PARASITIC INFECTIONS OF MAN AND ANIMALS IN HAWAII

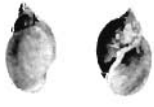
Joseph E. Alicata

This pdf file contains pages excerpted from Technical Bulletin 61 that relate to *Angiostrongylus cantonensis*, the rat lungworm, its rat host (p. 80–84), its intermediate mollusk hosts (p. 24–26), and information on angiostrongylosis disease in humans (p. 31–36). The entire 138-page bulletin is available as a pdf file (~37 MB) at the community home page of the College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, on ScholarSpace:
http://scholarspace.manoa.hawaii.edu/handle/10125/1877

HAWAII AGRICULTURAL EXPERIMENT STATION
COLLEGE OF TROPICAL AGRICULTURE
UNIVERSITY OF HAWAII
HONOLULU, HAWAII NOVEMBER 1964

TECHNICAL BULLETIN NO. 61

MOLLUSKS OF PARASITOLOGICAL IMPORTANCE IN HAWAII

MOLLUSK (NATURAL SIZE)	LOCATION FOUND	IMPORTANCE
SNAILS		
Achatina fulica 	On land	Intermediate host for the rat lungworm, *Angiostrongylus cantonensis,* which produces cerebral angiostrongylosis (parasitic eosinophilic meningoencephalitis) in man (*see* pp. 31–36).
Bradybaena similaris 	On land	Intermediate host for: (a) the cat lungworms, *Anafilaroides rostratus* and *Aelurostrongylus abstrusus;* (b) the chicken cecal fluke, *Postharmostomum gallinum;* (c) the rat lungworm, *Angiostrongylus cantonensis,* which produces cerebral angiostrongylosis (parasitic eosinophilic meningoencephalitis) in man (*see* pp. 31–36).
Fossaria ollula 	On banks of freshwater streams and swamps	Intermediate host for the cattle liver flukes, *Fasciola gigantica* and ***F. hepatica.***

MOLLUSKS OF PARASITOLOGICAL IMPORTANCE IN HAWAII

MOLLUSK (NATURAL SIZE)	LOCATION FOUND	IMPORTANCE
Littorina pintado 	On marine rocks	Intermediate host for the blood fluke, *Austrobilharzia variglandis,* of certain fish-eating birds. The larvae (cercariae) emerging from the snails are potentially able to produce dermatitis in man.
Opeas javanicum 	On land	Intermediate host for the rat lungworm, *Angiostrongylus cantonensis (see Achatina fulica).*
Pseudosuccinea columella 	On banks of fresh-water streams and swamps	(Same as *Fossaria ollula*)
Stenomelania newcombi 	In fresh-water streams	Intermediate host for the following intestinal flukes: (a) *Centrocestus formosanus* in the night heron and rat; (b) *Haplorchis yokogawai* in the night heron; (c) *Stellantchasmus falcatus* in the cat, dog, man, and rat. Also intermediate host for the eye-fluke, *Philophthalmus gralli,* in the Hawaiian coot, and also capable of developing in mammals.
Subulina octona 	On land	(Same as *Bradybaena similaris*)

MOLLUSKS OF PARASITOLOGICAL IMPORTANCE IN HAWAII

MOLLUSK (NATURAL SIZE)	LOCATION FOUND	IMPORTANCE
Thiara granifera 	In fresh-water streams	Intermediate host for the following intestinal flukes: (a) *Centrocestus formosanus* in the night heron and rat; (b) *Haplorchis taichui* and *H. yokogawai* in the night heron; (c) *Stellantchasmus falcatus* in the cat, dog, man, and rat. Also intermediate host for the eye-fluke, *Philophthalmus gralli*, in the Hawaiian coot, and also capable of developing in mammals. Potential host for the lung fluke, *Paragonimus westermani*, in man.
SLUGS		
Deroceras laeve 	On land and vegetation	Intermediate host for the rat lungworm, *Angiostrongylus cantonensis* (*see Achatina fulica*).
Veronicella alte 	On land and young ones occasionally on vegetation	Intermediate host for the rat lungworm, *Angiostrongylus cantonensis* (*see Achatina fulica*).

in a child in the continental United States (Dent *et al.,* 1956); consequently, therefore, cerebral toxocarosis may give rise to eosinophilic meningoencephalitis.

In 1961, the rat lungworm, *Angiostrongylus cantonensis,* was recovered in Hawaii at an autopsy on the brain of a Filipino with a history of eosinophilic meningoencephalitis (Rosen *et al.,* 1961, 1962). This finding followed the discovery by Ash (1962*b; see* Parasites of Rat) of the adult stage of *A. cantonensis* (fig. 31*d*) in the lungs of local rats, and confirmed the speculation originally made by Alicata (1961, 1962*a*) that this parasite may be the causative agent of eosinophilic meningoencephalitis in the Pacific (*see also* Alicata and McCarthy, 1964). A case of this disease, also referred to as parasitic meningoencephalitis and cerebral angiostrongylosis, occurred in a Japanese laborer in Hawaii following ingestion of two garden slugs, *Veronicella alte* (*see* Horio and Alicata, 1961).

A. cantonensis is normally a parasite of rats and utilizes mollusks (pp. 24–26) as intermediate hosts (*see* Parasites of Rat). Land planarians (*Geoplana septemlineata*) in Hawaii, and fresh-water prawns (*Macrobrachium* sp.) and land crabs in other Pacific areas, have been found to serve as paratenic or transport hosts for the infective larvae (Alicata and McCarthy, 1964); experimentally, pigs and calves have also been found to serve in that capacity (Alicata, 1964*b*).

Human infection with *A. cantonensis* most likely occurs as a result of eating uncooked food (fig. 3) containing infective larvae of the parasite. Eating habits and customs of people may play an important part. In Tahiti, the common occurrence of eosinophilic meningoencephalitis has been traced to the customary habit of eating raw prawns, including, possibly, "taioro." The latter consists of grated coconut to which is added prawn juice, prepared by grinding the stomach and surrounding portions of the prawns in fresh water (Alicata and Brown, 1962). In Thailand, the disease is believed to be acquired as a result of eating the large amphibious snail, *Pila ampullacea* (*see* Punyagupta, 1964). The fleshy head-foot part of the snails is cut and then either dipped in boiling water or stored in an icebox to keep it fresh. It is then eaten after being chopped into small pieces, seasoned with lime juice, and mixed with vegetables. In New Caledonia and Hawaii, where eosinophilic meningoencephalitis occurs sporadically, it is probably acquired through the accidental ingestion of an infected small garden slug, or a carrier host such as a land planarian, with contaminated salad greens (Alicata, 1963*a;* Mead, 1963). Furthermore, in some areas, human infection may possibly take place from eating raw land crabs (Alicata, 1964*a*) and improperly cooked liver or other internal organs of swine or calves (Alicata, 1964*b*). These animals in their foraging habits are believed to ingest live mollusks.

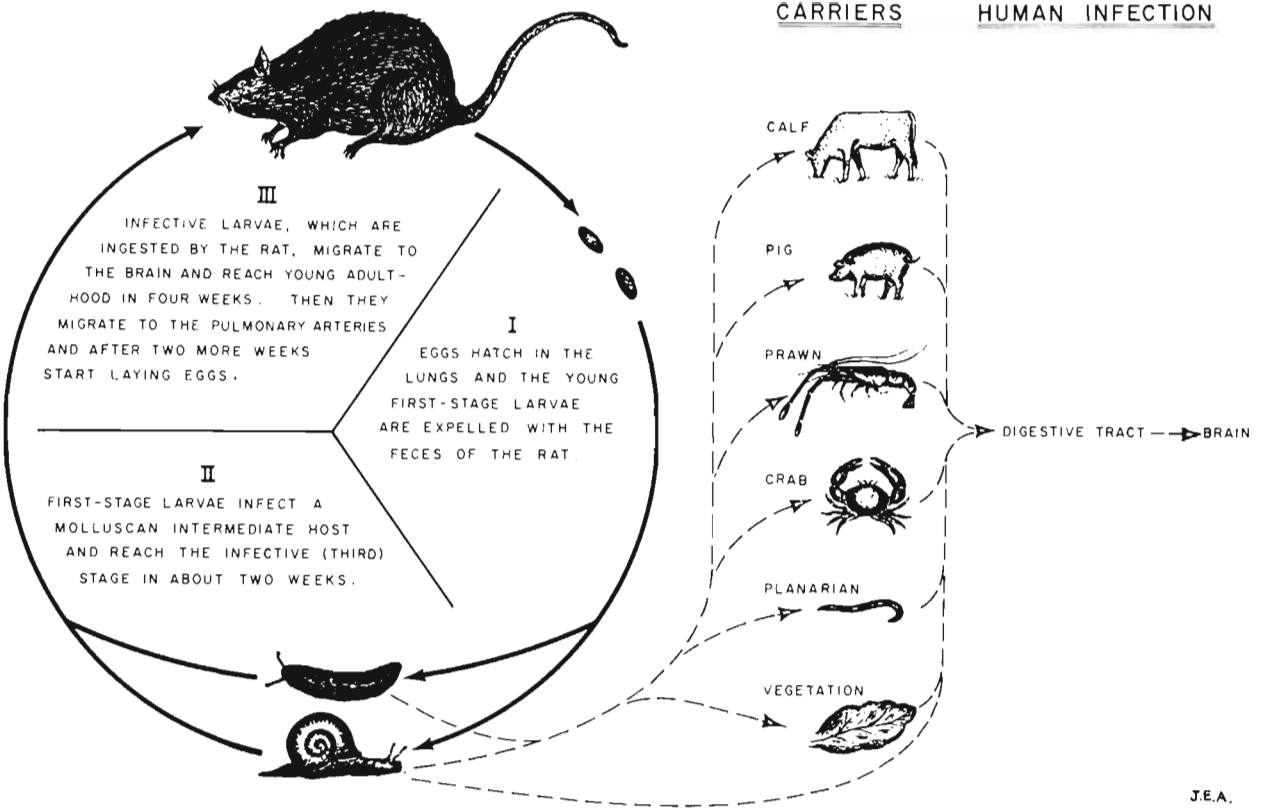


FIGURE 3. Life cycle of the rat lungworm, *Angiostrongylus cantonensis*, and possible avenues of human infection. (Original.)

Experimentally, living larvae of *A. cantonensis* have been found in the stomach wall, liver, lungs, and spleen of pigs and calves 2 weeks after infection. In the pig, however, the larvae were found encapsulated and dead in the above organs 5 weeks after infection. The comparatively early encapsulation of the larvae, therefore, appears to minimize the importance of the pig as a carrier host. Experimentally, these larvae have not been found to migrate to the voluntary muscles of pigs or calves (Alicata, 1963*c*, 1964*b*). To what extent pigs and calves are infected with larvae of *A. cantonensis* under natural conditions and thus serve as sources of human infection remains to be determined.

Eosinophilic meningoencephalitis is a syndrome characterized by the presence of eosinophils in the cerebrospinal fluid. In man this syndrome has at times been noted in connection with cases of nonhelminthic and helminthic infections involving the central nervous system. Nonhelminthic infections have been observed in some cases of cerebral tumors, epidemic cerebrospinal meningitis, neurosyphilis, purulent meningitis, and tubercular meningitis (Kaczynski, 1936). Helminthic infections include cerebral angiostrongylosis (Horio and Alicata, 1961; Rosen *et al.*, 1962; Alicata, 1963*a*), cerebral cysticercosis (Kulkov, 1930), cerebral echinococcosis (Applebaum and Wexberg, 1944), cerebral paragonimiasis (Uematsu and Shiozaki, 1935; Nonomura, 1941), and cerebral schistosomiasis (Castaigne *et al.*, 1959).

In the Pacific Basin, cases of eosinophilic meningoencephalitis have been reported from Micronesia, Polynesia, and Melanesia. A few additional cases have been reported from Japan (Nonomura, 1941) and the Philippines (Sison *et al.*, 1951). In Southeast Asia, cases have occurred in Thailand (Punyagupta, 1964) and Sumatra (Smit, 1962). Laboratory and field evidence suggests that *A. cantonensis* is in most cases the causative agent of eosinophilic meningoencephalitis in Hawaii and other Pacific islands. This evidence includes: (a) recovery of young adult *A. cantonensis* from man in two cases of eosinophilic meningoencephalitis (Nomura and Lin, 1945; Rosen *et al.*, 1962); (b) capability of the larvae of *A. cantonensis* to travel to the central nervous system of simian primates and to give rise to eosinophilic meningoencephalitis (Alicata, 1962*a*; Alicata, Loison, and Cavallo, 1963; Weinstein *et al.*, 1963); (c) record of two human cases of eosinophilic meningoencephalitis following the willful ingestion of raw slugs from endemic areas (Horio and Alicata, 1961; Alicata, 1963*a*); (d) record of a human case of the disease in Honolulu following the ingestion of six raw giant African snails, *Achatina fulica* (*see* Mookini, 1964); (e) presence of lungworms among rats in all the Pacific islands (fig. 4; *see also* Parasites of Rat) in which eosinophilic meningoencephalitis has been recorded, namely, Cook Islands (Alicata and McCarthy, 1964), Formosa (Nomura and Lin, 1945), Guam (Loison, 1963), Hawaii (Horio and Alicata, 1961; Rosen *et al.*,

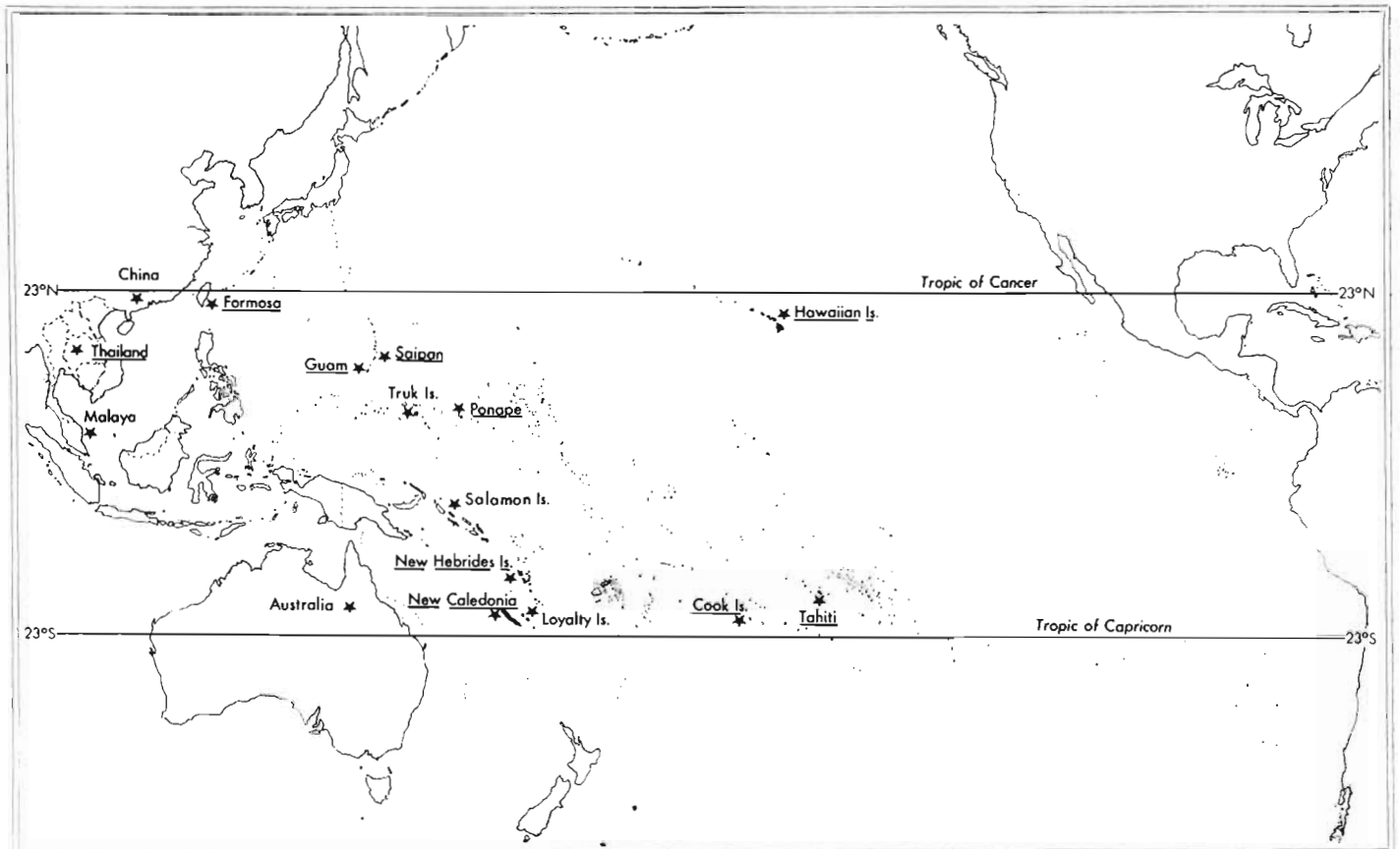


FIGURE 4. Geographical distribution of the rat lungworm, *Angiostrongylus cantonensis,* in the Pacific islands and Southeast Asia (*indicated by stars*), and its relationship to the distribution of eosinophilic meningoencephalitis in man (*underscored*). (*See* text, pp. 31–36.)

1962), New Caledonia (Trubert, 1952), New Hebrides (Loison, 1963), Ponape (Bailey, 1948), Saipan (Allison, 1962), and Tahiti (Franco *et al.,* 1960); (f) absence of the disease in areas of the Pacific where the rat lungworm is not known to occur, namely, Fiji, Samoa, Tonga, and Wallis (Loison, 1963); (g) high incidence of eosinophilic meningoencephalitis in Tahiti correlated with the frequent consumption of raw prawns, 4 percent of which have been found infected with the larvae of *A. cantonensis* (*see* Alicata and Brown, 1962); and (h) widespread incidence of the disease in parts of Thailand correlated with consumption of insufficiently cooked amphibious snails, *Pila ampullacea* (*see* Punyagupta, 1964).

The cause of eosinophilic meningoencephalitis reported from Japan and possibly from the Philippines, where *A. cantonensis* is not known to occur, in all probability is due to cerebral paragonimiasis. In Japan, Uematsu and Shiozaki (1935) reported a pleocytosis of 1,441 cells per cubic millimeter, consisting of practically all eosinophils, in the cerebrospinal fluid of an individual who showed meningeal irritations, cloudiness of both lungs in the X-ray examination, and numerous *Paragonimus* eggs in the sputum. In the same way, Nonomura (1941) reported a pleocytosis with 98 percent eosinophils in the cerebrospinal fluid of another patient in Japan. Although no fluke eggs were found in the sputum of this patient, Nonomura concluded that the pleocytosis was most likely produced by cerebral paragonimiasis. Furthermore, the sporadic cases of eosinophilic meningoencephalitis, which have been reported from Europe and North and South America, where *A. cantonensis* is not known to occur, are possibly caused by one or more species of helminths which occasionally invade the central nervous system (Smit, 1962). Of importance in this connection is the finding of eosinophilic infiltration of the meninges, resulting from larval infection of *Toxocara canis,* which has been observed in a child in the continental United States (Dent *et al.,* 1956). Etiologically, however, infection with larvae of *Toxocara* occurs most commonly in young children, whereas eosinophilic meningoencephalitis in the Pacific area occurs chiefly among adults.

Of interest is the apparent absence of *A. cantonensis* among rats in Fiji, the Philippines, Samoa, Tonga, and Wallis Islands, whose climatic conditions and fauna are generally similar to those of other Pacific islands in which the parasite occurs. In all probability, this condition points out that the parasite is a recent immigrant to the Pacific islands and one which as yet has not become more widely distributed. Its original source of dispersal appears to be Eastern Asia. It was first recorded from Canton, China, by Chen in 1935, and in 1937 it was reported by Matsumoto and Yokogawa from Formosa. It appears to have gradually spread to various Pacific islands either through importation of infected mollusks or infected rats. This has probably been brought about by recent increased commercial and military shipping

operations, especially during World War II, from Eastern Asia to various Pacific ports. Further evidence of the recent dispersal of the rat lungworm in the Pacific region appears to be the recent occurrence of eosinophilic meningoencephalitis in the Pacific islands. This syndrome was first noted in Formosa in 1944 (Nomura and Lin, 1945), Ponape in 1947 (Bailey, 1948), New Caledonia in 1951 (Trubert, 1952), and Tahiti in 1958 (Franco *et al.*, 1960).

As indicated above, *A. cantonensis* was first discovered in East Asia in 1935. Furthermore, the first case of eosinophilic meningoencephalitis in the Pacific was reported from Formosa in 1944. In this connection, it is of importance to note that these findings followed shortly after the introduction of the giant African snail, *Achatina fulica,* in the areas. *A. fulica* is an ideal intermediate host of *A. cantonensis.* According to Mead (1961), during the nineteenth century, the achatinid snails became dispersed from their East African home to Southeast Asia and from there to East Asia and the Pacific islands. They were first found in Malaya in 1911, Indonesia in about 1930, China in 1931, Formosa in 1932, the Mariana and Hawaiian Islands in 1936. These data point out that *A. fulica* might have imported or assisted in the spread of the rat lungworm in Asia and in the Pacific islands. If this is true, it is possible that the original habitat of the parasite is East Africa, the same as that of *A. fulica.* Although *A. fulica* is not known to occur in Australia, New Caledonia, or Tahiti, where *A. cantonensis* is now found, it is possible that the parasite was imported in these areas through infected land mollusks or infected rats from Southeast Asia or Indonesia after it had become established there. The probability that *A. cantonensis* might have originated from East Africa or nearby areas is being further investigated by the author.*

The geographical area in which *A. cantonensis* is presently known to occur in man and rodents is limited to the tropical belt which extends approximately from the Tropic of Cancer (23° North latitude) to the Tropic of Capricorn (23° South latitude) (fig. 4), and from Thailand (100° East longitude) to the island of Tahiti (150° West longitude). This area is characterized by tropical and subtropical climate, moderate to heavy rainfall, and considerable vegetation. All these factors are highly conducive for the propagation and spread of mollusks and rodents.

TAPEWORMS

Most cases of tapeworm infection that have occurred in Hawaii probably represent infections acquired elsewhere. In a survey carried out by Powers

* After this manuscript was submitted for publication, Dr. Kenichi Nishimura and Dr. Mariano G. Yogore reported to the writer of finding *Angiostrongylus cantonensis* among rats in Manila. The writer has also found *A. cantonensis* in the lungs of rats on the islands of Mauritius, Madagascar, and Ceylon.

ARTHROPODS

The mite, *Psoroptes equi cuniculi,* which causes ear mange, is the most important external parasite affecting domestic rabbits. It is as troublesome in Hawaii as in other areas. The inflammatory reaction produced by the mite causes a brownish discharge which cakes inside of the ears. Affected animals frequently shake their head and try to scratch their ears with their hind feet. The mite, *Notoedres cati cuniculi,* has also been collected from the face of the rabbit (Haramoto, 1961). Mites are transmitted by contact.

RAT

PROTOZOA

The blood flagellate, *Trypanosoma lewisi,* has been reported from wild rats inhabiting a gulch in the Hamakua District of the island of Hawaii (Kartman, 1954). The incidence of infection among the field rat, *Rattus exulans,* was said to be almost four times that of *R. norvegicus* and about two times that of *R. rattus* and its subspecies. On the basis of epizootiological evidence, it was suggested that the rat flea, *Xenopsylla vexabilis hawaiiensis,* is the principal intermediate host. *Trypanosoma conorhini,* a blood parasite of an unknown vertebrate, has been reported from the reduviid bug, *Triatoma rubrofasciata,* collected under a chicken coop on the island of Oahu (Wood, 1946). This parasite has been grown experimentally in rats and mice, and in culture media (Johnson, 1947).

ROUNDWORMS

In a survey of parasites of rats in Honolulu, the following species and percentages of roundworms were found (Ash, 1962*b*): stomach worms, *Gongylonema neoplasticum* (fig. 31*a*), 53; *Physaloptera muris-braziliensis* (fig. 31*c*), 37; intestinal worms, *Heterakis spumosa,* 46; *Nippostrongylus brasiliensis,* 17; *Strongyloides ratti,* 17; *Syphacia obvelata,* 44; urinary bladderworm, *Trichosomoides crassicauda* (fig. 31*b*), 17; lungworm, *Angiostrongylus cantonensis* (fig. 31*d*), 12; liver capillarid, *Capillaria hepatica* (fig. 31*e*), 28. The intestinal capillarid, *Capillaria traverae,* and the acanthocephalan, *Moniliformis moniliformis,* were also reported. A fatal case of *C. hepatica* infection has also been reported from a child in Hawaii (*see* Parasites of Man).

In addition to the above, *Trichinella spiralis* (fig. 32*a*) occurred in 2.7 percent of the rats examined from the island of Hawaii, and in 0.09 percent from the island of Maui (Alicata, 1938*c*). No trichinae have been found among rats on the islands of Oahu and Kauai. This parasite occurs in man and swine in Hawaii (*see* Parasites of Man, and Swine).

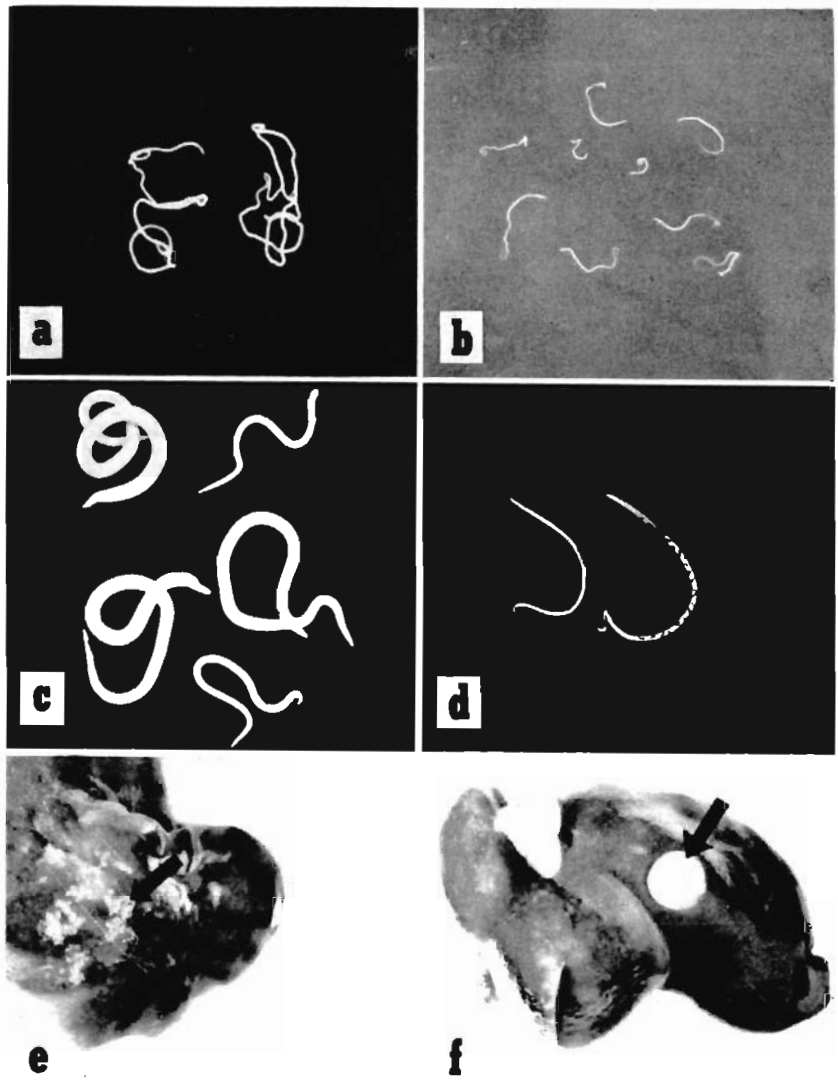


FIGURE 31. Parasites of the rat: *a,* adult *Gongylonema neoplasticum; b,* adult bladderworms, *Trichosomoides crassicauda; c,* adult stomach worms, *Physaloptera muris-brasiliensis; d,* adult lungworms, *Angiostrongylus cantonensis; e,* liver showing clusters (*arrow*) of eggs and adults of *Capillaria hepatica; f,* liver showing (*arrow*) encysted infective larval stage (strobilocercus) of the cat tapeworm. *Hydatigera taeniaeformis.* All natural size. (Original.)

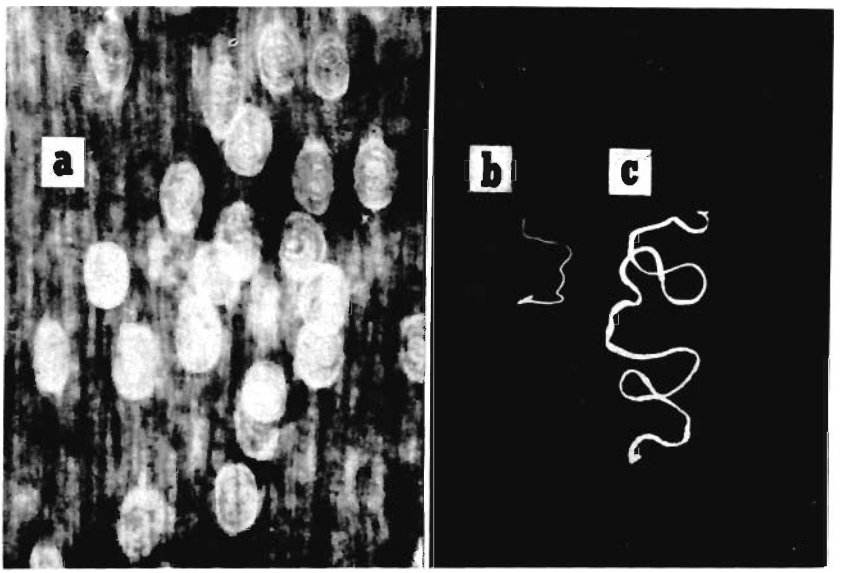


FIGURE 32. *a*, Infective larvae of *Trichinella spiralis* encysted in the diaphragm of rat, highly magnified; *b*, adult tapeworm, *Hymenolepis nana*, natural size; *c*, adult tapeworm, *Hymenolepis diminuta*, natural size. (Original.)

Of the above roundworms, *Gongylonema neoplasticum* utilizes certain cockroaches and beetles as intermediate hosts. These include *Blatella germanica, Periplaneta americana,* and *Tenebrio molitor* (*see* Hall, 1929), all of which occur in Hawaii. According to O'Dea (1964), the stomach worm, *Physaloptera muris-brasiliensis,* has been experimentally determined to utilize the following arthropods as intermediate hosts: (Order: Coleoptera) *Dermestes vulpinus, Tenebroides nana,* and *Tribolium castaneum;* (Order: Orthoptera) *Nauphoeta cinerea* and *Periplaneta americana.*

The lungworm, *Angiostrongylus cantonensis,* utilizes a mollusk as intermediate host (pp. 24, 26 and fig. 3). The development of this parasite to the infective or third-larval stage (fig. 33*e*) in the garden slug, *Deroceras laeve,* was first described by Mackerras and Sandars (1955). These writers also traced the development of the parasite in the rat host and determined that during larval development it invaded the brain and produced dilation of the meningeal vessels and leucocytic infiltration. The rat lungworm was first found in Hawaii by Ash in November, 1960 (Ash, 1962*b*). Subsequently the giant African snail, *Achatina fulica,* the garden snails, *Bradybaena similaris* and *Subulina octona,* and the garden slug, *Veronicella alte,* were found to be suitable ex-

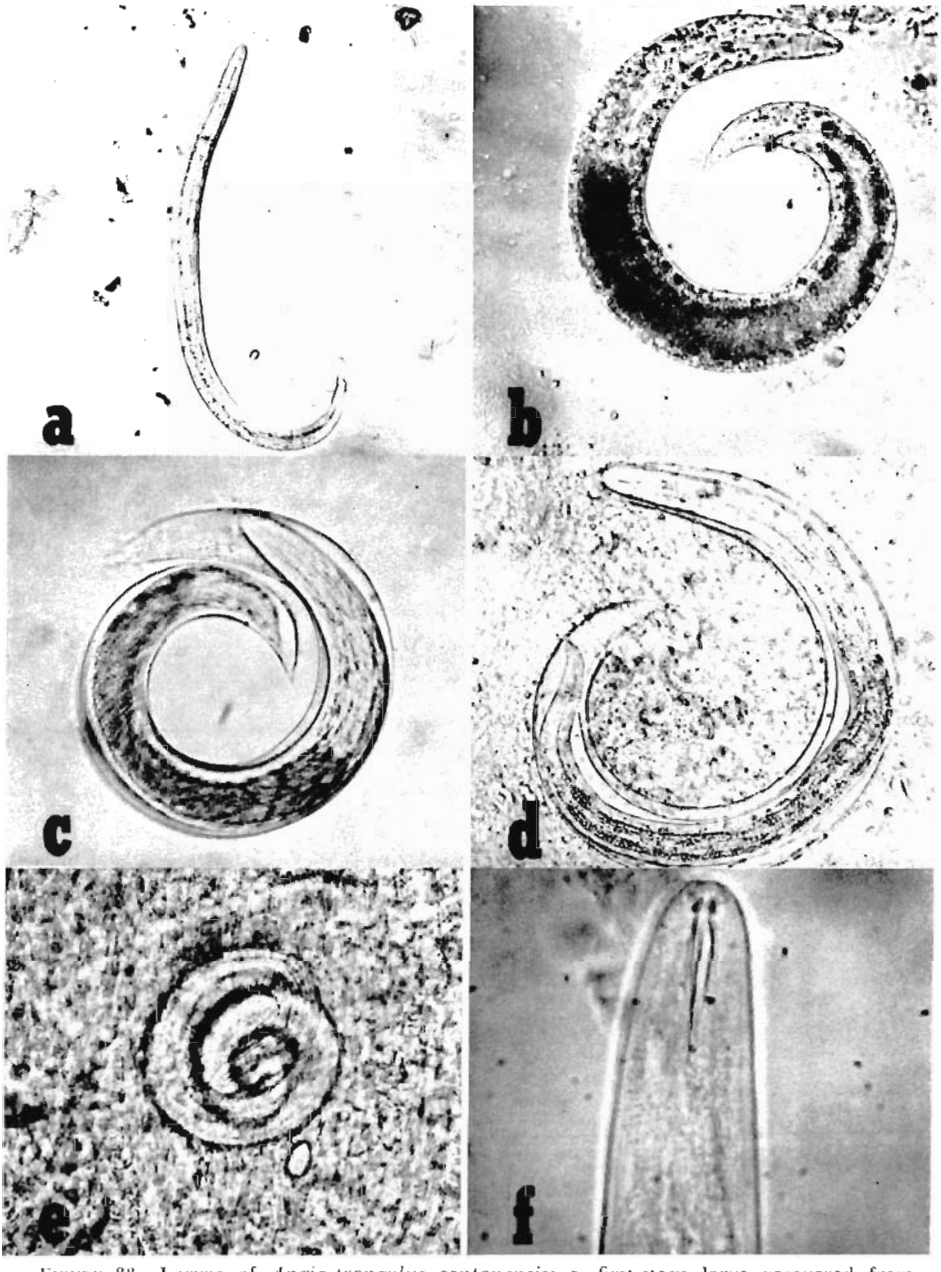


FIGURE 33. Larvae of *Angiostrongylus cantonensis: a*, first-stage larva recovered from feces of rat, ×300; *b*, full-grown first-stage larva from snail, ×300; *c*, second-stage larva enclosed within cuticle of first molt from snail, ×300; *d*, third-stage larva enclosed within cast cuticles of the first and second molt from snail, ×300; *e*, third-stage larva coiled in the musculature of snail, ×300; *f*, anterior end of third-stage larva showing the characteristic sclerotized stomatorhabdions in buccal cavity, ×610. (*a–e*, Original; *f*, after Alicata, 1962, courtesy of *Canadian Journal of Zoology*.)

perimental intermediate hosts (Alicata, 1962*a*). Included also is the garden snail, *Opeas javanicum*, and possibly other members of this genus. According to Kondo (1964), malacologist, Bishop Museum, seven species of *Opeas* occur in Hawaii as follows: *O. beckianum*, *O. clavulinum*, *O. goodalli*, *O. javanicum*, *O. mauritianum*, *O. oparanum*, and *O. opella*. The fresh-water snail, *Fossaria ollula*, was also found to be a suitable experimental host (Alicata and Brown, 1962). Of the above mollusks, *A. fulica*, *B. similaris*, *S. octona*, *O. javanicum*, *V. alte*, and *D. laeve* have been found naturally infected with the larvae of the rat lungworm. The land planarian, *Geoplana septemlineata*, in Hawaii also frequently harbors the infective lungworm larvae (Alicata, 1962*a*). Planarians, however, serve only as paratenic or transport hosts and acquire the larvae from feeding on the bodies of naturally infected snails. *A. cantonensis* is able to invade the brain of man and of the monkey and to produce cerebral angiostrongylosis (parasitic eosinophilic meningoencephalitis) (*see* Parasites of Man).

In addition to Hawaii, *A. cantonensis* has been reported among rats from other islands of the Pacific and parts of Southeast Asia, as follows (fig. 4): Espiritu Santo, New Hebrides (Alicata, 1963*a*); Formosa (Yokogawa, 1937); Guadalcanal, Solomon Islands (Loison, 1964); Guam (Lindquist and Li, 1955); Lifou, Loyalty Islands (Alicata, 1963*a*); Malaya (Schacher and Cheong, 1960); New Caledonia (Alicata, 1963*a*); Moen, Pingalap, and Ponape, Caroline Islands (Jackson, 1962); Rarotonga, Cook Islands (Alicata and McCarthy, 1964); Rota, Saipan, and Tinian, Mariana Islands (Alicata, 1961*c*); Tahiti (Alicata, 1962*a*); China (Chen, 1935); and Thailand (Punyagupta, 1964). In addition to rats of the genus *Rattus*, *A. cantonensis* has also been reported from the bandicoot rat, *Bandicota indica nemorivaga*, in Formosa (Kuntz and Myers, 1964).

TAPEWORMS

In a survey conducted by Ash (1962*b*), *Hymenolepis nana* (fig. 32*b*) and *H. diminuta* (fig. 32*c*) were recovered in approximately 50 percent of the rats examined in Honolulu. The infective stage (strobilocercus) of the cat tapeworm, *Hydatigera taeniaeformis*, was found in the liver of about 10 percent of the rats examined (fig. 31*f*). The high incidence of this larval parasite in the rat corresponded with the frequency of occurrence of the adult parasite in the cat (*see* Parasites of Cat). *H. nana* also has been found in man in Hawaii (*see* Parasites of Man).

Although most tapeworms have an indirect life cycle, *H. nana* can have either a direct or an indirect life cycle. In the former, the eggs are ingested by the definitive host and the young larvae penetrate the intestinal wall to form a tailless cysticercoid. These eventually emerge into the lumen of the