primitive. They believe that when human stools are deposited on the ground their destruction by insects, chickens or rain eliminates their injurious effects as completely as the physical evidence is removed. That there should be any living organism left to infect or reinfect anyone after the physical evidence of the pollution has disappeared is entirely beyond any conception they have, and it is not easy to convince them that such is the case. They are in many cases almost oriental in their indifference to the presence of

human feces in their immediate environment. Though there seems to be an inherent inclination to retire from view for defecation, generations of isolation have considerably tempered that inclination. While adults do usually seek the nearest shelter the young children rarely retire from view. Even children of school age frequently seem utterly lacking in the usual ideas of modesty in this respect and they are unchecked by their parents.

To such people the use of even the simplest privy seems to be a new idea and they are accustomed to consider such devices for the concentration of the feces as obnoxious, perhaps necessary under the degenerating influences of town life but as wholly unnecessary under the free conditions of the country. Their response, therefore, to the importunities and instruction of the sanitary officials is often very slow. In one county for example after two years of effort the sanitary inspector had not been able to convince the school board that there was any need for sanitary conveniences in the rural schools, and a majority of them still had no privies. In some isolated communities which we visited, even some of the wealthier families, who lived in large, well-built houses and had reached the stage of the automobile and the radio, were still entirely without privies. Of the 329 families from the mountain sections which were especially studied 211 had privies but in many cases they were not used to any extent or only by the adult members of the family.

Where the privies are exclusively used they of course gradually eliminate ascaris infestation. There are in fact areas of considerable size in the mountain regions of Tennessee where intensive sanitary work combined with the other factors that have raised the general cultural and economic level of the population have developed household sanitation to the point where ascaris infestation has practically disappeared. There are also individual families even in the most backward communities that have followed the instructions of the sanitary officers and have developed for themselves a type of sanitation that has almost if not entirely rid them of this parasite. On the other hand the attitude toward excreta disposal discussed above is still widely prevalent, as is indicated by the large number of almost unsanitated communities and by the large proportion of the mountain regions of the state where ascaris incidence is still surprisingly high.

Of special interest are the large number of families where heavy ascaris infestation exists in spite of the presence of privies. How numerous such families are is indicated by the fact that of the 203 families in our mountain series that are classed as having heavy

ascaris infestation 107 had privies. While in some of these families the privies are little used in most of them they appeared to be in use by some members of the families. In these cases it was found as in the earlier studies in Panama and Wise County, Virginia (Cort, Stoll, Riley and Sweet, 1929; Cort, Otto and Spindler, 1930), that it was the failure of young children to use the privies that maintained the heavy ascaris infestation. In such families as well as in those without any sanitary provision the young children have the heaviest infestations and their habits are chiefly responsible for the spread of this parasite.

It seems advisable at this point to give some further discussion of the sanitary situation in the numerous mining camps where the people from the surrounding country are collected under conditions quite different from those in their rural homes. The conditions in the Tennessee mining camps were very much like those in Wise County, Virginia (Cort, Otto, and Spindler, 1930). Even in the most backward unsanitated counties the coal companies operating the mines had almost invariably provided some type of privy for every house in the camp. These varied from fairly modern water closets with septic tanks to the crudest type of open back privy. It was found that where the privies were of the better type, especially those with septic tanks, they were used by most of the people because they are very convenient and are found only in the best camps which recruit the better type of employees. In most of the mining camps, however, even if the privies are used by the adults there is no attempt to control the children. In fact in many of the camps where the people had no part in building the privies, their disregard of them was even more pronounced than where isolated families had been persuaded to build them. In fact some of the poorer mining camps represented the worst type of situation found. In such places, in spite of the presence of privies, pollution was found in nearly every yard and the crowded conditions added to the difficulties of the situation. In spite of the almost universal pollution in such camps, some families were almost always found above the general level. When such families lived without soil pollution in their own yards, even when close to bad ascaris families, they were usually worm free or at most had one or two light cases. These families are the best evidence of how strictly limited to the individual household the sources of ascaris infestation usually are. They also emphasize the point that heavy ascaris infestations are only built up under conditions of continued exposure to intense sources of infection.

In the families studied in Tennessee the soil pollution habits most efficient in spreading ascaris were found to be much the same as those

already described in the Virginia mountains (Cort, Otto and Spindler, 1930). On the premises of infested families human stools were found plentifully scattered in dooryards, under the houses, in the pathways, close along the sides of the houses and especially in the places used by children as their playgrounds. Just as in the Virginia area the places under the houses where the children commonly played usually contained human stools in numbers or ascaris eggs in the soil. In a few of the poorest homes fresh stools and remnants of old ones were found on the floors of the porches and even within the houses themselves. It perhaps needs to be emphasized again that we have abundant evidence that ascaris eggs deposited on the most exposed and hard packed soil of the dooryards can develop to the infective stage and remain viable for a considerable time. This has been experimentally demonstrated (Otto, 1929) and in both the Virginia and Tennessee studies embryonated ascaris eggs have been repeatedly isolated in numbers from such yards. Concentration of stools close to the houses and in other places where children play seeds with enormous numbers of worm eggs the very places where the children come in closest contact with the soil. Hand to mouth transfer of the eggs must in such situations constantly occur.

Just how important pollution near the houses is in the spread of ascaris in these mountain areas can be best understood from the consideration of the conditions found in those families which were classed as having heavy ascaris infestation. Inspection of the premises of 194 ascaris families of our series resulted in the finding of human stools close to the houses in 130 cases. Such pollution was as often present at those houses with privies as at those without. Evidence is also available that at most of the other 64 houses such pollution did occur even if not present at the time of the inspection. In many of these cases the inspection followed rains or the presence of numerous chickens suggested that they had removed the visible signs of pollution. In a number of these families the parents either voluntarily remarked or admitted when questioned that the children defecated near the houses. As a further check on pollution near the houses 90 samples of the soil were taken from the yards of 27 of the ascaris families when the inspection showed no signs of pollution. These samples were examined for worm eggs by a modification of the Caldwell-Brown flotation technic (Spindler, 1929 a). Of these 90 soil samples 35 from 19 of the 27 yards were found to contain ascaris eggs. Since the eggs are naturally concentrated where the stool was deposited, a small number of negative samples might readily be obtained from

soil generally heavily seeded with eggs. The possibility of this is shown by the fact that in our series samples taken only a short distance from others which were positive were sometimes negative. A large number of the negative samples in the above series are also accounted for by the fact that some of the samples were taken at a distance away from suspected pollution areas in an attempt to determine the extent to which the eggs are scattered. This series of soil examinations adds to the evidence from the soil pollution studies that ascaris eggs are plentiful in the soil of the yards of houses where the children harbor this parasite. In addition to this positive evidence that soil pollution close to the houses is the chief factor in the spread of ascaris there is also evidence that where the only pollution by a family is at some distance from the house heavy ascaris infestations will not be built up. Cases of this type in which the family was negative or only very lightly infested and where the only pollution was found at some distance from the house were reported in the Virginia studies (Cort, Otto and Spindler, 1930; 23) and in the earlier investigations in Panama (Cort, Stoll, Riley and Sweet, 1929; 176). They also occurred in the Tennessee mountain series. Even more conclusive evidence on this point will be brought forward in connection with the absence of ascaris infestation in some of the lowland families discussed in a later section.

It seems evident that ascaris eggs would be widely scattered from the places where they were deposited by a number of different factors. Certainly the eggs would be constantly carried into the houses on the feet of the people or by other methods, producing sources of infection within the house itself. The washing of the rain would also tend to distribute the eggs widely. We hope at some later date to have the opportunity of studying intensively the distribution of the eggs around some heavy ascaris families. One very obvious factor that would tend to distribute the eggs widely which was investigated in some of the Tennessee environmental studies was the presence of domesticated animals. Chickens were commonly seen feeding on the human stools. This immediately raised the question of whether the eggs of ascaris pass through the digestive tract of chickens in a viable condition. To test this 56 specimens of chicken droppings were collected from the yards of 14 different houses where the families had heavy ascaris infestations. Twenty-six of these specimens from 10 different yards were found to contain human ascaris eggs in the one-celled stage that appeared to be viable. Thirteen specimens from 7 yards contained what appeared to be viable trichuris eggs.

Though the ascaris eggs found in chicken droppings appeared to be perfectly normal it seemed advisable to inquire into their viability. Previous work by other investigators has demonstrated that hookworm eggs usually pass uninjured through the digestive tract of mammals but are largely destroyed by passage through chickens and insects (Ackert, 1922 a and b, and Chandler, 1924 and 1926). Ramsey (1924) reported that hookworm eggs passed in viable condition through pigs but that those of ascaris and trichuris were killed, which is contrary to the general conception of the greater resistance of these eggs. This is also contrary to the results of experiments on the viability and destruction of ascaris and trichuris eggs which were carried out by one of us (Otto), a description of which follows.

Pure cultures of pig ascaris eggs were obtained from the uteri of mature worms. Samples of these eggs were mixed with water and the numbers in a known quantity of water estimated by dilution count. A known number of the eggs were then concentrated by centrifugation and fed by capsule to experimental animals. Three chickens, three dogs and one cat were fed with numbers of eggs varying from 203,000 to 439,500 per animal; unfortunately pigs were not available at the time. The entire fecal output of each animal was collected until two stools were negative by the Lane direct centrifugation method (Lane, 1924). The number of eggs in each stool was estimated by the Stoll dilution egg counting method; when the count was low the Lane method was also used. By this method the eggs recovered from the three experimental chickens were estimated as 16.5 per cent, 40.5 per cent and 33.5 per cent of the numbers fed. In the three dogs the estimated recovery was 76.2 per cent, 52.3 per cent and 72.8 per cent and in the cat it was 69 per cent. The greater loss of eggs in passing through the alimentary tract of the chickens was laid to the grinding action of the gizzard. As evidence of this there were found in the chicken droppings, in addition to the normal eggs reported above, the remnants of a considerable number of crushed ascaris eggs, which in one case amounted to about one-eighth of the total eggs found. Feces from all these animals which contained the pig ascaris eggs that had passed through the digestive tract were cultured on sand, in charcoal mixtures and in water. In all cases the development proceeded normally to the embryonated stage.

It is conceivable from the discussion given above that chickens might serve in a dual capacity in relation to the dissemination of ascaris eggs. By feeding on stools deposited near the houses they would destroy a part of the eggs that were ingested and perhaps

scatter at some distances those that remained viable. In our series of family studies, however, we obtained no direct evidence suggesting a reduction of infestations by chickens. In fact it seemed evident that in most cases at least where pollution was found near the houses a sufficient part of the stools would be left to seed the soil with quantities of the eggs. On the other hand chickens might in the same way carry the eggs from open back privies or distant pollution spots to situations close to the houses or to the playgrounds of the children. It seems very probable that occasional infestations might be acquired in this way. In several cases we found single heavily infested children in families of the best type in the community where we could find no evidence of soil pollution near the house. Chicken droppings were, however, plentiful in the dooryard and it is possible that the chickens may have thus carried the eggs from the open back privies, where they were seen feeding, to the dooryards. One should not lose sight of the fact, however, that these children might easily have obtained their infestations from some neighbor's home, from the school, or from some unnoticed community source of infection. We have no evidence that the infestations in ascaris families were ever built up as a result of the feeding habits of chickens or other animals and it seems to us improbable that domesticated animals can be a factor of any appreciable significance in the epidemiology of ascariasis in these regions.

Although our studies in Tennessee have tended to emphasize the importance in the spread of ascaris of those factors centered in the family as a unit, there were found in addition community sources of infection that cannot be ignored. Here again it is impossible to evaluate the part played by such sources of infection in building up the worm burden of the community. In the first place it is evident that infection must often be obtained by children from sanitary homes when they visit ascaris families where soil pollution was present. Several such instances were cited in the report of the Virginia studies and their number could be increased from the Tennessee families. A striking case of this kind came to light in one of the districts visited in Overton County. In one of the families there were two heavily infested children, a girl of eleven and a boy of seven. There was nothing in the situation at the house where they lived to explain the source of their worms, since the privy was in use, no soil pollution could be found and the family appeared to be unusually intelligent and well off. Two older brothers of these children lived with their families in the neighborhood. Both of these families were typical

ascaris families of the worst type. There were seven heavily infested children in one and three in the other. Soil pollution was found in both places and one was without a privy. When we were informed that the two children from the well sanitated house spent a considerable proportion of their time playing with their nieces and nephews at the other two houses it was easy to understand the source of their ascaris burden.

Other possible community sources of infection were suggested by pollution seen in the yards of court houses, jails and even churches. The most clear cut evidence on this point came from the inspection of rural schools. A specific example of a school visited on the Cumberland Plateau will serve as an illustration. This school had two teachers and about 65 pupils. Although the building was well constructed and comparatively new, there were no privies for either the boys or the girls. A search for soil pollution revealed dozens of stools scattered in a rather dense woods about 25 yards from the school. One of the pupils stated that this was the area visited by the girls. This general area also served as a playground because there were found several playhouses made of stones and branches of trees. On the other side of the school was a stream with very steep banks, along which were found numerous stools. Since many of the children in this school were known to have worms, it can be seen that the pollution near the school was probably an important source of infection. It is of interest in this connection that in four families which were visited in the community around this school there was almost no evidence of soil pollution and conditions did not seem favorable for ascaris spread. In spite of this rather heavy infestations were found in the children of school age. These children were all pupils at the school and may have obtained their infestations from the pollution areas around the school. That this was no an isolated case was shown by the statement made by the sanitary inspector of this county that only 18 of the 60 schools in the county had sanitary privies and that at many of them gross soil pollution occurred. In this particular county sanitary work had been under way for two years but it had been impossible for the inspector to convince the majority of the school board that money for school privies was a proper expenditure. In two other counties in the same general region where a sanitary inspector had just been appointed we were informed that very few of the rural schools were provided with privies. Such situations are not at all uncommon and indicate that in many parts of the mountainous areas where ascaris is prevalent the schools are not only failing in

their opportunity to teach the simplest rudiments of sanitation but also are important centers for the spread of worms.

Studies on the whip worm, Trichuris trichiura, in the mountain sections.

As far as our observations go the same human habits that are responsible for the spread of ascaris also spread trichuris. In spite of this the distribution of trichuris is much more restricted in Tennessee than that of ascaris, the trichuris incidence in our series being 7.8 per cent and that of ascaris 26.3 per cent. While practically without exception ascaris is present in families infested with trichuris, there were as already noted a considerable proportion of the families in which ascaris only was found. A similar situation in certain mountain areas of Virginia was explained by Spindler (1929 b) on the basis of differences in the moisture requirements of the eggs of the two parasites. He showed experimentally that the eggs of trichuris are less resistant to desiccation than those of ascaris and require more moisture for their development. It would be expected, therefore, that in families with heavy trichuris infestation the places in the yards where the eggs were deposited would on the whole be more moist than those in the yards of families harboring ascaris only. It was in fact found by Spindler that the dooryards of families heavily infested with trichuris were almost always damp on account of dense shade or poor drainage.

The studies in Tennessee gave us a splendid opportunity to check these findings over a wide area with a rather uniform rainfall. In our series of families in the mountainous sections for which environmental studies were made there were 90 in which trichuris was present. Forty-nine of these with two or more fairly heavy cases of this parasite were classified as trichuris families. No differences between these trichuris families, in which in every case ascaris was also present, and those positive for ascaris but negative for trichuris could be found in regional distribution, soil conditions, sanitation or habits of the people. In fact the only difference that we were able to discover was that almost invariably in the trichuris families there were local conditions causing the yards where the pollution occurred to be damp. Our records show that in 42 of these 49 trichuris families the conditions were such that the yards were distinctly damp. This situation was produced in 22 cases by dense shade, in 15 cases by dense shade and drainage from steep mountain sides and in five cases by seepage from creeks. In two of the remaining seven trichuris families the pollution was concentrated in the protected area under the house where the

soil was much more moist than in the unshaded yard, a situation like that found by Spindler (1929 b) in some of his trichuris families in the Virginia series. In the 41 families with light trichuris 21 were found to have moist yards either from shade or poor drainage. Nothing was found in the environment the other 20 families at the time of our visit to distinguish them from the situations where only ascaris was found.

One very interesting situation was found in a trichuris family in Jackson County. The shack in which this family lived was above the road on a barren unshaded mountain side. When the house was reached, however, a small level yard with scattered pollution was found which instead of being dry as our distant observation indicated was soaked with water from leakage from a reservoir higher up on the hill.

Our records of the moisture conditions in the yards of the total series of families which harbored only ascaris are unfortunately not as complete as those just given for the trichuris families. In our studies from Clay and Jackson Counties, however, we have such a series which can be compared with the families from the same counties harboring both trichuris and ascaris. The inspections of both types of families from these two counties were made by the same individuals, on the same field trip and after a considerable period of drouth. This made it very easy to spot situations where the soil was moist. Also, since some of the worst trichuris families in our whole series were from these two counties, special attention was paid on this trip to differences between these families and those with ascaris only. In 12 of the families visited in these counties there was heavy ascaris infestation without any trichuris and in 16 both worms were present in the same family. These 16 were of the type that are classed as trichuris families. Both types of families were in the same communities and often not far apart. The soil was a reddish clay throughout. People of different economic levels were found in both series, but all were alike in the presence of the kind of dooryard pollution which has been shown to be effective in the spreading of these worms. In 10 of the 12 families where ascaris only was found our records show that the yards were well drained, unshaded and dry at the time of our visit. In the other two, the yards were reported as unshaded, but slightly moist on account of only fairly good drainage. A typical situation in this series was a house with a yard entirely without shade standing on the top of a hill with the ground sloping away on every side and the soil appearing completely dried out by the sun's rays.

Contrast with this series those families in which ascaris and trichuris were both present. In spite of the fact that there had been no rain for about three weeks before our trip the yards of 13 of these 16 families were reported as either moist or wet. This condition was due either to dense shade in the yards or to poor drainage produced by the position of the house at the foot of a mountain. In fact the worst trichuris families of this group were those located at the bottom of narrow valleys with yards densely shaded by trees.

In Hancock County in an entirely different section of the state there was also an unusually large number of heavy trichuris families. Here too the houses were in damp densely shaded places in the deep valleys or in "coves" higher up among the mountains. Here, too, the trichuris free ascaris families were found to be living under more arid conditions. The evidence certainly seems clear that in the mountain sections of the southeastern United States, at least, heavy infestations with trichuris can only be built up under conditions where the polluted areas near the house are kept moist by dense shade or poor drainage and that the difference in distribution of the two parasites in this region depends on differences in the moisture requirements of the eggs.

Studies on the hookworm, Necator americanus, in the mountain sections.

Tennessee is near the northern limits of the hookworm belt and has a fairly cold winter, especially in the mountainous sections. Also the amount and distribution of rainfall are not that usually associated with the worst hookworm areas. Added to these limiting factors is the even more important one which has long been known but recently emphasized in the report of a survey by Rickard and Kerr (1926) that hookworm infestation in Tennessee is almost entirely limited to regions with a mellow, porous soil, i.e. sandy soil. It is evident, therefore, that real clinical hookworm disease in Tennessee would be found only in areas with a sandy soil where human habits were particularly favorable for its spread. In fact the evidence from the earlier surveys indicates that hookworm disease was much less widespread in this state than in some of those farther south. We have evidence also that the incidence of hookworm infestation and clinical disease has greatly decreased in Tennessee since the days of the Rockefeller Sanitary Commission. An account of the extent of this reduction and the reasons for it have been included in another paper by one of us (Keller, 1931). The discussion of hookworm in the present paper will be limited to an analysis of the factors influencing the spread of hookworm in our series of families for which environmental studies

were made. In these families the sources of hookworm infection which we were able to discover were just as definitely limited to the general environment of the home as were those for ascaris and trichuris.

We will present first some of our local evidence on the relation of hookworm dissemination to sandy soil. There were only 13 families in our whole series that were listed as having heavy hookworm infestation. All of these lived on the Cumberland Plateau, nine in Fentress County and four in Cumberland County. In fact 37 of the 75 families positive for hookworm were from these two counties, while the rest were from nine widely scattered counties.* The outstanding feature of Fentress and Cumberland Counties is the predominating sandy soil. They contain the most important centers of hookworm in Tennessee, since out of the 56 families visited within their boundaries only 16 were negative for hookworm. Five of these were controls where the habits of the people were unfavorable for the spread of any kind of worms. Of the other 11 families negative for hookworm, all of which had rather heavy ascaris infestation, five lived on clay soil, four on a clay and sand mixture and only two on sandy soil. On the other hand, of the 40 families positive for hookworm only one lived on clay soil, 18 had a soil that was a mixture of sand and clay and 21 had a soil classed as sandy. This soil relation becomes all the more striking when the families studied from the neighboring counties of Overton, Clay and Jackson are compared with those just discussed. The areas covered in these three counties have less sanitation than those of Fentress and Cumberland Counties and their ascaris and trichuris infestations are on the whole heavier. Only nine of the 38 families visited in these three counties were positive for hookworm, with a total of 11 cases. Six of these cases had egg counts under 1,000 eggs per cc., four were under 2,000 and the only count of any size was of 5,100. It is significant that the family containing this heavily infested individual had another case also and lived on sandy soil. Of the other eight families with hookworm cases from these three counties three lived on a sandy clay soil and five on clay soil. On the other hand 27 of the 29 families negative for hookworm lived on clay soil and two on a mixture of sand and clay. These records supplement those already available and show how almost completely hookworm infestation under the conditions in Tennessee is limited to a sandy soil.

It is of interest to consider the type of soil pollution habits that serve to build up hookworm infestations in Tennessee. The soil

* There were other parts of the state where hookworm was shown to be present from the egg counts from which no family studies are included in this series.

pollution habits we have come to associate so definitely with heavy ascaris infestation apparently are not usually favorable for the spread of hookworm, since a number of ascaris families have been studied in the hookworm areas living on sandy soil in which hookworm was not present. This situation seemed to be due to the fact that the conditions in unshaded dooryards, with their hard packed soil, appeared distinctly unfavorable for the development of hookworm larvae. On the other hand a few families were visited where the sandy soil of the dooryard was fairly loose and well shaded and where the hookworm infestation appeared to come from this source. At one house in Crossville, Cumberland County, for example, the only possible source of hookworm infection seemed to be pollution on the moist sandy soil under the dense shade of trees close to the back of the house. It is very significant in this connection that, wherever, in these sandy areas, the soil close to the house was moist enough for the spread of trichuris, hookworm was also present.

In the case of most of the families with hookworm infestation, however, there were found shaded pollution areas with loose soil at some distance from the immediate dooryards. In a few cases these pollution areas were in barns or outhouses. Much more common at the houses of hookworm families were pollution spots in gardens and corn fields, where the soil was loosened by cultivation and where the people would come often in contact with any infective larvae that developed. Such pollution areas between rows of corn were very similar to those found in the sugar cane fields of Trinidad and Porto Rico (Cort and Payne, 1922; Cort, Payne and Riley, 1923). However, the most common pollution areas found in the hookworm families of the Tennessee series were those in woods. Such conditions were frequently found on the Cumberland Plateau and in Hancock County, where the isolated houses were in small clearings. In some of these cases the stools were widely scattered in the woods, while in others there were definite pollution spots at some distance from the houses resembling those found in many tropical countries, where the houses are close to woods or groves. This association of hookworm infestation with the pollution of the soil outside of the immediate yard was a common characteristic of almost all the hookworm families visited.

Studies on ascaris in the lowlands of Tennessee.

It has been recognized since the early examinations at the time of the Rockefeller Sanitary Commission that the incidence of ascaris is much less in the lowlands of western Tennessee than in the eastern

mountain areas or on the Cumberland Plateau. The records of these early examinations as well as those of our present series show an incidence usually well under 10 per cent in the lowlands between the Mississippi River and the plateau slope of west Tennessee. Also in the central basin what records we have show a low incidence. A somewhat higher incidence is reported in the higher lands east of the Tennessee River but nothing comparable to that on the Cumberland Plateau or in the eastern mountain sections.

This distribution fits in with the general information we have on the distribution of ascaris in the southeastern United States as a whole where the important endemic areas are in the mountain sections and where the incidence is low on the Atlantic Seaboard, along the Gulf of Mexico and near the Mississippi River. At present there is no way to explain this peculiar distribution since certainly nowhere else in the world is ascaris infestation found to be strikingly more prevalent in the mountains than on the plains. Over this whole region the trichuris distribution follows in general that of ascaris although the incidence is very much less. On the other hand most of the worst endemic centers for hookworm disease in the southeastern United States are in the areas with the low ascaris incidence.

The low incidence of ascaris in the lowlands and plains areas of Tennessee as well as elsewhere in the southern United States outside of the mountains has usually been popularly explained on differences in the soil or on the grounds of general physiographic differences. The suggestion has often been made, as for example by Caldwell and Caldwell (1926, 144), that the peculiar distribution of this parasite is in some way related to the character of the top soil. We have been informed several times that limestone or sandy regions are unsuitable for the spread of ascaris. This view is not supported, however, by epidemiological or experimental evidence. In fact ascaris is very common in areas of sandy soil on the Cumberland Plateau and elsewhere in the state. Ascaris eggs are so resistant to the different acids, alkalies and organic disinfectants that it is hard to believe that such differences as might be present in the chemical make up of the different soils could have the slightest influence on their development. While ascaris eggs appear to be more readily killed in direct sunlight on sandy than on clay or other soils (Brown, 1927 b), this factor could not be of any significance in the low incidence of this parasite in western Tennessee since the soil of this region is predominately clay.

Previous to the surveys by the egg counting method of our present study the information on the distribution of ascaris in Tennessee

came entirely from incidence statistics. It was noticed, when these data were carefully examined, that the ascaris cases found in the lightly infested areas tended to be grouped in families. Later when the egg counts from our studies in these areas were analyzed the very important fact became clear that individual infestations were frequently just as heavy as those found in the mountain sections. Further the ascaris cases tended to be grouped in ascaris families which frequently showed just as heavy infestations as the ascaris families of the mountain section. The difference in incidence between the two areas was found to be due, therefore, to the smaller proportion of the ascaris families in the lowlands as compared with the mountains.

Further, most of these heavy ascaris families which were scattered widely in western Tennessee had been living all their lives in the same general regions where they were examined. It is evident then that throughout this entire region conditions favorable for the building up and maintaining of heavy ascaris infestations are present at the situations where these particular families live. This points to differences in household conditions, probably differences in human habits rather than general environmental conditions, as the explanation of this low incidence of ascaris in western Tennessee.

A study was, therefore, made of 202 families from that part of the state west of the Cumberland Plateau. Of this number 42 were classified as harboring heavy and 70 light ascaris infestations, of which 10 were also infested with trichuris. A few scattered hookworm cases were also included, while 90 families were listed as worm free as judged by the members examined. It will be of interest to consider first the general conditions under which these families live as compared with those studied in the mountain sections of the state.

We have already called attention to the general similarity of the top soil of this region to that of mountains. However, the whole area is agriculturally more prosperous than the mountain regions already discussed. There are a great many successful farmers and wealthy landowners whose families are amply protected from worm infection by their sanitary provisions. Though this group of the population must to some extent account for a lower incidence of ascaris the point of chief interest is the low incidence among the tenant farmers and poor landowners in the less tillable parts of the area. These are the groups to which our studies were confined. The living conditions of these families are in general no better than those of the poorer type of mountaineers. The annual cash overturn of the poorest group in the western part of the state is probably greater than that of those

living in the mountains but the nutritional and housing conditions are essentially the same. One is struck also by the lack of personal cleanliness and the fact that sanitary provisions are not noticeably better than those in the mountains. We have already called attention to the fact that ascaris infestation in the mountains is not controlled by the mere presence of a privy. This same thing is evident in other parts of the state as well (table 1).

The soil pollution close to the houses characteristic of the ascaris families in the mountains was also characteristic of the small number of heavily infested families of the western highlands and lowlands and central basin. Of the 10 families with heavy ascaris found west of the central basin gross soil pollution close to the house was seen in five; in two others ascaris eggs were isolated from the soil of the dooryards; another lived a few feet from a heavy ascaris family where pollution was plentiful; one of the remaining families had moved into the new location a few days previous to our visit and was away from home at the time. It is probable that pollution occurred here too. It is interesting to note that here and in the central basin also such families were often found close to the cities. They represent the poverty stricken type of people who having no property or prospects collect in and near the cities. One such family was found within the city limits of Memphis while several were found close to Memphis and to Nashville.

In the area listed as the central basin are included a great many people living in the rugged foothill type of country surrounding and included in the central basin. Most of the 32 ascaris families listed in table 1 from the central basin were living in such mountain like retreats and in every respect were essentially the same as those ascaris families found in the mountains. The others were living in or close to the cities in poverty and degradation and were frequently a source of annoyance to their neighbors because of their pollution habits. It seems evident then that the personal and family pollution habits of ascaris families are essentially the same no matter where in Tennessee they may be located.

Consideration will next be given to the 90 ascaris free families and the 70 families with single light cases, classed as light ascaris, in these same two regions, which can be discussed together because they offer the same contrast to the ascaris families. This whole group for convenience in discussion will be termed ascaris free families.

The 55 ascaris free families listed from the central basin are for the most part families of the same general type as the ascaris families

TABLE 1.

Showing the number of families visited and per cent having privies and the per cent in which any visible pollution was found near the houses or in the yards.

Area	Heavy ascaris			Light ascaris			No ascaris			Total		
	Number visited	Per cent		Number visited	Per cent		Number visited	Per cent		Number visited	Per cent	
		Privies*	Pollution		Privies*	Pollution		Privies*	Pollution		Privies*	Pollution
Mountains and Cumberland Plateau	203	53	67	51	73	41	75	85	35	329	63	56
Central basin and vicinity	32	38	56	35	63	26	20	90	5	87	60	32
Western highlands and lowlands	10	51	50	35	54	22	70	59	20	115	56	23
Total	245	51	65	121	64	31	165	74	25	531	61	45

* Attention should here be called to the fact that any structure no matter how inadequate, little used, or obnoxious it may be is listed as a privy if it is specifically provided for that purpose. The percentage of first class sanitary privies is small in the entire region.

of the same region though in many cases living in more open country in the same communities. This group together with the similar group from the mountains not only has a larger percentage of privies than any of the other groups (table 1) but they also show the largest ratio of sanitary privies to the less satisfactory type. That this alone cannot control ascaris is evident since heavy ascaris infestation associated with heavy dooryard pollution in the presence of sanitary privies has already been pointed out in this area. While dooryard pollution was found to be spreading ascaris even when a good privy was present yet that privy represents the first step in ascaris control. This step has usually been taken in this region by those families who were doing what is the more important, i.e. maintaining ascaris free yards. There were a number of families, however, who were ascaris free because of pollution free dooryards without having any privy at all. These are more typically representative of the western highlands and lowlands, which will be discussed next.

In the area just mentioned we visited 105 ascaris free families of the same type as the ascaris families and living under essentially the same conditions in the same communities. The percentage having privies is practically the same as among the ascaris families but the striking thing is that no matter how unsatisfactory the general sanitary conditions might be there was a noticeable absence of pollution near the house and in the yard (table 1). Even in the few families of this group listed as showing dooryard pollution it was unusual to find more than a single fresh or dried stool. Rarely did we see the gross dooryard pollution associated with heavy ascaris. The commonest type of pollution was that concentrated in and around outbuildings. The chicken house, in the absence of a privy, was almost without exception the central pollution spot though the barn often was in use too. While such pollution habits are far from satisfactory from the point of view of household or community sanitation they are nevertheless apparently controlling ascaris. This would be true of ascaris and not of bacterial infections because of the immobile nature of the ascaris eggs and the massive and repeated dosage apparently required to build up an infestation.

As already stated there is little difference economically, socially, and in general sanitary concept between that great mass of poor people in the western part of the state who are worm free and the ascaris families in the mountains. It seems surprising then at first thought that there should be this striking difference in pollution habits just discussed. Upon further study, however, one is led to believe that

these differences can not be due to any fundamental difference in the people but rather to the effects of topography upon their habits. While few of the type of people who pollute the soil show any great amount of modesty in regard to the defecation habit they almost all show some tendency to retire to the seclusion of some shelter. In the open country of the western part of the state this shelter is furnished, in the absence of a privy, by the outbuildings. Occasionally a ravine or clump of trees some distance away may be used but rarely is the dooryard itself so protected. In the mountains, however, the dooryard itself is protected from view and through generations of primitive living the dooryard has become the regular pollution site. In the midst of such conditions a family with these habits ingrained within its members may continue them even when they move into more open places. On the other hand people in the western part of the state are for the most part living in houses in view of the whole countryside. The area is not heavily wooded and is relatively flat. In such open country the only shelter available is an occasional ravine or clump of trees, usually some distance from the house, or the outbuildings on the premises. This tendency to retire to some particular spot on the part of adults seems to transmit itself to the children, who have a tendency to follow that habit for the most part. Ascaris families in this area are, therefore, usually quite degraded and never are they numbered among the better people in the community as in the mountain areas of Tennessee.

Trichuris and hookworm infestations are practically missing from the western half of the state. Trichuris, because of the small egg production and lower resistance of the egg, is probably much less qualified to maintain itself under unfavorable pollution habits. Hookworm, depending upon the activity of the free living larvae for infection, seems to be kept down by the unfavorable heavy clay soils of much of the area and partly by the concentration of pollution in localized places unfavorable to their development.

Attention should here be called to two communities in the western half of the state which seem to contradict our views on the differential pollution habits and their relation to ascaris dissemination. In one closely compact negro community at the edge of a city in the central basin heavy ascaris infestation was found but on two visits we were unable to find visible evidence of soil pollution. School had not been in session for several months but a portion of shaded ground along the edge of the playground looked as though it might have been used in place of the privy. School children told us that the newly built

outdoor toilets, equipped with modern plumbing and connected with the city sewer, were kept locked except at stated times and that the grove had to be used on all other occasions. Ascaris eggs were isolated from soil at this edge of the playground though not in great numbers.

An exactly opposite condition was found in the lowlands along Reelfoot Lake in Obion County. Here we found a group which harbored but light ascaris infestation scattered sparsely though the community. The seven families visited lived near the lake and were on shaded lands frequently flooded in the spring. Privies were present in two cases and stools were seen near the house in both these cases as well as in two others. The pollution was not very heavy or concentrated near the houses but was more general than found elsewhere in the western section of the state. Similarly we found a number of homes in the unshaded floodlands of Lauderdale County where pollution was concentrated under the house in the complete absence of ascaris infestation. The community discussed above and these scattered families found in Lauderdale County, however, seem to be exceptions. Apparently these few families in the midst of otherwise clean communities do not build up heavy infestations unless they are unusually careless in the matter of defecation near the houses.

This brings up again the question of the relations of the individual family to the community level of the infestation. It has been repeatedly pointed out that a single family can and usually does maintain its source of reinfestation. However, there must be considerable interfamily infection, which helps maintain the community worm burden in heavily infested areas. Where the number of typical ascaris families is small the amount of interfamily infection and the number of community sources of infection are greatly reduced. If any given ascaris family loses its worms during a period when its own source of infection has been reduced for any reason, its chances of regaining the infestation must be roughly proportional to the percentage of the population maintaining household sources of infection. This must be of considerable importance in community ascaris infestation because the rapidity of the turnover in the worm burden (Cort, Schapiro, Riley and Stoll, 1929; Cort, Schapiro and Stoll, 1929; Otto, 1930; Caldwell, Caldwell and Davis, 1930) requires a constant source of reinfection. Hence though a given ascaris family may protect itself from or maintain its own source of ascaris infection and reinfection, there must be a definite community interrelationship, which is difficult to evaluate, in the maintenance of the family and community infestation.

That the limiting of soil pollution to areas removed from the house is the only factor operating to control ascaris in the central basin and western highlands and lowlands of Tennessee, we are not prepared to argue. But we do believe that it is the only factor of general importance in Tennessee at least. While topography does not directly limit the potential sources of infection it has an important part in molding, through generations, the natural pollution habits of the people and by affecting the fertility of any area influences the distribution of the various economic groups of the population. Consequently, except for the improvements resulting from organized health work, the ascaris infestation in Tennessee is quite closely correlated with the topography of the region, the more mountainous and less tillable areas retaining the more shiftless and indigenous people and by the seclusion making them more careless, particularly in their pollution habits with the resultant heavy ascaris infestation.

Examples of families illustrating the factors involved in the spread of ascaris, trichuris and hookworm.

In order to illustrate the interplay of the factors involved in the spread of the three common round worms in Tennessee, which have been discussed in the previous sections, it will be helpful to point out specifically the situations in families taken from our series that show different combinations of parasites and different types of situations. In fact one of the most helpful methods of separating the factors concerned with the spread of ascaris, trichuris and hookworm proved to be the comparison of families infested with different combinations of them. It would take too long to detail all the facts obtained in regard to each of these families, so only a summary of the situation will be given with the interpretation that we made.

Family number 56, Crossville, Cumberland County. The five children examined in this family which lived in the town of Crossville were all infested with ascaris, four had light cases of trichuris and three were positive for hookworm. A good privy was present which had been built only one month and was only partly in use. Soil pollution was present both next to the house and a little farther back in the yard where the children played. The whole back yard was densely shaded and the drainage was poor, so the loose sandy soil was quite moist. The family was very poor and of a very low type. It was particularly interesting since there appeared to be centered in the yard itself all the conditions favorable for the spread of all three of the round worms.

In our series there were about 20 families with triple infestations. In most of them pollution was found in well shaded damp places near the houses, which appeared to be favorable for the spread of ascaris and trichuris, and other pollution spots were present in gardens or woods at a little distance from the houses where the sandy soil would be suitable for the development of hookworm larvae.

Family number 2, Crab Orchard, Cumberland County. In this family, which lived at a little distance outside the village of Crab Orchard, three of the four children were infested with both ascaris and hookworm, the infestations with both of the parasites being heavy in two cases; they were entirely negative for trichuris. They were rather poor people but were fairly clean and appeared to be rather intelligent. No privy was present and gross soil pollution said to come from the youngest children was found in the unshaded dooryard to the front and side of the house. Back of the cleared yard about 60 feet from the house were several small shaded clearings in the dense woods where there was a swing and other evidence of children's play. A number of fresh stools and traces of old pollution were found in this densely shaded area where the soil was a moist sandy humus. The soil conditions looked very favorable for the development of hookworm larvae. It seemed evident that the barefoot children running through this area would have every chance of becoming infected. This situation, therefore, had two quite different types of soil pollution, one of which appeared favorable for the spread of ascaris and the other for hookworm. The dry unshaded character of the pollution area near the house would appear to account for the absence of trichuris. Our series contained 39 families with the ascaris-hookworm combination. In a number of these families a situation similar to the above was found where pollution in a dry unshaded dooryard would account for the ascaris infestation and other pollution spots in gardens or woods at a distance from the house would seem to be favorable for hookworm dissemination.

Family number 13, Crossville, Cumberland County. This was one of only two families in our whole series that had a combination of trichuris and hookworm without ascaris. In this case among the four children there were three light cases of trichuris and four light hookworm cases. This family was very poor and lived in a rather poor house. They had a privy in use and the yard was clean and well kept. Careful search of the premises showed one stool in the large space under the house. The whole situation suggested that soil pollution was probably rare and the family had reached a fairly good

condition of household sanitation. Nothing was found that would explain the hookworm infestation although it should be noted that the family had only lived at the house that was inspected for six months. It seems possible that this family represents a situation in which improved sanitation was gradually reducing the worm burden and that ascaris with its more rapid turnover (Otto, 1930) was the first of the three parasites to fade out. It is of course also possible that some ascaris infestation was still spreading but that at the time of the examination none of the children happened to harbor adult female worms.

Family number 5, Crab Orchard, Cumberland County. Of the three children in this family the two older boys, age seven and nine, had moderately heavy hookworm infestation and the 4 year old boy was entirely negative for all three worms. The family had lived for two years in the house which was in a cleared place near the edge of thick woods. The whole yard was clean and hard packed and without any shade. Although the family was without a privy there was no evidence of any pollution near the house. In the woods about 75 feet from the house an area of soil pollution was found where the moist humus sandy soil seemed very favorable for the development of hookworm larvae. We were informed that the family used various places in the woods for defecation purposes. The mother stated that the boys had often suffered from toe itch. It was, therefore, easy to account for the hookworm from infection from the pollution areas in the woods. The absence of ascaris could be associated with the entire absence of pollution in the yard.

There were a few other families in our series with hookworm infestations only where the only pollution found was in gardens or woods at some distance from the house. Such situations give additional evidence that it is the pollution of the soil close to the houses that is most important in the spread of ascaris and trichuris.

Family number 9, Willow Grove, Clay County. This family represented a combination of very heavy ascaris and trichuris infestations. Of the eight children all were infested with ascaris and six with trichuris. One very light hookworm case was also present. This family was extremely poor and degraded. The soil of the yard was clay and densely shaded and moist at the time of our visit. No privy was present and the grossest type of soil pollution was found in the yard near the house. In fact this was one of the worst situations visited in respect to soil pollution near the house. The family had lived in the house for twelve years. It is typical of the worst ascaris families

where the degraded condition of the people, the absence of a privy and the presence of numerous children produced ideal conditions for the spread of this worm. The dense shade near the house also made the soil moist enough to build up heavy trichuris infestation. In fact three of the trichuris cases found in this family were among the heaviest recorded from Tennessee.

Family number 3362, Loyston, Union County. This family was one of the most prosperous visited. It lived on a large farm in a wide valley with a type of house and barns that would appear to bring the people into the class of the better farmers in any region. The house was set in a spacious yard which was shaded in part by a row of apple trees and one large shade tree. A lawn covered most of the yard but close to the house the clay soil was entirely bare. Water was obtained from a deep driven well and there was a good sanitary privy about 100 feet from the house which was in use. No signs of soil pollution were found anywhere on the premises. The family had always lived on this place. All four of the children from six to nine years of age in this family were infested with ascaris and two with trichuris. All the infestations were rather light. Since no soil pollution was found to account for the infestations five soil samples were taken from various parts of the yard both next to the house and under the apple trees where the children played much of the time. All five of these samples were found to be positive for ascaris eggs and one for trichuris. The ascaris eggs were plentiful in the soil samples and in every state of development although most of them were embryonated. There seemed no other way to explain this wide scattering of the ascaris eggs in the yard except by pollution of the soil by the children. The distance of the privy from the house was probably a factor in the soil pollution by the children. This situation is of particular interest because it shows that ascaris and trichuris also where it is moist enough can be kept up in a family of the best type by soil pollution by young children in the yard. The study of this family is also a very good example of how the egg isolation method can be used to explain situations where no soil pollution can be found.

The last two families are examples of a very common type in our series in which soil pollution near the houses in yards kept moist by shade or poor drainage produces both ascaris and trichuris infestations. In all, 86 of the families of our series had a combination of ascaris and trichuris. It is interesting that in our particular series this combination of ascaris and trichuris is found only in areas with clay soil. In the sandy areas trichuris was never found unless hookworm

was also present, although there were plenty of cases where ascaris alone is present on sandy soil. This indicates that on sandy soil, whenever a situation is moist enough for the development of trichuris eggs, hookworm also can spread.

Family number 3156, Walland, Blount County. This family is typical of the poorer, more isolated mountaineers. The three children from 9 to 12 years of age all had cases of ascaris. The mother stated that she had treated them two years before and that they had passed large numbers of round worms. The house was a poor shack in a clearing in the woods at the base of the mountain. The native timber came close to the house and the mountain kept the place damp and cool. The clay soil of the yard was well drained and free from vegetation. The yard was clean except for the presence of human stools. The house was built on sloping ground and there was a large open space under it. In the absence of any privy it was not surprising to find human stools under the house, all around it and scattered along a path leading farther up the hollow. This pollution easily explained how the ascaris spread although it is perhaps surprising that no trichuris was found.

Family number 3757, Sharps Chapel, Union County. To this family belonged one of the better educated school teachers of the county. The father was one of the more prosperous farmers and had spent two years in college, and the mother was a daughter of one of the leading physicians of the county. The family lived in a beautiful new suburban home with the front and side yards in a well-kept lawn. When first viewed it seemed that the listing of this family as an ascaris family, because the three children from five to ten years were all reported as infested, must have been a mistake. A privy was present about 100 feet from the house and was found to be in use. Inspection made it possible to explain the ascaris cases because evidences of soil pollution were found in a pathway back of the house where the children were playing. This family is another example of the situation where ascaris infestation may spread among the children of families of the very best type on account of soil pollution near the house.

Examples of ascaris families which were negative for trichuris and hookworm might be greatly multiplied since they were very common in our series both in the sandy and clay regions. Such families show different degrees of infestation corresponding to different degrees of sanitation. They include not only some of the poorest people in the communities but also some of the most intelligent and well-to-do.

Here the common factor that produces the ascaris infestation is almost always soil pollution by children near the houses.

Family number 17, Forbus, Fentress County. The five children examined in this family were all infested with hookworms, four with trichuris and two with ascaris. The two ascaris cases were very light but two of the trichuris and three of the hookworm cases were fairly heavy. These people lived in a good frame house, had a good privy in use and no evidence of soil pollution could be found. They had lived in the house, where the inspection was made, for two years. No information was obtained either from conversation with this family or from inspection of their premises to explain the infestations that they harbored.

This case is brought in to represent a fairly common situation in our series of family studies, where in spite of infestation of different grades of severity and with different combinations of worms nothing can be found to explain the sources of infection. When it is considered that in most cases only one visit can be made to a house and that the study of the individual family can at best be only rather superficial, it seems probable that in some of these cases at least soil pollution does occur but did not happen to be present or was overlooked at the time of the visit. This seems to be the most probable explanation of the few cases where in spite of the absence of a privy no evidence of soil pollution could be found. Some of the families of this type, especially where the infestations are light, without doubt represent those which at the time of our visit were living under satisfactory sanitary conditions but still retained the remains of infestations that came from former soil pollution habits. There were also evidently cases like that described earlier where the children from a well sanitated home obtained infection by playing with children at houses where the soil was infested. Infestations unexplained by family conditions might also come from community sources such as schools without privies. With so many possible factors operating it has always been a source of surprise to us to find such a very large proportion of our infested families where sources of infection could be located on the premises themselves.

Family number 5, Sneedville, Hancock County. All members of this family, the father and mother and four children from 4 to 11 years of age, were examined and found to be entirely negative for parasitic worms. This family was a typical isolated mountain family of the better type. They lived in a log house which was kept clean and had a clean yard. There was no privy and some evidence of

soil pollution was found in the yard. The mother reported that the children had been treated with oil of chenopodium a year before and that two of the children had passed worms not long before the examination.

This family represents those cases that are not particularly uncommon where there is no privy and traces of soil pollution but no worms. Such a situation as far as ascaris is concerned might be attributed to the limiting of soil pollution to places at a distance from the houses, a condition very common in the ascaris free families of the lowland areas. There is considerable evidence that in many cases negative individuals in places where conditions appear favorable for the spread of ascaris had lost their worms shortly before either naturally or by treatment and there had not yet been time for adult females to develop. This appeared to be the case with at least two members of the negative family reported above who were said to have passed worms not long before they were examined.

Family number 1, Nashville, Davidson County. This family consisted of a man and his wife and seven children who lived several miles from Nashville. All except the father were heavily infested with worms; in fact it was one of the worst ascaris families of our whole series. Two light cases of trichuris were also present. These people had come from Williamson County about two months before, where they owned a small farm from which they had not been able to make a living. They were very poor at the present time since the father was earning only one dollar a day. They had no privy and gross soil pollution was found in the yard next to the house. This family in the central basin had, therefore, an ascaris infestation comparable to the worst ever found in the mountain sections built up by soil pollution near the house in the same way as in the mountain ascaris families. It is representative of the small series of heavy ascaris families found in western Tennessee where the soil pollution conditions were like those of the mountain areas.

Family number 3, Gold Dust, Lauderdale County. This family lived on the edge of the flood area near the Mississippi River, in an old box house supported on stilts about ten feet above the ground. It was representative of the poverty stricken tenant type of farmer. The house was rather unkept and dirty and dish water and scraps of food were thrown into the yard giving a very untidy appearance. There was no privy present and the heavily shaded yard looked like an exceptional place for the development of ascaris and trichuris eggs. Yet the five members of this family examined were worm free. The

chicken house was used in lieu of a privy and seemed to serve in this capacity to the exclusion of all other places. A few stools were found behind the chicken house but none anywhere else on the premises. The mother said the men folks used the barn but denied that anyone ever used the fields or the yard. This family is included as representative of the considerable number of negative or very light infested families visited in western Tennessee in which soil pollution was found only at a distance from the house, and in which the absence of pollution close to the houses appeared to account for the absence of ascaris.

Abstract summary.

Environmental studies were made of 329 families in the mountain regions of Tennessee and 202 families living in the central basin and western plains and lowlands of the state. The ascaris and trichuris infestations were confined largely to the mountain areas, though considerable infestation was found in the rugged foothill type of country around the central basin. The incidence of ascaris was less than 10 per cent in practically all of the central basin and area west of it.

A consideration of all the factors involved emphasized the role of promiscuous dooryard pollution in the spread of this parasite. Temperature and rainfall vary but little over the state. Ascaris infestations of every grade are found on every type of soil in the mountains and are equally absent from every type of soil in the western part of the state. In the western part of the state the few ascaris cases tended to be grouped into families, frequently comparable to those in the mountains. Here as in the mountains heavy dooryard polution was usually seen. Dooryard polution and with it heavy ascaris infestation was present regardless of the presence or absence of privies. However, the privy was present more often than not in the ascaris free families of the mountains and central basin but not necessarily so in the western part of the state. In the western part of the state most people in the absence of a privy retired for defecation to the outbuildings or some other shelter usually some distance from the house, the chicken house usually being used. This concentration of the human feces some distance from the house is indicated as a protection against ascaris and trichuris because these eggs are themselves immobile and continuous massive doses are required to build up and maintain heavy infestations. These differences in pollution habits are seen not as fundamental differences in the people but rather as the effects for generations of the topography of the region on their natural habits.

Instances were found of children from well sanitated and pollution free houses becoming infested by visiting at houses where soil pollution was bad. In certain regions the lack of sanitation and the prevalence of soil pollution at some of the rural schools indicated that they must be important sources of community infection.

While trichuris infestation was much lower than ascaris the two were roughly parallel. Families with heavy trichuris were almost invariably ascaris families, in which the dooryard where soil pollution occurred, was kept quite damp either by shade, poor drainage or a combination of both. The more resistant eggs of ascaris, however, seemed to maintain heavy sources of reinfection in unshaded and seemingly dry areas.

Human ascaris and trichuris eggs were found in a number of cases in chicken droppings. It was demonstrated experimentally that while some of the ascaris eggs were ground up in the gizzard those that passed through were able to develop to the embryonated stage. It was also shown that ascaris eggs were still viable after passage through dogs and cats. It is possible that the ingestion of human stools by domesticated animals might be a factor in the distribution of these nematode eggs, but in our studies we found nothing to indicate that they in any way altered the extent of the infestation.

The hookworm infestation was found definitely correlated with the sandy soil provinces of the state particularly of the Cumberland Plateau. The source of the infection was usually some moist sandy area. In the absence of ascaris infestation this was usually some distance from the house. Frequently, however, all three parasites were present, the ascaris and trichuris apparently being maintained and spread by children defecating close to the shaded houses and the hookworm by adults and older children defecating in the looser shaded soil some distance away. It is worthy of note that in the sandy soil province when the area was sufficiently moist to maintain trichuris, hookworm was also present as well as ascaris.

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