Journal of the Tennessee Academy of Science
Volume 31, Number 4, October, 1956

VARIATIONS IN HYMENOLEPIS SERRULA OSWALD, 1951, (CESTODA: HYMENOLEPIDIDAE), A CESTODE FROM THE SMOKY SHREW, SOREX FUMEUS MILLER, 1895, WITH SPECIAL REFERENCE TO THREE GEOGRAPHIC AREAS[1]

Danny D. Cox[2], Honorico Ciordia[3], and Arthur W. Jones
University of Tennessee, Department of Zoology and Entomology
Knoxville, Tennessee

INTRODUCTION

Among the cestodes recovered in 1950 from two smoky shrews *(Sorex fumeus)* were many specimens apparently belonging to *Hymenolepis serrula* Oswald, 1951. Since these specimens differed in several respects from the type species as described, a study of variation was undertaken.

Variation in the species of *Hymenolepis* Weinland, 1858, has been considered by Voge (1952), Neiland (1953), and Senger (1955). Other workers, Baylis (1924), Fuhrmann (1924), Mayhew (1925), Hughes (1941), Jones (1948), Rausch et al. (1948) and Baer (1940, 1951) have discussed variation in cestodes in general. Voge (1952) considers variation in number and size of organs, the size of mature worms, and many other aspects. Concerning the strobila length in *Hymenolepis diminuta*, Voge states that "size differences are not always particularly significant, and it is necessary to study numerous specimens in order to determine variation in this respect." She also writes that "studies of large numbers of specimens from different host individuals or species obtained from different parts of the host's range would greatly increase our knowledge of intraspecific variation." In a summarizing statement she says "size alone is not a dependable criterion for specific differentiation unless it is thoroughly studied."

Baylis (1924) also considers the size of individual specimens and reaches the conclusion that "*Hymenolepis nana*, in rats and mice, is a species with an exceptionally wide range of variation among mature individuals." Rausch *et al.* (1948) deal with variation in the distribution and number of testes.

Baer (1951) discusses the situation in which groups of hosts or host species that are isolated, geographically or for some other

[1]This paper was condensed from a thesis submitted to the Graduate Council of the University of Tennessee in partial fulfillment of the requirements for the degree of Master of Science.

[2]The senior author's present address is The Department of Veterinary Science, University of Wisconsin, Madison, Wisconsin.

[3]Present address U.S.D.A. Experiment Station, Griffin, Georgia.

reason, harbor parasites that tend to split into a great number of subspecies, and points out that inbreeding of isolated populations tends to preserve genetic changes. He further points out that, since most tapeworms are self-fertilizing, the conditions existing in isolated populations are particularly favorable for preserving all the genetic variations that may occur. It is clear that if an intermediate host is involved in the life cycle of a cestode and is restricted by isolation to the same area as the definitive host, the chances of preserving the genetic changes that may occur in that population of cestodes are considerable. Jones (1948) mentions intraspecific variations and suggests that rare "species" may be genetically unique "populations."

Fuhrmann (1924), in his consideration of the genus *Hymenolepis*, includes within his list six species whose members possess a variable number of rostellar hooks. This is in contrast to the usual situation in which the members of an armed species of cestode possess a contstant and uniform number of rostellar hooks. Mayhew (1925) also records a range in hook number in his description of *Hymenolepis lobulata*. Baer (1940), however, reports a constant number of rostellar hooks in members of the latter species. Neiland (1953) studied specimens of *Hymenolepis longi* which had ten instead of eight hooks. He concludes that "a study of additional eastern specimens, as well as more western specimens from other hosts and localities, will be necessary before it can be determined if two separate species are involved." Senger (1955) observed considerable variation in both number and size of hooks in species of *Hymenolepis* from shrews, concluding that probably "the most important characters are the shape of the rostellar hooks along with the general body morphology." Hughes (1941) points out that size, shape, and number of hooks are characteristics of considerable taxonomic importance in the study of armed cestodes.

As will be shown later, variation in hook number as well as in the size of other structures and organs was present in *Hymenolepis serrula*. The taxonomic importance of these variations will be considered.

Cestodes studied were from three smoky shrews, trapped, respectively in the Fall Creek Falls State Park, Tennessee, the Great Smoky Mountains National Park, Tennessee, and Hocking County, Ohio. The cestodes of the latter host were loaned for study by the U.S. National Museum and by Vernon H. Oswald. The Tennessee specimens were fixed in Carnoy by shaking and were mounted unstained for study with phase contrast optics. The Ohio specimens had been lightly stained, but were susceptible to the same method of study. American Optical Co. phase equipment, Dark M. type, was used. The camera lucida was used for drawing and measurement.

Measurements were made as follows.

The diameter of the scolex was measured at the level of the suckers. Measurements of the suckers were usually taken from those which were spherical in outline but in some instances also from those which were turned slightly so as to be somewhat ellipsoidal. The values obtained for the suckers of each individual were averaged and recorded as the sucker diameter.

Two measurements were taken only from hooks which were in a completely horizontal or vertical plane, one being from the tip of the dorsal root to the tip of the blade and the other from the tip of the ventral root to the tip of the blade.

The width of the rostellum was measured about half-way along its length. This region ordinarily represents the widest part of that structure.

The width of the specimen was taken at its widest point, usually in the first one-half or two-thirds of the worm in the region corresponding to mature or post-mature but not gravid proglottids.

The length and width of the cirrus sac were determined by measuring this structure in a mature proglottid of each worm. The width was taken at the region of maximum diameter which was usually about mid-way along its length. In an attempt to obtain comparable measurements in different worms it was decided that the proglottid in which these measurements were to be taken would be the last one before the ovary attained a size that would obscure the testes and prevent their measurement. The diameter of each of the three testes was taken in this same proglottid, averaged and recorded as the diameter of the testes of that worm.

The diameter of the yolk gland was measured in the proglottid in which it achieved its greatest size. This proglottid was determined by observing whole mounts of the worms and following the development of the gland in successive proglottids until the one possessing the yolk gland showing the maximum development was reached.

The values in the table beside the heading "mean deviation from the mean" were obtained by the following method. The measurements were summed and a mean obtained. The object of this procedure was to obtain an index to the variability of the structure measured. A very low mean deviation, therefore, would indicate that the measured structure was probably almost constant in size.

OBSERVATIONS AND RESULTS

For reference in the comparisons to follow, Oswald's (1951) description is given:

"Strobila 1 to 2 mm. in length; greatest width, attained in gravid proglottids, 230 to 290 microns. Margins of strobila serrate. Proglottids 23 to 27 in number; mature proglottids wider than long, gravid proglottids becoming elongate. Scolex spherical, 88 to 135 microns in diameter, not distinctly set off from neck. Suckers 19 to 46 microns in diameter. Rostellum approximately 25 microns in diameter; armed with eight hooks 18 to 21 microns long. Rostellar sac 38 by 45 microns. Excretory system undulating, without transverse connectives; ventral canals 3.5 to 5.5 microns in diameter; dorsal canals about 1.0 micron in diameter, situated directly dorsal to former. Genital pores unilateral and dextral; located anterior in proglottid. Genital ducts pass dorsally to both excretory canals. Cirrus sac 93 to 100 microns long and 10 to 15 microns in diameter; external seminal vesicle gives appearance of cirrus sac extending to aporal excretory canals. Cirrus spinose, 60 to 80 microns long when protruded. External seminal vesicle recurved porad, dorsal to cirrus sac. Testes three in number, ovoid, 20 to 34 microns in transverse diameter; situated in a transverse straight line in posterior portion of proglottid. Ovary irregular, transversely elongate; situated anterior in proglottid.- Vitellarium ovoid, 19 to 26 microns in transverse diameter; located at posterior margin of ovary between the two aporal testes. Vagina ventral to cirrus sac; seminal receptacle dorsal to ovary, not prominent. Uterus reticulate; eggs fill entire gravid proglottid. Eggs ovoid, 30 to 46 by 23 to 34 microns. Larval hooks 7.6 to 8.3 microns in length."

Figure 1, Plate I, shows a drawing of an entire worm done with the aid of the camera lucida. There was no observed exception to Oswald's (1951) description of the strobila margins, shape of mature and gravid proglottids, and the shape and attachment of the scolex.

Length of strobila. Values given in Table I indicate considerable variation among the three geographic areas with the lowest value being 0.96 mm. and occurring in a specimen from the Great Smoky Mountains National Park, and the highest 2.10 mm. occurring in a specimen from south central Ohio. The average values for the total of twenty-nine specimens from all areas, however, were well within the range of 1 to 2 mm. given by Oswald.

Width of strobila. The ranges of values obtained from specimens of both the Great Smoky Mountains and Fall Creek Falls overlap slightly the

TABLE I

Data showing variation in the size of various organs and structures and in the number of rostellar hooks in Hymenolepis serrula from three geographic areas
(measurements are in millimeters)

	Great Smoky Mountains National Park	Fall Creek Falls State Park	South Central (Hocking Co.) Ohio
Length Strobila			
Range	0.96-1.72	1.09-1.16	1.00-2.10
Average	1.35	1.12	1.39
Mean Deviation from Mean	0.32	0.02	0.23
Number Measured	4	6	19
Width Strobila			
Range	0.19-0.25	0.13-0.27	0.22-0.37
Average	0.22	0.19	0.27
Mean Deviation from Mean	0.02	0.03	0.03
Number Measured	5	10	20
Number Proglottids			
Range	16-21	11-25	14-27
Average	19	16	23
Number Worms Observed	5	9	29
Diameter Embryo			
Range	0.012-0.015	0.015-0.016	0.013-0.017
Average	0.013	0.016	0.015
Number Measured	4	4	16
Diameter Egg			
Range	0.017-0.020	0.020-0.023	0.021-0.028
Average	0.019	0.022	0.024
Number Measured	4	4	16

TABLE I
(Continued)

Data showing variation in the size of various organs and structures and in the number of rostellar hooks in Hymenolepis serrula from three geographic areas
(measurements are in millimeters)

	Great Smoky Mountains National Park	Fall Creek Falls State Park	South Central (Hocking Co.) Ohio
Maximum Width Scolex			
Range	0.063-0.080	0.075-0.121	0.051-0.135
Average	0.074	0.099	0.089
Number Measured	5	11	22
Width Suckers			
Range	0.022-0.031	0.033-0.046	0.019-0.032
Average	0.028	0.039	0.026
Number Measured	5	11	21
Length Rostellum			
Range	0.022-0.037	0.022-0.038	0.013-0.032
Average	0.028	0.028	0.021
Number Measured	5	12	22
Width Rostellum			
Range	0.021-0.027	0.025-0.032	0.016-0.027
Average	0.024	0.028	0.022
Number Measured	5	12	22
Diameter Testes			
Range	0.020-0.030	0.020-0.038	0.023-0.043
Average	0.026	0.027	0.033
Number Measured	5	13	27
Length Cirrus Sac			
Range	0.100-0.125	0.099-0.123	0.063-0.139
Average	0.110	0.111	0.103
Number Measured	5	13	27
Width Cirrus Sac			
Range	0.013-0.019	0.017-0.030	0.011-0.020
Average	0.017	0.023	0.015
Number Measured	5	13	27
Diameter Yolk Gland			
Range	0.027-0.034	0.023-0.034	0.021-0.039
Average	0.031	0.029	0.030
Number Measured	5	11	27
Dorsal Root to Blade			
Range	0.019-0.024	0.017-0.021	0.014-0.023
Average	0.022	0.019	0.019
Mean Deviation from Mean	0.001	0.001	0.001
Number Hooks Measured	21	26	150
Ventral Root to Blade			
Range	0.005-0.009	0.006-0.008	0.005-0.008
Average	0.008	0.007	0.007
Mean Deviation from Mean	0.001	0.000	0.001
Number Hooks Measured	21	26	150

range of 230 to 290 microns given by Oswald but the average values are well below his range, possibly indicating that the majority of the specimens from these two areas are not as wide as those from Ohio. It is interesting that, although the average value obtained for the Ohio specimens is within the range given in Oswald's description, the diameter of many of the specimens approached the upper limits of that range and some exceeded it. One possible explanation may be found by considering the region of the worm where the measurement was taken. Oswald (1951) states that the greatest width is attained in the gravid proglottids. The maximum width of mature, relaxed specimens considered in this study was, almost without exception, attained in the mature or post-mature rather than the gravid proglottids.

Number of proglottids. In this characteristic a situation similar to the preceding is present. The average values obtained for specimens from the Great Smoky Mountains and from Fall Creek Falls (Table I) fail to fall within the range of 23 to 27 given in Oswald's description. The range in values obtained from specimens from the Great Smoky Mountains (16 to 21) is below the range given by Oswald but the range in values from Fall Creek Falls specimens (11 to 25) overlaps his range slightly. The range in values obtained from the Ohio specimens is 14 to 27 with an average of 22. This range overlaps considerably that given by Oswald and which was based on a study of these and other specimens. The average value is also within his range. These data, therefore, indicated that there are definite differences in specimens from these three geographic areas. The comparison of the data based on a study of the Ohio specimens with Oswald's description indicates that possibly one or more worms were included in this study that Oswald felt were missing segments. This would account for the smaller number of proglottids counted in an Ohio specimen by these authors.

Diameter of egg. Figures 3 and 4, Plate I, show an immature and a mature egg respecively. The diameters of the eggs of specimens from the three geographical areas are given in Table I. The ovoid condition of the eggs described by Oswald was not observed in this study but because the fixative used for the worms from the Tennessee shrews was not the best for the preservation of eggs and few eggs were masured this difference may not be significant. A range of 21 to 28 microns and an average of 24 microns was found for the size of eggs in specimens from Ohio. This compares favorably with the 23 to 34 microns range given by Oswald as the smaller dimension of the ovoid eggs. For this reason it is believed that the values recorded for egg size in Table I represent the smaller diameter of the egg, if indeed the eggs are ovid. The range of values and the average value for egg size in specimens from both the Great Smoky Mountains National Park and Fall Creek Falls State Park fall below the range given by Oswald, indicating that the eggs of worms from these areas are smaller.

Diameter of embryo. This measurement was taken across the same axis of the egg as the egg diameter. Table I shows values for the three areas which are closer together than those relating to egg diameters. There is a possibility that, in the future, the diameter of embryos may be shown to be a more reliable measurement than the egg diameters because of a lower sensitivity to fixation damage. The embryo diameters are similar to the egg diameters in that the specimens from the Great Smoky Mountains show the lowest average value and those from Fall Creek Falls show an average value which is closer to that obtained for the specimens from Ohio.

Figure 5, Plate I, shows the female reproductive system. There was no observed exception to Oswald's description of the shape and position of the ovary and the yolk gland.

Observations made in this study are in complete agreement with those of Oswald regarding the number and position of the genital pore and the description of the excretory system. Unfortunately the excretory canals were not measured in this study and therefore no comparison can be made with the dimensions given in Oswald's description but it was observed that the dorsal canal is considerably smaller than the ventral canal.

Diameter of yolk gland. Table I gives the ranges and average values for the maximum yolk gland diameter in specimens from three geographic areas. The average values obtained for specimens from all three areas are greater than the upper limit of the range given by Oswald (26 microns). The lower limit of the range of values found for specimens from the Great Smoky Mountains is above the upper limit given in his description indicating a considerably larger gland size in specimens from this area. The ranges in values obtained from specimens from the Fall Creek Falls State Park and south central Ohio overlap Oswald's range slightly.

Figure 6, Plate II, shows the male reproductive system. In all specimens studied the number, shape, and arrangement of testes compared favorably to Oswald's description. The same is true of the shape and position of the external seminal vesicle (Fig. 6, Plate II).

Diameter of testes. As is shown in Table I the average values for specimens from the three geographic areas considered are within the range of 20 to 34 microns given by Oswald. However, the upper limit of the range of values in both the Fall Creek Falls and the Ohio specimens exceeds the 34 micron limit found by Oswald. Even though in this characteristic the specimens from the Great Smoky Mountains National Park resemble more closely those from Fall Creek Falls State Park the specimens are by no means uniform and there is considerable variation within each of the three geographic areas in addition to differences between these areas.

Length and width of cirrus sac. Table I gives values which are considerably different for specimens from the three areas. The average value obtained for the length of the cirrus sac for specimens from each area is above the range given by Oswald (83-100 microns). The average values obtained for the width of the cirrus sac for specimens from the Great Smoky Mountains and Fall Creek Falls are also above the upper limit of his range (10-15 microns). The average values for both the length and width of the cirrus sac are lowest for specimens from the Great Smoky Mountains, and highest for specimens from Fall Creek Falls. This indicates not only that considerable size variation in this structure occurs but also that, while the ranges of variation in the different areas may overlap, the majority of the individuals may lie in any part of a range. It is believed that the average values give some indication concerning this majority and in so doing supply useful information not found in the range of values alone.

Diameter of scolex, suckers, and rostellum. Figure 10, Plate II, shows the scolex with its suckers and the armed, withdrawn rostellum. Oswald (1951) states that the diameter of the scolex is 88 to 135 microns, the suckers 19 to 46 microns, and the rostellum approximately 25 microns. Table I shows that the variation in the values obtained by measurement of these structures follows no definite pattern with regard to the geographical areas. The specimens from Fall Creek Falls show the largest average values for the diameter of all three structures. Although the average values obtained from specimens of the three geographic areas for the diameter of the suckers were within the limits of the range given by Oswald, the average value from the Great Smoky Mountains specimens was below the lower limit of his range for the scolex diameter.

Length of rostellum. The data given in Table I show similar average values and ranges in values for specimens from the Great Smoky Mountains

National Park and Fall Creek Falls State Park. Specimens from south central Ohio show a range with the lower limit well below that of either of the other two areas and an average which is also below those of the other areas. Since Oswald does not include this measurement in his description no comparison can be made. Measurements involving the rostellar sac were not taken in this study and hence no comparison can be made with values given by Oswald.

Measurements of hooks. Figure 2 shows two views of a rostellar hook of the type found in *Hymenolepis serrula*. Hooks of this species are also shown *in situ* in Figure 10, Plate II. Oswald (1951) states that these hooks are 18 to 21 microns long. It is shown in Table I that the range in length (dorsal root to blade) is slightly greater than that given by Oswald. The average values obtained for specimens from Fall Creek Falls and south central Ohio were within his range. The average value for the hook length for specimens from the Great Smoky Mountains was 22 microns. This value was above Oswald's range and was noticeably higher than the average value of either of the other two areas. Data are also given in Table I regarding the distance from the ventral root to the blade. In this measurement also the specimens from the Great Smoky Mountains showed the largest average value. It appears, therefore, that the rostellar hooks of specimens from the Great Smoky Mountains are distinctive in both measurements whereas the hooks of specimens from the otheer two areas appear to be very similar. Since the measurement from the ventral root to the blade was not taken by Oswald, no comparison can be made.

Number of hooks. Oswald (1951) states that there are eight hooks. This characteristic shows the most outstanding variation in this study. Figure 11 is a graph showing variation in the number of rostellar hooks from six to eleven among specimens from all three geographic areas. It is interesting to note, however, that even though a variation in hook number is present the most frequent number among the Ohio specimens is eight and for the two Tennesseee areas combined, nine. (According to Senger, 1955, a specimen from Montana has 10 hooks, but was identified by Oswald as *H. serrula*. The writers have not seen this specimen.)

Evidence for cross-fertilization. Figure 7, Plate II, shows the vagina of a worm containing the cirrus from another worm. This condition was observed in five segments of one worm. The fact that the cirrus in each of the five segments where this condition occurred was in its normal unextended position plus the fact of the small size of the worm, which enables one to study each segment and ascertain that the cirri are present, immediately eliminates the possibility that self-fertilization of the same segment or a folding upon itself and cross-fertilization between different proglottids with the loss of cirri has occurred. This evidence is therefore believed to be proof of cross-fertilization between worms, the significance of which will be discussed later. It is unknown whether or not the loss of the cirrus after copulation is the usual situation but it seems highly improbable that this is the case because every worm observed appears to have all its cirri as well as mature, apparently fertilized eggs while only one showed the result of the loss of cirri by another worm.

Figure 8, Plate II, shows part of an extended cirrus with a shortened cirrus sac. The latter condition seems to be a not infrequent result of full protusion and possibly a partial pulling out. Figure 9, Plate II, shows a fully extended cirrus and the cirrus sac. As is shown, with full extension the internal seminal vesicle is stretched and becomes the ejaculatory duct. The characteristic spinose condition of the cirrus observed by Oswald was present without exception in the specimens observed in this study. The

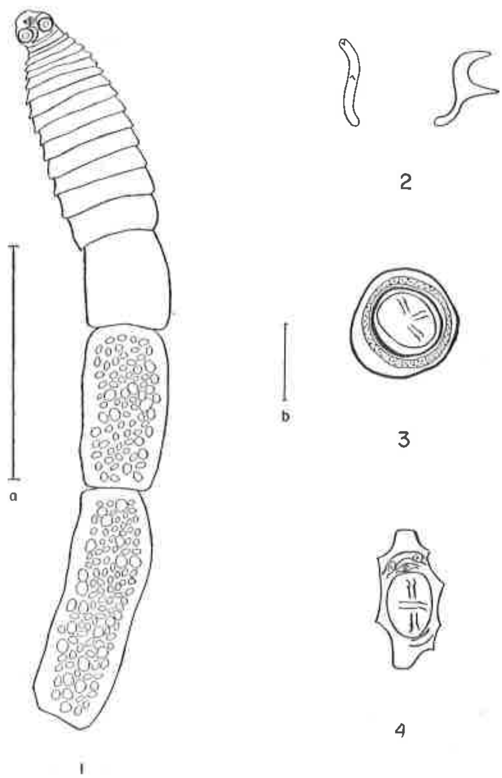
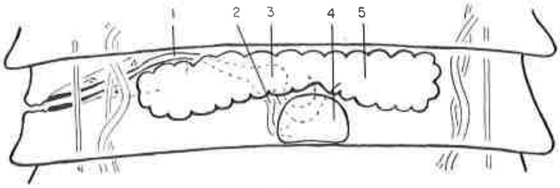


Plate I

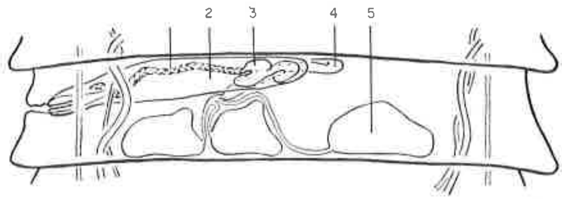
values obtained for the few cirri that were measured were within Oswald's range of 60 to 80 microns for the length of the cirrus.

The results of this investigation are included below as a supplementary revision of Oswald's (1951) description of *Hymenolepis serrula.*

Strobila 0.96 to 2.1 mm. in length; greatest width, attained in mature or post-mature (?) proglottids, 0.13 to 0.37 mm. Proglottids 11 to 27 in number. Scolex diameter 0.051 to 0.135 mm. Suckers 0.019 to 0.046 mm. in diameter. Length of rostellum 0.013 to 0.038 mm., diameter 0.016 to 0.032 mm. Hooks 6 to 11 in number, with 8 and 9 being the most frequent; length (dorsal root to blade tip) 0.014 o 0.024 mm.; ventral root to blade tip 0.005 to 0.009 mm. Cirrus sac 0.063 to 0.139 mm. in length, 0.011 to 0.030 mm. in width. Testes diameter 0.020 to 0.043 mm. Diameter of yolk gland 0.021 to 0.039 mm.

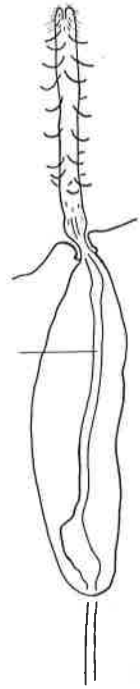


5

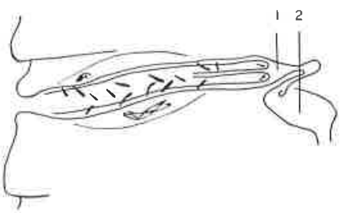


6

a

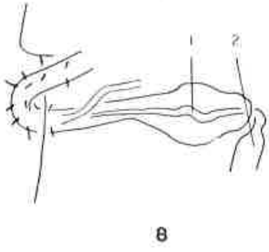


9

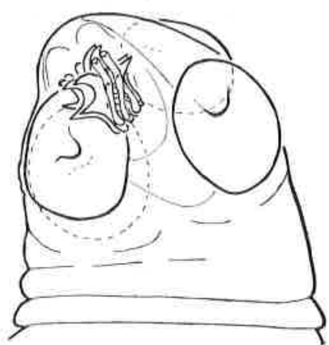


7

b



8



10

Plate II

EXPLANATION OF FIGURES

1. Toto-mount of *Hymenolepis serrula*
2. Two views of rostellar hook
3. Immature egg showing larval hooks and membranes
4. Mature egg showing larval hooks and fixation-distorted membranes
   Scale (a), 0.5 mm, applies to figure 1. Scale (b), 0.02 mm, applies to figures 2-4.
5. Proglottid showing the female reproductive system (1, vagina; 2, yolk duct; 3, seminal receptacle; 4, yolk gland; 5, ovary)
6. Proglottid showing the male reproductive system (1, cirrus; 2, cirrus sac; 3, internal seminal vesicle; 4, external seminal vesicle; 5, testis)
7. Evidence of cross-fertilization (1, vagina; 2, seminal receptacle)
8. Extended cirrus and shortened cirrus sac (1, ejaculatory duct; 2, external seminal vesicle)
9. Cirrus sac with fully extended cirrus (1, ejaculatory duct)
10. Scolex with withdrawn rostellum
    Scale (a), 0.1 mm, applies to figures 5-6. Scale (b), 0.05 mm, applies to figures 7-10.
11. Graph showing variation in hook number

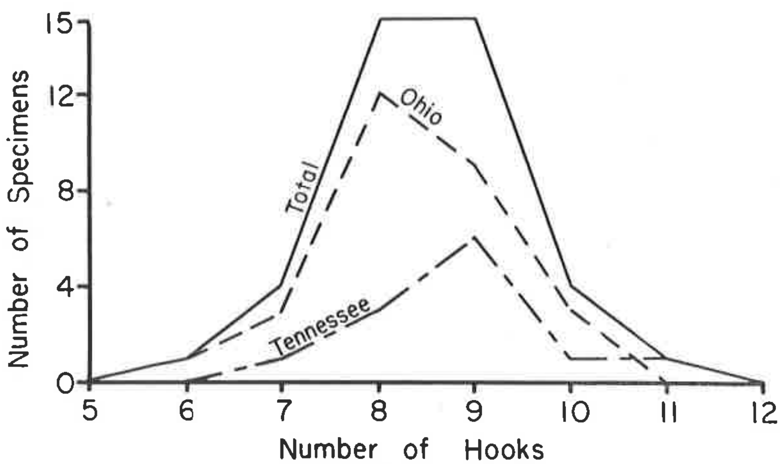


Fig. 11

Discussion

The problem of variation within cestode species has been the subject of relatively few investigations. Specimens of *Hymenolepis serrula* were studied in an attempt to determine the amount of variation in this species.

It has been shown that with regard to the length and width of the worms, the number of proglottids, the diameter of the suckers, and the width of the rostellum and the cirrus sac the specimens from Fall Creek Falls State Park seem to be a distinctive group. The specimens from the Great Smoky Mountains National Park appear to be distinctive with regard to the diameter of the embryos and eggs, the maximum diameter of the scolex, and the size of the rostellar hooks. Specimens from south central Ohio appear distinctive upon consideration of the length of the rostellum and the cirrus sac and the diameter of the testes. Some specimens from each group appeared to be intermediate between that group and another.

From the preceding discussion concerning the "distinctiveness" of the specimens from each geographic area with regard to the size and number of some of the structures and organs it is clear that each population has a different distribution of characters. There is, however, considerable overlapping of the ranges of variations among the populations from the three geographic areas and for this reason it seems best to consider them as three populations of a single species rather than three separate species or subspecies.

Variation such as the above may be either environmentally or genetically determined. Since evidence of the nature of environmental factors in the variation of *H. serrula* seems lacking, these factors cannot be discussed. Several genetic factors are known, however, which may have effected variation in these cestodes.

Genetic changes occurring by chance, when prevented by isolating factors from spreading throughout a species, may result in population differences. Isolating factors between the Blue Ridge Province, where the Great Smoky Mountains are, and the Appalachian Plateau, where both Hocking County, Ohio and Fall Creek Falls State Park, Tennessee, are located, consist of a large valley and rivers.

The data show that variations exist among specimens from one host of each area as well as among groups of specimens from the three geographic areas. It is also shown that the cestodes from Fall Creek Falls State Park differ considerably in several respects from those of south central Ohio. The latter fact is of interest because if geographic isolation of hosts is the major factor resulting in speciation among their parasites the cestodes from these two areas should show few differences, since the only major isolating factor is distance. Further evidence that geographic isolation is not the only factor in speciation is the amount of variation that was present among the cestodes of each host.

It is possible to explain the unexpected difference between populations of the same geologic province by either of two hypotheses. First, cross-fertilization, with the possibility of hybridization, is indicated by the observation of a cirrus from one strobila inserted in the vagina of another. Jones (1951) reported other evidence of hybridization. Second, a high mutation rate could result in such instability that intra-population variation would conceal or mask such inter-population differences as would be preserved and accumulated by isolating factors. In normally self-fertilizing organisms, such as tapeworms, the tendency would be toward homozygosity and uniformity with variation being unusual, unless a high mutation rate with consequent mutation pressure acts to produce variations. It is possible, therefore, that occasional cross-fertilization and a high mutation rate may account for many of the variations observed in specimens of *Hymenolepis serrula,* with any geographic isolation tending to preserve as races the populations in which these variations occur.

Summary

Specimens of *Hymenolepis serrula* obtained from the Great Smoky Mountains National Park and Fall Creek Falls State Park in Tennessee and from south central (Hocking County) Ohio were examined to determine the extent of variation in the size and number of some organs and structures in this species.

The presence of a cirrus of one worm in the vagina of another worm is presented as evidence of cross-fertilization.

Based on the data, it is the author's belief that the three groups sampled should be considered as populations of *Hymenolepis serrula,* rather than three separate species or subspecies, because of the overlapping ranges of variations.

The results of this investigation are incorporated into a supplementary revision of Oswald's (1951) description of *Hymenolepis serrula.*

LITERATURE CITED

Baer, J. G. 1940. Some avian tapeworms from Antigua. *Parasit.,* 32:174-197.

Baer, J. G. 1951. *Ecology of animal parasites.* Pp. 155, 213. University of Illinois Press, Urbana.

Baylis, H. A. 1924. The range of variation of *Hymenolepis nana* in rats and mice. *Parasit.,* 16: 415-418.

Fuhrmann, O. 1924. *Hymenolepis macracanthos* v. Linstow. Considerations sur le genre *Hymenolepis. Jour. Parasit.,* 11: 33-43.

Hughes, R. C. 1941. A key to the species of tapeworms in *Hymenolepis. Trans. Amer. Micr. Soc.,* 60: 378-414.

Jones, A. W. 1948. Speciation in the Cestoda. *Jour. Parasit.,* 34 (Suppl.): 22.

Jones, A. W. 1951. Hybridization in the tapeworm. *Jour. Heredity,* 42 (5): 264-266.

Mayhew, R. L. 1925. Studies on the avian species of the cestode family Hymenolepididae. *Illinois Biol. Monog.,* 10: 1-125.

Neiland, Kenneth A. 1953. Helminths of Northwestern mammals, Part V. Observations on cestodes of shrews with the description of new species of *Liga* Weinland, 1857, and *Hymenolepis* Weinland, 1858. *Jour. Parasit.,* 39 (5): 487-494.

Oswald, V. H. 1951. Three new hymenolepidid cestodes from the smoky shrew, *Sorex fumeus* Miller. *Jour. Parasit.,* 37 (6): 573-576.

Rausch, R., E. L. Schiller, and B. B. Morgan. 1948. Variation in *Andrya macrocephala* Douthitt, 1915 (Cestoda: Anoplocephalidae). *Jour. Parasit.,* 34 (Suppl.): 23.

Senger, Clyde M. 1955. Observations on cestodes of the genus *Hymenolepis* in North American shrews. *Jour. Parasit.,* 41 (2): 167-170.

Voge, Marietta. 1952. Variations in some unarmed Hymenolepididae (Cestoda) from rodents. *Univ. Calif. Publ. Zool.,* 57 (1): 1-52.