INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films
the text directly from the original or copy submitted. Thus, some thesis and
dissertation copies are in typewriter face, while others may be from any type of
computer printer.

The quality of this reproduction is dependent upon the quality of the
copy submitted. Broken or indistinct print, colored or poor quality illustrations
and photographs, print bleedthrough, substandard margins, and improper
alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript
and there are missing pages, these will be noted. Also, if unauthorized
copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by
sectioning the original, beginning at the upper left-hand corner and continuing
from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

UMI®
THE HELMINTH PARASITES OF THE BOB-WHITE QUAIL

by

JACKSON DAN WEBSTER

M.Sc. Cornell University, 1941

The first of two theses presented
to the Faculty of the Rice Institute
In partial fulfillment of requirements
for the Degree of Doctor of Philosophy
Department of Biology

HOUSTON, TEXAS
JUNE, 1947

49-4922
ACKNOWLEDGEMENTS

This investigation was made under the direction of Professor Asa C. Chandler, to whom I wish to express my appreciation for his inspiration and his many valuable suggestions.

I must pay special tribute, because thanks are no longer possible, to the work of the late Dr. Clarence J. Addis; his post-mortem examinations of 201 quail form an integral part of this thesis. Mr. Valgene W. Lehmann, first as an agent of the Texas Game, Fish and Oyster Commission, later as wild life manager of the King Ranch, provided most of the quail examined. My thanks are also due to Mrs. William H. Fike for her assistance in microscopical technique and to Mr. W. Garner Fuller, Mr. Rollin H. Baker, and Mr. J. E. Carlisle (all of the Texas Game, Fish and Oyster Commission) and Dr. Wilton E. Fisher for quail sent in for examination. Numerous friends and assistants have helped me in diverse ways too numerous to mention.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. Historical review of previous work</td>
<td>1</td>
</tr>
<tr>
<td>3. Materials and methods used in the present work</td>
<td>5</td>
</tr>
<tr>
<td>4. Annotated list of helminths found in Texas Bob-white</td>
<td>8</td>
</tr>
<tr>
<td>a. General</td>
<td>8</td>
</tr>
<tr>
<td>b. <em>Raillietina klebergi</em></td>
<td>8</td>
</tr>
<tr>
<td>c. <em>Raillietina colinia Webster</em></td>
<td>10</td>
</tr>
<tr>
<td>d. <em>Raillietina tetragona</em> (Molin)</td>
<td>12</td>
</tr>
<tr>
<td>e. <em>Raillietina minuta</em> n. sp.</td>
<td>12</td>
</tr>
<tr>
<td>f. <em>Raillietina cesticillus</em> (Molin)</td>
<td>12</td>
</tr>
<tr>
<td>g. <em>Raricterotaenia</em> sp.</td>
<td>14</td>
</tr>
<tr>
<td>h. <em>Rhabdometra odiosa</em> (Leidy)*</td>
<td>14</td>
</tr>
<tr>
<td>i. Unidentifiable cestodes</td>
<td>14</td>
</tr>
<tr>
<td>j. <em>Disteganius colini</em> n. gen. n. sp.</td>
<td>14</td>
</tr>
<tr>
<td>k. <em>Aulonocephalus lindquisti</em> Chandler</td>
<td>16</td>
</tr>
<tr>
<td>l. <em>Seurocrynea</em> sp.</td>
<td>19</td>
</tr>
<tr>
<td>m. <em>Syngamus trachea</em> (Montagu)</td>
<td>19</td>
</tr>
<tr>
<td>5. Distributional considerations</td>
<td>19</td>
</tr>
<tr>
<td>a. Ecological regions of Texas east of the 100th meridian</td>
<td>19</td>
</tr>
<tr>
<td>b. Subspeciation of the Bob-white</td>
<td>24</td>
</tr>
<tr>
<td>c. Descriptions of localities whence quail were examined</td>
<td>26</td>
</tr>
<tr>
<td>d. Distributional discussion of helminths</td>
<td>27</td>
</tr>
<tr>
<td>e. Summary of distributional considerations</td>
<td>32</td>
</tr>
<tr>
<td>6. Summary</td>
<td>34</td>
</tr>
<tr>
<td>7. Bibliography</td>
<td>36</td>
</tr>
</tbody>
</table>
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Plate</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate I.</td>
<td><em>Raillietina colinia</em> n. sp. (figs. 1-5)</td>
<td>10</td>
</tr>
<tr>
<td>Plate II.</td>
<td><em>Raillietina klebergi</em> n. sp. (figs. 2-4) and <em>Raillietina minuta</em> n. sp. (figs. 1)</td>
<td>12</td>
</tr>
<tr>
<td>Plate III.</td>
<td><em>Disteranianus colini</em> n. gen. n. sp. (figs. 10-11)</td>
<td>16</td>
</tr>
<tr>
<td>Plate IV.</td>
<td>Map of eastern Texas, showing biotic provinces and locations of helminth records.</td>
<td>25</td>
</tr>
<tr>
<td>Plate V.</td>
<td>Map of eastern Texas, showing biotic regions and locations whence quail were examined.</td>
<td>27</td>
</tr>
<tr>
<td>Plate VI.</td>
<td>Map of South Texas, showing locations referred to in the text.</td>
<td>29</td>
</tr>
<tr>
<td>Plate VII.</td>
<td>Map of eastern Texas, showing subspecies 32 of the Bob-white and locations whence quail were examined.</td>
<td>32</td>
</tr>
</tbody>
</table>
THE HELMINTH PARASITES OF THE BOB-WHITE

INTRODUCTION

The parasitic fauna of the Bob-white Quail (*Colinus virginianus*) has been thoroughly known from the eastern United States for several years. However, the first two examinations of the species at Rice Institute uncovered a new species of parasite. Therefore, in the hope that systematic and distributional data of value might be discovered, examination of an extensive series of Bob-White from the State of Texas was undertaken.

Life history experiments on two species of cestodes were unsuccessful. However, systematic and distributional records of worms were indeed unusual. The faunally unique position of South Texas in the United States was emphasized. Data was supplied which will be of value to game managers in the state. It may be noted that the Bob-white is at present the most important game bird in Texas.

REVIEW OF LITERATURE

The first report of helminth parasites of the Bob-white was by Joseph Leidy (1887) who described *Taenia odiosa* (=*Habdometra odiosa*) from four birds taken in Florida, and listed *Heterakis vesicularis* (Froelich, 1791) Dujardin, 1845 (=*H. gallinae*), from the same collection.

Cram (1927) reported *Trichostrongylus perrectacilis* (Cobb, 1873) Railliet and Henry, 1909, and described *Cyrnea colini* (=*Saurocyrnea colini*) as found in her early examinations of Bob-white (reported in full later, Cram and Jones, 1931).

Walton (1927) reported *Heterakis papillosa* (Bloch, 1792) Railliet 1885 (=*H. gallinae*) and *Ascaridia compar* (Schrank, 1790) Dujardin, 1845 as present in the Leidy collection from Bob-white taken in Florida. He also described *Diplostriaenoides minutus* and *Spiroptera tenuis* (later,
Walton, 1928, name changed to *S. bialata*). Later Cram and Jones (1931) stated that *Spiroptera tenuis* Walton as well as *Spiroptera bialata* Walton were synonymous with *Seurocyrnea colini* (Cram, 1927).

Canavan (1929) reported the examination of a single *Colinus virginianus texanus* from Texas which had been in captivity for 48 days, which harbored *Heterakis gallinae* (Gmelin, 1790) Freeborn, 1923 in the cecae and *Subulura brumpti* (Lopez-Neyra, 1922) Cram, 1926 and *Cyrnea colini* (=*Seurocyrnea colini*) in the proventriculus. He also found a single infection of *Subulura brumpti* in another Texas Bob-white (4 years in captivity), but no nematodes in 68 other captive Bob-white.

Jones (1929) redescribed *Rhabdometra odiosa* from Leidy's material plus new material (see below) from Florida and Georgia. Jones (1930) reported *Hymenolepis cantaniana* (Polonio, 1860) Ransom, 1909, from Bob-white in Maryland.

Beaudette and Hudson (1930) and Beaudette, Black, and Hudson (1933) reported on the examining of 26 captive quail in New Jersey. They found *Diapharynx spiralis* (Molin, 1858) Skrjabin 1916 in 2 birds, *Cyrnea colini* (=*Seurocyrnea colini*) in 2 birds, and *Tetramereo americana* in 1 bird. The identification of the worms in the former two cases was confirmed by Cram, who later reported the same records (Cram and Jones, 1931).

Thomas (1930) reported finding *Capillaria annulata* (Molin, 1858) Michalka, 1924 in a few captive Bob-white in Florida.

Cram and Jones (1931) reported on the examination of 496 quail in the Cooperative Quail Investigation of 1924-30, in which the authors performed about 93 autopsies and identified the worms from 403 others. Distribution of the quail autopsied was: Mississippi 18, Alabama 7, Tennessee 27, Georgia and northern Florida 228, South Carolina 81,
North Carolina 45, Virginia 50, Maryland about 20, Pennsylvania about 10, Massachusetts about 10. A few New Jersey reports were also included.

About one fourth of the birds were captives.

Cram and Jones (1931) reported the following results (figures refer to number of infested birds):

**Harmostomum** sp. (=*Brachylaemus* sp.) -2

*Raillietina tetragona* (Molin, 1858) Joyeux, 1927-26

*Raillietina cesticillus* (Molin, 1858) Joyeux, 1923 -38

*Hymenolepis carioca* (Magalhaes, 1898) Ransom, 1902 about 20

*Rhabdometra odiosa* (Leidy, 1887) Jones, 1929 -7

*Hymenolepis canteniana* (Polonio, 1860) Ransom, 1909-about 4

Unidentified cestodes -23

*Capillaria annulata* (Molin, 1858) Michalka, 1924 -about 10, all captives

*Capillaria contorta* (Creplin, 1839) Travassos, 1915 -1 experimental infection

*Capillaria retusa* (Railliet, 1893) Travassos, 1915 -1 experimental infection.

*Strongyloides avium* Cram, 1929 -2 experimental infections

*Heterakis bonasae* Cram, 1927 -about 260

*Heterakis gallinacea* (Jmelin, 1790) Freeborn, 1923 -50, all captives

*Subulura strongylina* (Rudolphi, 1819) Railliet and Henry, 1912 -4, all captives.

*Ascaridia lineata* (Schneider, 1866) Railliet and Henry 1912 -2 both captives.

*Syngamus tracheae* (Montagu, 1811) Chapin, 1925 -about 10, all captives

*Trichostrongylus pergracilis* (Cobbold, 1873) Railliet and Henry, 1909-123

*Dispharynx spiralis* (Molin, 1858) Skrjabin, 1916 -2, both captives

*Gongylonema infulicola* (Ransom, 1904) -1, captive

*Tetrameres americana* Cram, 1927 -about 60

*Habronema pileata* Walton, 1927 -1, captive

*Seurocyrnea colini* (Cram, 1927 Strand, 1929 -about 227

*Cheilospirura spinosa* Cram, 1927 -56
Aproctella stoddardi Cram, 1931 -8

Cram (1932 and 1932a) reported a single infestation of Dispharynx spiralis from which she infected sow bugs and pill bugs. Cram (1933 and 1933a) reported 2 quail, one from North Carolina and one from Maryland, infected with a new species, Tetrameres pattersoni, and incidentally recorded Seurocyrnea colini from the Maryland bird. The last record was evidently referred to again in life history experiments (1933b), wherein grasshoppers and cockroaches were found to be the intermediate hosts of Seurocyrnea.

Venard (1933) reported on the examination of 67 quail from Ohio. He found Subulura strongylina in 8; Hymenolepis sp. in 2 quail; Heterakis gallincae in 25; and Dispharynx spiralis, Seurocyrnea colini and Heterakis bonasae, in an unspecified number of birds.

Caballero (1937) described Oxyspirura (Oxyspirura) toroi from the nictitating membrane of Colinus graysoni (=Colinus virginianus graysoni) from the state of Morelos, Mexico. He made no reference to other parasites found in that host.

Goble and Kutz (1945) reported finding Dispharynx nasuta (Rudolphi, 1819) Stiles and Hassall, 1920, in 2 Bob-white examinations in New York. They regarded spiralis as a synonym of nasuta.

Ward (1945, 1945a, and 1946) reported on the examination of 283 wild-taken Bob-white from Mississippi. His three reports evidently all covered the same work. His infestation records were as follows, the numbers referring to the number of birds infested:

Hymenolepis carioca -4
Rhabdometra odiosa -2
Heterakis gallincae -2
Heterakis bonasae - number infested not given
Subulura brumpti - 6
Seurocyrnea colini - number infested not given
Habronema pileata - 2
Syngamus trachea - 1
Trichostrongylus pergracilis - number infested not given
Raeillietina cesticillus (Skrjabinia) - number infested not given

Webster (1944 and 1945) published two preliminary notes on the parasites of Texas Bob-white, based on work reported in the present manuscript.

MATERIALS AND METHODS

The parasitic worms reported in the present paper represent several collections, times and localities, as follows:

Two Bob-white collected by Rollin H. Baker in Trinity County September 4, 1941, were examined by Dr. Asa C. Chandler the next day. He found two species of tapeworms in one bird, and kindly gave the specimens to the writer.

In 1942 the cooperation of the Texas Game, Fish, and Oyster Commission was solicited and several of its agents responded by sending in quail. Mr. J. M. Carlisle sent two quail from Coleman County to Houston, and they were examined by the writer. Mr. Rollin H. Baker sent eight sets of quail viscera from Eagle Lake, Colorado County. The writer examined these and also two quail taken by himself in Houston, Harris County. Mr. Valgene W. Lehmann, who was conducting quail research for the Commission in South Texas, contributed six entire quail and sixty-nine sets of quail viscera taken in the spring and summer of 1942 and preserved in formalin. The writer examined these and completed identifi-
cation of all the worms so far obtained before he left for service in
the United States Army.

Mr. Lehmann, assisted by Mr. W. Garner Fuller, sent to Rice
Institute the formalin-fixed viscera of 201 quail taken in Jim Hogg
County, South Texas, in December, 1942, and January, 1943. These
viscera were examined for parasites during 1943 by the late Clarence
J. Addis, who segregated all the worms in vials in alcohol. In 1944
he shipped these vials to the writer, who was then stationed at Ogden,
Utah. At Ogden, the nematodes were identified (50% of the worms from
each bird were scrutinized) as temporary mounts in liquid phenol and
all the cestodes were identified as permanent mounts in clarite.

After his return to Rice Institute in 1946 the writer examined
nine sets of quail viscera obtained in northwestern Denton County by
Dr. William M. Fischer in November, 1946. Mr. Lehmann was now working
for the King Ranch, and he helped very generously. He sent 54 sets of
quail viscera in thermos bottles and about 500 sets in formalin. All
of the former were examined, but only 246 of the latter. Unsuccessful
life history experiments were performed on cestodes from the fresh materi-
al. From these 300 examinations of Kleberg County quail taken in Decem-
ber, 1946, and January 1947, all cestodes and acanthocephala were mounted
whole in balsam. All the nematodes from light infestations and about
50% of the nematodes from heavy infestations were scrutinized under the
dissecting microscope. When doubt existed as to their identity, the
nematodes were cleared in phenol and studied in detail.

All cestodes and acanthocephala studied in the present work were
stained in 6 to 8% carmalum, cleared in cedar oil, and mounted in clarite
or balsam. All the worms from South Texas had been fixed in formalin
in situ and most of them were, therefore, in poor condition for systematic
study. Fortunately, the large amount of material permitted specific identification in most cases.

In summary, the quail examined from Texas were distributed as follows:

Trinity County -2
Houston, Harris County -2 (No parasites found)
Eagle Lake, Colorado County -8 (No parasites found)
Northwestern Denton County -9 (No parasites found)
Coleman County -2
Western Kleberg County -300
Southern Jim Wells County -4
Southern Duval County -8
Northern Jim Hogg County -258
Northeastern Zapata County -6

Total 599

It must be admitted that a serious fault in the examinations herein reported is the paucity of examinations of crops and body cavities, correlated with no report of capillariids or filariids. However, 41 crops and 12 entire bodies were examined by the writer. Also, about 300 of the quail were eviscerated by trained zoologists (Dr. Fisher, Mr. Lehmann, Mr. Fuller) who surely would have noticed and preserved any large fillariids, such as Aproctella, present in the body cavities. Of the 576 quail examined from South Texas, all included intestinal tract, gizzard, proventriculus, liver, and heart, except that 17 proventriculi were missing. Also, over 50% included esophagi; many included other organs, such as bursa fabricii, lungs, kidneys, etc.; and 35 included crops.
GENERAL

In the course of examination of 599 Bob-white from Texas, nine species of Helminth parasites were identified, of which four were new to science. Of the other five species, two are common in poultry, one is found in many kinds of wild and domestic birds, one is found in another species of quail (the present record constituting a new host record), and one is found in Bob-white in many states. In addition, several unidentifiable cestodes were found, as well as two forms of helminths identifiable only as to genus. Of the last, one genus represents a new host record.

Raillietina (Raillietina) klebergi n. sp. (Plate II.)

Diagnosis. Characters of the genus and subgenus. Genital pores unilateral on left side. Worms with gravid proglottids 34 to 55 mm. long, with a maximum breadth of 0.7 to 1.1 mm. Scolex 195 to 273 μ in width; restellum 55 to 69 μ in width (retracted), bearing 66 to 76 hooks in a double row; rostellar hooks 10 to 13 μ long; posterior row of rostellar hooks set back from anterior row 1 μ or less. Suckers 104 to 122 μ in longitudinal diameter, armed with four to five rows of hooks; sucker hooks 9 to 12 μ long. Neck as broad, or almost so, as scolex, even when fully extended.

Cirrus pouch ellipsoid, 71 to 93 μ by 35 to 42 μ; cirrus stout and unarmed. 29 to 39 testes almost surround the ovary. Ellipsoid testes 49 to 51 μ long at maximum development.

Lobate vitelline gland posterior to ovary; ovoid Mehlis gland ventral to ovary; slender seminal receptacle slightly antero-oral to ovary; terminal part of vagina thick-walled; bilobate ovary in the middle segment. Uterus forms as a sac beside shell gland, branches out ventral
to ovary and testes, forms a reticulum, finally breaks down into uterine capsules 91 to 127 \( \mu \) long. 6 to 12 (most often 8) spherical onchospheres, 14 to 15 \( \mu \) in diameter, in each uterine capsule.

**Type.** U. S. Nat. Mus. Helm. Coll. slide No. Paratype from same host, on second slide under same museum number.

**Location:** Jejunum.

**Host:** Bob-white Quail, *Colinus virginianus texanus*.

**Locality:** Kleberg County, Texas.

**Discussion:** This description is based upon 46 complete or nearly-complete specimens, including 17 scolices. All measurements except diameter of testis and onchosphere were made on 10 or more specimens; the rostellar hooks were counted and measured in all 17 scolices.

**Differentiation.** *Raillietina (Raillietina) klebergi* n. sp. may be differentiated from all other species of the subgenus by the smaller number of rostellar hooks it possesses. The closest relatives appear to be *R. (R.) tetragona* (Molin, 1858) Railliet, 1921, and *R. (R.) colinia* Webster, 1944. *Klebergi* has somewhat longer rostellar hooks than *tetragona* (6 to 9 \( \mu \) in *tetragona*), as well as fewer of them (90 to 130 \( \mu \) in *tetragona*).

*Klebergi* has an ellipsoid cirrus pouch and a thick neck, *tetragona* a pear-shaped cirrus pouch, and a slender neck. (See Ransom, 1904 and 1905 and Lang, 1929, for the anatomy of *tetragona*. A specimen taken by the writer from a chicken and two from quail were also compared.) *Klebergi* has fewer rostellar hooks and longer sucker hooks than *colinia* and has mature relaxed segments only 1 1/2 times as broad as long, and some testes anterior to ovary; *colinia* has 100 to 108 rostellar hooks, sucker hooks 7 to 9 \( \mu \) long, mature relaxed segments three to four times as broad as long, and all testes lateral to ovary.
Occurrence. This new species was found in 21 quail from Kleberg County. In one case there was a mixed infection with Raillietina (Raillietina) tetragona. In two cases there were mixed infections with Raillietina (Paroniella) minuta.

Life history. Attempts to infect two species of adult beetles (Tenebrio mollitor and Tribolium castanum) and one species of beetle larvae (Phylyphaga sp.) with eggs from gravid segments were made. Dissection of the insects two to four weeks later revealed no infections.

Raillietina (Raillietina) colinia Webster, 1944 (Plate I.)

Diagnosis. Characters of genus and subgenus. Genital pores unilateral on left side. Genital ducts passing between the lateral excretory vessels. Dorsal excretory vessels 15 to 18 μ in diameter; ventral excretory vessels 40 to 46 μ in diameter. Worms with gravid proglottids are 60 to 90 mm. long and have a maximum width of 1.5 to 2.0 mm. Scolex 202 to 238 μ in width; rostellum 51 to 60 μ in diameter, armed with 100 to 108 hooks arranged in a double row; rostellar hooks 11.3 to 12.2 μ long; suckers 69 to 78 μ in longitudinal diameter, armed with four to five rows of hooks; sucker hooks 7 to 9 μ long. Neck as broad, or almost so, as scolex, even when fully extended.

Cirrus pouch plump, 71 to 80 μ by 40 to 47 μ, containing a stout, unarmed cirrus. 29 to 40 roughly ellipsoid testes, 38 to 46 μ long at maximum development, situated lateral to ovary.

Vitelline gland lobate; saccate Mehlis gland ventral to ovary; slender seminal receptacle considerably poral to ovary; vagina passing laterally posterior to vas deferens and cirrus pouch; ovary bilobate, placed slightly poral to the median line. Uterus forms as a sac beside the Mehlis gland, spreads in branching arms dorsal to vagina and ventral to most
PLATE I

Raillietina coliniae n. sp.
NEW CESTODE FROM THE BOB-WHITE.

EXPLANATION OF PLATE

Raillietina coliniae n. sp. All figures were drawn with the aid of a camera lucida.

FIG. 1. Ventral view of mature segment.

FIG. 2. Cross section of mature segment, posterior view.

C, Cirrus. 
DV, Dorsal excretory vessel. 
LM, Longitudinal muscle fiber. 
N, Longitudinal nerve. 
O, Ovary. 
T, Testis. 
TM, Transverse muscle fiber. 
V, Vagina. 
VD, Vas deferens. 
VV, Ventral excretory vessel. 
V, Vitelline gland.

FIG. 3. Dorsal view of partially-matured segment, showing development of the branching uterus.

FIG. 4. Rostellar hook.

FIG. 5. Hook from sucker. Drawn to same scale as Fig. 4, above.
testes, comes to form a reticulum through most of the proglottid, later breaks down into uterine capsules 124 to 136 \( \mu \) in diameter. Four to seven embryos in each uterine capsule.

**Type and paratype.** U. S. Nat. Mus. Helm. Coll. slide No. 36870.

**Host:** Bob-white Quail, *Colinus virginianus mexicanus.*

**Location:** Intestine.

**Occurrence.** This description is based upon 23 specimens from a single quail, collected in Trinity County, Texas, September 4, 1941.

**Discussion.** A single proglottid of one specimen had a reversed genital pore; i.e., placed on the right hand border of the segment, rather than on the left. The nearest relatives of this tapeworm are *R. (R.) tetragona* (Molin, 1858) Railliet, 1921, *R. (R.) klebergi* n. sp., and *R. (R.) vivieni* Joyceux and Baer, 1935. For differentiation from *klebergi*, see under the description of that species above. *Tetragona* has rostellar hooks 6 to 9 \( \mu \) long, a slender neck, and a pear-shaped cirrus pouch 90 to 110 \( \mu \) long; whereas *colinia* has longer rostellar hooks, a broad neck, and ellipsoid, shorter cirrus pouch. *Vivieni* has 22 to 25 testes, cirrus pouch 55 to 65 \( \mu \) long, and a total length of 30 to 40 mm; whereas *colinia* has more testes, longer cirrus pouch, and a total length twice as long. *Colinia* also has a close resemblance to *R. (R.) capillaris* (Fuhrmann, 1909) Fuhrmann, 1932, from a Brazilian tinamou (*Crypturus* sp.). *Capillaris* has 120 rostellar hooks, uterine capsules 140 to 170 \( \mu \) in diameter, and 10 to 12 embryos per uterine capsule; whereas *colinia* has 100 to 108 rostellar hooks, uterine capsules 124 to 170 \( \mu \) in diameter, and 4 to 7 embryos per uterine capsule.
Raillietina (Raillietina) tetragona (Molin, 1858) Railliet, 1921

Two cestodes found in a mixed infestation with Raillietina klebergi in a single quail from Kleberg County, Texas, taken December 21, 1946, were identified as belonging to this cosmopolitan species. The species has also been taken by the writer from a chicken at Houston, Texas. It is found in chickens and domestic turkeys throughout most of the world.

The morphology of the quail specimens included: Neck long and slender; scolex 219 μ in width; sucker hooks 8 to 8.6 μ long; mature segments 5 to 6 times as broad as long when relaxed. Testes 26 to 32; cirrus pouch pear-shaped and 78 to 91 μ long; no testes anterior to ovary. 8 to 11 eggs per uterine capsule.

It is well to point out that this is the type species of the genus and subgenus.

Raillietina (Paroniella) minuta new species (Plate II.)

Fig. 9

Diagnosis. Characters of the genus and subgenus. Genital pores unilateral on right side. Nearly complete, relaxed worms 24 to 34 mm. long, with a maximum width of 0.4 mm. Mature relaxed segments vary in shape from square to twice as long as wide. Scolex unknown.

Ovoid cirrus pouch 44 to 62 μ long by 22 to 27 μ in maximum diameter. Cirrus slender and unarmed, 31 μ long when extruded. 14 to 22 ellipsoid testes 31 to 36 μ long at maximum development, situated on all sides of the ovary.

Bilobate vitelline gland posterior to Mehlis gland; ovoid Mehlis gland posterior to ovary; slender seminal receptacle oral to ovary; subterminal portion of vagina thick walled; quadrilobate ovary in the middle of the segment. Uterus forms as a bilobate sac ventral to ovary, spreads through the segment, finally breaks down into 50 to 100 capsules 31 to 35 μ in diameter, each containing one egg. Spherical onchospheres
PLATE II

Fig. 1. Raillietina minuta n. sp.
Mature segment, ventral view.

Fig. 2. Raillietina klebergi n. sp.
Mature segment, ventral view.

Fig. 3. Raillietina klebergi
hooks from sucker.

Fig. 4. Raillietina klebergi
rostellar hooks.

(All figures drawn with the aid of a camera lucida.)
15 to 18 μ in diameter.


Location: Intestine.

Host: Bob-white Quail, Colinus virginianus texanus.

Locality: Kleberg County, Texas.

Discussion. This description is based upon 12 fragmented specimens from 4 host individuals. No scolices were present, but the anatomy of the genitalia seemed definitely to assign the worms to this systematic position. As such, they form a rather unique species and the second record of this subgenus from North American galliform birds. In two cases there were mixed infections with *R. (R.) klebergi*.

Differentiation. *Raillietina (Paroniella) minuta* n. sp. may easily be differentiated from all other members of the subgenus occurring in Galliformes by the very small cirrus pouch and very small total size. The closest relative appears to be *R. (P.) tinguiana* Tubangui and Masilungan, 1937 (see original description for data), which agrees with *minuta* in the presence of an unarmed cirrus and the lack of a swelling in the lumen of the subterminal part of the vagina. However, *minuta* has the cirrus pouch 44 to 62 μ long and 14 to 22 testes, whereas *tinguiana* has the cirrus pouch 110 to 130 μ long and 32 to 44 testes.

Life history. Attempts to infect two species of adult beetles (*Tenebrio mollitor* and *Tribolium castanum*) and one species of beetle larvae (*Phylllophaga* sp.) with eggs from gravid segments were made. Dissection of the invertebrates two to four weeks later revealed no infections.

*Raillietina (Skrjabinia) cesticillus* (Molin, 1858) Joyeux, 1923

This common poultry cestode was encountered only once, a heavy infestation in the same bird that harbored *Raillietina (Raillietina)*
colinia, which was taken September 4, 1941, in Trinity County.

**Paricterotaenia** sp.

Paricterotaenia sp. was encountered only once. A single poorly-preserved strobila without scolex was taken from a bird taken December 23, 1942, in Jim Hogg County.

This specimen has irregularly-alternating genital pores, saccate uterus, and a dilepidid-like cirrus apparatus. It might belong to the genus *Anomotaenia*, but on the basis of probability I regard it as belonging to an undescribed species of the genus *Paricterotaenia* Fuhrmann 1932.

**Rhabdometra odiosa** (Leidy, 1887) Jones, 1929

This cestode was taken from 14 out of 276 quail from the Hebbronville region and 3 out of 300 quail from Kleberg County. There was 19% infestation in 47 quail taken in South Texas from May to August, but only 1 2/3% infestation in 505 birds taken there in December and January. The heaviest worm burden was only seven worms of this species. In no case was this species in a mixed infection with another cestode.

**UNIDENTIFIABLE CESTODES**

Fragments of tapeworms which could not be identified as to family were found in four quail from Kleberg County. One of these fragments showed regularly alternating genital pores, which character has not been found in any Bob-white cestode. It is suggested that this fragment may represent an undescribed species of the genus *Davainea*.

**Disteganius colini**, new genus, new species  (Plate III.)

**Generic diagnosis of Disteganius n. gen.:** Large Gigantorhynchidae (Diagnosis of family by Meyer, 1933) with or without distinct pseudo-segmentation. Proboscis divided into two parts by the insertion of the proboscis receptacle, the anterior part bearing hooks, the posterior
part bearing spines. Proboscis receptacle a double-walled muscular sac, with one or both walls thicker dorsally than ventrally. Some or all of proboscis inverter muscle fibers emerge from the receptacle at posterior margin of the outer sac. Lemnisci short, with few nuclei. Cement glands 6 to 8. Testes near posterior end. Eggs with compact, granular shell. Parasitic in intestine of terrestrial birds. Type species, Diataganus giganteus (Meyer, 1931) new combination (=Empodius giganteus, Meyer, 1931.)

Specific description of Diataganus colini, n. sp: Diataganus. Male unknown. Females (on basis of 3 specimens) 24 to 31 mm. long by 0.6 to 1.0 mm. wide. Pseudosegmentation slight. Cuticular vascular ducts prominent. Proboscis conical, bearing 84 anterior hooks, each 31 to 35 μ long (including the root), and arranged in 12 spiral rows of 7 hooks each. (Counted in longitudinal rows, there are 24 rows of alternately 3 and 4 hooks.) Proboscis 228 μ wide and (estimated) 292 μ long. Posterior spines 26 to 28 μ long, arranged in about 40 longitudinal rows of 3 hooks each.

Proboscis receptacle a double-walled muscular sac 1077 to 1250 μ long by 274 μ wide; both walls thicker dorsally than ventrally. Some of the inverter muscle fibers of the proboscis emerging from receptacle at posterior margin of outer sac. Lemnisci 3476 to 3564 μ long, each with 8 and 9 nuclei. (Nuclei observed in one specimen only.) Ovoid brain in center of anterior part of proboscis receptacle.

Nearly-mature eggs, in body cavity, with granular outer shell, 29 to 36 μ by 18 to 21 μ.

Location: Jejunum.

Host: Colinus virginianus texanus, the Texas Bob-white Quail.

Locality: Kleberg County, Texas.

Occurrence: There were 3 mature females, of which the anterior extremity of one was missing and the proboscis of another inverted, in a single quail taken December 11, 1946. The present record represents the first occurrence of acanthocephalans in the Western Hemisphere in native galliform birds, and of Gigantorhynchidae in the Western Hemisphere in any galliform bird. There were only 3 specimens, as noted above; the proboscis apparatus and lemnisci of the inverted specimen were dissected out and mounted separately.

Differentiation: The present species may be differentiated from the other species of the new genus by the large number of hooks (more than in any other species save D. turnixena) and the small size of the hooks - smaller than reported for any other species.

Discussion: The Acanthocephala of the family Gigantorhynchidae occurring in birds have been subjected to much confusing controversy, which was reviewed by Moore (1942, Ms.). The following generic names have been applied:

Heteroplus Kostylew, 1914, type by original designation Heteroplus otidis (Miescher) (=Disterania otidis-boubarae Miescher) -- a homonym of Heteroplus Kuls. Rey, 1871, coleopteran.

Mediorhynchus Van Cleave, 1916, type by original designation Mediorhynchus papillosus Van Cleave -- a valid genus with numerous species.

Empodius Travassos, 1917, type by absolute tautonomy Empodius empodius (Skrjabin, 1913) (=Mediorhynchus) -- an invalid genus, based upon variable characters (see Dollfus, 1936) including number of hooks and extent of inversion of the proboscis. Meyer (1933) recognized that Empodius empodius
PLATE III

Disteganius colini n. gen. n. sp.
Upper, anterior end of female, lateral view.
Lower, hooks from proboscis.

(Both drawings made with the aid of a camera lucida.)
with _Mediorhynchus papillosus_, but neglected to give a new name to his well-defined generic concept of "**Empodius**"!

**Micracanthorhyncus** Travassos, 1917, type by original designation

**Micracanthorhyncus emberizae** (Rudolphi, 1819) (=**Mediorhynchus e.**) -- an invalid genus based upon a misconception of the placement of the spines, as shown by Van Cleave (1924).

**Disteganthus** new genus is actually only a substitute name for the generic concept of **Empodius** by Southwell and Macfie (1925), Meyer (1933), and Tubangui (1933). It does not seem practical to leave this concept, (based mainly a double-walled proboscis receptacle) without a name, as advocated by Dollfus (1936) and Moore (1942, Ms.), simply because several species are incompletely known. It is worth noting that the hosts of **Disteganthus** are all more or less birds of the prairie and all **Gruiformes** or **Galliformes**, with the exception of a single record from the **Charadriiformes**, whereas **Mediorhynchus** as here restricted is found in numerous habitats and orders of birds, but not in **Galliformes** or **Charadriiformes** and only in two records in the **Gruiformes**.

I recognize these six species of **Disteganthus**:

**D. otidis-houbarae** (Miescher, first published by Diesing, 1851).

**D. taeniatus** (Linstow, 1901). Described by Meyer (1933) and Dollfus (1936) as having 27 or 30 hooks and 165 or 315 to 546 spines. Doubtfully distinct from *otidis-houbarae*.

**D. numidae** (Baer, 1925). Described by Baer as having 36 hooks and 112 spines. Possibly this form belongs to the genus **Mediorhynchus**, because Baer figured only one wall of the receptacle. If so, it would be the only species of **Mediorhynchus** found in galliform birds.

**D. giganteus** (Meyer, 1931). Described by Meyer (1931 and 1933) as having 72 hooks and 140 spines.
D. colini n. sp. 84 hooks and 120 spines.

D. turnixena (Tubangui, 1933). Described by Tubangui as having 104 to 140 hooks (possibly he meant 117 to 126 hooks) and 156 to 196 spines.

The specimens referred by Southwell and Macfie (1925) to Erpodius segmentatus (Marval) are here regarded as probably conspecific with Disteganius giganteus (Meyer, 1931). Marval (1905) with his single imperfect specimen in hand, pronounced his species, Echinorhynchus segmentatus Marval, 1902, a synonym of Echinorhynchus taeniatus (Linstow, 1901). Whether Marval was right or wrong, the specimen is not now extant; Marval (1905) remains the first reviser; upsetting his early nomenclature seems unwise. Accordingly, Echinorhynchus segmentatus Marval, 1902, is retained as a synonym of Disteganius taeniatus (Linstow, 1901).

Other records of Gigantorhynchidae from old world galliform and gruiform birds do not seem identifiable to genus, let alone to species.

Aulonocephalus lindquisti Chandler, 1935

Before the onset of the present study, this peculiar nematode had been reported only in the original description (Chandler, 1935), which was based on specimens from a Scaled Quail (Callipepla squamata). As to anatomy, little can be added to the original description. However, position of the vulva was found to be slightly anterior to the middle of the body, dividing the body in a ratio of from 10:11 to 10:13 (fifteen females measured from fifteen hosts), whereas Chandler reported that the vulva in his three females was at, or slightly posterior to, the middle of the body. In the fresh material, it was noticed that mature worms of both sexes were bright pink in color.
This species of nematode was found in one out of two quail examined from Coleman County, in 92% of the 270 full-grown quail examined from the Hebbronville area, and in 88% of the 300 full-grown quail examined from Kleberg County. In the Hebbronville area, there were 1 to 315 worms in a bird, or an average of 30 per infested bird. In Kleberg County, there were 1 to 143 worms in a bird, or an average of 15 per infested bird. The worms were mostly in the caeca, although a few frequently were found in the lower ileum and rectum.

**Seurocyrnea** sp.

Two males of this small proventricular nematode were taken from a quail taken June 17, 1942, at Los Machos Ranch, Jim Wells County, by Mr. Lehmann. There were no proventricular worms in the 3 other birds taken from the same locality the same day, nor from the 576 proventriculi examined from other parts of Texas.

It may be explained that the identification "Cyrsnea sp." published in a preliminary paper (Webster and Addis, 1945) was a bibliographic error for *Seurocyrnea* sp. The worms in question were lost before a specific identification could be made.

**Syngamus trachea** (Montagu, 1811) Chapin, 1925

This cosmopolitan nematode was taken twice from birds taken September 15, 1942, in southern Duval County, and July 8, 1942, in northern Jim Hogg County. In one case there was a single pair of worms and in another case a lone female.

**DISTRIBUTIONAL CONSIDERATIONS**

**ECOLOGICAL REGIONS OF TEXAS EAST OF THE 100th MERIDIAN**

Biogeography is expressed in terms of either of three theories, each of which is widely accepted: (1) The life zone theory, first set forth in detail by Merriam (1898); (2) The biome theory, originally
outlined by Clements (1916); and (3) the biotic province theory, recently put forth by Dice (1943).

The life zone theory is particularly applicable in mountainous regions as in California (Grinnell, 1927 and 1935). Briefly, it states that the distribution of plants and animals depends upon climatic temperature. North America is divided into seven transcontinental bands, or life zones; each of the southerly ones is divided into an eastern, humid section, and a western, arid section. Grinnell (1927) noted that life zones depend upon temperature, precipitation, and annual march. Grinnell (1935) remarked that no one with adequate field experience would doubt that objectively determinable zones of life having a general relation to temperature do exist.

The biome theory was recently expounded and mapped by Clements and Shelford (1939). This theory emphasizes the dynamics of ecology; it expresses biogeography in terms of the biome, which is defined as a superorganism, a synonym of formation and of climax. Thus a biome is bounded by the boundaries of its climaxes. Each biome is characterized by a single life form (e.g., grassland, coniferous forest) within its climax area. This theory seems reasonable if applied to non-mountainous regions.

Dice (1943) recently advanced his "biotic provinces" theory of biogeography. He defined a biotic province as, "A considerable and continuous geographic area characterized by the occurrence of one or more important ecological associations that differ, at least in proportional area covered, from the associations of adjacent provinces." His biotic provinces (thereafter in North America) correspond more or less to the "associations" of Clements and Shelford, save that mountains
are included in the surrounding biotic province. In the opinion of the writer, Dice's scheme fails, even more seriously than does that of Clements, when it considers mountainous areas. Admittedly, however, Dice's mapping of East Texas biotic provinces seems to represent the facts of biogeography in that area, as of the present time, better than any other biogeographic map.

In Texas east of the 100th meridian of longitude, life zones were last mapped by Bailey (1905). He classified the area as entirely within the Lower Austral Zone, but drew a north-south line between the humid Astroriparian section and the arid Lower Sonoran section. This line extended northwest from the ocean at Port Lavaca, mostly along the Guadalupe River to Austin, thence due north to the Oklahoma boundary. In drawing this line north of Austin (see Plate 7), I have modified it slightly to follow the edge of the first plateau, which defines the more recently determined eastern limit of the breeding range of numerous western birds (Davis, 1940) along the edge of the first plateau. The best indicator species of this boundary are the mesquite (*Prosopis glandularis*) and Ladder-backed Woodpecker (*Dryobates scalaris*) both of whose eastern boundaries are thereby defined. East of this boundary, the best indicator species seem to be the Gray Squirrel (*Sciurus griseus*) and Red-bellied Woodpecker (*Centurus carolinensis*), whose western boundaries are thereby defined. According to Price and Gunter (1942), the mesquite spread from 1905 to 1930, northeast along the coast for a distance of 50 miles, and is abundant as far as the Colorado River. This extension appeared to stop about 1930. Accordingly, the arid-humid boundary would probably better be drawn along the Colorado River from Matagorda Bay to Austin.
Cahn (1926) reviewed and classified the biotic areas of Texas in a manner similar to that applied later by Clements and Shelford (1939), although he reached very different conclusions. Northeastern Texas was divided into two areas, a wedge of "temperate deciduous forest" pointing south, from the Oklahoma and Arkansas borders, with its apex near Houston, and east of the Trinity a large triangle of "Southeastern coniferous forest." West of Houston and the pine forests was a narrow strip of "Oak grove Savannah," extending west to the edge of the first plateau. All along the coast north and east of Matagorda Bay was recognized a narrow (10-40 miles wide) strip of "Coastal prairie." West and north of the "break of the plains," upon the first plateau, was recognized "Grassland," largely overgrown of recent years by mesquite and other woody plants. South from Corpus Christi and Uvalde was recognized "Mesquite semi-desert", characterized by chaparral (Opuntia-Prospis-Brayondendron-Acacia-Celtis-Condalia).

Tharp (1926) studied the botanical ecology of Texas east of 98° and north of Corpus Christi. His floral areas were very similar to those of Cahn (1926).

Clements and Shelford (1939) divided Texas east of the 100th meridian into three biomes: deciduous forest, southeastern coniferous forest (boundary between these two not indicated) and grassland. The last was divided into three associations -- coastal prairie, mixed prairie, and desert plains. The western boundary of the deciduous forest was drawn from a point on the coast about at High Island, thence northwest to near Crockett, thence north to the Oklahoma border near Paris. Most of the grassland biome was included in the coastal prairie (see map, Plate IV), save for small triangles of desert plains just
northwest of Laredo and east of San Angelo. A fairly large triangle of mixed prairie was included, the northwest corner of the area (north of Abilene and west of Wichita Falls). The differences between the south Texas chaparral and true coastal prairie (as found in Harris County, for instance) and between central Texas live oak-mesquite (Quercus-Prospis-Juniperus) and true coastal prairie were dismissed as the result of overgrazing in the first case and the overlooking by many investigators in the second case, of the general grass climax dotted with woodland post-climax.

Price and Gunter (1942) discussed the spread of the mesquite, the armadillo (Dasypus novemcinctus) and other South Texas biota and the replacement of the South Texas prairie areas by chaparral in the period 1870-1930.

Dice (1943) divided Texas east of the 100th meridian into slices of five biotic provinces (see Plate Y). The Chihuahuan province included a small triangle near Laredo, characterized by presence of the creosote bush (Covillea), yucca (Yucca), agave (Agave), sotol (Dasylirion), cactus (Cactus), and several species of large Kangaroo Rats (Dipodomys). The Comanchian province included all the plateau areas and the western lowlands south to the northern edge of Duval and Webb counties, and was characterized by arid grassland interspersed with oak, mesquite, and Juniper. The Texas province extended in a north-south strip from Oklahoma to Matagorda Bay and Corpus Christi and was bounded on the west by the edge of the first plateau and on the east by the edge of the pine forests. It was characterized by intermingling of prairies (with chiefly the grasses Stipa, Koeleria, and Andropogon) and oak and hickory (Carya buckleyi) woodlands. The
Australriparian province extended into Texas as the easternmost slice, where it was characterized by pine (Pinus), with islands of hardwoods (chiefly Quercus, Carya, Taxodium, Nyssa, Magnolia).

Diaz's Tamaulipan province included Texas south of Laredo and Corpus Christi, characterized by the presence of dense chaparral composed chiefly of prickly pear (Opuntia), mesquite, huisache (Acacia), grenjeno (Celtis), shin oak (Quercus), and black persimmon (Brayodendron). Common mammal and bird species largely or exclusively confined to this area in their United States ranges are: Peccary (Pecari angulatus), Ocelot (Felis pardalis), Yaguarundi (Felis cacomitli), Armadillo (Dasypus novemcinctus), Spiny Rat (Liomys texensis), Greater Hog-nosed Skunk (Conotopus leuconotus), Texas Kangaroo Rat (Dipodomys compactus), Chachalaca (Ortalis vetula), Texas Kingfisher (Chloroceryle americana), Derby Flycatcher (Pitangus sulphuratus), Vermillion Flycatcher (Pyrocephalus rubinus), Green Jay (Xanthoura luxuosa), Audubon Oriole (Icterus melanocephalus), Sennett Oriole (Icterus cucullatus), Red-eyed Cowbird (Tangavius aenius), Sharpe Seedeater (Sporophila moreletti).

THE SUBSPECIES OF THE BOB-WHITE QUAIL

The Bob-white Quail (Colinus virginianus) occupies the Transition, Upper, Austral, and Lower Austral life zones of eastern Canada, the United States east of the Rocky Mountains, and Mexico. In addition, an introduced population persists in the lowlands of Oregon, Washington, Idaho, and British Columbia. In Texas east of 100°, the species occurs in almost every locality.

Aldrich (1946) recently revised the United States races of Colinus virginianus. He recognized six present-day races: (1) taylori in the Great Plains and Northwest and south in Texas to Eastland and Cooke counties; (2) mexicanus in the Mississippi Valley and west in Texas.
to Cooke, Dallas, Anderson, and Montgomery counties; (3) texanus in south and southwest Texas northeast to Fort Bend, Waller, McLennan, and Edwards counties; (4) marilandicus in New England and the eastern Middle Atlantic states; (5) virginianus in the South Atlantic states; (6) floridanus in peninsular Florida. Peters (1934) placed the central Mexican form, graysoni, as a subspecies of Colinus virginianus.

All of the published records of parasites from the Bob-white were made in the United States east of the Rockies, except that by Caballero (1937), which pertains to the race graysoni in Mexico. The records by Leidy (1887), Cram and Walton (1927), and Jones (1929) and most of the records by Cram and Jones (1931) and Cram (1933 and 1933a), pertain to the race virginianus. The records by Canavan (1929) refer to long-captive texanus. Some of the records by Cram and Jones (1931) refer to marilandicus, as do those by Beaudette and Hudson (1930) and Beaudette, Black and Hudson (1933), some of those by Cram (1932, 1932a, 1933, 1933a) and that by Goble and Kutz (1945). The records of worms by Venard (1933) and Ward (1945, 1945a, and 1946) and the few Tennessee records by Cram and Jones (1931) refer to mexicanus. It may be seen from Plate VI that the present records from Zapata, Jim Hogg, Duval, Jim Wells, Kleberg, and Colorado counties refer to the race texanus; the records from Harris County to intergrades of texanus and mexicanus; the records from Trinity County to mexicanus; the records from Denton and Coleman Counties to taylori.

There have been many thousands of "Mexican" quail transported from South Texas and liberated in various eastern states. However, Aldrich (1946) discovered that these birds had a very poor survival rate, and that the massive introductions produced very little mixing of characters.
PLATE IV

Texas east of the 100th meridian.

1 1 1 1 1 Edge of the first plateau.

... . Boundaries of biotic provinces, after Dice (1943)

Figures show location of helminth parasites recorded.
DESCRIPTION OF LOCALITIES

The locality within Trinity County whence quail were examined is not known. The entire county, however, is within the Austroriparian life zone division. The climax vegetation is hardwood forest, but today the county consists chiefly of stands of short-leaf pine interspersed with cleared pastures. The terrain is flat, the soil varied.

The Eagle Lake region in Colorado County includes some areas of almost native prairie grassland (chiefly *Andropogon*) but they are in a minority as compared with the cultivated rice fields. The terrain is flat, the soil black waxy. The life zone division is Austroriparian.

The birds from Houston were taken on the Rice Institute campus. The area is a small island of mixed grassland (probably it was never timbered) almost completely surrounded by the buildings and lawns of the city. The life zone division is Austroriparian.

Northwestern Denton County is on the level Grand Prairie, in the Austroriparian life zone division. The soil is deep and black, the cultivation rather intense.

The locality within Coleman County whence quail were examined is not known. The entire county, however, is within the Lower Sonoran life zone division, although tending somewhat toward the Upper Sonoran which begins just to the west. The uncultivated parts of the rolling plateau country are grown up to chaparral of live oak and mesquite.

The quail examined from Kleberg County were all taken on that part of the King Ranch which is in southeastern Kleberg County, near the town of Riviera, and west of the U. S. Highway 77. (See Plate VI.) The area was described by Mr. Lehmann (in litt.) as one of, "Sandy soil. The grassy cover is predominantly *Andropogon* and *Aristida*. Mesquites
in a density varying from very light to quite heavy are the dominant woody cover. There is also considerable grengeno (*Celtis pallida*). The area is near the coast, within the Lower Sonoran life zone division.

The quail examined from Jim Hogg County were taken on the W. W. Jones Ranch, just south of Hebbronville. The area was described by Mr. Lehmann (in litt.) as a region, "of deep, loose, sandy soil. The grassy cover is predominantly *Atripogon* and *Aristida*. Mesquites in a density varying from very light to quite heavy are the dominant woody cover." The area is in the South Texas part of the Lower Sonoran life zone division.

The areas in Duval, Jim Wells, and Zapata Counties whence quail were examined are very similar to northern Jim Hogg County; all are in the South Texas part of the Lower Sonoran life zone division.

**DISTRIBUTIONAL DISCUSSION OF HELMINTHS**

In the following discussion, all helminths ever reported from Bob-white are listed. The life zone theory of distribution is utilized, with the biotic province name, where different, in parentheses. All records are from wild quail unless stated otherwise.

*Brachylaemus* sp. The rare occurrences of this fluke in the Atlantic Coast Austrooriparian (or "humid") and Carolinian (or "humid") divisions of the Lower Austral and Upper Austral life zones (in Maryland and Northern Carolina) probably represent accidental occurrences in Bob-white or a Ruffed Grouse parasite. Quail seldom eat snails, but Ruffed Grouse (*Bonasa umbellus*) commonly do. However, flukes are scarce in United States Ruffed Grouse. Under natural conditions, in interior Labrador, Cram (1931) found that 35% of Ruffed Grouse were infested with *Clyphryostomum* sp. (a genus closely related to *Brachylaemus*.)

*Raillietina* tetragona. This common poultry cestode has been
PLATE V

Eastern Texas (east of the 100th meridian), showing biotic regions and locations whence quail were examined.

. . . . . .  Boundaries of biotic provinces after Dice (1943)

x x x x x x  Boundaries of biomes, after Clements and Shelford (1939)

l l l l l l  Edge of first plateau

- - - - -  Boundary between Lower Sonoran and Austrailian life zone divisions, after Bailey (1905)

Eight Bob-white examined from this point.
reported from Bob-white in Virginia (captives), North Carolina, South Carolina, Georgia, Florida, and South Texas, all in the Lower Austral life zone (Austroriparian and Tamaulipan biotic provinces.)

Rallietina klebergi. This is another tapeworm recorded only from South Texas, in the Lower Sonoran life zone division (Tamaulipan biotic province.)

Rallietina minuta. This is another tapeworm recorded only from South Texas, in the Lower Sonoran life zone division (Tamaulipan biotic province.)

Rallietina cesticillus. This common poultry cestode has been reported from Bob-white in Maryland, North Carolina, Georgia, Florida, Mississippi, and Northeast Texas, in the Carolinian and Austroriparian life zone divisions.

Paricterotaenia sp. This tapeworm genus has been recorded only once, from South Texas, in the Lower Sonoran life zone division (Tamaulipan biotic province.)

Rhabdometra odiosa. This tapeworm has been reported from Bob-white in Florida, Georgia, Mississippi, and South Texas. It may be regarded as an endemic quail parasite found throughout the Lower Austral life zone (Austroriparian, Tamaulipan, and probably, Texas biotic provinces.) The only record from another host was by Swales (1934) who reported the species from the Sharp-tailed Grouse (Pedicetes phasianellus) in the Canadian life zone in the province of Quebec, Canada.

Hymenolepis carioca. This poultry cestode has been reported from captive and wild Bob-white in Georgia, Florida, and Virginia, all in the Austroriparian life zone division.

Hymenolepis cantianana. This poultry cestode has been reported only once from Bob-white from Maryland, in the Carolinian life zone
division.

**Disteganius colini.** The record from South Texas (Lower Sonoran life zone division, Tamaulipan biotic province) is the only one of Acanthocephala in Bob-white. It may be noted, however, that Acanthocephala are not very host-specific, and that the species doubtless occurs in the other galliform birds of the region -- Wild Turkey (Meleagris gallopavo), Scaled Quail (Callipepla squamata), and Chachalaca (Ortalis vetula).

**Capillaria annulata.** This common poultry nematode has been reported from Bob-white only from captive birds in Virginia and Florida.

**Capillaria contorta.** This common poultry nematode has been reported only as an experimental infection in Bob-white.

**Capillaria retusa.** This common poultry nematode has been reported only as an experimental infection in Bob-white.

**Strongyloides avium.** This scarce poultry nematode has been reported only as an experimental infection in Bob-white.

**Heterakis bonasae.** This nematode is found in Ruffed Grouse in the Alleghanina, Carolinian, and Austroriparian life zone divisions (Cram, 1927, and Cram and Jones, 1931). In Bob-white it has been reported from Tennessee, Alabama, Mississippi, Florida, Georgia, South Carolina, and North Carolina, all within the Austroriparian life zone division. No other host has been reported.

**Heterakis gallinae.** This common poultry nematode has been found in captive Bob-white in Pennsylvania and Virginia and in wild Bob-white in Ohio, Mississippi, and Florida, all in the Carolinian and Austroriparian life zone divisions.
PLATE VI

South Texas, showing county lines and locations referred to in the text.
**Subulura brumpti.** This nematode has a curious distribution, which suggests misidentifications. It has been reported rarely from various galliform birds in scattered parts of the world. In the United States it has been reported by Canavan (1929) from captive quail and turkeys in Pennsylvania and by Venard (1933) and Ward (1945) from wild Bob-white in Ohio and Mississippi, in the Carolinian and Austroriparian life zone divisions.

**Subulura strongylina.** This species, also, has a rather curious distribution, having only occasionally been reported, and from various galliform birds in various parts of the Western Hemisphere. In the Bob-white, it has been found in North Carolina and Georgia, in the Austroriparian life zone division.

**Aulonocephalus lindquisti.** This species has been reported from the Bob-white in South Texas, Lower Sonoran life zone division (=Tamaulipan biotic province) and from the Bob-white and Scaled Quail in central Texas, Lower Sonoran life zone division (=Comanchian biotic province.)

**Ascaridia compar.** This species has been reported in Bob-white only from Florida, in the Austroriparian life zone division.

**Ascaridia lineata.** This common poultry nematode has been reported from Bob-white only from captive birds in Georgia.

**Syngamus trachea.** This widely distributed and non-host-specific nematode has been reported from captive quail in Virginia and wild quail in Mississippi and Texas, all localities being in the Lower Austral life zone (Austroriparian and Tamaulipan biotic provinces).

**Trichostrongylus pergracilis.** This species has been found in wild galliform birds in Europe and the United States. In the United States it has been reported from Bob-white in Tennessee, Alabama,
Mississippi, Florida, Georgia and South Carolina, all in the Austroriparian life zone division.

*Habronema pileata.* This nematode has been reported from Bob-white in Georgia and Mississippi, in the Austroriparian life zone division.

*Seurocyrnea colini.* This nematode has been reported from Bob-white in Ohio, Pennsylvania, New Jersey, Georgia, Florida, Alabama, Mississippi, North Carolina, and possibly (Seurocyrnea sp.) South Texas, in the Carolinian, Austroriparian, and Lower Sonoran life zone divisions (Carolinian, Austroriparian, and Tamaulipan biotic provinces.)

*Congylonema ingluvicola.* This poultry nematode was reported from a single captive quail in Georgia.

*Oxyspirura toroi.* This species is known only from Central Mexico, in the Lower Sonoran life zone division.

*Cheilospirura spinosa.* This Ruffed Grouse nematode was reported from Bob-white at Grand Junction, Tennessee, and in captives in eastern Virginia, both places being at the edge of the Austroriparian zone, but within the range of the Ruffed Grouse. In the Ruffed Grouse (Cram, 1927 and Cram and Jones, 1931) the species has been found in the Alleghanian and Carolinian life zone divisions.

*Dispharynx nasuta.* This widely distributed, non-host-specific nematode has been reported from Bob-white in Ohio, New York, and New Jersey, in the Alleghanian (=Canadian biotic province) and Carolinian life zone divisions.

*Tetrameres americana.* This American nematode, nowadays common in chickens, has been reported from Bob-white in New Jersey, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, and Tennessee. All records are in the Austroriparian life zone division, except that from New Jersey,
in the Carolinian life zone division, which is by Beaudette, Black, and Hudson (1933). This antedates the description of *T. pattersoni* and probably belongs to that form.

**Tetrameres pattersoni.** This nematode has been reported only from the Bob-white and in only two birds, from central North Carolina and Maryland, respectively, both in the Carolinian life zone division.

**Diplostriaenoides minutus.** This filariid nematode is known only from a single record from Florida, in the Austroriparian life zone division.

**Aproctella stoddardi.** This filariid nematode has been reported in Bob-white from South Carolina, Georgia, and Florida, all in the Austroriparian life zone division. The only other host is the Ruffed Grouse, in which Cram (in Cram and Jones, 1931) reported a record from Massachusetts, in the Alleghanian life zone division.

**DISCUSSION AND SUMMATION OF DATA ON DISTRIBUTION OF BOB-WHITE HELMINTHS**

Six species of nematodes mentioned in the previous section have occurred in Bob-white only in captive birds or in experimental infections; therefore they are omitted from the present section.

Six species of helminths are believed to be primarily poultry parasites (although one, *Syngamus trachea*, is probably native in North America) and are widely distributed in poultry, so that their distribution is perhaps of little significance. They are: *Hymenolepis cantaniana*, which has been found in quail only in the Carolinian life zone division; *Raillietina cesticillus* and *Heterakis gallinae*, which have been found in the Carolinian and Austroriparian life zone divisions; *Hymenolepis carioca*, which has been found in quail only in the Austroriparian life zone division; and *Raillietina tetragona* and *Syngamus trachea*,
PLATE VII

Texas east of the 100th meridian, showing the areas occupied by the three subspecies of Bob-white and (ciphers) locations whence Bob-white were examined.
which have been found in both the Australriparian and Lower Sonoran divisions of the Lower Austral life zone. That the first four mentioned species are governed by life zones is indicated by their absence from Kleberg County. From there 300 quail were examined from an area where free contact with poultry (on the outskirts of the little town of Riviera) has been maintained for many years.

Twenty-two species of helminths found in the Bob-white are probably native in North America and in the Bob-white. *Dispharynx nasuta* has been found in the Alleghanian and Carolinian life zone divisions. *Tetrameres pattersoni* has been found in the Carolinian life division only. *Brachylaemus* sp., *Subulura brumpti*, and *Seurocyrnea colini* have been found in the Carolinian and Australriparian life zone divisions. *Raillietina colinia*, *Subulura strongylina*, *Ascaridia compar*, *Trichostrongylus pergracilis*, *Habronema pileata*, *Tetrameres americana*, *Diplotriaenoides minutus*, *Heterakis bonasae*, *Cheilospirura spinosa*, and *Aproctella stoddardi* have been found in the Australriparian life zone division only. The last three mentioned species, however, have occurred in more boreal zones in the Ruffed Grouse, and probably do so also in the Bob-white. *Thabdometra odiosa* has occurred in both the Australriparian and Lower Sonoran divisions of the Lower Austral life zone. *Raillietina Klebergi*, *Raillietina minuta*, *Paricterotaenia* sp., *Disteganius colini*, *Aulonocephalus lindquisti*, and *Oxyspirura toroi* have been found in the Lower Sonoran life zone division only.

No species of helminth has been definitely recorded in the Bob-white in more than two life zone divisions. Within the prairie portion of the Australriparian life zone division in Texas (= Texan biotic province) 19 Bob-white were examined without a single helminth being found (see Plate LV). So far as is known, nowhere else has so large a sample
been examined without finding any parasites.

An analysis of the 22 native species of Bob-white helminths (see above) was made in conjunction with the subspecies of the Bob-white as mapped by Aldrich (1946). 4 species of helminths have been found in the race virginianus only; 2 species in the race mexicanus only; 3 species in the race texanus only; 1 species in the race graysoni only; 2 species in the races marilandicus and mexicanus only; 2 species in the races marilandicus and virginianus only; 4 species in the races virginianus and mexicanus only; 1 species in the races texanus and taylori only. 1 species has been found in the races marilandicus, virginianus, and mexicanus; 1 species has been found in the races virginianus, mexicanus, and texanus. Also, the areas of negative parasitic examinations in Texas (see preceding paragraph) fall into three races -- taylori, texanus, and mexicanus.

SUMMARY

1. Examination of 599 Bob-white from Texas revealed the presence of seven species of cestodes including three new species of the genus Raillietina. A single species of acanthocephalan, new to science, was found. Three species of nematodes, all previously known, were found.

2. The distribution of the helminths found in Bob-white in Texas was found to correspond rather closely with life zones as mapped by Bailey (1905) and biotic provinces as mapped by Dice (1943), but only fairly well with biomes as mapped by Clements and Shelford (1939) and poorly with the subspecies of the Bob-white. It is suggested that the geographical distribution of helminths in any one species of host probably always tends to correlate better with biotic districts than with subspecies of the host.
3. A consideration of the distribution of all the helminths ever reported from Bob-white shows a general correlation with life zones or biotic provinces, but not with subspecies of the host.

4. The three new species of helminths described herein from South Texas, (two of which are strikingly distinct from all other quail parasites) serve to emphasize the faunal distinctness of South Texas as contrasted with the rest of the United States, particularly because they are from a common, widely-distributed host.
<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Publication Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hudson, C. B.</td>
<td>Capillaria annulata infestation in the common fowl.</td>
<td></td>
</tr>
<tr>
<td>Black, J. J., and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hudson, C. B.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cahn, A. R.</td>
<td>Natural Areas and regions of Texas, 502-515 in Shelford, et. al.,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&quot;naturalist's Guide to the Americas. 1-761. (Baltimore, Williams and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wilkins Co.).</td>
<td></td>
</tr>
<tr>
<td>Shelford, V. E.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spirurata, Bull.</td>
<td></td>
</tr>
</tbody>
</table>
Cram, E. B.  
1932a  
New records of nematodes of birds, Journ. Parasitol., 19:93-94

Cram, E. B.  
1933  

Cram, E. B.  
1933a  

Cram, E. B.  
1933b  

Cram, E. B. and Jones, M. F.  
1931  
Parasites and diseases of quail, in Stoddard, W. L. the Bob-white Quail; its habits, preservation and increase. (Charles Scribner's Sons, New York) 1-559.

Davis, W. B.  
1940  
Birds of Brazos County, Texas. Condor, 42:1-35.

Dice, L. R.  
1943  

Diesing, K.  
1851  
Systema helminthum. 2 vols., 1-679, 1-588 (Vienna, Wilhelm, Braumuller).

Dollfus, R.  
1936  

Fuhrmann, O.  
1909  

Fuhrmann, O.  
1932  

Grinnell, J.  
1927  
The designation of birds' ranges. Auk, 44:322-325

Grinnell, J.  
1929  

Coble, F. C. and Kutz, H. L.  
1945  

Hughes, R. C. and Schultz, R. L.  
1942  

Jones, M. F.  
1929  
Jones, M. F. 1930


Joyeux, C.
and Baer, J.G.
1935


Kostylew, N.N.
1914


Lang, R.
1929


Leidy, J.
1887


Linstow, O. von
1901


Marval, L. de
1902


Marval, L. de
1905


Merriam, C. H.
1898


Meyer, A.
1931


Meyer, A.
1933

Dr. H. G. Bronns Klassen and Ordnungen des Tierreichs, Acanthocephala. Vol. 4(2)2:1-582.

Moore, D. V.
1942


Peters, J. L.
1934

Price, W. A. and Gunter, G.  
1942  

Ransom, B. H.  
1904  

Ransom, B. H.  
1904a  

Rudolphi, C. A.  
1819  
Entozoorum synopsis, cui accedunt mantissa duplex et indices locupletissimi. 1-811. (Berlin, the Author).

Skrjabin, K. J.  
1913  

Southwell, T. and Macfie, J.W.S.  
1925  

Swales, W. E.  
1934  
Rhabdometra odiosa (Leidy, 1887) Jones, 1929, a cestode parasite of Pedioctes phasinellus in Quebec. Journ Parasitol. 21:

Tharp, B. C.  
1926  

Thomas, E. F.  
1930  

Travassos, L.  
1917  

Tubangui, M. A.  
1933  

Tubangui, M. A. and Kasilungan, V.A.  
1937  
Acanthocephala of the genera Centrarchus, Thysanozoon, and Polydactylus from North America.

Van Cleave, H. J.


Walton, A. C.

1927


1928


Ward, J. W.

1945


1946


1947

STUDIES ON THE LIFE HISTORY OF
Mesocestoides latus Mueller

by

Jackson Dan Webster
M.Sc. Cornell University, 1941

The second of two theses presented to the Faculty of the Rice Institute in partial fulfillment of the requirements for the Degree of Doctor of Philosophy
Department of Biology

Houston, Texas
June, 1947

49-4923
ACKNOWLEDGMENTS

This investigation was made under the direction of Professor Asa C. Chandler, to whom I wish to express my appreciation for his inspiration, for his many valuable suggestions, and for the loan of specimens of *Kesocestoides* from his personal collection.

My thanks are due to Dr. H. J. Reinhard of Texas A. and M. College and to Mr. C. P. Read of Rice Institute for the identification of adult beetles; to Dr. W. H. Anderson of the U. S. National Museum for the identification of beetle larvae; to Dr. M. R. Smith of the U. S. National Museum for the identification of ants; to Dr. J. P. E. Morrison of the U. S. National Museum for the identification of snails.

Dr. Wilton W. Fisher of Baylor Medical School courteously supplied white mice. My wife, Juanita Ross Webster, and my father-in-law, Mr. K. J. Ross, caught many of the adult beetles used in the experiments.
TABLE OF CONTENTS

1. Introduction ............................................. 1
2. Systematic position ..................................... 1
3. Historical review of previous work on the life cycle of *Mesocestoides* ................. 6
4. Discussion of probable life cycle ..................... 10
5. Materials and methods .................................. 14
6. Accounts of experiments designed to find the first intermediate host ..................... 15
7. Discussion of results ................................... 22
8. Descriptions of life history stages ................. 23
   a. Adult .................................................. 23
   b. Onchosphere .......................................... 25
   c. *Tetrathyridium* ...................................... 26
9. Summary .................................................. 28
10. Bibliography ............................................ 29

LIST OF FIGURES

Plate I. (Figs. 1 and 2) *Mesocestoides latus*, gravid segment ........................................ 2

Plate II. (Figs. 1 to 3) *Tetrathyridium* of *Mesocestoides* spp.

(Fig. 4) Onchosphere of *Mesocestoides latus* .......................... 24
INTRODUCTION

The genus *Mesocestoides* comprises a small, homogenous group of cyclophyllidean tapeworm species. They are very common in most carnivorous mammals and birds of Europe, Asia, and Africa, but in North America they are only fairly common and occur only in a few species of carnivorous mammals, and rarely in man (Chandler, 1942a). The life cycle was first postulated, more or less correctly, by Leukart (1874), but it was not until 1927 that the first real experimental work was reported, demonstrating the second half of the life cycle. The first phase of the life cycle remains to be discovered.

The work herein reported consisted of attempts to elucidate the first phase of the life cycle. The subject had previously been attacked by several of the world's most renowned helminthologists. The efforts of the writer, also, were unsuccessful, although some theoretically possible life cycle courses were eliminated.

SYSTEMATIC POSITION

The group of tapeworms with which the present study deals belongs to the phylum *Platyhelminthes*, class *Cestoidea*, subclass *Cestoda* Canus, 1885, order *Cyclophyllidea* Braun, 1900, family *Mesocestoididae* Fhrmann, 1907, genus *Mesocestoides* Vaillant, 1863.

The family *Mesocestoididae* is characterized thus (adapted from Joyeux and Baer, 1936, and Chandler, 1946): *Cyclophyllideidae* in which the scolex is unarmed and without rostellum. Genital orifices on the median ventral surface. Uterus delivering its eggs into a paruterine organ, which consists of a single thick-walled egg capsule. Uterus tubular. Type and only genus *Mesocestoides* Vaillant, 1863.

The genus *Mesocestoides* may be characterized as: Characters of the family. Adults in birds and mammals. It is notable that
some of the species have two separate vitellaria, being the only species of the Cyclophyllidae so constituted. In some species, however, there is a single vitellarium, strongly lobed, and in one species, there is a single vitellarium which is only slightly lobed.

Several generic names or names of collective groups of larvae have been applied to the second stage larvae of Mesocestoides. (According to the International Code of Zoological Nomenclature, names for collective groups of larvae must follow the same rules as generic names). The earliest applicable name is Tetrathyridium Rudolphi, 1819, as pointed out by Henry (1927). Tetrathyridium has page priority, as well as clearer applicability over Dithyridium Rudolphi, 1819. Rudolphi (1819) on page 514 proposed Tetrathyridium for a worm which he had found in Perdix saxatilis, and on page 559 proposed Dithyridium for larvae described by Kremser as having only two suckers and occurring in Lacerta viridis and Lacerta muralis, but both names refer to larvae of the mesocestoidid type. Specific names in Tetrathyridium exist in profusion, but differential characters are even less tangible than among adult species. It appears most logical for the present to refer to new records of this group to Tetrathyridium sp. or to use the specific name of the mesocestoidid species to which the specimens can best be referred.

Specific differentiation within Mesocestoides is difficult. In fact, it appears from the literature to be almost impossible in Europe, the Near East, and North Africa, to differentiate the species inhabiting mammals. The description by Nuhrmann (1909) of M. charadrii is adequate, but no other description prior to 1925 can be certainly allocated. Since 1924 there have been several detailed studies, but the various workers have disagreed markedly. Hoepli (1925) described M. corti from a house mouse in Colorado,
PLATE I
Mesocestoides latus

Upper, gravid segment, ventral view,
drawn with the aid of a camera lucida.

Lower, same segment, ventral view,
free hand sketch of ovarian region.
(The plate is inverted.)
Cameron (1925) described two new species - *M. mesorchis* from a fox from Nepal and *M. caestus* from a ratel (*Heliolophus*) from northeastern Africa. Mueller (1927, 1928, 1930) examined numerous specimens from Europe and North America in a partial revision of the genus as occurring in mammals. He recognized the species *M. lineatus* (Goeze), *M. litteratus* (Batsch) and *M. conti* Hoepli, and described as new *M. variabilis* from a gray fox and two genera of skunks from California, and *M. latus* from a skunk and a kitten in Minnesota and an oppossum from Illinois. Fuhrmann (1932) recognized three species in birds - *M. alouiae* (Stossich), *M. perlatus* (Goeze), and *M. charadrii*.

Joyeux and Baer (1933) revived the name *ambiguus* Vaillant, 1863, for specimens experimentally produced in a cat in France. (According to modern standards, Vaillant's description was no more than generic in scope. It was based upon specimens from a civet-cat in France.) Baer (1933) described as new *M. dissimilis* from a mustelid (*Lynx*) in Tanganyika. In a prime example of "lumping", Wittenberg (1934) reviewed the genus, with specimens from Europe and Palestine only. He recognized only two species from birds - *charadrii* and *perlatus* - and only one species from mammals - *lineatus*, which was supposed to include all the forms from all continents, Joyeux and Baer (1936) in their monograph of the cestodes, recognized three species from birds and two from mammals - *lineatus* and *ambiguus*. Korkowski (1934) recognized two species - *lineatus* and *litteratus* - in adults he produced experimentally in dogs in Poland.

The status of the North American forms of *Mesocestoides* is in better shape than that of the European forms. Chandler (1942) described as new *M. munteri* from a lynx in Nebraska and differentiated specimens of *latus* from an oppossum from Texas and of *variabilis* from raccoons from Texas and Nebraska and from a dog from Nebraska.
Later Chandler described a human infestation with *variabilis*, (1942a), described a new species, *M. kirbyi*, from the coyote in California, (1944), and corrected certain details in the anatomy of *latus* from an oppossum, (1946).

The following table, based upon the literature, includes all the species of adult *Mesocestoides* reported from North America: (See Table, on page 5.)

Differential characters of scolex and vitellaria, as described by Mueller, seem to be valid but do not lend themselves to tabular arrangements.

Material used for the infection experiments reported herein was all obtained from a single oppossum (*Didelphis virginiana*). The animal was captured alive in Hermann Park, Houston, Texas, November 2, 1946, and caged for the duration of the experiments, being fed on dried prepared commercial dog food, varied occasionally with fresh horse meat. Segments were passed the day after the animal was captured and nearly every day for eight months thereafter. Some of these gravid proglottids, as well as sections of strobila which were passed on three occasions, were stained in carmalum and mounted in balsam. They appeared identical in all respects with the two perfectly-prepared complete specimens of *Mesocestoides latus* Mueller, 1927, which had been studied by Chandler (1946).
<table>
<thead>
<tr>
<th>Name and Author, followed by references</th>
<th>The American Species of Mesocestoides</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Testes</td>
<td>Length of Cirrus pouch in u</td>
</tr>
<tr>
<td><strong>M. bassarisci</strong> MacCallum (MacCallum, 1921)</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>M. corti</strong> Hoepli (Hoepli, 1925 and Mueller, 1928)</td>
<td>35-40</td>
<td>100</td>
</tr>
<tr>
<td><strong>M. manteri</strong> Chandler (Chandler, 1942)</td>
<td>30-45</td>
<td>88-140</td>
</tr>
<tr>
<td><strong>M. variabils</strong> Mueller (Mueller, 1927, 1928 and Chandler, 1942, from various carnivorous mammals)</td>
<td>40-45</td>
<td>130</td>
</tr>
<tr>
<td><strong>M. variabils</strong> Mueller (Chandler, 1942a from man)</td>
<td>60-65</td>
<td>135-155</td>
</tr>
<tr>
<td><strong>M. kirbyi</strong> Chandler (Chandler, 1944)</td>
<td>100-120</td>
<td>180-210</td>
</tr>
</tbody>
</table>
HISTORICAL REVIEW OF THE LITERATURE ON LIFE HISTORY OF MESOCESTOIDES

Leukart (1874) first called attention to the morphological similarity between the scolices of Tetrathyridium in lizards and the scolices of Taenia litterata Batsch (=Mesocestoides litteratus) in the intestine of foxes, and suggested that the former was the larva of the latter. The first experimental work was performed by Neumann (1896). Neumann fed Tetrathyridium from a cat to one dog and one cat and recovered immature Mesocestoides sp. on the 47th and 74th days respectively. Later he fed gravid segments of Mesocestoides lineatus from a dog and a cat to four dogs and recovered immature Mesocestoides on the 62d day from one of them. His experiments are open to serious question, however, because the cats and dogs were neither experimentally raised, nor held under controlled conditions, nor given an anthelmintic prior to the beginning of the experiments.

Skrjabin and Schulz (1926) pointed out the morphological similarity between the scolices of Tetrathyridium found in mice and those of Mesocestoides lineatus in carnivores.

Henry (1927) fed specimens of Tetrathyridium from a cat to three experimentally-raised cats. He recovered an immature Mesocestoides lineatus from one cat on the 44th day; one cat dying on the 204th day was negative; one cat began passing gravid segments of Mesocestoides lineatus after a little more than five months. Henry attempted, without success, to infect dogs, cats, rabbits, guinea-pigs, sheep, white mice, chickens, ducks, geese, pigeons, frogs, flies (Musca domestica and Calliphora sp. adults), and cockroaches by feeding them gravid segments of Mesocestoides lineatus from a cat. He concluded that Tetrathyridium represents the larval stage in the second intermediate host and that the first larval stage remained to be found.

Later, Schwartz (1927) reported feeding Tetrathyridium from a mongoose (imported into the United States) to experimental dogs and
cats and recovering mature *Mesocestoides* in both hosts 46 and 51 days later. Similarly Schulz (1927) obtained immature *Mesocestoides* sp. in a cat five weeks after feeding it *Tetrathyridium* from a house mouse. Schulz (1927) also made similar experiments. He found *Tetrathyridium* in one of twelve house mice fed with ripe segments of *Mesocestoides*. It is not clear from the context whether he had eliminated the possibility of natural infection. Schwartz (1928) failed to infect a cat with *Tetrathyridium* from a baboon imported from Africa.

Joyeux and Baer (1932, 1933) failed to infect a cat with *Tetrathyridium* from a chicken. They succeeded in infecting a cat with *Tetrathyridium ambiguus* from a snake from Marseille, most of the worms reaching maturity in 56 days. Other specimens of the snake *Tetrathyridium* were fed to frogs and snakes, in which they lost their bodies in the host intestine. The scoles penetrated the gut wall and migrated to the peritoneum, where in 37 days they formed typical *Tetrathyridium* bodies and re-encysted. Joyeux, Baer and Martin (1933) reported additional experiments upon *Tetrathyridium* from a snake from Bizerte, North Africa. A cat and a dog became infected with *Mesocestoides ambiguus*, but two ferrets did not. They also reported infecting two out of two cats with *Tetrathyridium* by feeding them gravid segments of *Mesocestoides lineatus* from a dog. However, no precautions were taken to be sure that the cats had not been previously infected.

Markowski (1934) fed *Tetrathyridium* from a rook to an experimental dog and produced mature *Mesocestoides litteratus* in only 13 days. He also produced adult *M. lineatus* in a dog from *Tetrathyridium* in an unspecified species of corvid bird. He fed ripe segments of *lineatus* to white mice, a rook, and a crow in unsuccessful attempts to find the first intermediate host. He suggested that the unarmed cysticercoid from a beetle larve (*Geotrupes* sp.) reported to Joyeux (1920) might have been *Mesocestoides*.

Witenberg (1934) performed an extensive series of experiments
on Mesocestoides in Palestine. "M. lineatus forma lineata" was produced in experimental dogs fed Tetrathyridium from lizards, cats and a hedgehog. An experimental jackal was infected with the same species of adult worm by feeding it Tetrathyridium from a cat. Experimental cats were infected with the same species of adult worm (or sometimes Tetrathyridium) by feeding them Tetrathyridium from cats and a hedgehog. Experimental white mice became infested with Tetrathyridium when fed Tetrathyridium from cats and a fox. A hedgehog and two hawks were negative after having been fed Tetrathyridium from cats. Witenberg also fed gravid segments of "M. lineatus forma lineata" from cats, dogs, and jackals to white mice and lizards, without producing any infections, even though some of the lizards were the same species which had yielded the Tetrathyridium for the experimental infection in the definitive host which produced the gravid segments. Also, he fed gravid segments to house flies and cockroaches without producing any infections.

Witenberg noted that eggs encased in gravid segments remained viable for 8 days in physiological saline. He suggested that unarmed cysticercoids reported by Joyeux and Koboziel (1928) from a dung beetle (Geotrupes sylvaticus) might have been Mesocestoides.

Hubbard (1938) reported feeding numerous "plerocercoids" from a snake to a cat, which was negative upon autopsy 30 days later. The plerocercoids, judging from Hubbard’s figures, were mature Tetrathyridium. The size and proportions of the scolex suggest Mesocestoides manteri and M. corti of the described North American species.

Witenberg (1934) listed all the records known to him of Tetrathyridium. He listed 29 species of mammalian hosts, 15 avian hosts, 10 lizard hosts, and 12 snake hosts as having harbored Tetrathyridium one or more times. He did not mention frogs; Joyeux and Baer (1933) reported Hyla as an experimental host. Hughes, Baker, and Dawson (1941) listed several other recent records from reptiles in addition to those listed by Witenberg. There have been only three records from native North
American animals. Smith (1908) recorded *Cysticercus fasciolaris* from the muskrat (*Fiber zibethicus*) from Pennsylvania, which report was referred by Witenberg (1934) to *Tetrathyridium*. Hubbard (1938) recorded plerocercoids from a whip snake (*Masticophis flagellum*) in Oklahoma, which were named *Tetrathyridium hubbardi* by Hughes, Baker, and Dawson (1941). Harwood (1932) recorded *Cysticercus* sp. from two species of lizards in Texas, but Witenberg listed these specimens as belonging to *Tetrathyridium*. Besides the above, there are three records of *Tetrathyridium* in imported animals in the National Zoological Park in Washington (Ransom, 1907; Schwartz, 1927, 1928).
THE PROBABLE LIFE CYCLE OF MESOCESTOIDES

It seems reasonable to assume that the life cycles of the several species of *Mesocestoides* are almost identical, because the adult tapeworms are so similar that the different species are distinguished with difficulty if at all. Therefore, one may use the data on life history of a single species.

The writer believes that the life history of *Mesocestoides* is as follows:

If the egg is eaten by a suitable invertebrate, it hatches in the gut and the onchosphere penetrates the gut wall. In the body cavity it develops into a minute encysted cysticercoid. If the host is eaten by any tetrapod vertebrate, the plerocercoid is freed by digestion from the surrounding tissue and cyst. It penetrates the intestinal wall and lives either free in the body cavity, or burrowing in the liver, or encysted in the mesentery, peritoneum, heart muscle, or subcutaneous tissue, reaching any of the sites by active migration. It grows into a mature plerocercoid, or *Tetrathyridium*. If this second host is eaten by a suitable mammal or bird host, the plerocercoid develops in the intestine into a mature tapeworm. If this host is eaten by a tetrapod vertebrate other than a suitable final host, the *Tetrathyridium* penetrates the gut wall and re-encysts in the body cavity or mesentery.

The above theoretical life cycle follows the postulates of Henry (1927) and Witenberg (1934). Two alternatives are open to consideration, by analogy with other tapeworm life histories.

(1) The invertebrate first intermediate host step might be omitted. That is to say, the *Tetrathyridium* might be the only larval stage. This hypothesis is supported by a few uncontrolled experiments as reported by Neumann (1896) and Joyeau, Baer, and Martin (1933) on cats
and by Schulz (1927) on house mice. It seems more reasonable to doubt these experiments and to trust the numerous controlled experiments performed by Henry (1927), Schwartz (1927), Joyeux and Baer (1933), Markowski (1934), and Witenberg (1934) on numerous species of mammals, birds, and reptiles. All these experiments were negative, and tended to show that direct infection of vertebrates with the eggs of *Mesocestoides* is not possible. That this hypothesis is unwarranted seems to be shown, also, by the fact that the commonest hosts of *Tetrathyridium* are small, largely insectivorous vertebrates (lizards, rodents, mongooses, shrews, snakes).

(2) The vertebrate second intermediate host might be only a non-obligatory stage, inserted into the life cycle only is the invertebrate intermediate host was eaten by a vertebrate in which the tapeworm could not develop to maturity. Such an insertion of an unnecessary transport host occurs in many nematodes and in at least one species of acanthocephalan. It has been described for a cestode only as an addition to a plerocercoid second intermediate host stage. The common occurrence of *Tetrathyridium* in the same species which also harbor adult *Mesocestoides* in Europe and the Near East was emphasized by Witenberg (1934) who observed it in numerous species of Canidae, Felidae, and Mustelidae. In Witenberg's and the writer's opinions, that fact militates against the possibility of the omission of the *Tetrathyridium* stage. It seems logical to assume that the cats and dogs acquire the *Tetrathyridium* by eating the invertebrate first intermediate host, just as the reptiles and rodents acquire it.

**The Identity of the First Intermediate Host.** That the first intermediate host of *Mesocestoides* is a widely-distributed invertebrate is indicated by the wide range of *Mesocestoides* (Europe, Asia, Africa,
North America). That the invertebrate host is a single small systematic group with no close terrestrial relatives seems probable because the tapeworm genus is a small one with no close relatives. It seems probable that adaptation to this distinct group of invertebrates acted as the isolating mechanism which produced the unique group Neocestoides in the course of evolution of the tapeworms, since the present day hosts of the adult tapeworms belong to several families, four orders, and two classes. If the isolating mechanism was adaptation to some definitive host, then the evolution must have been in some now extinct group of carnivorous mammals to which Neocestoides was once confined.

That the first intermediate host is terrestrial is indicated by the following facts: Adult Neocestoides are found only in strictly terrestrial birds and mammals, although a few, such as raccoons and opossums, occasionally eat shellfish and fish. Within the family Mustelidae, no forms of Neocestoides are found in the semi-aquatic minks, otters, and fishers; adult Neocestoides are found in civet-cats, skunks, and Myonax; both Tetrathyridium and adult Neocestoides are found in badgers, weasels, martens, and polecats. The common occurrence of Neocestoides in such an arid country as Palestine argues against an aquatic or amphibious invertebrate.

It seems quite probable that the invertebrate in question is a predacious form which would eat the entire segment - a rather large piece of mucoid flesh - during the day or two after passage. Large ground beetles or flesh-eating ants would fit this hypothesis. However, it is also possible that the segments habitually disintegrate on the ground and are eaten by a fairly small form that feeds on any decaying animal matter. It is unlikely that such a very small form as a mite could eat the eggs before they had died within their shells.
That the invertebrate in question is an arthropod, rather than an annelid or mollusc seems probable from an inspection of the list of hosts of *Tetrathyridium* as given by Witenberg (1934). Many of these hosts (house mice, marmots, monkeys, bats, lizards, small snakes) seldom or never eat earthworms or molluscs but subsist largely on arthropods. Neither could these forms have acquired the *Tetrathyridium* by eating another vertebrate because they seldom or never eat other vertebrates.

Witenberg (1934) and Markowski (1934) both suggested dung beetles of the genus *Geotrupes*. The possibility that the invertebrate in question is a parasite such as a flea or louse seems unlikely, as a corollary to the necessity of a second intermediate host. If the first host were a flea or a louse, living on or near the opossum, how could the small vertebrate become infected?

In summary, it seems probable that the first intermediate host of *Mesocestoides* is a widely-distributed terrestrial arthropod belonging to a small, systematically isolated group.
MATERIALS AND METHODS

The plan of this work was to determine the identity of the first intermediate host. Gravid segments were obtained in large numbers from a naturally infected opossum, which was kept in a slat-bottomed cage over a pan of water. Each day gravid segments were removed from the pan, washed in physiological saline, and stored at room temperature in a covered dish. The bottom of the dish was covered with several layers of filter paper moistened with physiological saline. For each species of experimental animal, some of the segments used were fresh, some one or two days old, and some three to six days old.

Invertebrates for the experiments, with few exceptions, were captured in woodlands where opossums were common, in Houston, Harris County, near Richmond, Brazoria County, and near Willis, Montgomery County. Grouse locusts and ground beetles were taken with a sweep net, aquatic crustaceans in woodland pools with a water net, the slower moving terrestrial forms by hand or with hand and shovel. Grasshoppers and katydids were taken in the open fields of the Rice Institute campus. The white mice were laboratory-raised at the Baylor Medical School and donated by Dr. Wilton M. Fisher. The grain beetles were laboratory raised by the writer. The ants were trapped in the Physics Building of the Rice Institute.

After preliminary trials, little difficulty was experienced in keeping most of the invertebrates alive for the necessary two or three weeks. Most of them were kept in simple aquaria or finger bowl terraria. Snail terraria were made following the directions of Krull (1937). Grasshoppers and katydids were kept in screened cases with plenty of fresh green grass and a large dish of wet cotton for moisture. Earthworms, darkling ground beetle larvae, and scarabaeid beetle larvae were kept in individual small flower pots, following the directions of
Moore (1942, Ms.). White mice were kept in wire-bottomed cages and fed dehydrated dog biscuits and water only. It was found necessary to place each crayfish in an individual aquarium to avoid cannibalism.

In passing, it is well to note that metacercariae of *Brachylaemus opisthotrias* (Lutz) were found in one of seventeen snails, *Stenotrema monodon*, and seventeen of eighteen snails, *Mesodon thyroidus*, examined. But of the six opossums autopsied, only one was infected with the adult flukes. The incidence of adult *Mesocestoides* is as great or greater; by analogy it would seem logical to expect the incidence of first stage larvae to be somewhere near as great, if the proper first intermediate host were examined.

**ACCOUNT OF EXPERIMENTS PERFORMED**

Numerous animals were tested as possible first intermediate hosts for *Mesocestoides latum* by feeding them gravid segments. In most cases it was known that segments of eggs had been eaten, but in some cases this could not be determined. None of the animals were laboratory-raised, with the exception of the white mice and grain beetles. Many of the animals might, therefore, have been naturally infected with tapeworm larvae. However, no tapeworm larvae were found except in the pill bugs. The list of experiments which follows is arranged systematically according to the hosts tested. Except as noted otherwise, identification of the animals was by the writer, using the keys of Pratt (1935) and Essig (1926). Time on each experiment was reckoned from the day the infective meal was first given. The difference between the numbers of animals at the start of each experiment and at the end represents the number which escaped or died prior to the fourteenth day. Many experimental animals which died prior to the fourteenth day were dissected and found negative, but such records are not included here.

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Platyhelminthes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Turbellaria</td>
</tr>
</tbody>
</table>
Order Triclada

Two specimens of an unidentified triclade turbellarian, found under a log, were placed in a dish with numerous gravid segments for several days; then rotten wood was added. Apparently they did not eat the segments. After 49 days, the worms were negative for tapeworm cysts when dissected.

Phylum Annelida
Class Oligochaeta
Family Lumbricidae

Two specimens of Lumbricus sp. and two of Helodrilla sp. were placed in flowerpots with dissected segments mixed with the soil and with entire segments on the surface of the soil. They did not eat the entire segments. After 21 days two Lumbricus and one Helodrilla were negative.

Phylum Arthropoda
Class Crustacea
Sub-class Malacostraca
Order Isopoda
Family Armidilliidae

Fifty-one pill-bugs (Armadilloidium sp.) were placed in dishes with gravid segments. Many of them were seen to partake of the tape-worm material. After one to two days moss and leaves were added. Dissections were as follows: 25 to 28 days, 5 dissected; 36 to 38 days, 11 dissected; 41 to 44 days, 25 dissected; 53 days, 1 dissected. Two cysts, which were apparently immature tapeworm cysts, were found in separate pill bugs. However, their scarcity indicated that they were probably not experimentally produced.

Family Asellidae

Eight Asellus sp. were placed in an aquarium with several gravid segments. After one day leaves and debris were added. It was uncertain whether or not they ate the segments. After 16 days, four were negative.

Order Amphipoda
Family Gammaridae
Thirty-five *Gammarus* sp. were placed in aquaria with dissected and entire gravid segments. They ate all of the segments voraciously. After one day leaves and debris were added. In 14 to 19 days twenty-one were dissected and found negative.

Order Decapoda  
Family Astacidae

Eleven crayfish (*Cambarus* sp.) of various sizes were placed in aquaria and fed numerous gravid segments. Later feedings consisted of ground beef. In 17 to 26 days six crayfish were negative. Four more *Cambarus* were dissected without finding any natural infections.

Class Miriapoda  
Order Diplopoda  
Family Polyxenidae

Five millipedes (*Polyxenus* sp.) were placed in a dish with several gravid segments. After one day, the segments having been eaten, rotten wood and debris were added. After 32 days, a single millipede was negative.

Family Julidae

Four large millipedes of this family were placed in dishes with gravid segments, which they soon ate. After a few hours, rotten wood and debris were added. Later, corn meal was occasionally fed. In 23 days one millipede was negative.

Family Polydesmidae

Eight small millipedes of this family were placed in dishes with gravid segments, some of which they are. After one or two days, rotten wood and leaves were added. In 38 days four millipedes were negative.

Order Chilopoda  
Family Scolopendridae

Six small centipedes of this family were placed in dishes with gravid segments. After one day, rotten wood and debris were added. After 35 to 39 days, three centipedes were negative.

Class Insecta  
Order Collembola
Family Entomobryidae

Two springtails of this family were placed in terraria with gravid segments. It could not be determined whether or not the springtails ate any tapeworm. Debris and leaves were added after one day. In 38 to 39 days both springtails proved negative.

Order Orthoptera
Family Tettigidae

Ten grouse locusts of this family were placed in a flask with a portion of bran mash into which dissected and entire gravid segments had been stirred. A large part of the mash was eaten. After two days leaves were added and the mash removed. Twenty-two days after the start of the experiment two locusts were negative, as were two more in 35 days.

Families Locustidae and Tettigoniidae

Twelve assorted katydids and grasshoppers were placed in cages with portions of bran mash containing dissected gravid segments. Some of the mash was eaten. After two days grass was added and the mash removed. In 32 days one large grasshopper (Family Locustidae, Sub-family Locustinae) and one katydid (Family Tettigoniidae, Sub-family Decticinae) were negative.

Family Gryllidae

A single cricket, Gryllus sp., was placed in a flask with several gravid segments, of which it at least a part. After three days, the segments were removed. In 14 days, the cricket was negative.

Order Diptera
Family Muscidae

Fifty-four house fly (Musca domestica) larvae were placed in flasks with numerous gravid segments on filter paper. One day later many of the segments had been eaten; manure was added. After 15 days 5 pupae and 1 larva were negative; after 20 to 22 days one adult, one pupa, and six larvae were negative.
Order Coleoptera  
Family Carabidae

Four small ground beetles of this family were placed in finger bowls with gravid segments on damp filter paper. After one day parts of some segments were gone; the beetles were removed to debris-filled terraria. In 32 to 35 days two beetles were negative.

Family Elateridae

Eight of these predacious beetle larvae, Alaus sp., were placed in dishes with several gravid segments; it was not certain whether or not they ate any tapeworm. After one to two days the beetles were removed to terraria filled with rotten wood. In 35 to 39 days, four of the larvae were negative.

Family Tenebrionidae

Two larvae of darkling ground beetles of this family were placed in a dirt and manure-filled small flower pot into which numerous dissected and entire gravid segments had been stirred. After 38 days the one remaining larva was negative.

Twenty larvae and seven adults of the grain beetle Tenebrio molitor were placed in dishes with pieces of apple into which entire and partially dissected gravid segments had been mashed. After one day parts of the apple had been eaten; the apple was removed and bran added. In 29 to 31 days (all larvae had remained in the larval stage) seven adults and nineteen larvae were negative.

Three adult grain beetles, Tribolium confusum, were placed in a dish with a piece of apple into which several entire and dissected gravid segments had been mashed. It could not be determined whether or not the beetles had eaten tapeworm. After one day the apple was removed and bran added. After 31 days all three beetles were negative.

Family Scarabaeidae

Sixty-nine adult dung beetles were placed in covered dishes and starved for 1 to 2 days, then fed small balls of cow manure into which
numerous entire and dissected gravid segments had been mixed. In each case, the dung had been thoroughly eaten through and fragmented in from 1 to 2 days, and more dung was added. Dissections, all negative, were: \textit{Canthon laevis} (identified by H. J. Reinhard) - one in 32 days, three in 47 days, one in 59 days. \textit{Aphodius fimetarius} (identified by H. J. Reinhard) - two in 25 days, seven in 37 days. \textit{Phocera} sp. (identified by C. P. Read) - one in 18 days. \textit{Geotrupes blackburni} (identified by H. J. Reinhard) - three in 18 to 22 days. \textit{Hister} sp. (identified by H. J. Reinhard) - two in 28 days. Five more adult dung beetles (two \textit{Phocera} sp., three \textit{Aphodius fimetarius}) were dissected, without finding any natural infections.

Seventeen grubworms (larval May beetles) were placed in small flower pots full of dirt, mixed with manure, into which many entire and dissected gravid segments had been stirred. Dissections, all negative, were: \textit{Phyllophaga} sp. - one in 25 days, two in 35 days, two in 40 to 45 days. \textit{Felimnota punctata} (identified by W. H. Anderson) - three in 41 to 47 days, four in 54 to 60 days, three in 100 days.

Order Hymenoptera
Family Formicidae

About one hundred fire ants, \textit{Solenopsis geminata} (identified by H. R. Smith) were trapped in a piece of meat and placed in a covered jar of bran. Several gravid segments, at least some of which were apparently eaten, were added each of the first 3 days. After 20 days, the remaining 21 ants (one soldier and twenty workers) were negative.

Phylum Mollusca
Class Gastropoda
Order Pulmonata
Family Helicidae

Forty-six helicid snails collected in opossum-haunted woodlands were placed in terraria, starved for one day, and then fed dissected gravid segments mixed with cornmeal and entire segments. The smaller snails ate the former; the larger snails (\textit{Mesodon}) ate many plain seg-
ments as well as the infective corn meal. Later feedings were of corn meal, oatmeal, and calcium carbonate. Dissections, all negative, were: *Euconulus charsinus trochulus* (these and all other molluscs were identified by J. P. E. Morrison) – four in 33 days; *Oligyra orbiculata* – one in 33 days. *Stenotrema monodon aliciae* – seventeen in 28 to 33 days. *Mesodon thyroidus* – three in 25 days, fifteen in 34 to 39 days.

Family Zonitidae

Thirty-three of the small woodland snail *Zonitoides arboreus* were placed in terraria, starved for one day, then fed dissected gravid segments mixed with cornmeal. The snails ate at least some of the infective mixture. In 34 to 37 days twenty snails were negative.

Family Limacidae and
Family Philomycidae

Eight medium-sized slugs were placed in dishes with portions of a cornmeal-dissected-gravid-segment mixture. After from 2 to 4 days, some or all of the mixture having been eaten, the slugs were removed to terraria. In 28 and 36 days, two *Phylomyces carolinensis* were negative.

Phylum Chordata  
Class Mammalia  
Order Rodentia  
Family Muridae

Nine laboratory-raised white mice (*Mus musculus*) were fed three gravid segments each (some by pipette; some ate voluntarily). Dissections, all negative, were: four in 34 to 36 days, one in 42 days, three in 59 to 60 days, one in 79 days.
DISCUSSION OF RESULTS

The experiments herein reported failed to elucidate the identity of the first intermediate host of *Mesocestoides*. Negative results with mice serve to confirm the work of Henry, Schwartz, Markowski, and Witenberg, which had indicated that an invertebrate first intermediate host was necessary. Negative results with thirty-six species of invertebrates cast doubt upon the ability of these few species and higher systematic groups to act as intermediate hosts.

It is felt that the experiments are fairly conclusive in the cases of the pulmonate snails, the tenebrionid beetles, the dung beetles, the May beetle larvae, and the aquatic crustaceans. In other words, it is believed that further experiments in these groups are not warranted. It is suggested that numerous families and genera of ants, beetles, and terrestrial isopods are untested. Further experiments with many beetles (particularly the Carabaeidae), ants and terrestrial isopods should be made.

That the first intermediate host is not exclusively, if at all, coprophagous was indicated by the habit of the gravid segments to crawl out of the fecal mass.
DESIGNATIONS OF LIFE HISTORY STAGES

ADULT

The adult *Mesocestoides latus* is a narrow tapeworm with the anterior segments approximately square and the posterior segments bead-shaped. There are 500 to 1000 segments and entire worms with gravid segments are 100 to 123 cm. long. The anatomy has been described in detail by Mueller (1927, 1928, 1930) and Chandler (1942, 1946) and need not be repeated. However, a few points of anatomy do need clarification; none of them have been mentioned save in Mueller's second paper, where they were given very briefly. Mueller (1928) gave the number of testes as 27 to 30, the length of the cirrus pouch as 150 μ, and the diameter of the egg capsule as up to 600 μ. I find 51 to 59 testes; cirrus pouch 146 to 188 μ long; egg capsule 602 to 766 μ long by 465 to 565 μ wide.

The data in the preceding paragraph were based upon four entire specimens and numerous fragments (the last from the infestation which provided the material for all the experiments) from three individual opossums taken in Houston. Two of the complete specimens were those described by Chandler (1946).

A few observations on the course of the infestation in opossums are pertinent. One opossum was in captivity for 28 days; daily stool examinations were consistently negative for tapeworm segments. At the end of this time the animal was killed and autopsied; two *Mesocestoides latus* specimens, each about 40 cm. long, were in the intestine. They both were complete, but the final segments were only mature. The infested opossum (an adult male) which provided material for infection experiments passed usually 10 to 50 (sometimes as many as 100) gravid segments per day. Three times in the seven months, however, large portions of a strobila were passed, and each time for a week thereafter, no segments were passed. The animal appeared healthy except for small
"cage sores" on its ear lobes part of the time. It was noticeably more voracious and invariably ate more than any other opossum of the group. A total of nine opossums were examined, from Harris, Montgomery, and Brazoria Counties; two were found infested with *Mesocestoides latus*.

The gravid segments (see Plate II, figs. 1 and 2) are passed in the feces of the opossum and migrate actively out of the fecal mass. Segments removed from still-warm stools were observed to move fairly rapidly for a few minutes, traversing at least three inches. They crawled along a dry, horizontal or vertical glass surface or on filter paper moistened with physiological saline in a covered dish and their positions marked. Some of them moved more than an inch from about 15 minutes after passage to two hours later. Thereafter they did not move. None of the segments crawled under the paper.

Other freshly-passed segments were placed on damp sand at a temperature of 23°C, beside and open window. They moved slightly, horizontally, for the first hour, but showed no tendency to move under the grains of sand.

Actively crawling, freshly-passed segments were placed on a horizontal, damp glass surface. A bright light (150 watts) was placed to shine horizontally across the glass plate, the room being otherwise dark. No tendency to crawl either toward or away from the light was noted, the crawling being apparently aimless.

Two experiments were performed in order to test the viability of the ova within the gravid segment. A group of freshly-passed segments was placed on a piece of damp filter paper lying on an inch of damp soil in a finger bowl. The bowl was in an unheated room beside an open window. The weather was foggy, the room temperature 23°C, for the duration of the experiment. Five hours after the start of the experiment the filter paper appeared dry; it was turned over. Twenty-seven hours after the start of the experiment the segments appeared dry and
PLATE II

Fig. 1. *Mesocestoides* sp.; *Tetrathyridium* stage; longitudinal section; after Fuhrmann (1935); total length of specimen 15 mm.

Fig. 2. *Mesocestoides* sp.; *Tetrathyridium* stage; total mount; from lizard.

Fig. 3. *Mesocestoides* sp.; *Tetrathyridium* stage; total mount; from white-footed mouse.

Fig. 4. *Mesocestoides latus*; living onchosphere.
desicated; however, the onchospheres were viable when the eggs were dissected out of one segment and placed in physiological saline under a cover slip. Forty-eight hours after the start of the experiment the remaining segments appeared very dry and dessicated. The thickest segment was dissected, but no viable onchospheres could be found within it. (Onchospheres were noted as viable if movement could be detected within the eggs.)

Another group of freshly-passed segments was placed on a piece of filter paper, kept moistened with physiological saline on the bottom of a covered dish. One segment was dissected each day; viable onchospheres were found up to and including the ninth day. But on the tenth day no further movement of onchospheres was seen.

ONCHOSPHERE

Within the egg capsule of each gravid segment of *Mesocestoides latus* are 100 to 200 eg-s. Each egg has a single, rather thin, transparent shell, closely surrounding the mature hexacanth onchosphere.

The liberated onchosphere, as seen in living specimens, is a slow-moving body bearing six hooks anteriorly. Its shape is usually ellipsoid, but sometimes ovoid, with the large end anterior. In the ten specimens measured, the total length varied from 30 to 40 μ and the length of the median hooks from 16 to 17 μ. The four lateral hooks appear to be slightly shorter than the median pair, but this may by a matter of physical point of view. Certainly the differences among hooks are not as great as shown in the drawing (Plate II, *Fig. 4*), in which the lateral hooks are foreshortened.

Onchospheres were, in the laboratory, freed from the egg shell by placing them in a weak aqueous solution of pancreatic extract (Pangestin, Difco) under a cover slip. In ten or fifteen minutes some of the shells ruptured and the onchospheres began crawling out. In thirty minutes all of the shells had ruptured, being partially dissolved away, and all of
the onchospheres were free.

TETRATHYRIDIUM

The writer's knowledge of the Tetrathyridium stage of Mesocestoides is based upon two collections.

(1) Harwood (1932) recorded finding "Cysticercus sp." three times in lizards at Houston -- twice in Leiolopisma laterale and once in Eumeces fasciatus. He suggested that it belonged to the genus Occhoristica and stated that the invaginated scolex lay entirely free within the cyst wall. One specimen of this collection (which host not indicated), stained and mounted in balsam, still remained in the Rice Institute collection, where it was studied by the writer. The cyst is 0.7 mm. long and contains a completely inverted, partially-developed scolex 264 μ wide, bearing four suckers 83 to 88 μ long, with slit-like openings. According to the observations of the writer, the scolex is attached to the parenchyma by a few strands of tissue (Plate II, Fig. 2) and most of the body of the worm is filled with loose parenchyma. In my opinion, the almost solid, plerocercoid-like body indicates the genus Mesocestoides and the small size of the scolex of this worm indicates that it is the larval stage of M. variabilis. Figure 1, Plate II, was copied from Fuhrmann (1933: Fig. 417) and represents a longitudinal section of a Tetrathyridium from a hedgehog (Erinaceus deserti). Fuhrmann stated that the total length of the larva was 15 mm.

(2) On July 7, 1941, the writer removed more than 50 specimens of Tetrathyridium from the liver of a white-footed mouse, Peromyscus boylii boylii. The mouse had been trapped by Miss Jean T. Boulware and the host was identified by Mr. Joseph S. Dixon. The location was Miguel Meadow, Yosemite National Park, California, in the Transition life zone. Of the carnivorous mammals, foxes, coyotes, skunks, and
raccoons were common in the vicinity and several other species occasionally wandered by.

Twenty-seven stained and mounted specimens were studied in detail. Of these, five had a secondary evagination of the scolex (as in Plate II, Fig. 3). The worms varied in length from 2 to 5 mm.; the suckers were 182 to 237 u long (only 16 specimens measured for this character); the scolices were 347 to 529 u wide (only 16 measured). The small size of the scolices seems to indicate that these larvae are *M. variabilis* or *M. kirbyi*. 
SUMMARY

1. Second stage larvae (Tetrathyridium) of *Mesocestoides* are recorded from a white-footed mouse in California and a lizard in Texas.

2. Gravid segments of *Mesocestoides latus* were fed to white mice, but no infection resulted.

3. Gravid segments of *Mesocestoides latus* were fed to 531 individuals, of thirty-six species and four phyla, of invertebrates, but no infection resulted in the 263 individuals which were dissected after 14 to 100 days.

4. It is theorized that the first intermediate host of *Mesocestoides* is a terrestrial arthropod, probably either a beetle, an isopod, or an ant. It is further theorized that a second intermediate host, a vertebrate, is required before completion of the life cycle.
BIBLIOGRAPHY


Essig, E. O. Insects of Western North America. 1-1035. (New York, MacMillan Co.)


Rudolphi, C. A.  Entozooorum synopsis, cui accedunt mantissa duplex et inaices locupletissimi. 1-811. (Berlin, the Author).


