LIFE HISTORY OF ASCARIS LUMBRICOIDES AND RELATED FORMS

[PRELIMINARY NOTE]

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Recently Capt. F. H. Stewart,1 of the Indian Medical Service, in several publications has recorded the results of some experiments of great importance in the light which they throw upon the question of the life history of Ascaris lumbricoides, the common intestinal roundworm of man. The same parasite, or a form so closely related that it is morphologically indistinguishable so far as our present knowledge goes, is of very common occurrence in the intestine of pigs (A. suum or A. suilla). Stewart used both forms in his experiments. He failed in his attempts to infect pigs but found that if rats or mice were fed Ascaris eggs, the eggs hatched in the alimentary tract, and the embryos migrated to the liver, spleen, and lungs. In the course of their migrations they increased in size and passed through certain developmental changes, many of them finally reaching the alimentary tract again by way of the lungs, trachea, and esophagus. The young worms that succeeded in regaining the alimentary tract did not continue their development and soon passed out of the body in the feces, so that rats or mice surviving the pneumonia commonly caused by the invasion of the lungs became free of the parasites as early as the sixteenth day after infection.

As a result of his investigations Stewart was led to a conclusion contrary to the usually accepted opinion that the infection of man or pig with Ascaris results from the ingestion of the eggs of the parasite. He concluded that it is necessary in the life cycle for the eggs to be swallowed by rats or mice and that in these animals the embryos hatching from the eggs undergo certain migrations and developmental changes, after which they may be transferred in the feces or saliva of the rats or mice to food or other materials likely to be ingested by human beings or pigs, and thus ultimately reach their final hosts.

—. ON THE DEVELOPMENT OF ASCARIS LUMBRICOIDES LIN. AND ASCARIS SUILLA Duj. IN THE RAT AND MOUSE. In Parasitology, v. 9, no. 2, p. 213-227, 9 fig., 1 pl. 1917.

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In reviewing Stewart's work it appeared to us that, granting the correctness of his observations, the conclusions that he had drawn did not supply an adequate explanation of the mode of infection with Ascaris. On a number of occasions we had endeavored to infect pigs with Ascaris by feeding the eggs, although the results of these attempts had been negative or uncertain and thus in harmony with the experience of Stewart and other investigators, we nevertheless did not feel justified in accepting these results as evidence against the hypothesis of a direct development without an intermediate host, nor did it seem that Stewart's experiments with rats and mice were sufficient to lead to the conclusion that these animals act in any way as intermediate hosts in the life cycle of the parasite.

Repetition of Stewart's experiments in feeding rats and mice with Ascaris eggs gave results agreeing very closely with those which he has recorded. We have noted wider variations as to the time at which the larvae may be found in various organs and have observed them in several locations in addition to those in which they were seen by Stewart, but the results of our experiments were essentially the same as his, and point to a migration of the larvae to the liver, lungs, spleen, and other organs, and finally from the lungs to the alimentary tract by way of the air passages through the trachea and into the esophagus, during which migrations they undergo considerable development and structural change and increase to a size of 1.5 mm. or more in length.1 In most of our experiments the eggs of the pig Ascaris were used, as Ascaris from pigs was more easily obtainable than parasites from human beings. In addition to our experiments on rats and mice we made further attempts, with negative results, to infect pigs.

Our unsuccessful attempts to infect pigs by feeding Ascaris eggs were made on animals several months old.2 It is noteworthy that Epstein,3 in his carefully controlled experiments with A. lumbricoides used very young subjects and that the positive results which he obtained can scarcely be explained upon any other assumption than that a direct development of the parasites occurred following feeding of the eggs—that is, development without an intermediate host. The experience of one of us (B. H. R.) in certain investigations4 on the life history of Syngamus trachealis, our failures, and the failures of others to infect pigs with Ascaris, the fail-

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1 Since the preparation of this manuscript further investigations have shown that guinea pigs as well as rats and mice may be infected by feeding Ascaris eggs. In these animals the migration of the larvae was, as far as observed, identical with that noted by Stewart for rats and mice. All of the six infected guinea pigs died from pneumonia between seven and eight days after feeding with Ascaris eggs, the lungs being heavily infested with Ascaris larvae.

2 The pigs which Stewart used with negative results were stated by him to have been 2 months old. The ages of the animals used by various other investigators who failed to obtain positive results in experiments to bring about infestations by feeding the eggs of Ascaris are generally not stated, but in many of the negative experiments with human beings it is clear that adults were used as subjects.


4 Not yet published.
ures of various investigators to infect adult human beings, and Epstein's positive results in the case of young subjects, suggested the possibility that age is an important factor influencing the susceptibility of human beings and pigs to infection with Ascaris, and that many of the failures to bring about experimental infections would not have occurred if younger animals had been used as subjects. Our belief in this possibility was strengthened by the discovery of an Ascaris larva in a fragment of lung from a pig about 6 weeks old which had died from unknown causes in May, 1917, a finding which indicated a migration of larvae like that which occurs in rats and mice. The intestine of this pig contained numerous immature ascarids, the largest about 5 cm. long. In order to test the possibility of infecting very young pigs, after several disappointments because certain sows reserved for the purpose of providing young pigs for experimental use either failed to farrow or devoured their newborn offspring, we finally succeeded in obtaining two young pigs from a sow which was found by fecal examination to be free from egg-producing ascarids. In the latter part of September, at the age of about 2 weeks, one of these pigs was given a large number of Ascaris eggs containing motile vermiciform embryos. The number of eggs given was not determined, but there must have been at least several thousand. One week after feeding the pig which had been fed with Ascaris eggs was brought into the laboratory dead; death had occurred either the same day or late the day before; in any event, approximately one week had elapsed since the animal had been given a heavy dose of Ascaris eggs. The other pig continued in good health. Examination of the dead pig revealed a pneumonia, with numerous petechial hemorrhages in the lung tissue. Numerous ascarid larvae, varying in length from 0.7 to 1.2 mm. in length, were found in the lungs, trachea, and pharynx; none in the liver, spleen, esophagus, small intestine, or large intestine.

It is of interest to note in this connection that when rats or mice are fed large numbers of Ascaris eggs they commonly die of pneumonia about a week later, at a time when numerous larvae are present in the lungs, exactly as in the case of this pig. These findings are interpreted by us as clearly demonstrating that Ascaris larvae in young pigs, presumably also in children, behave in much the same way as in rats or mice, and strongly support the hypothesis that the migrations and development of the parasites are very similar in the two cases, the only important difference being that in rats or mice the worms are unable to continue their development to maturity.

Stewart's very important discoveries concerning the behavior of Ascaris larvae in rats and mice, the various contributions of other investigators toward the solution of the problem of the life history of A. lumbricoides and related parasites, and our own experiences outlined above, appear to justify certain conclusions, some of which in anticipation
of a more extended statement in a future paper, may be briefly given as follows:

The development of *A. lumbricoides* and closely related forms is direct, and no intermediate host is required.

The eggs, when swallowed, hatch out in the alimentary tract; the embryos, however, do not at once settle down in the intestine, but migrate to various other organs, including the liver, spleen, and lungs.

Within a week, in the case of the pig Ascaris, the migrating larvæ may be found in the lungs and have meanwhile undergone considerable development and growth.

From the lungs the larvæ migrate up the trachea and into the esophagus by way of the pharynx, and this migration up the trachea may already become established in pigs, as well as in artificially infected rats and mice, as early as a week after infection.

Upon reaching the alimentary tract a second time after their passage through the lungs, the larvæ, if in a suitable host, presumably settle down in the intestine and complete their development to maturity; if in an unsuitable host, such as rats and mice, they soon pass out of the body in the feces.

Heavy invasions of the lungs by the larvæ of Ascaris produce a serious pneumonia which is frequently fatal in rats and mice and apparently caused the death of a young pig one week after it had been fed with numerous Ascaris eggs.

It is not improbable that ascarids are frequently responsible for lung troubles in children, pigs, and other young animals. The fact that the larvæ invade the lungs as well as other organs beyond the alimentary tract and can cause a serious or even fatal pneumonia indicates that these parasites are endowed with greater capacity for harm than has heretofore been supposed.

Age is a highly important factor in determining susceptibility to infection with Ascaris, and susceptibility to infection greatly decreases as the host animal becomes older. This, of course, is in harmony with the well-known fact that it is particularly children and young pigs among which infestation with Ascaris is common, and that Ascaris is relatively of rare occurrence in adult human beings and in old hogs.