STUDIES ON THE TRANSMISSION OF HELMINTH OVA BY COCKROACHES

Phillip L. Young and Bert B. Babero

Department of Biological Sciences, Grambling College, Grambling, Louisiana, and Department of Biological Sciences, University of Nevada, Las Vegas, Nevada

Four species of cockroaches, three domestic and one wild, were fed on different occasions the eggs of 21 species of helminths, including eleven of Nematoda, nine of Cestoda, and one of Acanthocephala. The roaches voided undeveloped, mature and embryonated eggs over time intervals ranging from 24-96 hours. Concentrates of voided eggs of *Toxocara canis* and *Ascaridia galli* were found to be infective to rats and chickens, respectively. Eggs of *Hymenolepis diminuta* that passed through the digestive tract of cockroaches developed cysticercoids in flour beetles. Because of their intimate association with man and domestic animals, it is possible that cockroaches may play a more important role in the transmission of helminthic diseases than previously suspected.

Although cockroaches generally reside in close association with man and his domestic animals, the precise role that they may play, either as primary, intermediate, or transport hosts, in the transmission of helminth diseases has not been fully assessed. That they may act as transport hosts for certain helminths, have been experimentally demonstrated by Macfie (1), Morisita and Tsuchimochi (2), Porter (3, 4), and Akkerman (5). Most reports of helminth transmission by cockroaches, either as eggs or larvae have been concerned with the Nematoda and Acanthocephala. References concerning such transmission of the Trematoda and Cestoda are rare. Concerning the Trematoda, *Schistosoma haematobium* (Bilharz, 1852) eggs were recovered from cockroaches that had fed on infectious human feces smeared on bread (1). The writers are unaware of any other trematode infections, natural or experimental, transmitted by cockroaches. Eggs of the Cestoda have been infrequently reported as occurring naturally in cockroaches. A summary of these reports is in Table 1.

Reports of cockroaches as intermediate hosts for acanthocephalan parasites are not infrequent. The development of *Prosthenorchis elegans* (Diesing, 1851) in *Blattella germanica, Rhyparobia maderae* and *Blaberus fusca* was studied in 1938 by Brumpt and Urbain, Brumpt and Desportes, and Dollfus (6). Several species of the genus *Moniliformis* Travassos, 1915 are known to employ cockroaches, either in nature or experimentally, as intermediate hosts, including *M. clarki* (Ward, 1917), *M. dubius* (Meyer, 1932), *M. Kalahariensis* (Meyer, 1931) and *M. merionis* (Golvan, 1963.) *M. moniliformis* (Bremser, 1811) (genotype) has been reported in intermediate hosts, including *Blaps gigas, B. mucronata,* and *Periplaneta americana* (7). Acholonu and Finn (8) found cystacanths of *M. moniliformis* in seven of 53 *P. americana* collected in San Juan, Puerto Rico, the record comprised the first report of infection in this arthropod from the country, although earlier reports of adults of the species had been reported from rats.

Numerous species of nematodes are cited in literature to use cockroaches as intermediate or paratenic hosts. Some of these reports, obviously copied from other citations, involving certain nematodes are erroneous. The purposes of this paper are to report personal findings in which various species of cockroaches, experimentally infected, were observed to harbor helminth eggs and the results of several experimental infections of hosts with eggs that had passed through the digestive tract of these insects.

MATERIALS AND METHODS

A. Experimental feeding to cockroaches

Four species of cockroaches of the family Blattidae, three of which are domestic, were used in these investigations: *Periplaneta americana* (American cockroach), *Blattella germanica* (German cockroach), *Blaberus giganteus* (blaberus roach), and *Paracoblatta sp.* (woodroach), a wild species. Each species of roach was maintained

TABLE 1. *Eggs of helminths carried by cockroaches.*

Parasite	Host	Reference
Cestoda		
Hymenolepis sp.	*Periplaneta americana*	2
	Polyphaga saussurei	9
Taenia saginata	*Periplaneta americana*	1
Echinococcus granulosus	*Periplaneta americana*	10
unidentified cestode eggs	*Polyphaga saussurei*	8
Nematoda		
Enterobius vermicularis	*Blatta orientalis*	11
	Blatta germanica	
Ascaris lumbricoides	*Periplaneta americana*	4, 1
	Periplaneta australasiae	12
	Neostylophysa rhombifolia	2
Ascaris sp.	*Blatta orientalis*	13
	Periplaneta americana	10
Ancylostoma caninum	*Periplaneta americana*	5
A. ceylanicum	*Periplaneta americana*	1
A. duodenale	*Periplaneta americana*	3
Necator americana	*Periplaneta americana*	15
Hookworm eggs	*Periplaneta americana*	2
	Periplaneta australasiae	
	Neostylophysa rhombifolia	
Trichostrongylus sp.	*Blatta orientalis*	13
Capillaria hepatica	*Blatta orientalis*	14
Trichuris trichiura	*Blatta orientalis*	11
	Blattella germanica	1
	Periplaneta americana	1
	Periplaneta australasiae	2
	Neostylophysa rhombifolia	
Trematoda		
Schistosoma haematobium		1

in a specially constructed tin-reinforced compartment 6″ x 6″ x 6″, with a sliding screen top. For experimental feeding, selected groups of each of four species of cockroaches were starved for five days then isolated in half-pint circular ice cream containers whose bottoms had been removed and replaced with one-eighth inch screen wire to facilitate recovery of fecal pellets with minimum disturbance to the roaches. Fecal pellets were collected, pooled, and stored from each species of roach that had been fed a given type of helminth eggs. Concentrates of eggs, if present, were accomplished by employing a zinc-flotation technique.

Experimental infective meals consisted of sugar-sweetened banana paste in which were placed designated eggs of helminths. At intervals of 24, 32, 48, 72, and 96 hours, fecal pellets from the cockroaches were collected in glass saucers, whose bottoms were lined with folded, moist filter paper to prevent desiccation or distortion of eggs that might have been voided. Fecal pellets were then transferred to shallow watch glasses containing a few drops of distilled water, crushed and stirred to obtain a uniform mixture. A drop of this mixture was placed on a slide, covered with a coverslip and systematically examined microscopically for eggs.

Eggs of twenty-one species of helminths, including eleven Nematoda, nine Cestoda, and one Acanthocephala were fed to as many groups of cockroaches (Table 2). The helminth eggs employed in these experiments were collected directly from worms recovered from hosts. Except for *Physaloptera turgida* Rud., 1819, whose eggs are fully developed when oviposited, all nematode eggs were experimentally embryonated before feeding them to cockroaches.

B. Experimental feed to other hosts.

Embryonated eggs of *Ascaridia galli* (Schrank, 1788) which had been voided by experimentally fed cockroaches were pipetted into the esophagi of several eight-day old leghorn chicks. These young birds were sacrificed 12 days later and their small

intestines were examined for larval ascarids.

Voided embryonated eggs of *Toxocara canis* (Werner, 1782), collected from cockroaches over a 96-hour period were concentrated into a suspension and force-fed to parasite-free white rats (Nat: NLR (WI) SPF BR). The rats were necropsied at intervals of 10, 12, 15, and 20 days and examined for *T. canis* larvae.

About 15 beetles, *Tribolium confusum*, were introduced into each of six stender dishes, which had been previously lined with filter paper onto which had been placed a pinch of sugar and a drop of water containing eggs from the pooled concentrate of *Hymenolepis diminuta* Rud., 1819. The beetles remained in these stender dishes for approximately 12 hours, after which time they were transferred to untreated dishes and allowed to feed on a regular diet of flour. Two or three weeks after transference, the beetles were dissected and examined for cysticercoid larvae. White laboratory rats were also used, being fed the presumably experimentally infected beetles.

Cockroaches which had ingested food containing eggs of *Hydatigera taeniaformis* Batsch, 1788 were isolated without food or water in a box equipped with runways communicating with an adjacent compartment that contained parasite-free albino rats. The funnel-shaped exits from the roach-side of the box did not permit reentry by the insects once they entered the rat compartment.[1] The rat compartment contained a rack of Purina cat chow and a small flat tray of water. To prevent roaches from feeding on droppings of rats, the feces trays were emptied and washed twice daily, thus forcing the roaches to move about the screened-in compartment floor and increasing the possibility of their being ingested by rats. Presumably, infected roaches were continuously introduced into the roach compartment at intervals over a 10-week period. At the end of this time, the rats were autopsied and their livers were examined for strobilocerci larvae of *H. Taeniaeformis*.

[1] Details of the box and cage used will be furnished upon request.

TABLE 2. *Persistence of eggs of helminths in feces of species of cockroaches at various intervals after ingestion*

Parasite	Presence of eggs in feces				
	24 hours	32 hours	48 hours	72 hours	96 hours
NEMATODES					
Ascaris columnaris	+	+	+	+	+
A. suum	+	+	+	+	+
Ascaridia galli	+	+	+	+	−
Toxocara canis	+	+	+	+	−
T. cati	+	+	+	−	−
Syphacia obvelata	+	+	+	−	−
Physaloptera turgida	+	+	+	+	−
Toxascaris leonina	+	+	+	+	−
Setaria equina	+	+	+	−	−
Heterakis gallinarum	+	+	+	+	−
Porrocaecum ensicaudatum	+	+	+	+	−
CESTODES					
Hydatigera taeniaeformis	+	+	+	−	−
Taenia pisiformis	+	+	+	−	−
Cittotaenia pectinata	−	+	+	+	+
Dipylidium caninum	+	+	+	−	−
Mesocestoides lineatus	−	+	+	−	−
Hymenolepis diminuta	+	+	+	+	+
H. nana	+	+	+	+	+
Choanotaenia iola	+	+	+	+	−
Hymenofimbria macracanthus	+	+	+	−	−
ACANTHOCEPHALA					
Centrorhynchus sp.	+	+	+	−	−

+ = present; − = absent

RESULTS AND DISCUSSION

A. Infections of cockroaches

Domestic and wild cockroaches voided undeveloped, mature, and embryonated eggs of the twenty-one species of the helminths employed in this study. Viable eggs of most cestodes were recovered from roaches within four days after feeding. The survival index of the eggs was high, as indicated by their presence in the feces of cockroaches (Table 2).

Of the Nematoda, eggs of *Ascaris columnaris* Leidy, 1856, *A. lumbricoides* var. suum (Goeze, 1782), *Ascaridia galli*, *T. canis*, and *Physaloptera turgida* were voided by approximately 100% of the experimentally fed roaches. Other roundworm eggs showing a high survival index were *T. cati* Schrank, 1788, *T. leonina* Linstow, 1902 (voided by 100% of *Periplaneta*), *Porrocaecum ensicaudatum* (Zeder, 1800) and *Heterakis gallinarum* (Schrank, 1788) (Table 2). Eggs of the latter nematode were voided by each species of cockroach employed in this study. The American roach voided the lowest percentage of helminth eggs (65% of *T. cati*).

Although eggs of the roundworm, *Syphacia obvelata* (Rud., 1802) and *Setaria equina* (Abildgaard, 1789) were also fed to the four species of cockroaches, the number of insects voiding these eggs was consistently lower. Voiding of *S. obvelata* eggs by *Blaberus* was 80%, for *Periplaneta*, 65%, and for both *Blattella* and *Paracoblatta* the number was 50%. The eggs of *S. equina* showed a higher incidence of survival than those of *S. obvelata*, being found in feces of 80% of *Blattella* and *Blaberus*, 75% of *Periplanata*, and 75% of *Paracoblatta* sp. (Table 3).

Nearly 100% of each species of roach voided eggs of *H. taeniaformis*, *H. macracanthus* (Linstow, 1877), and *H. nana* (V. Siebold, 1851). *Dipylidium caninum* Linn., 1758 and *Choanotaenia iola* (Lincicome, 1939) were voided by 100% of the German cockroaches. The survival index of eggs of *C. iola* was slightly lower than that of *D. caninum*, as indicated by their presence in the feces of 80% of American and blaberus roaches and 85% of woodroaches.

Eggs of *Mesocoestoides lineatus* Goeze, 1782 were voided by 90% of woodroaches, 80% of German roaches and 67% of American and blaberus roaches, respectively. The incidence of eggs of *T. pisiformis* (Bloch, 1780) in the feces of roaches was lower than that of the other cestodes, being voided in 80% of *Blaberus*, 70% of *Periplaneta*, 67% of *Paracoblatta* sp., and 65% of *Blatella* (Table 4).

Cockroaches fed eggs of *H. diminuta* were later dissected for the presence of cysticercoid larvae; however, none were found in the 40 insects examined. On the basis of

TABLE 3. *The percentage of cockroaches ingesting eggs of nematodes to those voiding the eggs*

	Periplaneta americana		*Blattella germanica*		*Blaberus giganteus*		*Parcoblatta* sp.		Animals Infected
Eggs of Nematodes	Number roaches used	Percentage voiding eggs	Number roaches used	Percentage voiding eggs	Number roaches used	Percentage voiding eggs	Number roaches used	Percentage voiding eggs	
Ascaris columnaris	20	100	20	100	10	100	12	67	
A. suum	20	100	20	100	10	80	10	100	
Ascaridia galli	20	100	20	100	10	100	12	83	Chickens (3)
Toxocara canis	10	100	10	100	10	90	12	75	Rats (1)
T. cati	20	65	20	90	10	70	10	80	
Syphacia obvelata	20	65	20	50	10	80	10	50	
Physaloptera turgida	20	100	20	100	5	100	10	70	
Toxascaris leonina	20	100	20	95	10	80	10	70	
Setaria equina	20	75	20	80	10	80	10	75	
Heterakis gallinarum	20	80	20	90	5	80	10	100	
Porrocaecum ensicaudatum	20	75	20	85	10	70	10	80	

this observation, cockroaches, contrary to some reports, apparently do not serve as intermediate hosts for this tapeworm species. The present finding in this regard concurs with the observations of Chandler (15) and Riley and Johnson (16), who were unable to infect cockroaches with *H. diminuta*.

B. Infections of other hosts.

Of a group of 12 helminth-free rats with access to cockroaches that were presumed to be infected with eggs of *H. taeniaeformis*, four contained strobilocerci larvae in their livers (Table 4). The presence of only one cyst in the liver of each of the infected rats possibly is due to the strong immunity conferred in primary infections, as explained by Campbell (17). Even under natural conditions, it is unusual to find more than a few cysts in rodent hosts.

Of four rats force-fed eggs of *T. canis*, one was found to have several larvae in its lungs (Table 3). It is conceivable, therefore, that rats may become infected with this species under natural conditions by the ingestion of roaches.

Eggs of *A. galli*, fed to young chicks, hatched and produced infections in these latter hosts (Table 3), as evidenced by the presence of larval worms in their small intestines. Since chickens are known to feed to some extent on insects, it is conceivable that they could acquire *A. galli* infections by consuming cockroaches that act as transport hosts for the species.

When eggs of *H. diminuta* were fed to flour beetles, cysticercoids developed in the hemocoel of these insects. The possibility does exist that in nature cross-transmission of eggs of this species from cockroaches, acting as transport hosts, could conceivably be picked up by intermediate hosts such as certain species of beetles.

In assessing the importance of cockroaches in helminthic infections it may be presumed that any aspect of the life history of the parasite which overlaps the physical range of the cockroach conceivably could enhance infections of hosts. Numerous factors favor effective transmission, including: (a) indiscriminate eating habits-eating both food and feces of man and other animals, Snipes and Taubner (18), Jung and Schaffer (19); (b) being active migrators during hours of darkness, Laing (20); Jackson and Haier (21); (c) their delay in emptying their crops following a full meal, and (d) inability to digest the eggshells of helminths.

The fact that chickens eat cockroaches has been well established (22, 23). Cockroaches may be eaten as a regular article of diet, not only by numerous species of birds, but mammals as well. As experimental prey, cockroaches have been fed to dogs, cats and guinea pigs (24) and may be ingested by snakes and toads (25).

It has been suggested that roaches may at times depend upon feces as a source of food and it is not uncommon to find them in nests or burrows or rats and mice (26). Tiner (27, 28) suggested that rodents

TABLE 4. *The percentage of cockroaches ingesting eggs of cestodes to those voiding the eggs*

Eggs of Cestodes	*Periplaneta americana*		*Blattella germanica*		*Blaberus giganteus*		*Parcoblatta* sp.		Animals Infected
	Number roaches used	Percentage voiding eggs	Number roaches used	Percentage voiding eggs	Number roaches used	Percentage voiding eggs	Number roaches used	Percentage voiding eggs	
Hydatigera taeniaeformis	20	100	20	100	5	80	12	75	Rats (4)
Taenia pisiformis	20	70	20	65	6	80	12	67	
Cittotaenia pectinata	12	100	10	90	6	100	10	70	
Dipylidium caninum	20	80	10	100	6	67	10	70	
Mesocoestoides lineatus	10	67	10	80	6	67	12	90	
Hymenolepis diminuta	12	100	10	100	6	100	10	100	Flour beetles (3)
Hymenolepis nana	12	100	10	100	6	100	12	100	
Choanotaenia iola	10	80	10	100	5	80	12	85	
Hymenofimbria macracanthus	12	92	10	100	5	100	12	83	

were the intermediate hosts for the roundworm *Ascaris columnaris*, the definitive host being the raccoon and other susceptible animals that may prey upon infected rodents. The method by which the rodent becomes infected is not clear. It is conceivable that in nature a "mammal-wood-roach-rodent-mammal" chain may be involved, since our investigations showed that large numbers of embryonated eggs of *A. columnaris* were obtained from experimentally infected cockroaches.

REFERENCES

1. J. W. S. MACFIE, Ann. Trop. Med. Parasit. 16: 441-448 (1922).
2. K. MORISITA and K. TSUSCHIMOCHI, Jour. Med. Assoc. Formosa. 255: 566-599 (1936).
3. A. PORTER, So. African Jour. Sci. 25: 396-401 (1929).
4. A. PORTER, Jour. Med. Assoc. So. Africa. 4: 18-21 (1930).
5. K. AKKERMAN, Acta Leidensia. 8: 80-120 (1933).
6. G. D. SCHMIDT, Karger, Basel. Switz. pp. 144-156 (1972).
7. S. YAMAGUTI, *System Helminthum: Acanthocephala*, V. Intersc. Pub. N.Y. 1963 pp. 131-132.
8. A. D. ACHOLONU and O. J. FINN, Trans. Amer. Micro. Soc. 93: 141-142 (1974).
9. G. ZMEEV, THUDY TADZHIKSH, BAZY AKAD. Nauk SSSR. 6: 241-248 (1936).
10. V. PEREZ, Arch. Interna. Hidatiodosis, Madrid. 14: 119 (1955).
11. V. A. SONDAK, Parazit. Perencosch. i ladovit. Zhivotn. Sborn. Rabot Pavlovskii 1909-1934. pp. 316-327 (1935).
12. A. C. CHANDLER, Indian Med. Cas. 61: 209-212 (1926).
13. G. MARIANI and B. BESTA, Anch. Ital. Sci. Med. Colon e. Parasit. 17: 177-183 (1936).
14. M. GIORDANA, *Patalogia. parassitiologia ed igiene dei paesi caldi*. Bol. I, Italy, 1950, pp. 812.
15. A. C. CHANDLER, Jour. Amer. Med. Assoc. 78: 636-639 (1922).
16. W. A. RILEY and O. A. JOHNSON, *Medical Entomology*, McGraw-Hill, N.Y., 1939, pp. 485.
17. D. H. CAMPBELL, Amer. Jour. Hyg. 23: 104-113 (1936).
18. B. SNIPES and C. E. TAUBER, Ann. Ent. Soc. Amer. 30: 277-284 (1937).
19. R. C. JUNG and M. F. SCHAFFER, Amer. Jour. Trop. Med. Hyg. 1: 990-998 (1952).
20. J. LAING, Brit. Mus. (Nat. Hist.) Econ. Ser. 12: 1-24 (1938).
21. W. B. JACKSON and P. O. HAIER, Amer. Jour. Trop. Med. Hyg. 4: 141 (1955).
22. J. W. FIELDING, Austral. Jour. Exp. Biol. Med. Sci. 3: 225-232 (1926).
23. J. W. FIELDING, Austral. Jour. Exp. Biol. Med. Sci. 4: 273-281 (1927).
24. N. HOBMAIER, Jour. Parasit. 27: 233-235 (1941).
25. D. V. MOORE, Jour. Parasit. 32: 257-271 (1946).
26. F. N. YOUNG. Fla. Ent. 32: 77 (1949).
27. J. D. TINER. Jour. Parasit. 35: 13 (1949).
28. J. D. TINER, Jour. Mammal. 34: 153-167 (1953).