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FOREWORD

Parasites probably were introduced into Hawaii with the first colonization by man perhaps fifteen hundred or more years ago. However, parasitism appears not to have been important or at least not recognized until about 1800 when European and American ships began to call frequently. Since that time, parasites have been found in many species; for instance, in birds, including chickens, turkeys, pigeons, pheasants, doves, ducks, sparrows, herons, coots, and quails, and in mammals, including mice, rats, mongooses, rabbits, cats, dogs, pigs, sheep, cattle, horses, and man. There is a certain uniqueness in the compressed history of the infestations paralleling the sweeping spread of virus diseases when introduced into new territories.

The reports of these parasitic diseases have heretofore been widely scattered in the literature, and Professor Alicata's publication now provides an orderly and systematic presentation of the entire field. He considers in sequence the considerable number of diseases reported to be caused in Hawaii by protozoa, the very large number caused by nemathelminthes, and the smaller group caused by platyhelminthes. This publication will furnish basic information for future parasitologists who in turn will be immensely grateful.

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The major fields of research by the author have included the following: life history and control of livestock parasites; use of X-irradiation in pork for the control of human trichinosis; use of hexachloroethane for the control of bovine fascioliasis; survey of parasites of man and animals in the Pacific islands; epidemiology of typhus and leptospirosis in Hawaii; search for evidences pertaining to the theory first proposed by the author, that *Angiostrongylus cantonensis* may be the causative agent of eosinophilic meningoencephalitis of man in the Pacific.

PARASITIC INFECTIONS OF MAN AND ANIMALS IN HAWAII*

JOSEPH E. ALICATA

INTRODUCTION

There are no indications that parasites of man and animals were known or recognized by the early Hawaiians. Although it is likely that the first parasites in the Hawaiian Islands were introduced by migratory birds hundreds of years ago, in all probability most of those now present postdate the discovery of the Islands by Captain Cook in 1778. Since that time there has been in Hawaii a gradual influx of a variety of people, animals, and plants, largely from North America and Asia. All of these importations have resulted in the introduction of many species of parasites and their vectors. To what extent new ones will enter the Hawaiian Islands, especially with the expansion of modern air and ocean transportation, remains to be determined. Much is being done, however, through inspection, quarantine, and other State, Federal, and private agricultural regulatory measures, to prevent the introduction of additional disease-producing organisms and their vectors.

The Hawaiian Islands proper, with which this report is concerned, include the islands of Kauai, Niihau, Oahu, Maui, Molokai, Lanai, Kahoolawe, and Hawaii. Geographically, these islands represent the summit parts of the southeastern portion of the Hawaiian Archipelago, which extends in the mid-Pacific for a distance of about 2,000 miles. The mountains of these islands may be coastal, acentric, or centric in position, and they divide each island into windward and leeward sides. The windward areas are largely eroded to precipitous cliffs or penetrating valleys, and rainfall is greater there than on the leeward areas. This condition results in increased soil moisture, dense vegetation, and swampiness in the windward areas. Moreover, it

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favors the maintenance and dissemination of parasites, and the abundance of aquatic invertebrates which serve as vectors. On the other hand, the leeward areas do not show severe erosion, rainfall is less, and conditions are less favorable for the dissemination of parasites. However, the Islands do have an equable subtropical climate, and in areas below 2,500 feet, where most livestock are raised, the annual mean temperature is approximately 70° F. In general, therefore, topographical and climatic conditions in the Islands are highly favorable the year round for the propagation and spread of parasites and intermediate hosts.

Parasites have considerable veterinary and public health importance. In livestock raising, they may become so severe as to affect production and profits. Constant vigilance must therefore be maintained by the animal producer to see that infection is kept at a minimum. Parasitic diseases are often not spectacular, nor do they cause high mortality eventually. For this reason a stockman either may not be aware of their presence or may not place much importance on them. Frequently the major symptom associated with parasitism is that of general unthriftiness. In most instances this is a slow and gradual process which does not attract attention. The losses usually result from slow and stunted growth, uneconomical use of feed, reduced production, condemnation of meat carcasses in whole or in part, and a waste of time and effort on the part of the owner in maintaining unthrifty and unproductive animals.

Under ordinary animal-raising conditions it is almost impossible to maintain livestock that are free of parasites. However, much can be done to prevent parasites from becoming sufficiently numerous to endanger the health of the animals. This calls for sanitary practices and other specific preventive measures. Drug treatment often plays an important part in parasite control. Destruction of the parasites in the host assists not only in improving the health of the animal but also in reducing pasture or ground contamination. Drug treatment, however, should not be considered as the only means of parasite control, but as an adjunct to good sanitary and management practices.

In the field of public health, awareness of the presence and spread of disease-producing organisms in a community is important in that it assists in the detection, treatment, and prevention of the causative agent. With the exception of enterobiasis, parasitic infections of man acquired in the Hawaiian Islands are comparatively uncommon, and there exist none of the debilitant cases, such as malaria, filariasis, and schistosomiasis, so often found in tropical areas. The low incidence of human parasitism in Hawaii is undoubtedly due to the average high economic, educational, and sanitary levels of the population, plus the active surveillance of the local medical and veterinary authorities, and related workers. Constant alertness by the popula-

tion in the use of preventive measures does go a long way in the control of parasitic infections which have become endemic. These include not only enterobiasis, but also angiostrongylosis, ascariasis, cysticercosis, fascioliasis, heterophyidiasis, toxocarosis, trichinosis, and trichiuriasis, all of which occasionally occur in the Islands.

Of further public health importance is the fact that several parasites of man are acquired from animals. Indeed it is possible that some of the obscure ailments of man are due to these parasites. In Hawaii, parasites which are transmissible directly or indirectly from animals to man include at least the following: *Toxocara canis* and *Dipylidium caninum* from cats and dogs; *Fasciola gigantica* from cattle; *Angiostrongylus cantonensis, Capillaria hepatica,* and *Hymenolepis nana* from rats; *Taenia solium* and *Trichinella spiralis* from swine. Consideration should be given also to the fact that many parasites of man and animals are transmitted by various pests such as insects, mollusks, and rats. Public awareness and active control of these pests in a community are, therefore, important in the control of parasitic diseases.

In this bulletin, an attempt has been made to summarize information by various authors concerning the internal and external parasites of man and animals in the Hawaiian Islands. A list of intermediate hosts, whenever they are present, is also included. For the most part these reports have been compiled noncritically and have been cited in the body of the text and in the bibliography. Greater emphasis has been given to those parasites which have special medical and veterinary importance. It has become evident during the preparation of this report that parasitological information is either inadequate or entirely lacking in a number of important areas. It is hoped that subsequent investigators will be able to enlarge this useful field of knowledge.

CLASSIFICATION OF INTERNAL PARASITES OF MAN AND ANIMALS IN HAWAII

The following is a taxonomically arranged list of internal parasites of land vertebrates reported from the Hawaiian Islands. The classification of the Protozoa is based on that used by Honigberg *et al.* (1964) and Levine (1961), and, for the Nematoda, Cestoda, and Trematoda, for the most part that used by Yamaguti (1958, 1959, 1961). The parasites are classified with reference to the phylum, class, order, family, subfamily (when known), genus, and species.[1] The final host is indicated at the right.

[1] All orders are designated by an asterisk (*), all families by a single dagger (†), all subfamilies by a double dagger (‡); generic and specific names are italicized.

	FINAL HOST
PHYLUM: PROTOZOA	
Class: Zoomastigophorea (flagellates)	
Diplomonadida* Wenyon, 1926	
Hexamitidae† Saville Kent, 1880	
Giardia lamblia (Stiles, 1915)	Man
Kinetoplastida* Honigberg, 1963	
Trypanosomatidae† Doflein, 1901	
Trypanosoma conorhini (Donovan, 1909)	Mouse or Rat (?)
Trypanosoma lewisi (Kent, 1880)	Rat
Rhizomastigida* Doflein, 1916	
Mastigamoebidae†	
Histomonas meleagridis (Smith, 1895)	Chicken, Turkey
Trichomonadida* Kirby, 1947	
Trichomonadidae† Chalmers and Pekkola, 1918 emend. Kirby, 1946	
Pentatrichomonas hominis (Davaine, 1860)	Man
Trichomonas gallinae (Rivolta, 1878)	Pigeon
Class: Rhizopodea (amoebae)	
Amoebida* Kent, 1880	
Endamoebidae† Calkins, 1926	
Dientamoeba fragilis Jepps and Dobell, 1918	Man
Endolimax nana (Wenyon and O'Connor, 1917)	Man
Entamoeba coli (Grassi, 1879)	Man
Entamoeba hartmanni Von Prowazek, 1912	Man
Entamoeba histolytica Schaudinn, 1903	Man
Class: Telosporea (coccidia and haemosporidia)	
Eucoccida* Léger and Duboscq, 1910	
Eimeriidae† Poche, 1913	
Eimeria bovis (Zublin, 1908)	Cattle
Eimeria bukidnonensis Tubangui, 1931	Cattle
Eimeria cylindrica Wilson, 1931	Cattle
Eimeria debliecki Douwes, 1921	Swine
Eimeria scabra Henry, 1931	Swine
Eimeria spinosa Henry, 1931	Swine
Eimeria stiedae (Lindemann, 1865)	Rabbit
Eimeria tenella (Railliet and Lucet, 1891)	Chicken
Eimeria zurnii (Rivolta, 1878)	Cattle

	FINAL HOST
Plasmodiidae† Mesnil, 1903	
Haemoproteus columbae Kruse, 1890	Pigeon-fly
Plasmodium vaughani Novy and McNeal, 1904	Mosquito (?)
Class: Microsporidea (microsporidia)	
Microsporida* Balbiani, 1882	
Toxoplasmatidae†	
Encephalitozoon cuniculi Levaditi, Nicolau, and Schoen, 1923	Rabbit
Class: Ciliatea (ciliates)	
Trichostomatida* Bütschli, 1889	
Balantidiidae† Reichenow, 1929	
Balantidium coli (Malmsten, 1857)	Swine
PHYLUM: NEMATHELMINTHES	
Class: Nematoda (roundworms)	
Rhabdiasidea* Yamaguti, 1961	
Strongyloididae† Chitwood and McIntosh, 1934	
Strongyloides papillosus (Wedl, 1856)	Cattle
Strongyloides ransomi Schwartz and Alicata, 1930	Swine
Strongyloides ratti Sandground, 1925	Rat
Strongyloides stercoralis (Bavay, 1876)	Man
Ascarididea* Yamaguti, 1961	
Ascarididae† Blanchard, 1849	
Ascaridinae‡ Lane, 1923	
Ascaris lumbricoides Linnaeus, 1758	Man, Swine
Parascaris equorum (Goeze, 1782)	Horse
Toxascaris leonina (Linstow, 1902)	Dog
Ascaridiinae‡ Travassos, 1919	
Ascaridia galli (Schrank, 1788)	Chicken
Toxocarinae‡ Yamaguti, 1961	
Toxocara canis (Werner, 1782)	Cat, Dog
Oxyuridea* Weinland, 1858	
Heterakidae† Railliet and Henry, 1914	
Heterakis gallinarum (Schrank, 1788)	Chicken, Pheasant, Turkey
Heterakis spumosa Schneider, 1866	Rat

	FINAL HOST
Oxyuridae† Cobbold, 1864	
Oxyurinae‡ Hall, 1916	
Enterobius vermicularis (Linnaeus, 1758)	Man
Oxyuris equi (Schrank, 1788)	Horse
Passalurus ambiguus (Rudolphi, 1819)	Rabbit
Lauroiinae‡ Skrjabin and Shikhobalova, 1951	
Probstmayria vivipara (Probstmayr, 1865)	Horse
Syphaciinae‡ Railliet, 1916	
Syphacia obvelata (Rudolphi, 1802)	Rat
Subuluridae† Yorke and Maplestone, 1926	
Subulura brumpti (López-Neyra, 1922)	Chicken, Pheasant
Trichuridea* Yamaguti, 1961	
Trichinellidae† Ward, 1907	
Trichinella spiralis (Owen, 1835)	Man, Mongoose, Rat, Swine
Trichosomoididae† Yorke and Maplestone, 1926	
Trichosomoides crassicauda (Bellingham, 1840)	Rat
Trichuridae† Railliet, 1915	
Capillariinae‡ Railliet, 1915	
Capillaria hepatica (Bancroft, 1893)	Man, Rat
Capillaria traverae Ash, 1962	Rat
Trichurinae‡ Ransom, 1911	
Trichuris ovis (Abildgaard, 1795)	Cattle
Trichuris trichiura (Linnaeus, 1771)	Man, Swine
Trichuris vulpis (Froelich, 1789)	Dog
Strongylidea* Diesing, 1851	
Ancylostomatidae† Nicoll, 1927	
Ancylostomatinae‡ Nicoll, 1927	
Ancylostoma caninum (Ercolani, 1859)	Dog
Ancylostoma tubaeforme (Zeder, 1800)	Cat
Bunostominae‡ Looss, 1911	
Bunostomum phlebotomum (Railliet, 1900)	Cattle
Cyathostomidae† Yamaguti, 1961	
Cyathostominae‡ Nicoll, 1927	
Cyathostomum asymmetricum Theiler, 1923	Horse
Cyathostomum bicoronatum Looss, 1900	Horse
Cyathostomum calicatum Looss, 1900	Horse
Cyathostomum catinatum Looss, 1900	Horse
Cyathostomum coronatum (Looss, 1900)	Horse
Cyathostomum euproctum (Boulenger, 1917)	Horse

	FINAL HOST
Cyathostomum goldi (Boulenger, 1917)	Horse
Cyathostomum insigne (Boulenger, 1917)	Horse
Cyathostomum leptostomum (Kotlan, 1920)	Horse
Cyathostomum longibursatum (Yorke and Macfie, 1918)	Horse
Cyathostomum nassatum Looss, 1900	Horse
Cyathostomum pateratum (Yorke and Macfie, 1919)	Horse
Gyalocephalus capitatus Looss, 1900	Horse
Poteriostomum imparidentatum Quiel, 1919	Horse
Oesophagostominae‡ Railliet, 1916	
Oesophagostomum dentatum (Rudolphi, 1803)	Swine
Oesophagostomum radiatum (Rudolphi, 1803)	Cattle
Stephanuridae† Travassos and Vogelsang, 1933	
Stephanurus dentatus Diesing, 1839	Swine
Strongylidae† Baird, 1853	
Strongylinae‡ Railliet, 1893	
Alfortia edentata (Looss, 1900)	Horse
Delafondia vulgaris (Looss, 1900)	Horse
Strongylus equinus Mueller, 1780	Horse
Triodontophorus brevicauda Boulenger, 1916	Horse
Triodontophorus serratus (Looss, 1900)	Horse
Globocephalinae‡ Travassos and Vogelsang, 1932	
Globocephalus urosubulatus (Alessandrini, 1909)	Wild pig
Trichostrongylidae† Leiper, 1912	
Haemoncinae‡ Yamaguti, 1961	
Haemonchus contortus (Rudolphi, 1803)	Cattle, Sheep
Nematodirinae‡ Skrjabin and Orloff, 1934	
Nematodirus spathiger (Railliet, 1896)	Sheep
Ornithostrongylinae‡ Travassos, 1937	
Ornithostrongylus quadriradiatus (Stevenson, 1904)	Pigeon
Trichostrongylinae‡ Leiper, 1908	
Cooperia pectinata Ransom, 1907	Cattle
Cooperia punctata (Von Linstow, 1907)	Cattle, Deer
Cooperia spatulata Baylis, 1938	Cattle
Hyostrongylus rubidus (Hassall and Stiles, 1892)	Swine
Ostertagia circumcincta (Stadelmann, 1894)	Goat
Ostertagia ostertagi (Stiles, 1892)	Cattle
Trichostrongylus axei (Cobbold, 1789)	Horse
Trichostrongylus colubriformis (Giles, 1892)	Goat, Man, Sheep
Viannaiinae‡ Neveu-Lemaire, 1934	
Nippostrongylus brasiliensis (Travassos, 1914)	Rat

	FINAL HOST
Protostrongylidae† Leiper, 1926	
Angiostrongylinae‡ Bohm and Gebauer, 1934	
Angiostrongylus cantonensis (Chen, 1935)	Rat (immature parasites in man)
Dictyocaulinae‡ Skrjabin, 1933	
Dictyocaulus viviparus (Block, 1782)	Cattle
Metastrongylinae‡ Leiper, 1908	
Choerostrongylus pudendotectus (Wostkow, 1905)	Swine
Metastrongylus elongatus (Dujardin, 1845)	Swine
Protostrongylinae‡ Kamensky, 1905	
Aelurostrongylus abstrusus (Railliet, 1898)	Cat
Pseudaliidae† Railliet, 1916	
Filaroidinae‡ Skrjabin, 1932	
Anafilaroides rostratus Gerichter, 1949	Cat
Filaroides osleri (Cobbold, 1879)	Dog
Spiruridea* Diesing, 1861	
Acuariidae† Seurat, 1913	
Acuaria hamulosa (Diesing, 1851)	Chicken, Pheasant, Turkey
Dispharynx nasuta (Molin, 1858)	Chicken
Physalopteridae† Leiper, 1908	
Physalopterinae‡ Stossich, 1898	
Physaloptera muris-brasiliensis Diesing, 1861	Rat
Physaloptera praeputialis Linstow, 1899	Cat
Spiruridae† Oerley, 1885	
Ascaropsinae‡ Alicata and McIntosh, 1933	
Ascarops strongylina (Rudolphi, 1819)	Swine
Physocephalus sexalatus (Molin, 1860)	Swine
Gongylonematinae‡ Nicoll, 1927	
Gongylonema ingluvicola Ransom, 1904	Chicken
Gongylonema neoplasticum (Fibiger and Dittersen, 1914)	Rat
Gongylonema pulchrum Molin, 1857	Cattle
Spirurinae‡ Railliet, 1935	
Cyrnea graphophasiani (Yamaguti, 1935)	Pheasant
Habronema microstoma (Schneider, 1886)	Horse
Habronema muscae (Carter, 1961)	Horse
Thelaziidae† Skrjabin, 1915	
Oxyspirurinae‡ Yamaguti, 1961	
Oxyspirura mansoni (Cobbold, 1879)	Chicken, Dove, English sparrow, Mynah, Pheasant, Quail

	FINAL HOST
Tropisuridae† Yamaguti, 1961	
Microtetrameres sp.	Mynah
Tropisurus americanus (Cram, 1927)	Chicken
Tropisurus sp.	English sparrow
Filariidea* Yamaguti, 1961	
Dipetalonematidae† Wehr, 1935	
Dipetalonematinae‡ Wehr, 1935	
Dipetalonema sp.	Dog
Dirofilariinae‡ Wehr, 1935	
Dirofilaria immitis (Leidy, 1856)	Cat, Dog
Stephanofilariidae† Wehr, 1935	
Stephanofilaria stilesi Chitwood, 1934	Cattle

PHYLUM: PLATYHELMINTHES

Class: Cestoda (tapeworms)

Cyclophyllidea* Beneden in Braun, 1900	
Anoplocephalidae† Cholodkovsky, 1902	
Anoplocephalinae‡ Blanchard, 1891	
Anoplocephala magna (Abildgaard, 1789)	Horse
Anoplocephala perfoliata (Goeze, 1782)	Horse
Moniezia benedeni (Moniez, 1879)	Cattle
Moniezia expansa (Rudolphi, 1805)	Sheep
Davaineidae †Furhmann, 1907	
Davaineinae‡ Braun, 1900	
Raillietina cesticillus (Molin, 1858)	Chicken
Raillietina tetragona (Molin, 1858)	Chicken
Raillietina sp.	Chicken
Dilepididae† Railliet and Henry, 1909	
Dipylidiinae‡ Stiles, 1896	
Choanotaenia infundibulum (Block, 1779)	Chicken
Dipylidium caninum (Linnaeus, 1758)	Cat, Dog, Man
Hymenolepididae† Railliet and Henry, 1909	
Hymenolepidinae‡ Perrier, 1897	
Cloacotaenia megalops (Nitzsch in Creplin, 1829)	Hawaiian duck
Echinolepis carioca (Magalhaes, 1898)	Chicken
Hymenolepis diminuta (Rudolphi, 1819)	Rat
Hymenolepis nana Siebold, 1852	Man, Rat
Hymenosphenacanthus exiguus (Yoshida, 1910)	Chicken
Taeniidae† Ludwig, 1886	
Hydatigera taeniaeformis (Batsch, 1786)	Cat
Taenia hydatigena Pallas, 1766	Dog (*see* p. 74)
Taenia saginata Goeze, 1782	Man
Taenia solium Linnaeus, 1758	Man (*see* p. 37)

	FINAL HOST
Class: Trematoda (flukes)	
Digenea*	
Brachylaemidae† Joyeux and Foley, 1930	
Brachylaeminae‡ Joyeux and Foley, 1930	
Postharmostomum gallinum (Witenberg, 1923)	Chicken
Dicrocoeliidae† Odhner, 1911	
Dicrocoeliinae‡ Looss, 1899	
Platynosomum fastosum Kossack, 1910	Cat
Echinostomatidae† Poche, 1926	
Echinostomatinae‡ Faust, 1929	
Echinostoma sp.	Rat (experimental)
Fasciolidae† Railliet, 1895	
Fasciolinae‡ Stiles and Hassall, 1898	
Fasciola gigantica Cobbold, 1855	Cattle, Man, Swine
Fasciola hepatica Linnaeus, 1758	Cattle
Heterophyidae† Odhner, 1914	
Ascocotylinae‡ Yamaguti, 1961	
Phagicola longus Ransom, 1920	Cat, Dog
Centrocestinae‡ Looss, 1899	
Centrocestus formosanus Nishigori, 1924	Night heron, Rat
Haplorchinae‡ Looss, 1899	
Haplorchis taichui (Nishigori, 1924)	Night heron
Haplorchis yokogawai (Katsuda, 1932)	Night heron
Metagoniminae‡ Ciurea, 1924	
Stellantchasmus falcatus Onji and Nishio, 1915	Cat, Dog, Man, Rat
Philophthalmidae† Travassos, 1918	
Philophthalminae‡ Looss, 1899	
Philophthalmus gralli Mathis and Legar, 1910	Hawaiian coot
Plagiorchiidae† Ward, 1917	
Plagiorchiinae‡ Pratt, 1902	
Plagiorchis muris Tanabe, 1922	Rat
Schistosomatidae† Poche, 1907	
Schistosomatinae‡ Stiles and Hassall, 1898	
Austrobilharzia variglandis (Miller and Northup, 1926)	Ruddy turnstone

THE LIFE CYCLES OF PARASITES

A knowledge of the life cycles of parasites and their methods of infecting the final host is of paramount importance in determining methods of prevention and in formulating effective control measures. It helps to ascertain the weakest or most vulnerable point at which the parasite can best be attacked. Parasites may be controlled while in the final host by the use of chemotherapeutics, or when outside the final host by the use of chemicals and other means such as mechanical or biological destruction of the eggs, larvae, or their vectors. As a rule, each parasite has a specific course of development; however, the general pattern which the parasite follows is more or less similar to that of the group to which it belongs. Parasites have either a direct life cycle, in which they require only one host, or an indirect cycle, in which one or more intermediate hosts are required. An intermediate host is the one in which the young parasite undergoes development leading to the stage which is infective to the final host. When only one intermediate host is required, the infective stage is reached in the first host; when two are necessary, it is attained in the second. The final host is the one in which the parasite reaches the adult or sexual stage.

Animal parasites belong to five major groups; these are the unicellular organisms (Protozoa), and the multicellular forms which include the roundworms (Nematoda), the tapeworms (Cestoda), the flukes (Trematoda), and certain parasitic insects, mites, and ticks (Arthropoda). The roundworms, tapeworms, and flukes discussed here are all internal parasites, whereas the parasitic arthropods are primarily external parasites except for a relatively few insects which, during their larval stage, live in the body of the host. A summary of the life cycle pattern of each of the above groups of parasites which are represented in this bulletin is given below. For a detailed account of the life cycle of a variety of internal parasites, *see* Olsen (1962); for the arthropods, the reader should refer to various books on medical entomology.

Life Cycle of Protozoa

The known protozoan parasites of man and animals in Hawaii include the amoebae (Rhizopodea), the flagellates (Zoomastigophorea), the ciliates (Ciliatea), and the coccidia and haemosporidia (Telosporea). The haemosporidia are blood parasites which have an indirect life cycle. Included with the blood parasites are the flagellates, *Trypanosoma lewisi,* of rats, which utilize fleas as their vector, and the flagellates, *Trypanosoma conorhini,* believed to be parasites of rodents, which utilize reduviid bugs as their vector. All the other protozoa of man and animals in Hawaii live, for the most part, in the digestive tract, although some live in other tissues of the body and have a direct life cycle.

The amoebae, in the active or trophozoite stage, reproduce by fission in the body of the host. Some of the trophozoites pass out in the feces unchanged while others undergo encystment and are eliminated as infective cysts. Cysts are somewhat resistant to external environment, while most of the trophozoites degenerate rather quickly. Forms like *Dientamoeba fragilis* of man have no cysts, and the mode of infection is not clear; it has been suggested that it may be transmitted through the egg of *Enterobius vermicularis* (*see* Burrows and Swerdlow, 1956). Others, such as *Entamoeba coli* and *E. histolytica,* form multinucleated cysts. When these are ingested with contaminated food or water, they excyst, grow, divide, and establish an infection in the digestive tract.

The intestinal flagellates and ciliates, like the amoebae, multiply in the host by fission and are eliminated both as trophozoites and as cysts. Forms like *Giardia lamblia, Chilomastix mesnili,* and *Balantidium coli* have infective cysts. The trichomonads and histomonads do not form cysts and are infective in the trophozoite stage in which they are eliminated in the feces. By far the more common form of transmission of *Histomonas meleagridis,* however, is in the egg of the cecal worm, *Heterakis gallinarum* (*see* Parasites of Chicken and Other Avian Hosts). The blood flagellates, *Trypanosoma lewisi,* multiply by longitudinal division in the body of the host. Upon reaching the stomach of the flea vector, they assume the crithidial form, enter the epithelial cells, and multiply. Gradually they travel backwards towards the rectum where they change to the infective or metacyclic forms and are eliminated in the feces. Infection of the rat is believed to take place by eating infected fleas or their feces.

The coccidia have a characteristic nonsporulated oocyst stage in which they are eliminated in the feces of the host. In a few days each oocyst gives rise to spores (sporoblasts) which in turn divide into sporozoites, at which time it is known as a sporulated or an infective oocyst. When ingested by the definitive host, each sporozoite enters an intestinal cell and grows into a mature schizont which gives rise to a large number of merozoites. When the latter are liberated, they enter other intestinal cells and repeat the asexual cycle (schizogony). Some of these merozoites which enter new cells, however, become either macro- or microgametocytes and represent the first developmental stages of the sexual cycle. Each macrogametocyte, upon maturing, becomes a macrogamete (mature ovum). Each microgametocyte, on the other hand, gives rise to numerous comma-shaped, biflagellate microgametes (sperm cells). Following fertilization, the ovum (zygote) passes out in the feces of the host as a nonsporulated oocyst.

In the case of the bird-protozoa, *Haemoproteus columbae,* the infective sporozoites are transmitted through the bite of the pigeon-fly. The sporozoites start the schizogony cycle upon entering the reticulo-endothelial cells of

the liver and spleen of the avian host. They grow, multiply, and eventually form a large number of merozoites. When liberated from the host cells, some of the merozoites enter other endothelial cells and repeat the schizogony cycle. The others enter the red blood cells and begin the sexual cycle. In the blood cells, the parasites become sausage-shaped and develop into micro- and macrogametocytes. When ingested by the pigeon-fly, these cells go to the stomach and undergo further growth. The macrogametocyte matures into a macrogamete and each microgametocyte differentiates into a number of filamentous microgametes. Upon fertilization, the zygote thus formed becomes a motile ookinete. This enters the stomach wall and forms a pigmented oocyst. The latter gives rise to a large number of sporozoites which eventually escape and reach the salivary glands of the fly. The sporozoites are then transferred to susceptible birds through the bite of the infected fly.

Plasmodium vaughani is the only species of bird malaria known in Hawaii. It is probably mosquito-borne and its cycle is only partially known (Manwell, 1947; Laird, 1953).

Life Cycle of Roundworms

Roundworms are usually referred to as having five developmental stages in their life cycle, namely: (a) the first, second, third, and fourth larval stages and (b) the fifth or adult stage. There are four molts, one between each stage. The adult female worms are either oviparous or ovoviviparous. Oviparous nematodes (*Ascaris, Trichuris,* etc.) usually lay undeveloped eggs which are eliminated in the feces of the host. Ovoviviparous nematodes (*Ascarops, Enterobius,* etc.) usually lay eggs containing immature first-stage larvae which are also eliminated in the feces of the host. In some instances, the eggs of ovoviviparous worms develop to immature first-stage larvae which hatch out in the uterus of the female worms. Such immature larvae may be deposited under the skin (*Stephanofilaria*) or in the circulatory system (*Dirofilaria*) to be picked up by biting insects. The immature first-stage larvae of filarioid nematodes are referred to as "microfilariae."

Roundworms have either a direct or an indirect life cycle depending on whether they have an intermediate host.

Roundworms with a Direct Life Cycle

Roundworms that have a direct life cycle known to be present in Hawaii include members of the families Trichuridae, Trichosomoididae, Ascarididae, Heterakidae, Oxyuridae, Ancylostomatidae, Cyathostomidae, Stephanuridae, Strongylidae, Trichostrongylidae, Strongyloididae, and a member of the Protostrongylidae (*Dictyocaulus viviparus*).

The Trichuridae (*Trichuris* and *Capillaria*) are oviparous. The eggs of *Trichuris,* which are eliminated in the feces, become fully embryonated (contain young first-stage larvae) within a few weeks and are infective to the final host. Among the capillarids, there is considerable variation in the manner by which the transmission of the eggs from one host to another is accomplished. In *C. columbae,* occurring elsewhere, the eggs are eliminated in the feces and after embryonation are infective to the final host as in *Trichuris.* In *C. hepatica,* the eggs, which are laid and remain in the liver tissue, seldom escape in the feces of the rat (Momma, 1930). However, when the liver is eaten by another animal such as a cat or a rat, the eggs, once freed in the feces of these animals, become embryonated and are infective to the final host (Shorb, 1931). In certain species of capillarids (*C. caudinflata*), occurring elsewhere, an earthworm serves as an intermediate host (Wehr and Allen, 1945).

The Trichosomoididae (*Trichosomoides*) are ovoviviparous and the infective eggs are eliminated in the urine of the host.

The Ascarididae (*Ascaridia, Ascaris, Parascaris, Toxascaris,* and *Toxocara*) and the Heterakidae (*Heterakis*) are oviparous. The eggs, which are eliminated in the feces, become embryonated within 2 weeks and the larvae molt once before becoming infective (Alicata, 1934). Among the Oxyuridae (*Enterobius* and *Oxyuris*), the female worms are ovoviviparous and the eggs are believed to be infective soon after they are deposited. When the infective eggs of heterakids and oxyurids are ingested, they hatch in the body of the host and the young parasites migrate and develop solely in the digestive tract. Among the ascarids [except *Ascaridia* and *Toxascaris* (*see* Wright, 1935)], the hatched larvae migrate and develop partially in the lungs of the host before traveling and maturing in the intestinal tract.

Among members of the families Ancylostomatidae (*Ancylostoma* and *Bunostomum*), Cyathostomidae (*Cyathostomum,* etc.), Stephanuridae (*Stephanurus*), Strongylidae (*Alfortia,* etc.), and Trichostrongylidae (*Haemonchus, Nematodirus,* etc.), the female worms are oviparous and the eggs are eliminated from the body of the host in the feces, except in Stephanuridae, in which the eggs are eliminated in the urine. Usually after a few hours the eggs become fully embryonated and hatch. Within a few days the first three larval stages develop in the soil and these represent the free-living or preparasitic stages. In species of *Nematodirus,* the larvae develop slowly within the egg to the third stage and eventually hatch under suitable climatic conditions (Kates and Turner, 1955). Among parasites of the above five families, only the third-stage larvae are infective to the final host. These larvae are usually enclosed within the sheath of the second molt. In the first two stages the larvae of these parasites are referred to as rhabditiform larvae because their esophagus is composed of a corpus, isthmus, and bulb. The

third-stage larvae, on the contrary, do not have such a bulb and are referred to as filariform larvae. The infective larvae usually enter the final host through contaminated food or water, but some are able to enter by boring through the intact skin (*Ancylostoma, Nippostrongylus, Stephanurus*). Such larvae migrate and develop partially in the lungs or other tissues before settling in the specific site of the body where they reach sexual maturity.

Members of the Strongyloididae (*Strongyloides*) are oviparous and develop somewhat like the above Ancylostomatidae and related strongyles. The parasitic cycle, however, may alternate with a free-living cycle. In the latter case, the larvae at all stages and the adults are rhabditiform and develop in the soil as free-living organisms. Their offspring, however, may follow either the free-living or the parasitic cycle. If the parasitic cycle is followed, the third-stage larvae become filariform and are able to penetrate the intact skin of the host; they are not ensheathed.

Most members of the family Protostrongylidae have an indirect life cycle, except *Dictyocaulus viviparus* which is direct. In *D. viviparus,* the female worms are ovoviviparous. The eggs, which are deposited in the lungs, frequently hatch in the digestive tract of the host and are eliminated as first-stage larvae which develop in the soil to the third or infective stage. When ingested by cattle, the larvae migrate to the mesenteric lymph nodes and later to the lungs, where they reach sexual maturity (Porter and Cauthen, 1942).

Roundworms with an Indirect Life Cycle

Roundworms which have an indirect cycle usually undergo their first three larval stages in an intermediate host. In the latter, the third-stage larva may or may not encyst, but this is the stage which is infectious to the final host. The intermediate host is usually an annelid, a mollusk, or an arthropod.

In some cases, the infected intermediate host is ingested whole or in part by other invertebrate or vertebrate scavengers and the infective larvae are transferred and may re-encyst in the body of these scavengers. Such carriers are known as paratenic hosts. An example is the land planarian, which acquires the third-stage larvae of the rat lungworm, *Angiostrongylus cantonensis,* by feeding on the body of infected snails, the latter being the true intermediate hosts.

In Hawaii, roundworms which have an indirect life cycle include members of the families Acuaridae, Physalopteridae, Spiruridae, Subuluridae, Thelaziidae, Tropisuridae, Protostrongylidae (except *D. viviparus*), Pseudaliidae, Dipetalonematidae, Stephanofilariidae, and Trichinellidae.

In the Acuaridae (*Acuaria, Dispharynx*), Physalopteridae (*Physaloptera*), Spiruridae (*Ascarops, Cyrnea, Habronema, Gongylonema, Physocephalus*),

Subuluridae (*Subulura*), Thelaziidae (*Oxyspirura*), and Tropisuridae (*Tropisurus*), the adult females are ovoviviparous and the eggs are eliminated in the feces of the host. Whenever these eggs are ingested by an arthropod, they hatch and the larvae develop to the third or infective stage. These larvae then develop to maturity whenever the infected intermediate host is ingested by the final host.

Among the Protostrongylidae, some are oviparous (*Angiostrongylus, Aelurostrongylus*), and some ovoviviparous (*Choerostrongylus, Metastrongylus*). In *Angiostrongylus* and *Aelurostrongylus,* the eggs develop and hatch in the pulmonary capillaries. The first-stage larvae travel from the lungs to the trachea and out of the body in the feces. Certain land snails and slugs serve as intermediate hosts. In *Choerostrongylus* and *Metastrongylus,* the embryonated eggs are eliminated in the feces. Earthworms serve as intermediate hosts. When the eggs are ingested by earthworms, they hatch and the larvae develop to the third or infective stage. In the Pseudaliidae (*Anafilaroides*), the females lay young, first-stage larvae which travel from the lungs to the trachea and out of the body in the feces. Certain land snails and slugs serve as intermediate hosts. Whenever mollusks harboring infective larvae of *Anafilaroides* and *Aelurostrongylus* are ingested by rodents, the larvae re-encyst in the body of the rodent and retain the power to infect the final host. Rodents, therefore, can serve as paratenic hosts for these parasites.

In the Dipetalonematidae (*Dirofilaria, Dipetalonema*), the adult females produce microfilariae which enter the circulatory system. Various biting arthropods such as mosquitoes (for *Dirofilaria*) and fleas (for *Dipetalonema*) serve as the intermediate hosts. The females of the Stephanofilariidae (*Stephanofilaria*) also produce microfilariae which are deposited in the skin. Biting horn flies of cattle are believed to serve as intermediate hosts for *S. stilesi.*

In the Trichinellidae (*Trichinella*), the females are ovoviviparous and the immature first-stage larvae are formed *in utero.* Soon after birth the young larvae penetrate the intestinal wall, reach the circulatory system, and are distributed throughout the body. After undergoing a period of development, the larvae become encysted in the voluntary muscles, at which time they are infective to the final host. Trichinae differ from other nematodes having an indirect life cycle in that they utilize their final host as intermediate host also.

Life Cycle of Tapeworms

All the adult tapeworms known to occur in Hawaii are found in the digestive tract of the final host. The eggs of the parasites, and sometimes the terminal gravid segments containing the eggs, are eliminated in the feces

of the host. Each egg possesses a well-developed hexacanth embryo which is infective to the intermediate host. In the latter, the embryo develops to the stage which is infective to the final host. All tapeworms reported in this bulletin require either an arthropod or a mammalian intermediate host, except *Hymenolepis nana,* which usually develops without an intermediate host.

The following families of tapeworms are recorded from Hawaii, and the type of intermediate host used by them is shown in parentheses: Anoplocephalidae (free-living oribatid mites), Davaineidae (insects), Dilepididae (insects), Hymenolepididae (insects), and Taeniidae (mammals). Among the above-mentioned families (except Taeniidae), the hexacanth embryo develops in the intermediate host to the cysticercoid stage, which is infective to the final host. In the case of *H. nana,* when the egg is ingested by the final host, the hexacanth embryo enters an intestinal villus and forms a tailless cysticercoid. This then escapes to the lumen of the intestine and develops to maturity. In members of the Taeniidae (*Taenia saginata, T. hydatigena,* etc.), the egg, when ingested by a suitable mammalian intermediate host, develops into a comparatively large infective larva known as cysticercus or bladderworm stage.

Life Cycle of Flukes

There are comparatively few species of flukes reported as established in terrestrial vertebrates in Hawaii. These include members of the families Brachylaemidae (*Postharmostomum gallinum*), Dicrocoeliidae (*Platynosomum fastosum*), Echinostomatidae (*Echinostoma* sp.), Fasciolidae (*Fasciola hepatica* and *F. gigantica*), Heterophyidae (*Stellantchasmus falcatus,* etc.), Philophthalmidae (*Philophthalmus gralli*), Plagiorchiidae (*Plagiorchis muris*), and Schistosomatidae (*Austrobilharzia variglandis*).

All the above parasites are digenetic and require a snail as an intermediate host. In the Heterophyidae, two intermediate hosts are required, a fresh-water snail and a fish. The echinostomid and plagiorchid flukes possibly utilize fresh-water snails as both first and second intermediate hosts.

All the above-named flukes, except *Fasciola,* are ovoviviparous since the eggs contain a well-formed miracidium. In the fasciolids, the eggs develop after they have been eliminated in the feces of the final host. In the case of *Fasciola, Philophthalmus,* and *Austrobilharzia,* the eggs hatch in water and the miracidia actively bore into the tissue of the snail. In the other flukes reported herein, the eggs hatch after they are ingested by the snail host.

In the suitable snail host, each miracidium undergoes growth and asexual propagation which is terminated with the formation of numerous cercariae. In *Postharmostomum,* the mature cercariae reach the infective stage (meta-

cercaria) by entering the pericardial cavity of the same or of other land snails (Alicata, 1940). In other species of flukes, the cercariae emerge from the snail and swim in water. In the case of *Austrobilharzia,* the motile cercariae are able to enter the final host by active penetration of the skin. In *Fasciola* and *Philophthalmus,* the cercariae encyst as metacercariae on the surface of vegetation or other objects. In the heterophyids, the cercariae encyst as metacercariae in the musculature of the secondary intermediate host, which is a fish. In *Echinostoma* and *Plagiorchis,* the cercariae may encyst as metacercariae in the body of the same or another host. The encysted metacercariae are infective to the final host.

Life Cycle of Arthropods

Arthropods which are parasitic on man and animals in Hawaii include, for the most part, a variety of surface-feeding and blood-sucking insects (bed bugs, fleas, biting flies, biting and sucking lice, mosquitoes) and acarines (mites and ticks). Botflies, sheep nasal flies, and warble flies are, however, internal parasites in their larval stages.

Of the above insects, the fleas, flies, and mosquitoes have four phases in their life cycle, namely, egg, larva, pupa, and adult (complete metamorphosis). In the life cycle of the bed bugs and lice, on the other hand, there are three phases represented, namely, egg, nymph, and adult (incomplete metamorphosis). Among the species of insects considered in this bulletin, the lice are parasitic during their whole life cycle; others, such as fleas, horseflies, and mosquitoes, are temporarily parasitic during the adult stage only; others, such as warble flies, botflies, and sheep nasal flies, are parasitic only during the larval stage.

The life cycle of mites and ticks is divided into four phases, namely, egg, larva, nymph, and adult. Whereas the nymphs and adults have four pairs of legs, the larvae have three pairs. Parasitic mites of the genera *Demodex, Psoroptes,* and *Sarcoptes* reported herein spend their whole life cycle on the body of the host. Others, such as those of the genera *Laelaps, Ornithonyssus,* and *Pyemotes,* are free-living a great deal of the time and attack the host temporarily during the nymphal and adult stages. They drop from the host after each feeding.

The life cycles of two species of soft ticks (*Otobius megnini, Ornithodorus capensis*) and a species of hard tick (*Rhipicephalus sanguineus*) known in Hawaii differ in a few respects. *O. megnini* and *O. capensis* are parasitic only during the larval and nymphal stages, whereas *R. sanguineus* is parasitic during the larval, nymphal, and adult stages. Following engorgement, the soft ticks in the nymphal stage drop to the ground and after a few days molt and become adults. Following mating of the sexes, the gravid females

lay eggs. After hatching, the larvae (also known as seed ticks) attach themselves to hosts with which they come in contact and repeat the cycle. As for the hard tick, *R. sanguineus,* the important feature of its life cycle is that each of the three phases of the cycle (larva, nymph, adult) requires a separate animal. Both the larvae and nymphs, following engorgement, drop and molt into the next stage. The adult females, following engorgement, drop and lay eggs. After hatching, the larvae attach to another animal with which they come in contact and repeat the life cycle.

ROUTES OF INFECTION OF INTERNAL PARASITES

The final host may become infected with parasites by various methods, including oral, cutaneous, and prenatal routes, or combinations of these routes.

In oral infections, the infective cysts, eggs, or larvae are ingested with contaminated or infected food or water.

In cutaneous infections, the infective larvae of certain nematodes (*Strongyloides stercoralis, Ancylostoma caninum,* etc.) or trematodes (*Schistosoma mansoni,* etc.) are able to penetrate the intact skin of the host. Included also are certain protozoans (*Haemoproteus columbae,* etc.) or nematodes (*Dirofilaria immitis,* etc.) which are transmitted by the bite of arthropod vectors.

In prenatal infections, the unborn final host may become infected while *in utero.* Although this is rare among internal parasites, it is true among certain nematodes which in the larval stage migrate to various parts of the body and find their way from the maternal circulatory system to the fetal tissue. Prenatal infection has been reported for the nematodes, *Ancylostoma caninum* (*see* Yutuc, 1949), *Strongyloides ransomi* (*see* Stewart *et al.,* 1963), *Strongyloides westeri* (*see* Taylor, 1955), and *Toxocara canis* (*see* Sprent, 1958; Webster, 1958; Yutuc, 1949), and the blood fluke, *Schistosoma japonicum* (*see* Fujinami and Nakamura, 1911).

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).*

PARASITES OF MAN

PROTOZOA

According to a survey by Ching (1961*a*), seven species of intestinal protozoa in man have been recorded from Hawaii. These species, and the percentages of infection found among 1,380 persons examined, are as follows: *Dientamoeba fragilis,* 0.36; *Endolimax nana,* 0.84; *Entamoeba coli,* 1.96; *E. hartmanni,* 0.14; *E. histolytica,* 0.29; *Giardia lamblia,* 1.01; *Trichomonas hominis,* 0.07. Amoebic dysentery appears to be rare in Hawaii.

Human malaria has been diagnosed from civilian and military personnel who acquired the infection elsewhere. Natural transmission is not possible in Hawaii because of the absence of anopheline mosquitoes.

ROUNDWORMS

Various species of roundworms occur in Hawaii, and the incidence is more likely to be higher in the rural areas, especially among plantation laborers who have migrated from the Orient. In a stool examination of 1,009 persons living on a plantation on the island of Maui, Powers (1937) found the following percentages of roundworm infection: *Ascaris lumbricoides,* 0.99; *Enterobius vermicularis* (fig. 1*a*), 3.5; hookworm (species unknown), 13.6; *Trichuris trichiura,* 17.1. Of the persons examined, 387 were Filipino, 269 Japanese, 216 Portuguese, 100 Puerto Rican, and 37 unclassified.

Hall (1936) reports specimens of *Trichostrongylus colubriformis* from man which were given to him by a medical technician in Hilo, on the island

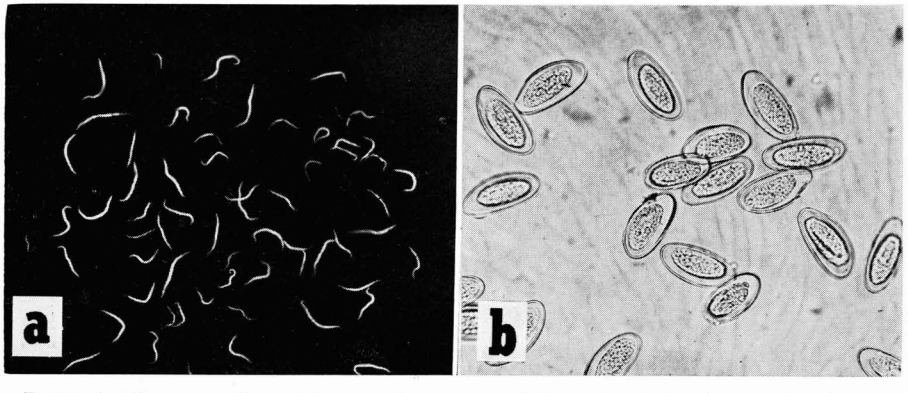

FIGURE 1. Pinworms, *Enterobius vermicularis: a,* adults, natural size; *b,* eggs, highly magnified. (After Alicata and Kartman, 1948, courtesy of *Hawaii Medical Journal.*)

of Hawaii. These are parasites which frequently occur in goats and sheep. Trichostrongyle eggs were also recorded from stool examinations on Maui.

In a survey involving the stool examination of 1,195 persons from the island of Oahu and 185 persons from the island of Hawaii, the following percentages of roundworm infection were found (Ching, 1961*a*): *Ascaris lumbricoides,* 0.94; *Enterobius vermicularis,* 0.58; *Strongyloides stercoralis,* 1.16; *Trichostrongylus* sp., 0.07; *Trichuris trichiura,* 2.03; hookworms, 0.58.

Infection produced by the pinworm, *Enterobius vermicularis,* appears to be common especially among children. In an examination (anal swab technique) of a group of 138 children from Honolulu in the age range of 2 to 7 years, 31.1 percent showed pinworm eggs (fig. 1*b*) (Alicata and Kartman, 1948).

Infections of the nonperiodic form of the filarioid, *Wuchereria bancrofti,* occur among Samoan immigrants to Hawaii. There is no record, however, that the infection has been transmitted to local inhabitants. Jackowski (1950) examined 72 Samoans who had lived in Hawaii less than 6 years and 8 showed microfilariae in the blood. None of 62 other Samoans who were born and reared in Hawaii showed infection. He postulated that, following last infection, microfilaremia persists for at least 5 years and disappears within 10 years. In Samoa, this parasite is transmitted by *Aedes scutellaris pseudoscutellaris* (*see* Byrd *et al.,* 1945), a mosquito which is not in Hawaii. Of the species of mosquitoes in Hawaii, the nonperiodic strain of *W. bancrofti* has been shown to develop in *Culex pipiens quinquefasciatus* (*see* Eyles and Most, 1947). This species appears, however, to be less receptive to the nonperiodic forms of *W. bancrofti* than *A. s. pseudoscutellaris.* Although *C. p. quinquefasciatus* is a potential vector of filariasis in Polynesia, its importance is not yet completely known (Rosen, 1953). Nelson *et al.* (1946) found that *C. p. quinquefasciatus* in Hawaii is susceptible to experimental infection with the periodic form of microfilariae of *W. bancrofti* from Okinawa. However, the microfilariae of *Brugia malayi* obtained from Koreans failed to develop to the third stage in this species of mosquito.

The first laboratory-proved case of human trichinosis, caused by *Trichinella spiralis* (fig. 32*a*), was found in Hawaii in 1936 (Alicata, 1938*e*). This led to a survey in the various islands to determine the infection among animals in nature (*see* Parasites of Swine). From 1936 to 1964, there were 112 cases of human trichinosis reported in the annual reports of the Hawaii Department of Health. Most of the infected persons had eaten, or were suspected of having eaten, improperly cooked wild pork or products made from wild pork. According to records of the Hawaii Department of Agriculture, during the 8-year period from 1933 through 1940 inclusive (Tinker, 1941), 32,724 wild hogs, or an average of 4,090 a year, were killed on the five larger

islands. Because of the moderately high incidence of trichinosis in local wild hogs (*see* Parasites of Swine), meat from these animals is believed to constitute a health menace unless proper precautions are taken in cooking, preserving, or refrigerating. In connection with the prevalence of local human infection with trichinae, in an examination of 133 diaphragms from autopsy cases in Honolulu, 7.4 percent showed encysted trichina larvae (Alicata, 1942*b*). The number of persons of the various ethnic groups examined and the number found positive (shown in parentheses) were as follows: Caucasian, 28 (3); Caucasian-Hawaiian, 7 (1); Caucasian-Japanese, 1 (0); Chinese, 9 (1); Chinese-Hawaiian, 2 (0); Chinese-Korean, 1 (0); Fijian, 1 (0); Filipino, 17 (1); Hawaiian, 24 (1); Japanese, 23 (0); Korean, 7 (2); Puerto Rican, 2 (0); unknown, 1 (0).

A fatal case of *Capillaria hepatica* infection was described in a 15-month-old child in Hawaii (Ewing and Tilden, 1956). The child had been known to eat dirt. The diagnosis was established before death by means of a liver biopsy which revealed many parasites and their ova (fig. 2*a*) within the liver. *C. hepatica* is normally a common parasite of the rat. Outside of Hawaii, it has also been reported from other mammals. Infection with this parasite results from the ingestion of embryonated eggs with contaminated food or water. Normally, in the rat, the adult worms deposit undeveloped eggs in the liver tissue (fig. 31*e*), and these eggs seldom escape in the feces of the rat (Momma, 1930). However, when the infected liver is eaten through cannibalism by another rat or predation by a cat, the eggs escape in the feces of these animals and eventually become embryonated and infective (Shorb, 1931). Although only four cases of *C. hepatica* have been recorded from man (Ewing and Tilden, 1956), there is a likelihood that the parasite may be more common in man than is suspected. The diagnosis is difficult because the eggs are seldom found in the feces.

A case of toxocarosis (visceral larva migrans) caused by the larvae of the dog and cat roundworm, *Toxocara canis* (fig. 28*d*), was reported from a 2-year-old boy in Hawaii with a history of eating dirt (Bruton and Jaffurs, 1957). The second-stage larvae of the parasite were recovered from a liver biopsy. According to the above writers, criteria which may aid in the diagnosis of this disease include the following: eosinophilia greater than 20 percent; history of eating dirt contaminated with embryonated eggs of *T. canis*; symptoms of the respiratory tract and nervous system; enlarged liver and spleen. Two other cases of larva migrans in Hawaii were reported by Ash (1962*a*). Outside of Hawaii, the syndrome of larva migrans appears to have been recognized only in children 15 to 36 months of age, and the majority at approximately 2 years of age (Beaver, 1962). Eosinophilic infiltration of the meninges resulting from invasion of larvae of *T. canis* has been reported

FIGURE 2. *a,* Section of human liver showing eggs and cross section of *Capillaria hepatica.* (After Ewing and Tilden, 1956, courtesy of *Journal of Pediatrics*); *b,* cross section of the cysticercus stage of *Taenia solium* from human liver, highly magnified. (Section, courtesy of Queen's Hospital, Honolulu.)

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.

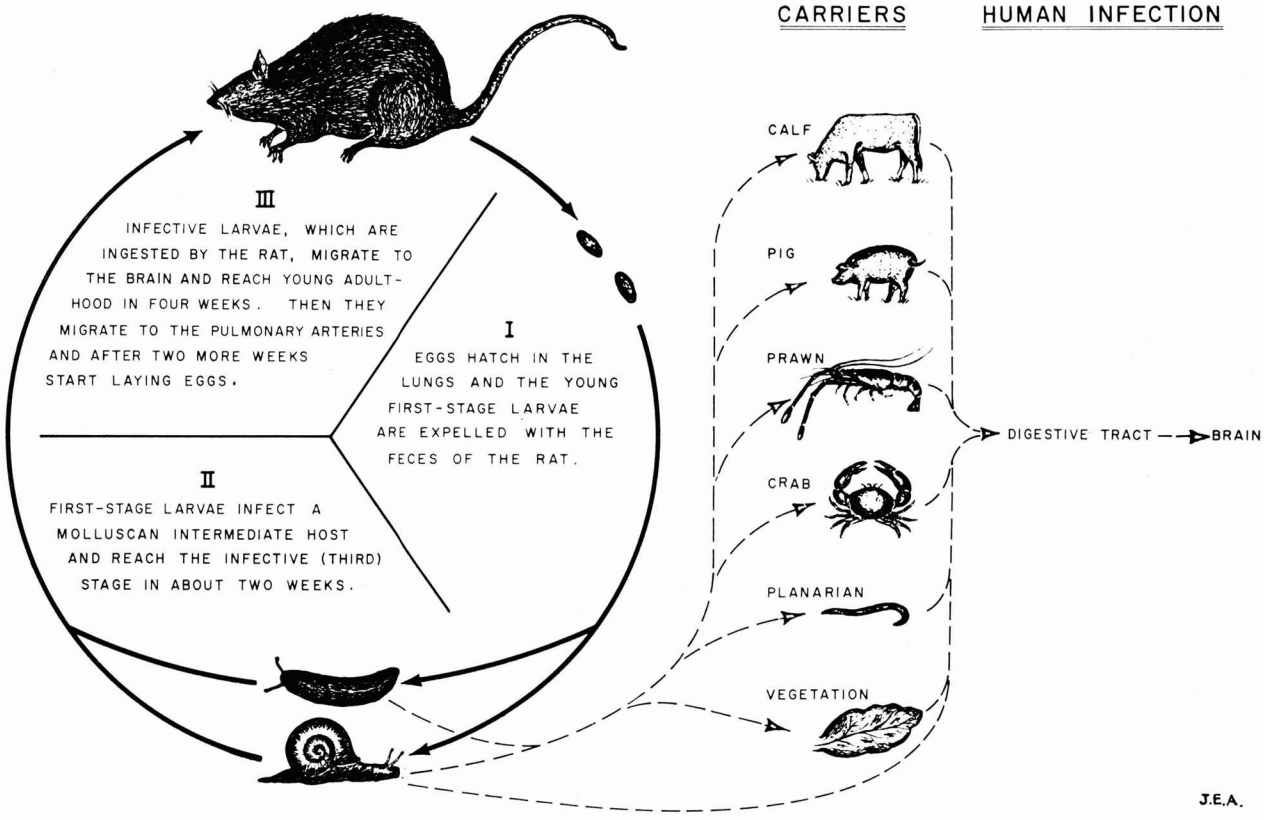

FIGURE 3. Life cycle of the rat lungworm, *Angiostrongylus cantonensis,* and possible avenues of human infection. (Original.)

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.*,

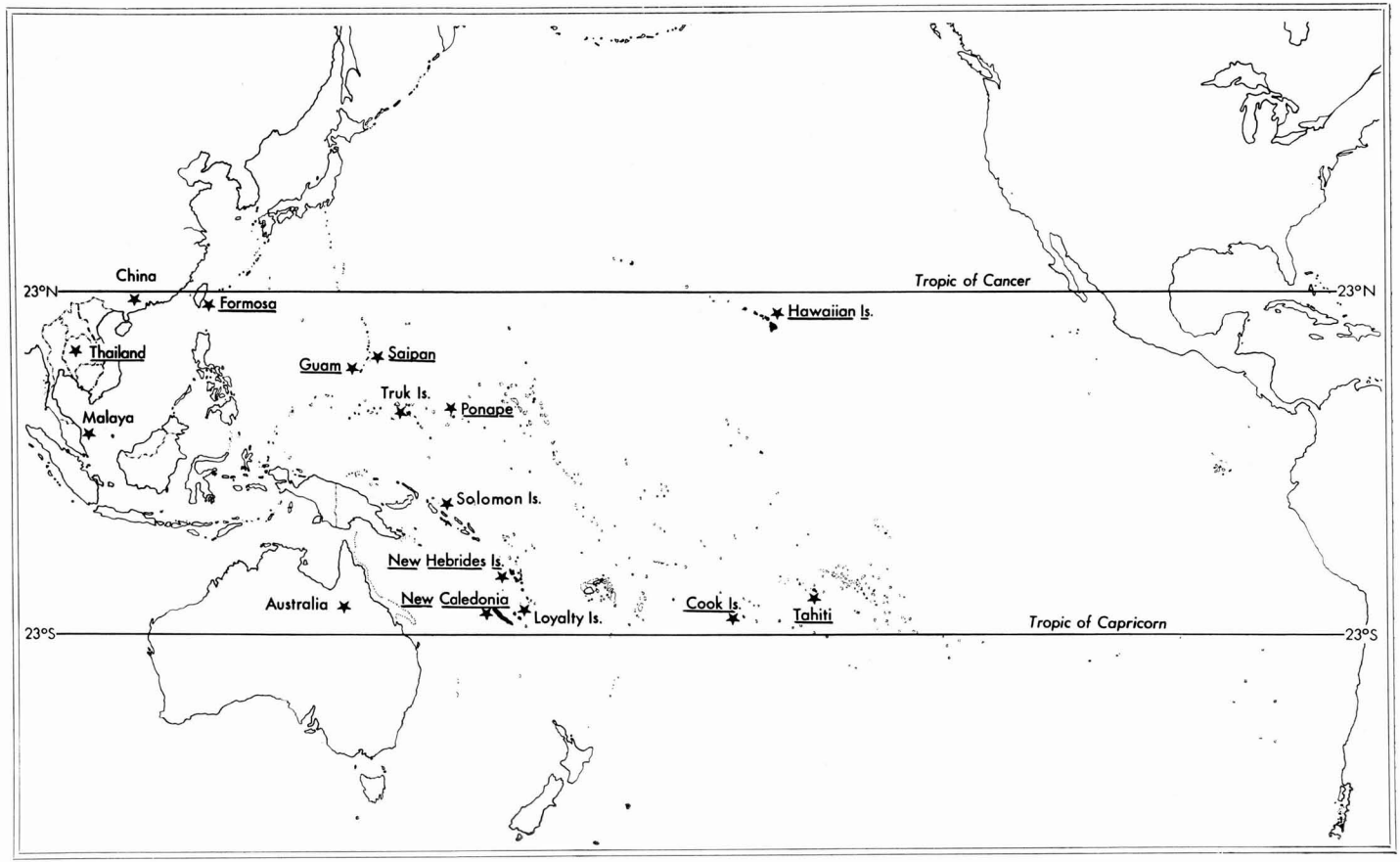

FIGURE 4. Geographical distribution of the rat lungworm, *Angiostrongylus cantonensis,* in the Pacific islands and Southeast Asia (*indicated by stars*), and its relationship to the distribution of eosinophilic meningoencephalitis in man (*underscored*). (*See* text, pp. 31–36.)

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.

(1937) among 1,009 plantation workers on the island of Maui, 0.3 percent harbored *Taenia saginata* and 0.8 percent *Hymenolepis nana.*

Cattle are the intermediate host to *T. saginata.* Man acquires the infection by eating raw or undercooked beef containing the infective bladderworm stage (cysticercus) encysted in the musculature. Infection with *H. nana* usually results either from ingesting the infective eggs of the parasite or from accidentally ingesting one of the infected arthropod intermediate hosts (*see* Parasites of Rat).

In Hawaii, *T. saginata* has been reported mostly from immigrant Filipino workers. Price (1946) reported that, of 126 cases of *T. saginata* diagnosed at Queen's Hospital in Honolulu during 1942 and 1945, the following ethnic distribution was represented: Caucasian, 7; Chinese, 2; Filipino, 110; Hawaiian and Part-Hawaiian, 4; Japanese, 2; Syrian, 1.

In a survey of parasites of man in Hawaii, Ching (1961*a*), found *Taenia* sp. and *H. nana* in 6 and 1 cases, respectively, out of 1,380 persons examined for parasite eggs.

A case of hydatid infection (larval stage of *Echinococcus granulosus*) was reported by Giles (1947), but the infection was believed to have been acquired outside of Hawaii. The 1954 annual report of the Hawaii Department of Health records the finding of *Dipylidium caninum* eggs in the stools of two patients. This is a normal and common parasite of dogs and cats (*see* Parasites of Dog); fleas and lice are the known intermediate hosts.

A fatal case of human cysticercosis (caused by the larval stage of *Taenia solium*) (fig. 2*b*) involving the brain, heart, lungs, and liver was diagnosed in 1954 at Queen's Hospital (autopsy No. A-2316) in a 30-year-old Japanese woman born on Kauai, who had not taken a trip away from the Islands. The adult stage of this parasite occurs only in man. Swine, as well as man, may serve as an intermediate host. Man usually acquires the adult worm by eating raw or undercooked pork containing the infective cysticerci (also known as bladderworms) encysted in the musculature. Swine and man acquire the cysticercus infection by ingesting food or water contaminated by human feces containing the eggs of the parasite. Man can also acquire cysticercosis through autoinfection. The above case of human cysticercosis implies, therefore, that the adult stage of *T. solium* has been introduced into Hawaii, perhaps by Filipino workers, since the parasite is widely distributed in the Philippines (Tubangui, 1947). Its presence among local inhabitants, therefore, constitutes a public health hazard.

FLUKES

There are two species of flukes known to occur in man in Hawaii, namely, *Fasciola gigantica* (fig. 5) and *Stellantchasmus falcatus* (fig. 6*a, d*). Hall (1936) reported a case of *F. hepatica* from man in Hawaii, but this proved

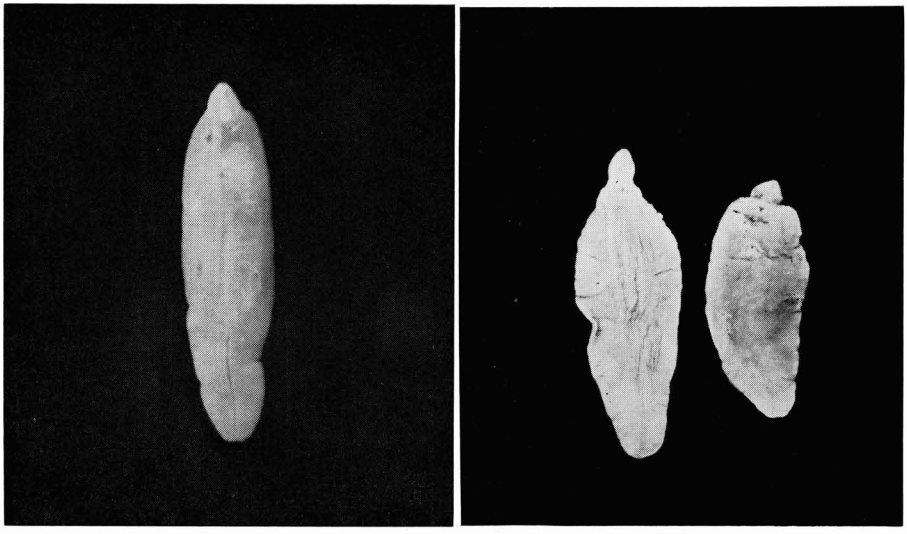

FIGURE 5. Liver flukes, *Fasciola gigantica:* adults recovered from the liver of man, natural size. (After Alicata, 1953, courtesy of *Hawaii Medical Journal.*)

to be *F. gigantica* (*see* Alicata, 1953*a*). *F. gigantica* is the common liver fluke of cattle, and infection in man is regarded as accidental. Such infection usually takes place by ingesting raw vegetation containing encysted fluke larvae (metacercariae, fig. 14*b*). In 1953, the writer summarized information concerning 19 cases which were known to have occurred in the Islands over a period extending from 1904 to 1951 (1953*a*). Three additional cases, together with their clinical and laboratory findings, were reported by Stemmermann (1953*a, b*). He was of the opinion that human fascioliasis in Hawaii is probably more frequent than the above figures indicate. Herbert (1907) and Hall (1936) pointed out that watercress may be a source of human infection. A study carried out subsequently by Alicata and Bonnet (1955, 1956) confirmed such a possibility. It was suggested that basic methods of preventing metacercariae contamination of watercress consist of raising this vegetation with artesian water rather than using stream water and of preventing cattle from grazing on or near areas where watercress is grown for human consumption.

Intestinal heterophyidiasis, caused by *S. falcatus,* was first recorded in Hawaii in 1938 (Alicata and Schattenburg, 1938). Heavy infections of this parasite may produce severe intestinal inflammation. Local fresh-water snails, *Stenomelania newcombi* and *Thiara granifera,* serve as the first intermediate hosts (Martin, 1958; Noda, 1959). Mullet, *Mugil cephalus,* serve as

the second intermediate host, and infection with the metacercariae (fig. 6*c*) of this parasite is of frequent occurrence (Alicata and Schattenburg, 1938; Martin, 1958). Local cats, dogs, and rats are known to harbor this parasite in the adult stage (Ash, 1962*a*, *b*).

Martin (1958) reported natural infection of the night heron, *Nycticorax nycticorax*, with three species of heterophyid flukes, namely, *Centrocestus formosanus*, *Haplorchis taichui*, and *H. yokogawai*. *C. formosanus* was also recovered from the rat. Since these flukes are able to develop in man, they are of public health importance. The melanid snail, *Stenomelania newcombi*, serves as the first intermediate host for *C. formosanus* and *H. yokogawai*. The melanid snail, *T. granifera*, serves as intermediate host for *H. taichui*. The mosquito fishes, *Gambusia affinis* and *Xiphophorus helleri*, and, rarely, the mullet, *Mugil cephalus*, are natural second intermediate hosts for *C. formosanus* and *H. taichui*. Experimentally, the fish, *Kuhlia sandvicensis*, is also susceptible to *C. formosanus* infection. The fishes, *G. affinis*, *Mollienesia formosus*, and, rarely, *M. cephalus*, serve as natural intermediate hosts for *H. taichui*. Experimentally, the Chinese catfish, *Clarias fuscus*, has been determined as a second intermediate host for *H. yokogawai*.

In a survey of parasites of man in Hawaii, Ching (1961*a*) records the following numbers of fluke infections found among 1,380 persons examined: heterophyids, 41; *Clonorchis* (= *Opisthorchis*) *sinensis*, 15; *Opisthorchis* sp., 1. The percentages of heterophyid flukes found among the various local ethnic groups examined, listed in order of their frequency, are as follows: Hawaiian or Part-Hawaiian, 7.9; Filipino, 7.2; Chinese and Japanese, less than 0.1; Caucasian, all negative. The findings indicate that these parasites are more common among those groups that customarily consume raw fish. In most instances the heterophyid infections were probably acquired in Hawaii.

In the above study by Ching, the Oriental liver fluke, *Opisthorchis sinensis*, was found only among persons of Chinese ancestry born in China or who had at some time resided there. The single infection with *Opisthorchis* sp. was from an elderly man born in Japan. Binford (1934) reported four cases of *O. sinensis* among persons born and reared in Hawaii. The diagnosis was based on fluke eggs found in the feces of these patients. The illustration of the eggs published by Binford, however, is not convincing evidence that the eggs are those of *O. sinensis*. They do not show the pronounced shoulders at the region where the operculum rests, a feature characteristic of *O. sinensis* eggs. It is likely that the eggs were those of heterophyids (fig. 6*b*), which are somewhat similar to liver fluke eggs and which were unknown in the Islands at the time of Binford's publication.

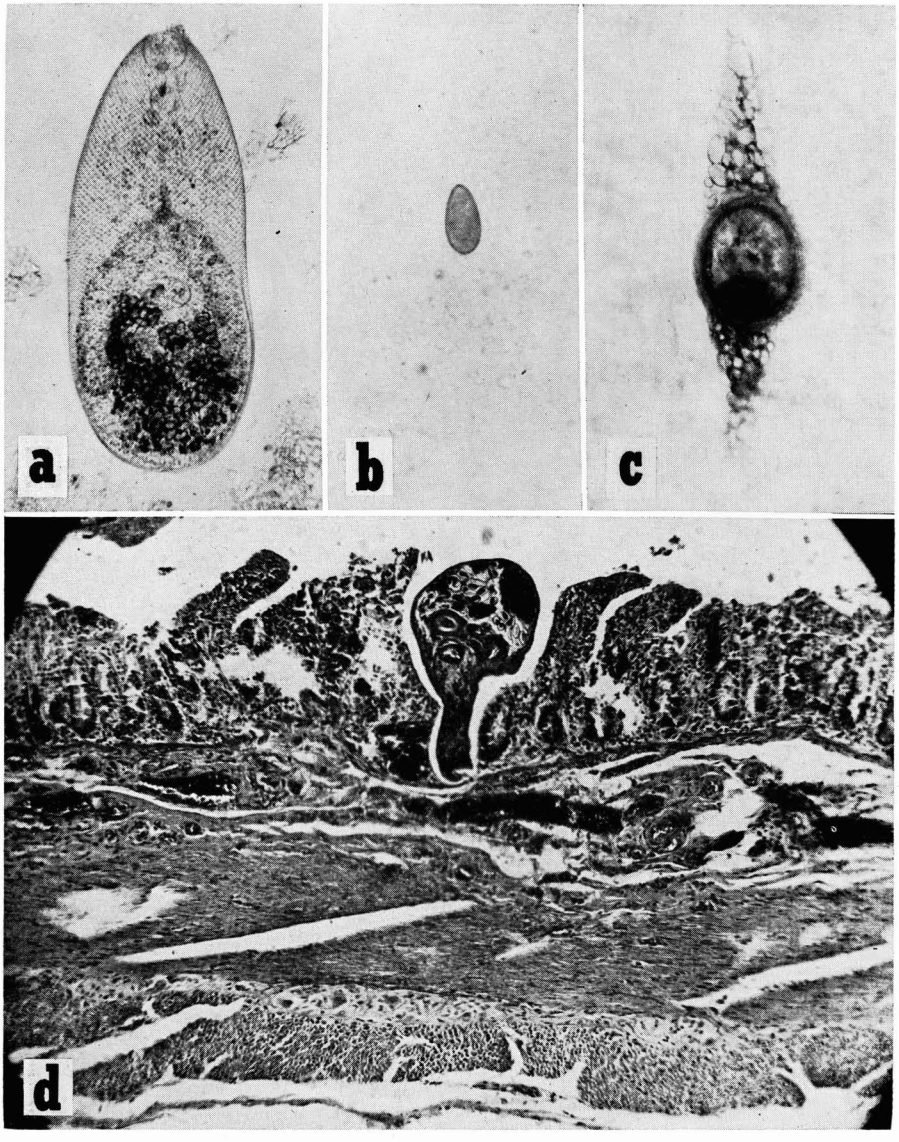

FIGURE 6. Heterophyid intestinal flukes, *Stellantchasmus falcatus: a,* adult, ×50; *b,* egg, highly magnified; *c,* metacercaria, encysted in the musculature of mullet, highly magnified; *d,* cross section of human intestine showing adult parasite embedded in mucosa, ×30. (*a–c,* After Alicata and Schattenburg, 1938, courtesy of *Journal of the American Medical Association; d,* original.)

The possibility of transmission of *O. sinensis* in Hawaii is uncertain. This parasite utilizes certain fresh-water snails as the first intermediate host, and a certain fresh-water fish as the second intermediate host. Man acquires the infection from eating the raw infected fish. In the Orient, three species of operculated snails of the family Amnicolidae serve as first intermediate hosts; in addition, three species of melanid snails including *Thiara granifera* have been implicated as hosts, although this is doubtful (Abbott, 1948). Of the species of operculated snails that are found in Hawaii, *Bulinus robustus minor, Thiara granifera,* and *Stenomelania newcombi* warrant investigation as possible intermediate hosts of *O. sinensis.* The spread and propagation of this parasite in Hawaii, however, does not seem likely because of the adequate disposal of local sewage and the usual unavailability of fresh-water fish in the markets.

A case of lung fluke, *Paragonimus westermani,* in Honolulu was reported to the writer by Min (1949), from a patient who had resided in Korea. This fluke requires certain fresh-water snails and crustaceans as first and second intermediate hosts, respectively. The melanid snail, *Thiara granifera,* has been reported as intermediate host for *P. westermani* in the Orient (Abbott, 1948). The snail, *T. granifera,* crayfish, and crabs present in the Islands could probably serve as intermediate hosts. Infection in man is acquired by eating infected fresh-water crayfish or crabs that are improperly cooked. As in *O. sinensis,* transmission of lung flukes in Hawaii is not likely because of the rarity of the infection here, and the adequate disposal of sewage.

Chu (1952) reported that certain schistosome cercariae recovered from the littorine snail, *Littorina pintado,* produce dermatitis when experimentally applied to the skin of man. These cercariae were later identified as the larval stage of *Austrobilharzia variglandis* (*see* Chu and Cutress, 1954). As adults, these flukes have been found in Hawaii in the mesenteric veins of the shore bird, *Arenaria interpres morinella,* known as the ruddy turnstone. Experimentally, chickens, ducks, and sooty and noddy terns have proved to be susceptible to infection. No case of human dermatitis has thus far been traced to natural infection with this parasite.

Philophthalmus gralli, located under the nictitating membrane of certain water birds (*see* Parasites of Chicken and Other Avian Hosts), and *Plagiorchis muris,* an intestinal fluke of rats (*see* Parasites of Rats), are potential parasites of man. Experimentally, *P. gralli* has been determined to develop in the eyes of rats and rabbits (Alicata and Ching, 1960). In Hawaii, these flukes utilize the melanid snails, *Stenomelania newcombi* and *Thiara granifera,* as intermediate hosts (Alicata and Noda, 1960). Related parasites have been reported in man for two areas, *P. lacrymosus* in Belgrade (Markovic, 1939) and *Philophthalmus* sp. in Ceylon (Dissanaike, 1958).

ARTHROPODS

Several species of arthropods in the Islands are known either to be permanent external parasites or occasionally to bite or sting man intermittently or by accident. These include the following (Pemberton, 1943): the human head louse, *Pediculus humanus capitis;* the human body louse, *P. h. humanus;* the pubic louse, *Phthirus pubis;* the bed bug, *Cimex lectularius;* the human flea, *Pulex irritans;* the Oriental rat flea, *Xenopsylla cheopis;* the Hawaiian field rat flea, *X. vexabilis hawaiiensis;* the northern rat flea, *Nosopsyllus fasciatus;* the cat flea, *Ctenocephalides felis;* the mouse flea, *Leptopsylla segnis;* the sticktight flea, *Echidnophaga gallinacea;* the daylight-feeding mosquitoes, *Aedes aegypti* and *A. albopictus,* and the night-feeding mosquito, *Culex pipiens quinquefasciatus;* the cone-nose or "kissing bug," *Triatoma rubrofasciata;* the common stable fly, *Stomoxys calcitrans;* the honey bee, *Apis mellifera;* a species of hornet, *Vespa occidentalis;* several species of wasps of the genus *Polistes;* the common fire ant, *Solenopsis geminata,* and the antlike insect, *Holepyrus hawaiiensis;* the common centipede, *Scolopendra subspinipes;* the common brown dog tick, *Rhipicephalus sanguineus;* and the black widow spider, *Latrodectus mactans.* Included also are the brown widow spider, *Latrodectus geometricus* (*see* Bonnet, 1948), and the clubionid spider, *Cheiracanthium diversum,* which are known to have bitten man (Bianchi, 1959; Gressitt, 1957; Hardy, 1957). The mosquito, *Aedes vexans nocturnus,* which is a voracious feeder and attacks at dusk and in the early evening or morning, was recently accidentally introduced into Hawaii (Hardy, 1962). The thrips, *Frankliniella sulphurea,* and possibly other species, have been reported to have bitten man (Carter, 1959).

Several species of mites, which occasionally bite or are capable of biting man, include *Ornithonyssus bacoti* (*see* Haramoto, 1964); *Laelaps echidninus* and *L. nuttalli,* common on rats; and *Pediculoides ventricosus* (= *Pyemotes boylei*), a common ectoparasite of grain insects (Pemberton, 1943). Other mites found in stored grain and feeds which may cause dermatitis are *Acarus siro, Dermatophagoides scheremetewskyi,* and *Glycyphagus domesticus* (*see* Haramoto, 1964). Included also is the tropical fowl mite, *Ornithonyssus bursa,* commonly found on poultry, poultry houses, nests of English sparrows and mynah birds, and also occasionally found infesting human dwellings (Zimmerman, 1944). The follicular mite, *Demodex folliculorum,* appears to be of common occurrence on man in Hawaii (Haramoto, 1964).

On at least one occasion, the "sheep head maggot," *Oestrus ovis,* larviposited in the eyes and nostrils of three men in Hawaii (Hardy, 1956).

Several of the above arthropods in Hawaii serve as intermediate hosts of parasites or as vectors of bacterial, rickettsial, and virus diseases of man. The fleas, *Ctenocephalides felis* and *Pulex irritans,* are known to be inter-

mediate hosts of the tapeworm, *Dipylidium caninum* (*see* Hall, 1929). According to epidemiological data, the fleas, *Xenopsylla cheopis* and *X. v. hawaiiensis,* are the principal vectors of bubonic plague (Eskey, 1934). *X. cheopis* and *Nosopsyllus fasciatus* are believed to be the principal vectors of endemic typhus (Doolittle, 1941). Experimentally, the chicken sticktight flea, *Echidnophaga gallinacea,* has been shown to serve as a suitable vector of endemic typhus (Alicata, 1942*a*). Dengue fever, which has occurred in Hawaii, is believed to be transmitted by the mosquito, *Aedes aegypti.*

PARASITES OF ANIMALS

CAT

PROTOZOA

No reports are available.

ROUNDWORMS

Of 107 stray cats examined, the following species and percentages of roundworms were found (Ash, 1962*a*): stomach worms, *Physaloptera praeputialis* (fig. 7*a*), 23 percent; ascarids, *Toxocara canis* (fig. 28), 8 percent; lungworms, *Aelurostrongylus abstrusus* and *Anafilaroides rostratus,* 4.0 and 2.0 percent, respectively; hookworms (fig. 7*b*), 58 percent. The hookworms were listed as *Ancylostoma caninum,* but these are actually *A. tubaeforme* (*see* Burrows, 1962). The microfilarial stage of the *Dirofilaria immitis* was seen by Ash in the peripheral blood of one cat, but no adult worms were found. Immature acanthocephalans, identified by Van Cleave (1947) as *Arythmorhynchus* sp., have been collected by the writer from the small intestine of a cat. Acanthocephalans of this genus are predominantly parasites of water birds. The cat, therefore, is believed to be an unnatural host. The ascarid, *T. canis,* is of public health interest, since its larvae are one of the chief causes of visceral larva migrans in children (*see* Parasites of Man).

Of the above parasites, the stomach worms and the lungworms require an intermediate host in their larval development. Experimental infection carried out elsewhere has shown that *P. praeputialis* is able to utilize the German cockroach, *Blatella germanica,* the camel cricket, *Centophilus* sp., and the field cricket, *Gryllus assimilis,* as intermediate hosts (Petri and Ameel, 1950).

The lungworm, *A. abstrusus,* is known to require snails and slugs as intermediate hosts (Hobmaier and Hobmaier, 1935; Gerichter, 1949). The land snail, *Subulina octona,* was reported by Van Volkenberg (1937) to be an intermediate host in Puerto Rico; in Hawaii, the writer (1947) infected the

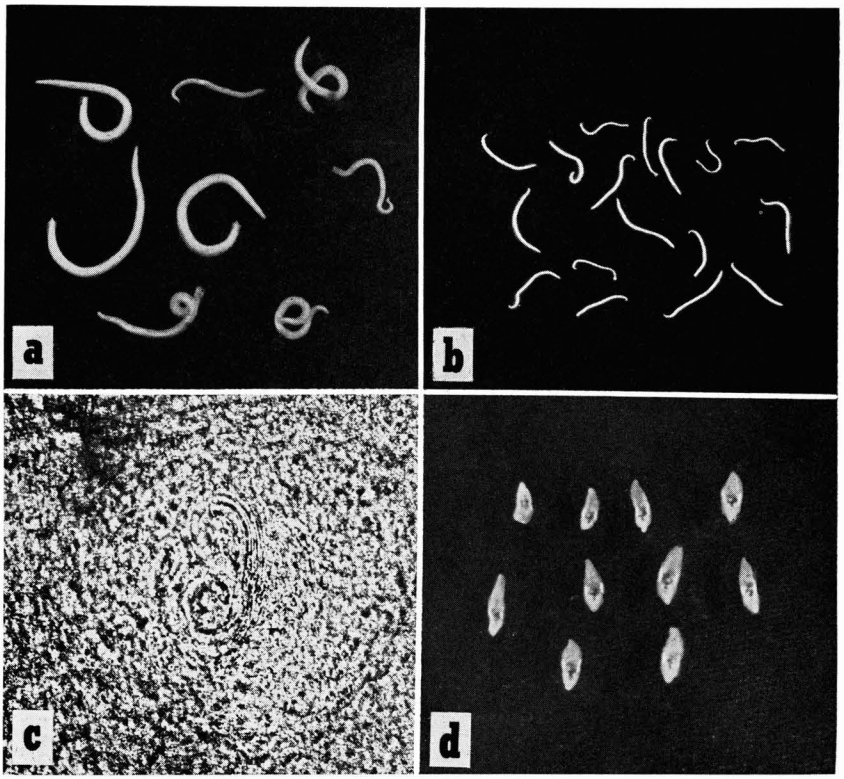

FIGURE 7. Parasites of the cat: *a,* adult stomach worms, *Physaloptera praeputialis,* natural size; *b,* adult hookworms, *Ancylostoma tubaeforme,* natural size; *c,* press preparation of rat liver showing a third-stage larva of the cat lungworm, *Anafilaroides rostratus,* experimentally fed to the rat, highly magnified; *d,* adult liver flukes, *Platynosomum fastosum,* natural size. (*a, b, d,* Original; *c,* after Alicata, 1963, courtesy of *Canadian Journal of Zoology.*)

land snail, *Bradybaena similaris,* with larvae of *A. abstrusus.* Cats may acquire this lungworm by eating infected mice (Cameron, 1927) or rats (Ash, 1962*b*). Rodents serve as paratenic hosts and acquire the infective larvae of this parasite by eating infected mollusks. In mice, the infective larvae of the lungworm migrate to and encyst in various parts of the body including musculature and omentum (Cameron, 1927; Mackerras, 1957). Ash (1962*b*) reported finding infective larvae of this parasite in the intercostal muscles of a rat 1 week after experimental infection.

The lungworm, *A. rostratus,* also utilizes land snails and slugs as intermediate hosts; rodents and birds can serve as paratenic hosts (Seneviratna, 1959). In rodents, the infective larvae (fig. 7*c*) encyst in the liver (Alicata, 1963*b*). Both *Subulina octona* and *Bradybaena similaris* can serve as inter-

mediate hosts in Hawaii (Ash, 1962*a*). Since cats do not usually eat mollusks, it appears most likely that they normally acquire lungworms from eating rodents harboring the infective lungworm larvae.

TAPEWORMS

Of 107 stray cats examined in Honolulu, 81 percent harbored *Dipylidium caninum* (fig. 8*a*) and 21 percent *Hydatigera taeniaeformis* (*see* Ash, 1962*a*). *D. caninum* utilizes fleas and lice as intermediate hosts. The adult stage of this parasite may also develop in man (*see* Parasites of Man). The tapeworm, *H. taeniaeformis* (fig. 8*b*), utilizes rats or mice as intermediate hosts. The infective larval stage (strobilocercus) is commonly found in the liver of rodents (fig. 31*f*) in Hawaii (*see* Parasites of Rat).

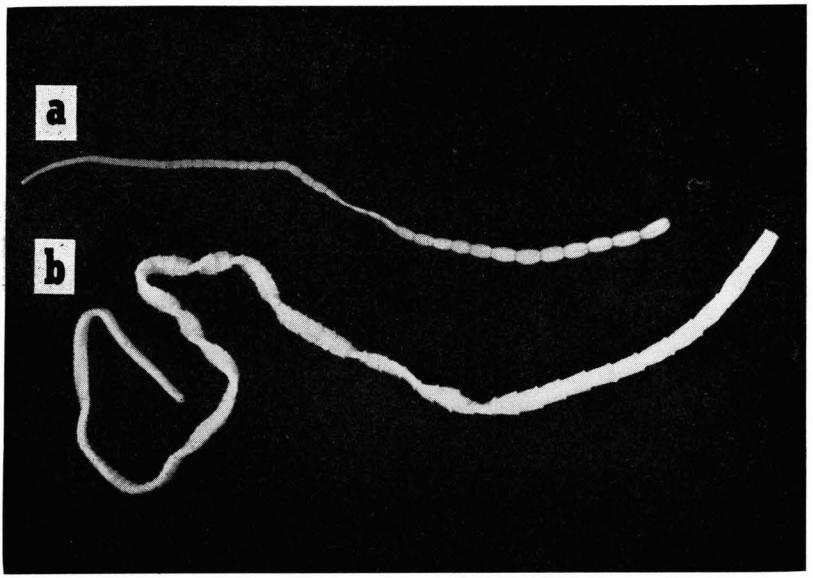

FIGURE 8. Tapeworms from the intestine of cat: *a,* adult *Dipylidium caninum; b,* adult *Hydatigera taeniaeformis.* Both natural size. (Original.)

FLUKES

Two species of heterophyid flukes, *Stellantchasmus falcatus* (fig. 6*a*) and *Phagicola longus,* were found in the intestinal tract of stray cats examined in Honolulu. They occurred in 8 and 1 percent, respectively, of 107 cats examined. The liver fluke, *Platynosomum fastosum* (fig. 7*d*), was recovered from 15 percent of the same cats examined (Ash, 1962*a*).

S. falcatus utilizes melanid snails as the first intermediate host and mullet as the second intermediate host (*see* Parasites of Man). *P. longus* also requires fresh-water snails and fish as first and second intermediate hosts, respectively, but these have not been determined in Hawaii.

P. fastosum has been shown, in Puerto Rico, to utilize the land snail, *Subulina octona,* as the first intermediate host, and the lizard, *Anolis cristatellus,* as the second intermediate host (Maldonado, 1945). In Hawaii, in addition to *S. octona, Bradybaena similaris* has also been determined to be a suitable first intermediate host (Ash, 1962*a*).

According to the above information, cats in Hawaii normally acquire heterophyid infection from eating raw mullet and possibly other fish, and they acquire the liver fluke, *P. fastosum,* from eating lizards.

ARTHROPODS

The cat flea, *Ctenocephalides felis,* and the sticktight flea, *Echidnophaga gallinacea,* are common on cats in Hawaii, the former occurring under houses and in other areas frequented by cats. The biting louse, *Felicola subrostrata* (*see* Zimmerman, 1944), and the mange mite, *Notoedres cati* (*see* Haramoto, 1964), have been collected from cats.

CATTLE

PROTOZOA

Four species of coccidia, *Eimeria bovis, E. bukidnonensis, E. cylindrica,* and *E. zurnii,* have been recovered from the feces of young calves (Cuckler and Alicata, 1943). Severe cases of coccidiosis, associated with emaciation, have occasionally been noted among calves in the Islands.

Anaplasmosis, an infectious disease of cattle characterized by anemia and the presence of marginal bodies in the red cells, has been recognized in Hawaii since 1954 (Hawaii Bd. Commrs. Agr. and Forestry, 1956). The exact nature of the causative organism, *Anaplasma marginale,* is still undetermined, but it is believed to be a one-celled body of complex nature (Roby, 1960). It is transmitted mechanically by ticks, horseflies, and probably by other biting insects, as well as by unclean instruments (Stiles, 1946; Dikmans, 1950) which are used in dehorning, earmarking, or other surgical operations.

ROUNDWORMS

In a survey involving the examination of about 375 adult cattle raised on various Hawaiian islands and slaughtered in Honolulu, the following per-

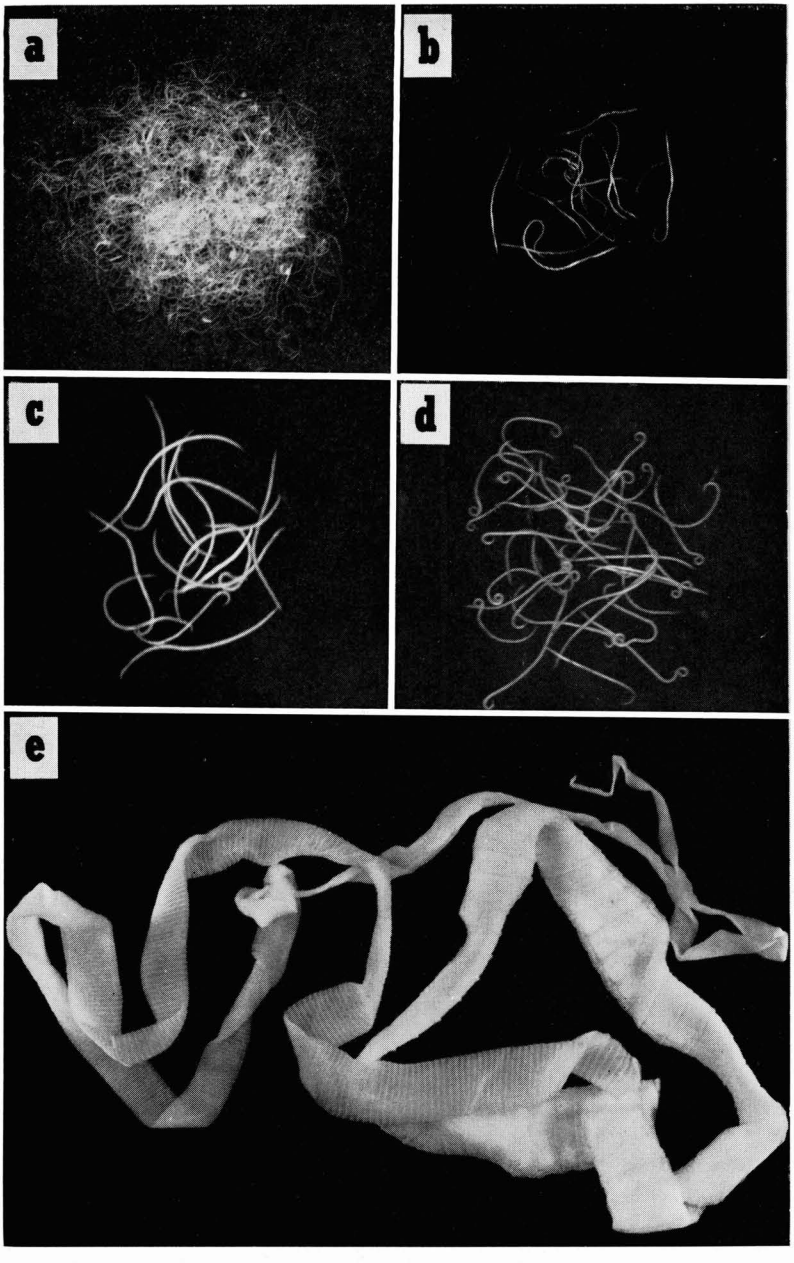

FIGURE 9. Adult parasites of cattle, natural size: *a,* intestinal roundworms, *Cooperia punctata; b,* stomach worms, *Haemonchus contortus; c,* hookworms, *Bunostomum phlebotomum; d,* nodular worms, *Oesophagostomum radiatum; e,* tapeworm, *Moniezia benedeni.* (Original.)

centages of roundworm infections were found (Cuckler and Alicata, 1943): gullet worms, *Gongylonema pulchrum,* 54.3; stomach worms, *Haemonchus contortus* (fig. 9*b*), 0.9; intestinal roundworms, *Bunostomum phlebotomum* (fig. 9*c*), 6.7; *Cooperia punctata* (fig. 9*a*), 4.0; *C. pectinata,* 0.3; skin filarioids, *Stephanofilaria stilesi* (fig. 10*b*), 89.8. *C. punctata* has also been reported from axis deer in Hawaii (*see* Parasites of Deer).

FIGURE 10. *a,* Skin of cattle from the region of the mid-ventral line showing characteristic lesions caused by the presence of *Stephanofilaria stilesi; b,* section of skin lesion showing presence of adult *S. stilesi,* highly magnified. (Original.)

In a study of parasites of 60 calves from 4 to 12 months of age, the following percentages of roundworms were found (Alicata, 1960): stomach worms, *Haemonchus contortus,* 38.3; *Ostertagia ostertagi,* 55.6; *Trichostrongylus axei,* 55.6; intestinal worms, *Bunostomum phlebotomum,* 40.0; *Cooperia punctata,* 95.0; *C. spatulata,* 13.3; *Oesophagostomum radiatum* (fig. 9*d*), 61.6; *Trichuris* sp., 30.0; *Strongyloides papillosus,* 56.7; lungworms, *Dictyocaulus viviparus,* 1.6.

The above study indicated that *C. punctata* is more common and more numerous among calves than any other helminth present in Hawaii and is more prevalent in areas of high rainfall. It is most common among calves 4 to 8 months of age. This parasite appears to be a major contributing factor to the unthriftiness often noted among local calves (Alicata, 1960). Calves experimentally infected with *C. punctata* have shown intermittent or continued diarrhea, progressive emaciation, reduced feed consumption, weight loss, and listlessness (Alicata and Lynd, 1961). Lungworm infection, although apparently uncommon, has on occasion been reported as producing death among calves in the Islands (Willers, 1945).

Of the above roundworms, *Gongylonema pulchrum* and *Stephanofilaria stilesi* require an intermediate host in their development. *G. pulchrum* is known to utilize one of various coprophagous beetles and cockroaches as an intermediate host in the continental United States (Alicata, 1935). Of the insects reported as hosts, *Aphodius lividus, Dermestes vulpinus,* and *Blatella germanica* occur in Hawaii. *S. stilesi* is known to utilize horn flies of cattle as intermediate hosts (Ivashkin *et al.,* 1963). In the continental United States, horn flies, *Haematobia irritans,* have been found naturally infected with third-stage larvae resembling those recovered from skin lesions of infected cattle (Hibler, 1964). *S. stilesi* usually occurs under the skin in lesions along the midline on the abdominal surface of cattle (fig. 10*a*). The lesions vary in size up to several inches. They are hairless and the skin is frequently broken and moist with blood and serum. These lesions may sometimes dry, forming scabs.

TAPEWORMS

Tapeworms identified as *Moniezia benedeni* (fig. 9*e*) have been recovered from beef and dairy calves in Hawaii (Alicata, 1960). Experimentally, in Russia, this species of tapeworm has been reported to utilize the free-living oribatid mites, *Galumna obvius* and *Scheloribates laevigatus* (fig. 11), as intermediate hosts (Kates and Runkel, 1948; Kates, 1965). Oribatid mites of the same genera are known to occur in Hawaii (Jacot, 1934) and may serve as vectors under local conditions.

The infective larval stage (cysticercus) of *Taenia saginata* has been found occasionally in the musculature of cattle in the Islands, according to Julien

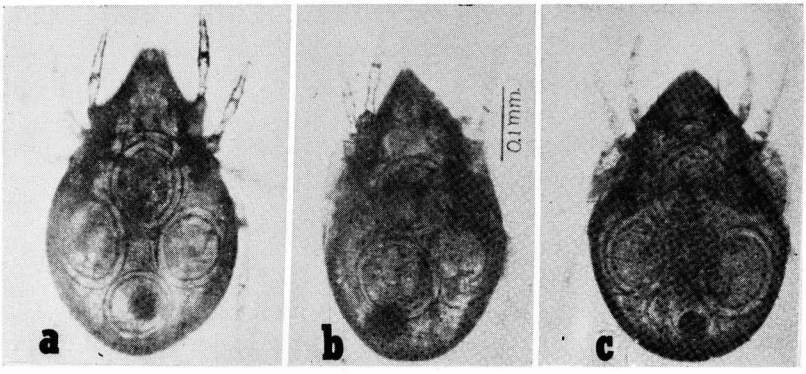

FIGURE 11. *a, b, c,* Oribatid mites containing the infective larval stage (cysticercoids) of the cattle tapeworm, *Moniezia expansa,* magnified. (After Kates and Runkel, 1948, courtesy of *Proceedings of the Helminthological Society of Washington.*)

(1947), federal meat inspector. The larvae reach maturity in the small intestine of man following ingestion of improperly cooked beef. Cattle acquire the cysticercus infection as a result of eating vegetation contaminated with human feces containing eggs of this parasite. It is generally believed that most cases of human infection occur among immigrants from the Orient, especially from the Philippines.

FLUKES

Three species of flukes have been recorded from beef and dairy cattle in the Islands, namely, the liver flukes, *Fasciola gigantica* (fig. 12*b*) and *F. hepatica,* and an unidentified rumen fluke reported by Hall (1936). Of these flukes, *F. gigantica* is the most common. *F. hepatica* is probably only rarely found in Hawaii. It has been observed only once in a cow born and raised on the island of Oahu, and its introduction into Hawaii is believed to be recent (Alicata, 1952*b*). No liver flukes were found in 14 wild cattle examined by Swanson (1939).

Liver fluke infection is the most important parasitic disease of cattle in the Hawaiian Islands (figs. 12, 13). Of 21,198 beef and dairy cattle slaughtered in 1962 at the Hawaii Meat Company, Honolulu, 3,395, or 16 percent, showed fluke infection of the liver. The origin, number examined, and percent infection of these animals were as follows: (beef cattle) Hawaii, 13,352, 9.6 percent; Kauai, 593, 59.0 percent; Maui, 2,770, 21.4 percent; Molokai, 448, 16.0 percent; Niihau, 333, 0 percent; Oahu, 1,775, 31.5 percent; unknown origin, 553, 8.3 percent; (dairy cattle) Hawaii, 57, 10.5 percent; Maui, 93, 16.1 percent; Oahu, 1,217, 39.3 percent; unknown origin, 6, 83.3 percent (Alicata, 1964*c*).

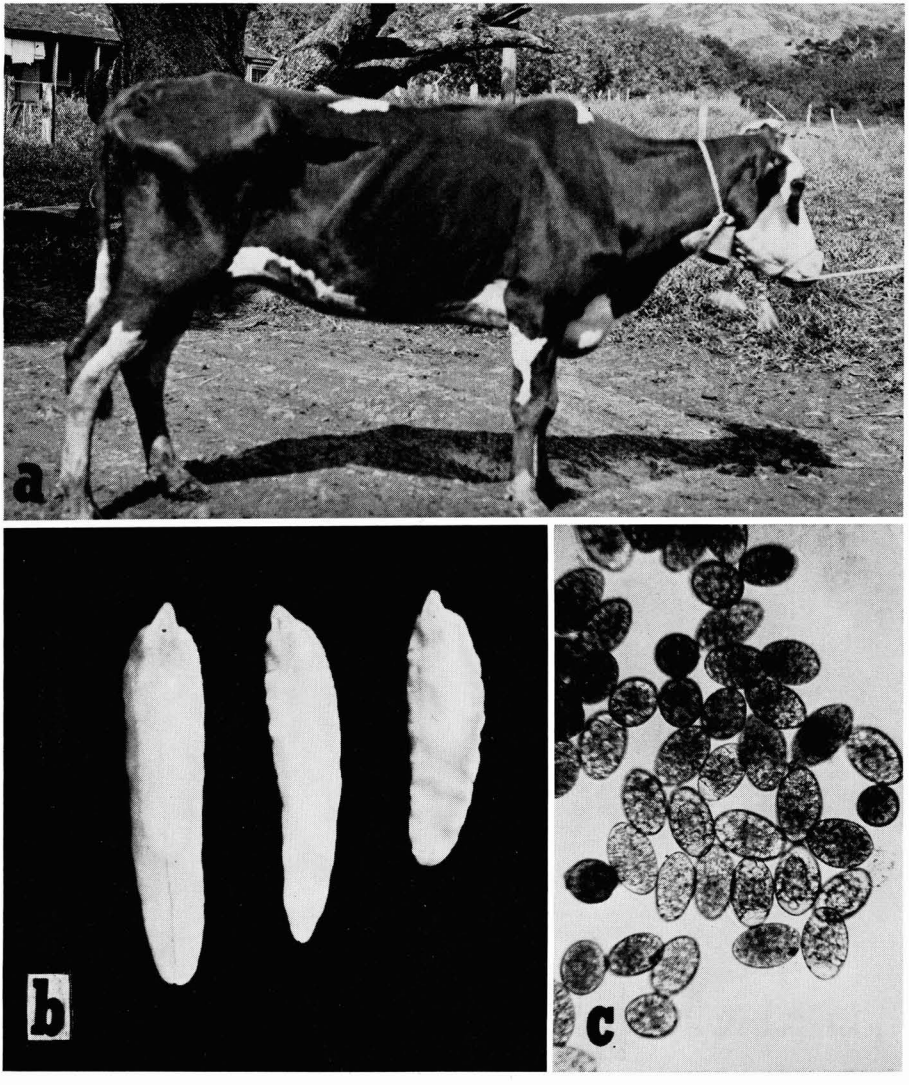

FIGURE 12. *a,* Cow heavily infected with liver flukes; *b,* adult liver flukes, *Fasciola gigantica,* natural size; *c,* eggs of *F. gigantica,* highly magnified. (Original.)

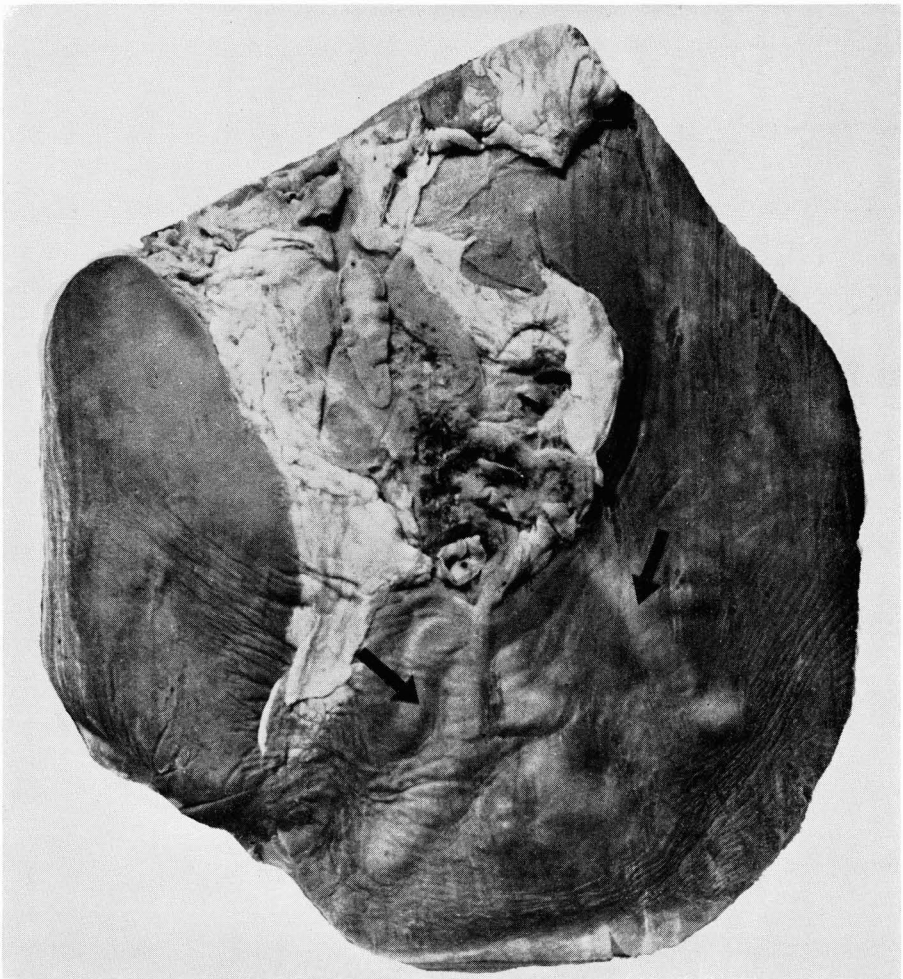

FIGURE 13. Liver of cow showing fluke lesions, about one-half natural size. The main bile duct has been cut to expose the flukes. Note thickening (*arrows*) of the bile ducts. (Original.)

Liver fluke infection in cattle was first reported by Lutz (1892) as being common on four of the larger Hawaiian islands. Although at that time the parasites were reported as *Fasciola hepatica,* more recent study has shown them to be *F. gigantica* (*see* Alicata and Swanson, 1937). The importation of

this fluke into Hawaii is not clearly understood, but it is believed to have come from the Orient with the introduction of water buffaloes. It is of interest to note that the limnaeid snail, *Fossaria ollula,* which serves as the intermediate host, has Japan and China as its geographic range (Alicata, 1938*a*). Experimentally, *F. ollula* has also been shown to serve as intermediate host for *Fasciola hepatica* (*see* Alicata, 1952*b*). This snail is widely distributed in Hawaii and is common along banks of streams and swampy lowlands (fig. 14*a*). In addition, another snail, *Pseudosuccinea columella,* apparently introduced recently into Hawaii, has been shown experimentally to be a suitable intermediate host for *F. gigantica* (*see* Alicata, 1953*b*).

The continuance of bovine fascioliasis in Hawaii, as elsewhere, is dependent on various factors of which topography, climatic conditions, and agricultural practices are very important. In Hawaii, the mountains descend to the ocean either abruptly or by gradual decline over relatively flat land with very little drainage. These poorly drained lowlands and valleys, especially on the windward side, often present rather extensive swamps. Rainfall is heaviest in winter months, but showers during other seasons of the year are sufficient to maintain swampy conditions. These wet areas and the mild Hawaiian climate encourage snail propagation the year round, as well as the development and hatching of the fluke eggs. Moreover, agricultural practices in the Islands have encouraged rather than hindered the maintenance of fluke infection. With ample supplies of vegetation, cattle have often been allowed to graze continuously. Many dairymen have long been in the habit of feeding cut forage from wet or swampy areas to cattle. These practices have been largely responsible for the widespread fluke infection. This disease is gradually being brought under control largely through (1) use of copper sulfate for the control of the snail vector in swamps or streams, (2) use of forage grass cut from dry areas, and (3) treatment of infected animals with hexachloroethane. This synthetic compound was first used for fluke control in Europe in 1926 (Thienel, 1926). In the United States it was first utilized on a large scale in Hawaii (Alicata, 1941*a*).

The possible use of snail predators for the control of lymnaeid snails in Hawaii has been advocated by the writer since 1939 (Alicata, 1941*a*). Japanese fireflies, *Luciola cruciata* and *L. lateralis,* were introduced into Hawaii from Japan during 1939, 1940, and 1952 for the control of the snails, but none became established (Alicata and Bess, 1953). In recent years, two species of sciomyzid flies, *Sciomyza dorsata* and *Sepenedon macropus,* have been imported and released in the Hawaiian Islands for the control of lymnaeid snails (Davis *et al.,* 1961; Chock *et al.,* 1961). The value of these flies remains to be determined.

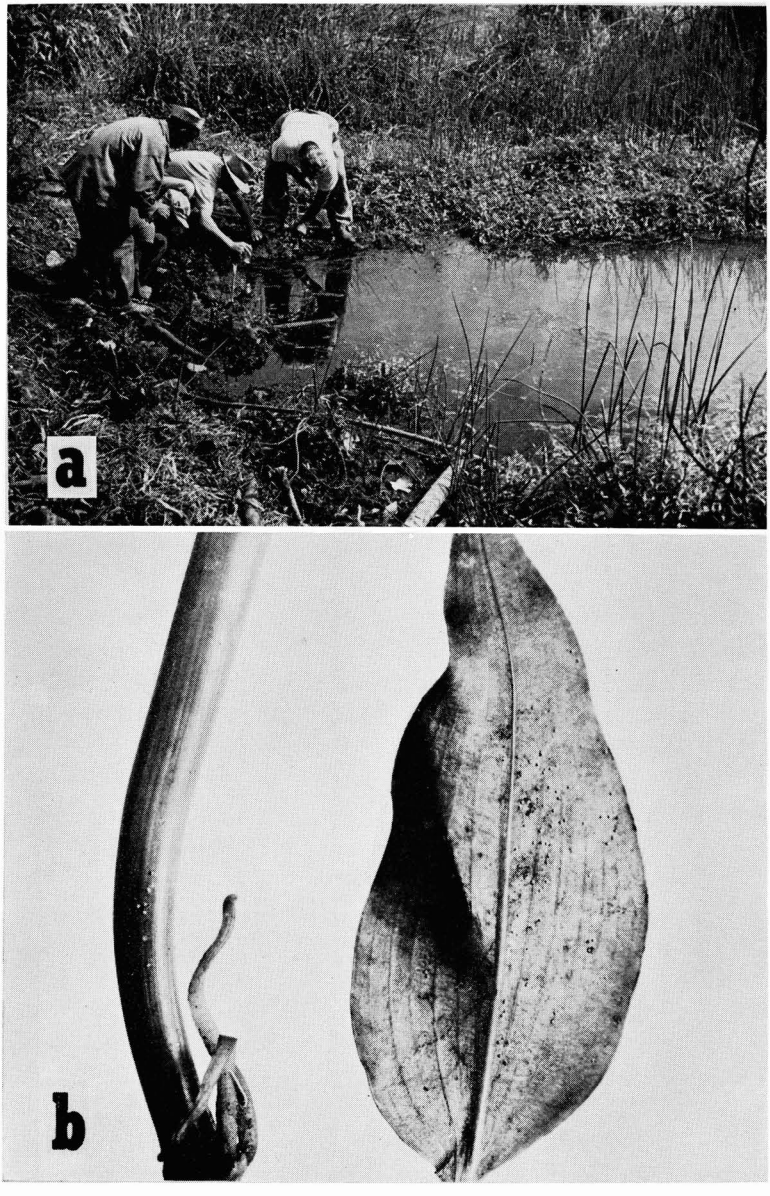

FIGURE 14. *a,* Muddy bank adjacent to a swamp where lymnaeid snails, *Fossaria ollula,* are found; *b,* a stem and blade of *Commelina diffusa* containing encysted metacercariae of liver flukes, *Fasciola gigantica,* ×3. (Original.)

ARTHROPODS

Several arthropods are known to be parasitic on cattle. In an examination of 303 animals (Cuckler and Alicata, 1943), 26.1 percent showed evidence of the cattle grub, *Hypoderma lineatum*. This fly was first reported in the Islands in 1906 (Bryan, 1934). It appears to be restricted to the island of Hawaii at regions between 1,500 and 6,000 feet (Bess, 1951). According to Sherman (1964), entomologist, the northern cattle grub, *H. bovis,* is also present in most of the Hawaiian Islands.

Cattle grubs (fig. 15) are recognized as injurious to cattle, causing loss of flesh and decreasing the value of the skin for leather. Pickerill (1935), of the Hawaii Meat Company, reported that, during the year 1934, of 15,099 hides of island cattle examined, 4,252, or 28.16 percent, were grubby.

In recent years, a report was made of attacks of blowflies on young calves on the island of Kauai (Holdaway, 1943, 1945). Observations indicated that three species of flies were involved, *Chrysomyia megacephala, C. rufifacies,* and, possibly, *Lucilia sericata*. These flies ordinarily breed in carcasses and other animal matter. However, they may deposit eggs in a number of differ-

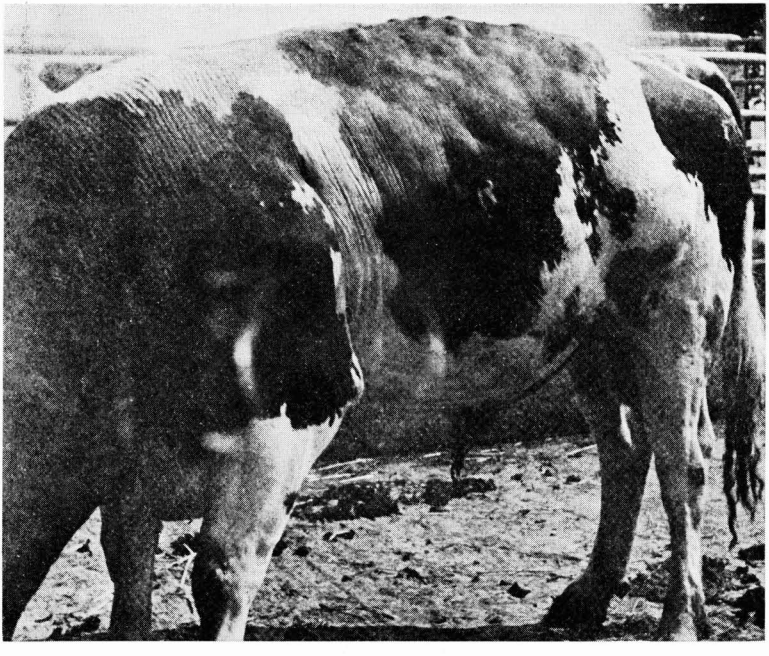

FIGURE 15. Cattle grubs, *Hypoderma* sp., under the skin of the back of a bull. (After Lapage, *Veterinary Parasitology,* courtesy of Pharmaceutical Division, Imperial Chemical Industries, Ltd., London.)

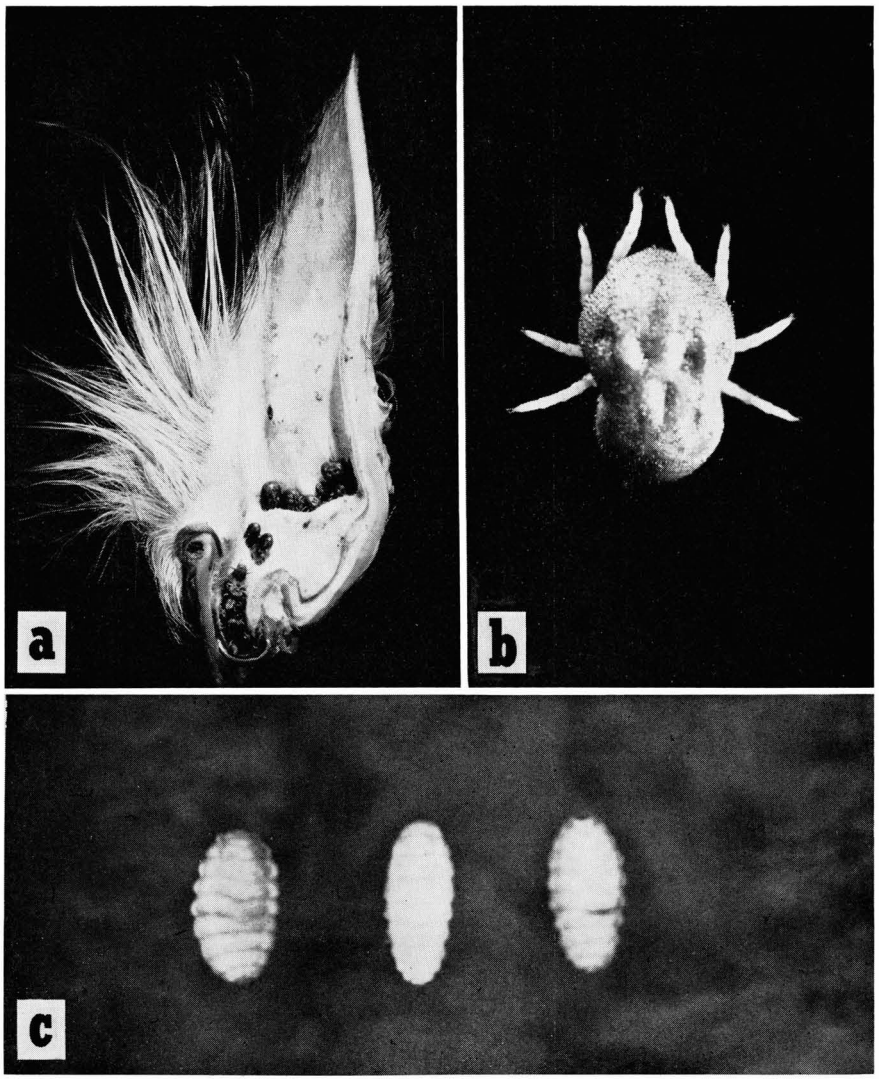

FIGURE 16. *a,* Ear of cattle cut to show ticks, *Otobius megnini,* in the deeper portion of the ear canal; *b,* fully engorged young (nymph) ear tick, greatly enlarged; *c,* third-larval stage of cattle grubs, *Hypoderma lineatum,* from the skin of cattle, slightly enlarged. (Original.)

ent places on recently born calves. The eggs hatch and the larvae or maggots feed on the surface layer and cause an inflamed, malodorous wound. Infested calves become debilitated and, unless treated, often die in a few days.

Auricular myiasis of cattle, caused by the larvae of *C. megacephala, C. rufifacies,* and *Fannia* sp., has been reported by Zimmerman (1944). Species of adult flies which are pestiferous on cattle in the Islands include the horn fly, *Haematobia irritans,* and the stable fly, *Stomoxys calcitrans* (*see* Bryan, 1934). The horn flies are known to serve as intermediate hosts for *Stephanofilaria stilesi* (*see* Ivashkin *et al.,* 1963; Hibler, 1964).

The sucking louse, *Haematopinus eurysternus* (*see* Cuckler and Alicata, 1943), and the biting louse, *Bovicola bovis* (*see* Zimmerman, 1944), have occasionally been found on cattle. General emaciation or unthriftiness is usually associated with these infestations.

The spinose ear tick, *Otobius megnini* (fig. 16), which was first noted in recent years (Alicata, 1941*b;* Cuckler and Alicata, 1943; Zimmerman, 1944), is widespread on beef cattle. Of 357 animals examined from Hawaii, Oahu, and Maui, 160, or 44.8 percent, showed infestation (Cuckler and Alicata, 1943). In several instances, the ticks were seen in large numbers in the ear canal (fig. 16*a*). These ectoparasites are known to puncture the tender skin of the ear and to suck blood. The wounds thus caused often ulcerate and a condition known as ear canker results.

CHICKEN AND OTHER AVIAN HOSTS

PROTOZOA

The coccidium, *Eimeria tenella,* which causes cecal coccidiosis, is the most important protozoan affecting chickens (fig. 17). Infection with this parasite is as troublesome in Hawaii as it is anywhere else. Undoubtedly, other species of coccidia occur among chickens in the Islands, but they have not been determined.

Pigeons in Hawaii are commonly infected with the blood parasite, *Haemoproteus columbae* (*see* Alicata, 1939*c*). Blood smears from 101 adult pigeons in Honolulu showed 83 to be infected (Kartman, 1949). *H. columbae* may produce anemia and lowered vitality. It is transmitted among pigeons through the bite of the pigeon-fly, *Pseudolynchia canariensis,* which is widely distributed (Bryan, 1934). Of a total of 25 *P. canariensis* dissected, 9, or 36 percent, were infected with *H. columbae* (*see* Kartman, 1949). The avian malarial organism, *Plasmodium vaughani,* in the Pekin nightingale, *Liothrix lutea,* was reported by Fisher and Baldwin in 1947. This parasite was noted in 1 of 11 birds examined from Hawaii National Park, island of Hawaii. *P. vaughani* is probably mosquito-borne and its life cycle is only partially known (Manwell, 1947; Laird, 1953).

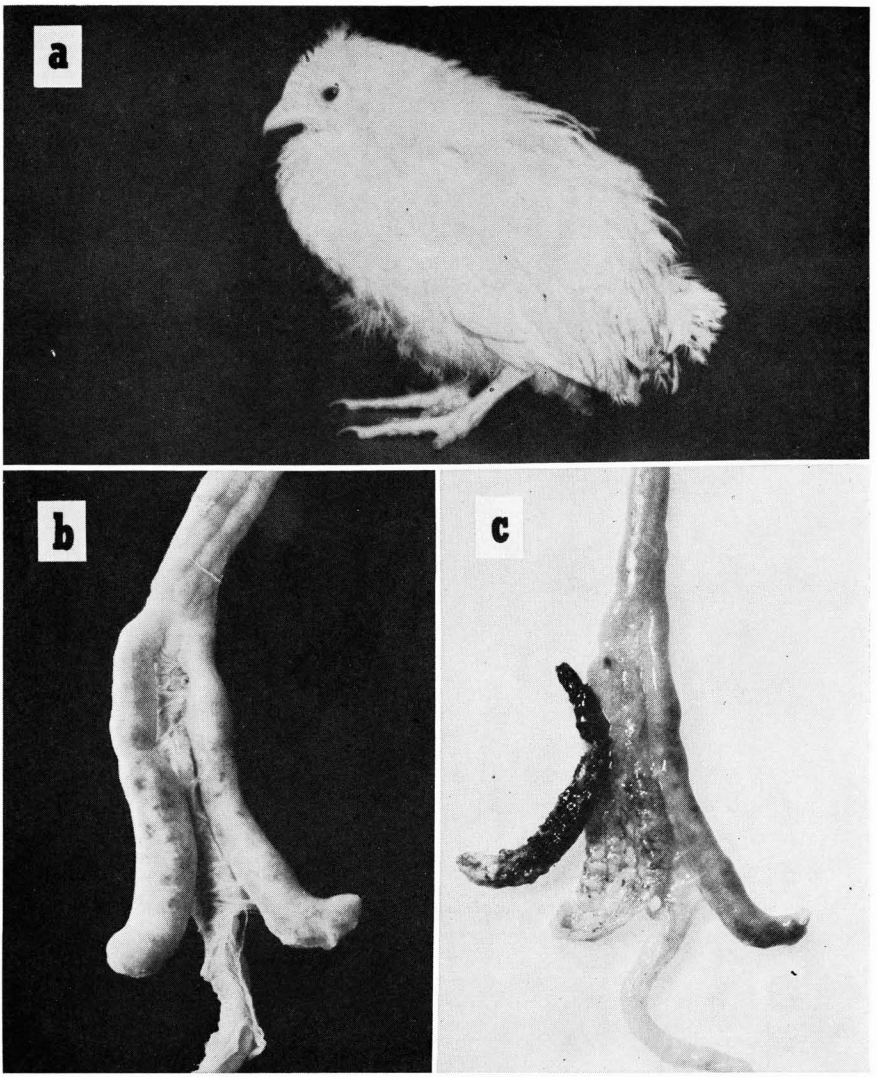

FIGURE 17. *a*, Chick suffering from cecal coccidiosis; *b*, enlarged cecal pouches caused by coccidial infection; *c*, one of the cecal pouches cut open to show cecal core, a whitish cheesy substance with dark bloody areas and containing numerous coccidial oocysts. *b* and *c*, Slightly enlarged. (Original.)

The flagellate, *Trichomonas gallinae*, has been associated with pathological conditions of the upper digestive tract of pigeons in Hawaii (Yager and Gleiser, 1946). Trichomoniasis is ordinarily considered a disease of squabs and young pigeons and is generally less important among older birds. The disease is known to be transmittable to chickens and turkeys, and pigeons may be the source of infection.

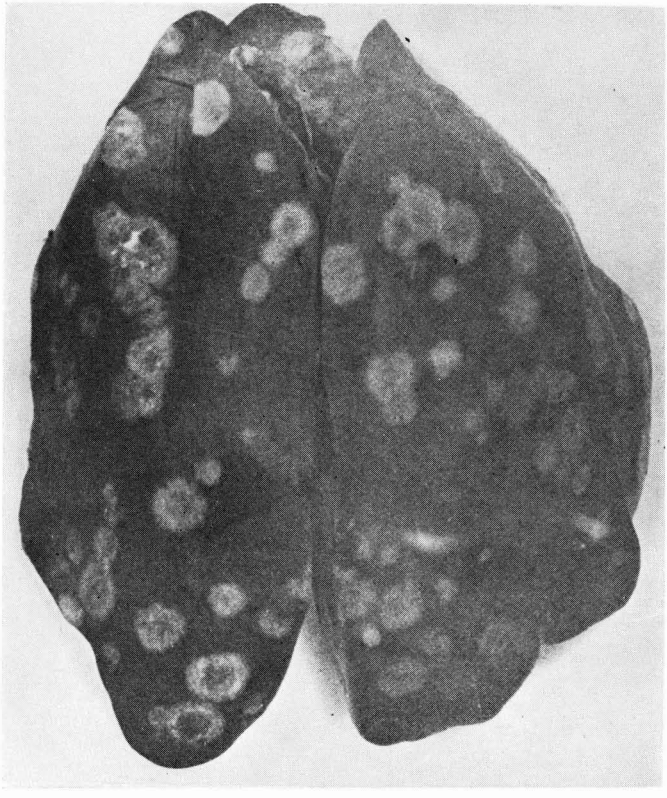

FIGURE 18. Liver of turkey showing characteristic necrotic areas caused by *Histomonas meleagridis.* (After Lapage, *Veterinary Parasitology,* courtesy of Boots Pure Drug Company, Ltd., Nottingham.)

Histomonas meleagridis, the causative organism of "blackhead," is responsible for sporadic outbreaks of this disease in turkeys (fig. 18) in various parts of the Islands. The disease is more frequent among turkeys than chickens. The parasite may be transmitted either by feed or water contaminated with droppings of infected chickens or turkeys or, most commonly, through the ingestion of eggs of the cecal worm, *Heterakis gallinarum,* which carry the small "blackhead" parasite (*see* Roundworms, below).

ROUNDWORMS

The gizzard-worm, *Acuaria hamulosa* (fig. 19*b*), is an important parasite of chickens and turkeys in Hawaii. Depending upon the degree of infection, the lining of the gizzard may contain from small to large ulcerations

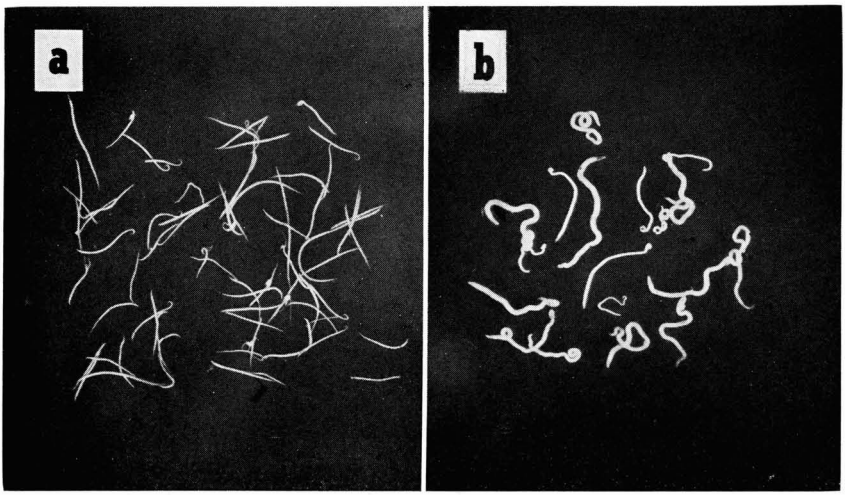

FIGURE 19. *a,* Adult cecal worms, *Heterakis gallinarum; b,* adult gizzard-worms, *Acuaria hamulosa.* All natural size. (Original.)

which may involve the muscular tissue. Soft nodules enclosing parasites are frequently noted in the thinner muscular portion of the gizzard. When heavily parasitized, the gizzard becomes enlarged and may assume a saccular appearance (fig. 20*a*). Up to several years ago, these parasites were very common in the Islands and were responsible for anemia, emaciation, and death, especially among chickens. The spread and incidence of the parasite was checked following the control of various arthropods which serve as intermediate hosts. The following serve as natural or experimental hosts: (Order: Coleoptera) *Carpophilus dimidiatus, Dactylosternum abdominale, Dermestes vulpinus, Epitragus diremptus, Euxestus* sp., *Gonocephalum seriatum, Litargus balteatus, Oxydema fusiforme, Palorus ratzeburgi, Sitophilus oryzae, Tenebroides nana, Tribolium castaneum,* and *Typhaea stercorea;* (Order: Orthoptera) *Atractomorpha ambigua, Conocephalus saltator,* and *Oxya chinensis;* (Order: Amphipoda) *Orchestia platensis.* (*See* Alicata, 1936, 1938*b*, 1939*c*.)

A. hamulosa has also been reported from the Chinese ring-necked pheasant, *Phasianus colchicus torquatus,* but no ill effects were noted (Schwartz and Schwartz, 1951). Another species of gizzard-worm, *Cyrnea graphophasiani,* was reported from the gizzard of one of the pheasants; this was regarded as a new host for this parasite.

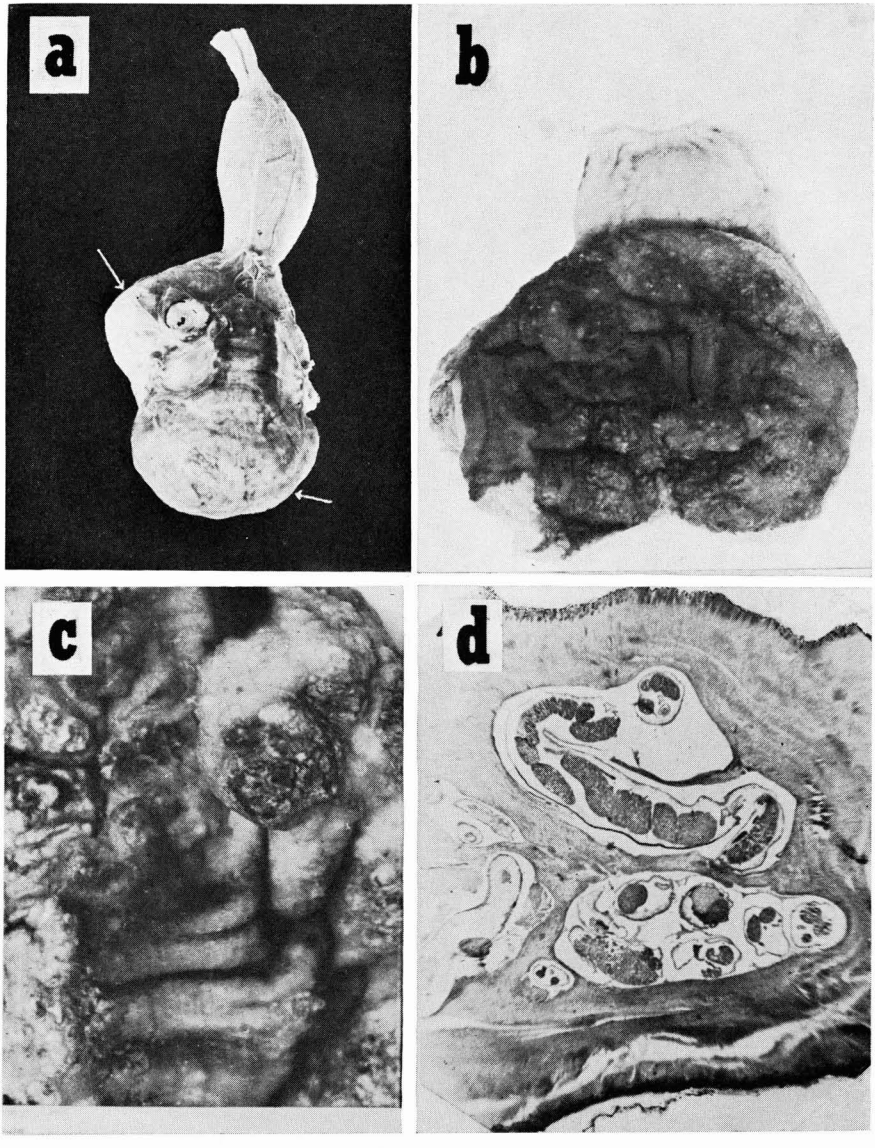

FIGURE 20. Lesions on the gizzard of chicken caused by *Acuaria hamulosa: a,* heavily infected gizzard showing enlargement of the anterior and posterior portions; *b, c,* lesions on the inner lining of the gizzard; *d,* cross section of gizzard showing sections of the worms within the wall. *c,* Enlarged; *d,* greatly enlarged. (After Alicata, 1938.)

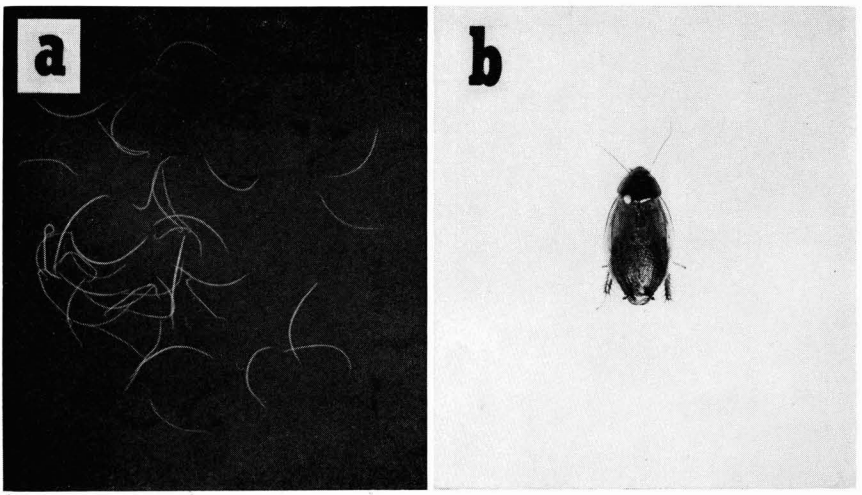

FIGURE 21. *a,* Adult eyeworms, *Oxyspirura mansoni,* natural size; *b,* adult cockroach, *Pycnoscelus surinamensis,* which serves as intermediate host, natural size. (Original.)

The eyeworm, *Oxyspirura mansoni* (fig. 21*a*), which utilizes the burrowing roach, *Pycnoscelus surinamensis* (fig. 21*b*), as intermediate host, was reported by the writer (1936) as being common among chickens in the Islands. However, in more recent years, with the availability and use of several powerful insecticides such as benzene hexachloride, "Parathion," and others (Kartman *et al.,* 1950), it has been possible to reduce the roach infestation and, as a result, to decrease the incidence of eyeworms. This parasite has also been recovered from the Chinese ring-necked pheasant (Swanson, 1939; Schwartz and Schwartz, 1951), the English sparrow (Illingworth, 1931), the mynah bird, the Chinese or lace-necked dove, and the Japanese quail (Schwartz and Schwartz, 1949, 1951). There is thus good reason to believe that wild birds serve as reservoir hosts from which infection can be acquired. An account of the life history of the eyeworm in the intermediate and final hosts in Hawaii was given by Schwabe in 1951. In the bird host, the parasites are located in the inner corner of the eye socket, between the eyeball and the nictitating membrane. In heavy infections, there is a puffiness around the eye and inflammation of the surrounding tissue (Schwabe, 1950). Infected birds blink their eyes continually, and the irritation causes the birds to scratch at their eyes with their claws for relief. The process of scratching frequently causes mechanical injury to the eyeball, which may lead to secondary bacterial and viral infections (Schwabe, 1950). Eyeworms are most

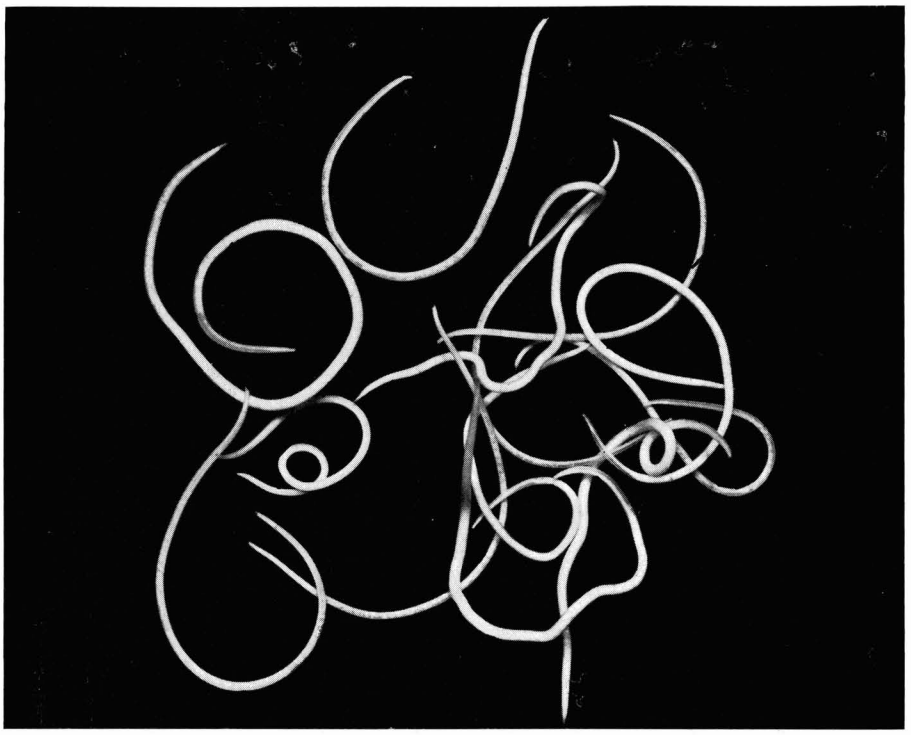

FIGURE 22. Adult intestinal roundworms, *Ascaridia galli,* natural size. (Original.)

prevalent in dry areas with loose sandy soil, in which the roaches thrive. As a means of controlling this disease, the writer has advocated the maintenance of the giant toad, *Bufo marinus,* in poultry yards. This toad is insectivorous and devours roaches readily. Insecticides, such as lindane or chlordane, when dusted on roach-infested ground, are also effective in the control of the burrowing roach (Alicata, 1952*a*).

The poultry ascarid, *Ascaridia galli* (fig. 22), and two species of cecal worms, *Heterakis gallinarum* (fig. 19*a*) and *Subulura brumpti,* are common among chickens. *S. brumpti* is the most prevalent, and, unlike *H. gallinarum,* requires an intermediate host, which may be any one of the following (Alicata, 1939*a*; Cuckler and Alicata, 1944): (Order: Coleoptera) *Alphitobius diaperinus, Ammophorus insularis, Dermestes vulpinus, Gonocephalum seriatum,* and *Tribolium castaneum;* (Order: Orthoptera) *Conocephalus saltator, Oxya chinensis;* (Order: Dermaptera) *Euborellia annulipes. Subulura brumpti, Heterakis gallinarum,* and an undetermined species of *Ascaridia*

(probably *A. galli*) have been reported from the Chinese ring-necked pheasant also (Schwartz and Schwartz, 1951). *A. galli* has been reported from a wide variety of birds, both domestic and wild; however, very little cross-infection work has been done with this ascarid from either domestic or wild game birds (Wehr, 1940). In chickens and turkeys, the cecal worm, *H. gallinarum,* is known to play an important part in the spread of "blackhead" disease although it is not the only factor. The blackhead organism, *Histomonas meleagridis,* may pass out of the bird's body enclosed in the egg of the cecal worm, and in this way it is protected from adverse climatic or environmental conditions.

The intestinal roundworm, *Ornithostrongylus quadriradiatus,* occurs commonly in pigeons in Hawaii and is believed responsible for unthriftiness and losses among these birds (Alicata, 1939*c*). The biology and pathogenicity of this parasite were described by Cuvillier (1937).

Other roundworms of chickens which require an intermediate host include the crop worm, *Gongylonema ingluvicola,* and the proventricular worms, *Tropisurus americanus* and *Dispharynx nasuta* (fig. 23*a*). *D. nasuta* is also known elsewhere to infect turkeys and pigeons. In the continental United States, *G. ingluvicola* utilizes the beetle, *Copris minutus,* as an intermediate host; in Hawaii, the related beetle, *C. incertus,* serves as a suitable host. *T. americanus* utilizes any of the following arthropods as intermediate

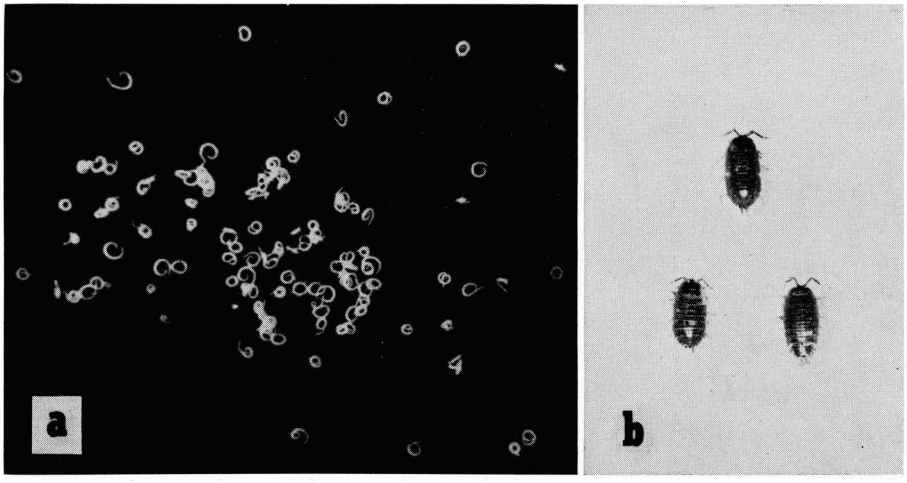

FIGURE 23. *a,* Adult stomach worms, *Dispharynx nasuta,* natural size; *b,* adult sow bugs, *Porcellio laevis,* which serve as intermediate hosts, natural size. (Original.)

hosts in the Islands (Alicata, 1938*c*): (Order: Coleoptera) *Dendrophilus* sp. (probably *D. punctatus*), *Dermestes vulpinus, Epitragus diremptus,* and *Gonocephalum seriatum;* (Order: Orthoptera) *Blatella germanica* and *Conocephalus saltator;* (Order: Dermaptera) *Euborellia annulipes;* (Order: Amphipoda) *Orchestia platensis.* The sow bug, (Order: Isopoda) *Porcellio laevis* (fig. 23*b*), serves as intermediate host for *D. nasuta;* this parasite often produces deep ulcerations of the proventricular wall (Alicata, 1938*c*). In the continental United States, *D. nasuta* is an important parasite of several wild game birds, including the grouse, Hungarian partridge, bobwhite quail, and pheasant (Wehr, 1940).

Kartman (1951) reported a species of *Tetrameres* (= *Tropisurus*) in the proventriculus of 22.2 percent of English sparrows examined, and he experimentally determined that two species of grasshoppers, *Conocephalus saltator* and *Oxya chinensis,* may serve as intermediate hosts. Attempts to infect chicks with the infective third-stage larvae of this parasite proved unsuccessful. Alicata, Kartman, and Fisher (1948) reported a species of *Microtetrameres* from the proventriculus of mynahs.

TAPEWORMS

Tapeworms are of common occurrence in chickens. Those known in Hawaii include the following: *Choanotaenia infundibulum* (fig. 24*b*), *Echinolepis carioca, Hymenosphenacanthus exiguus* (fig. 24*a*), *Raillietina cesticillus,* and *R. tetragona* (*see* Alicata, 1938*c*).

Various arthropods in Hawaii serve as intermediate hosts for the above-mentioned tapeworms, as follows (Alicata, 1938*c*; Hall, 1929): for *C. infundibulum:* (Order: Coleoptera) *Dermestes vulpinus, Epitragus diremptus, Gonocephalum seriatum,* and (Order: Diptera) *Musca domestica;* for *E. carioca:* (Order: Coleoptera) *Aphodius granarius* and (Order: Diptera) *Stomoxys calcitrans;* for *H. exiguus:* (Order: Amphipoda) *Orchestia platensis;* for *R. cesticillus:* (Order: Coleoptera) *Dermestes vulpinus* and *Gonocephalum seriatum;* and for *R. tetragona:* probably various species of ants (Order: Hymenoptera), especially those of the genera *Pheidole* and *Tetramorium.* Members of this group of ants (*Pheidole* sp. and *T. caespitum*) are known to be intermediate hosts of *R. tetragona* in the continental United States (Jones and Horsfall, 1935).

Tapeworm infection has been common among some of the local wild game birds, namely the Chinese dove, *Streptopelia chinensis,* and the feral pigeon, *Columba livia,* according to Schwartz and Schwartz (1949), but the names of the parasites were not determined. *Raillietina* sp. has been noted among local pigeons (Yager and Gleiser, 1946). A tapeworm collected from the intestine of the Hawaiian duck has been identified by McIntosh (1935) as *Hymenolepis* (= *Cloacotaenia*) *megalops.*

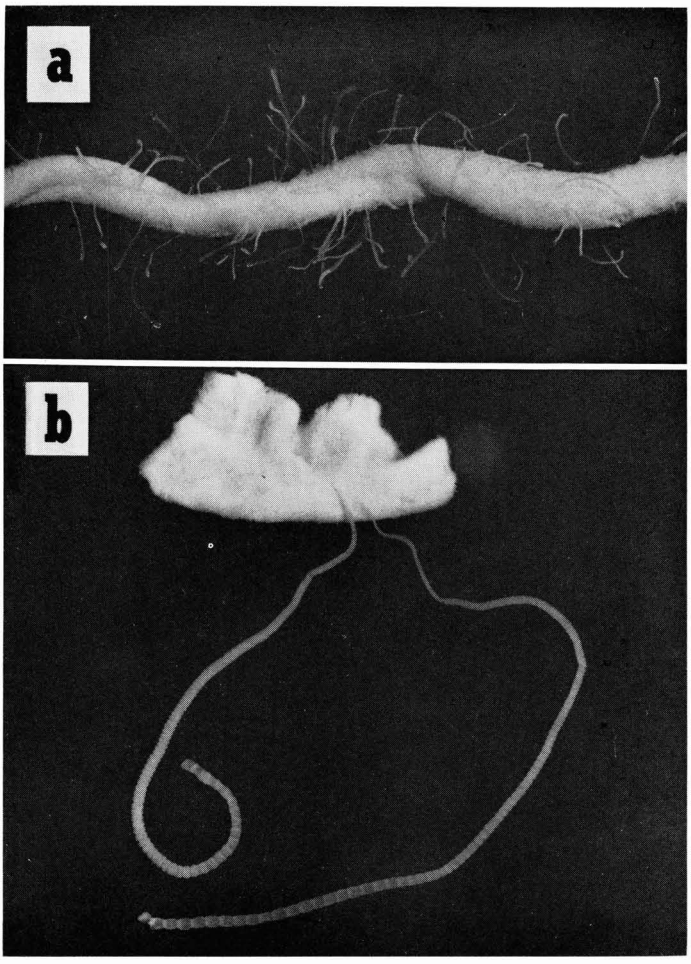

FIGURE 24. Tapeworms of chicken attached to inner lining of the intestinal wall, natural size: *a,* adult *Hymenosphenacanthus exiguus; b,* adult *Choanotaenia infundibulum.* (Original.)

FLUKES

The cecal fluke, *Postharmostomum gallinum* (fig. 25*b*), commonly infects adult chickens raised on the ground. Extensive cecal hemorrhages have been found to be associated with this parasite. Studies have shown that the snail, *Bradybaena similaris,* serves as first and second intermediate host, and *Subulina octona* as second intermediate host (Alicata, 1940). The adolescaria, which is infective to chickens, occurs in the pericardial cavity of the second intermediate host (fig. 25*a*).

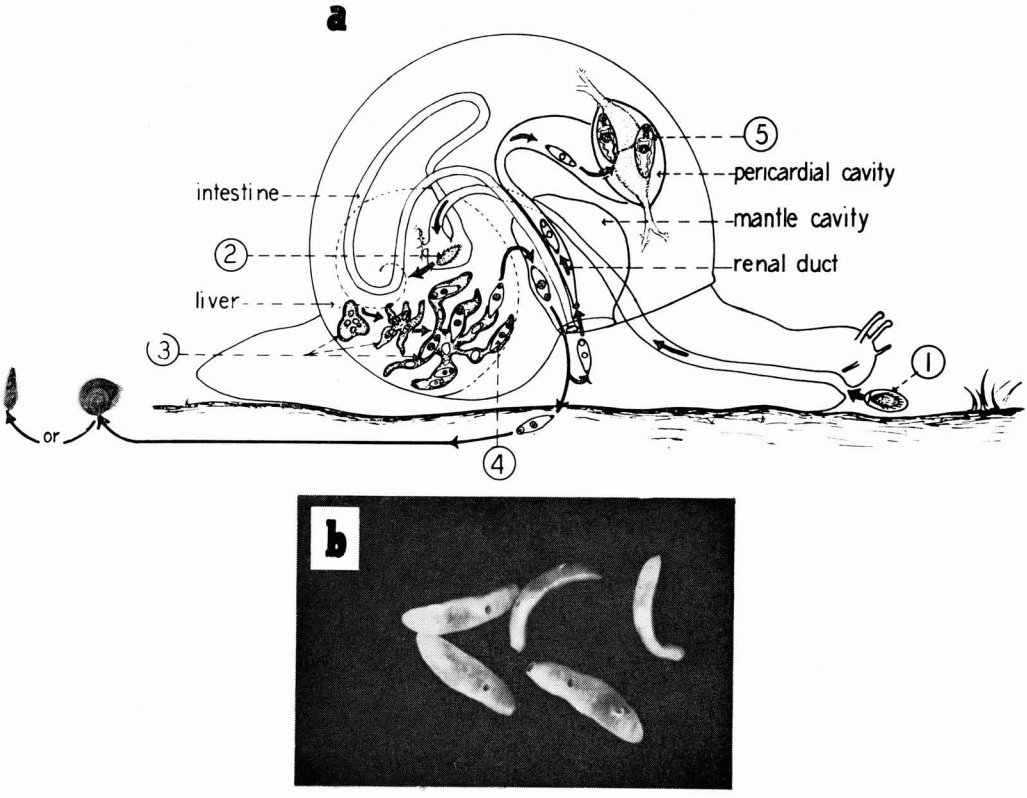

FIGURE 25. *a,* Life cycle of the cecal fluke, *Postharmostomum gallinum,* which is as follows: Fluke egg (1) containing miracidium is swallowed by the snail, *Bradybaena similaris.* Egg hatches in the digestive tract; miracidium (2) migrates to the liver and develops into a branched sporocyst (3), which gives rise to cercariae (4). Cercariae leave the sporocyst and crawl out of the snail. Cercariae, then, may enter the renal duct of the same snail or else that of another snail such as *Subulina octona.* From the renal duct the cercariae reach the pericardial cavity and develop to the adolescaria stage (5) which is infective to chickens. *b,* Adult cecal fluke, *P. gallinum,* ×1½. (Original.)

Martin (1958) reported the night heron as natural host for the heterophyid flukes, *Centrocestus formosanus, Haplorchis taichui,* and *H. yokogawai.* All of these utilize melanid snails and fish as first and second intermediate hosts, respectively (*see* Parasites of Man).

Chu and Cutress (1954) recovered *Austrobilharzia variglandis* in the mesenteric veins of the ruddy turnstone, *Arenaria interpres.* These flukes utilize the littorine snail, *Littorina pintado,* as intermediate host (p. 25).

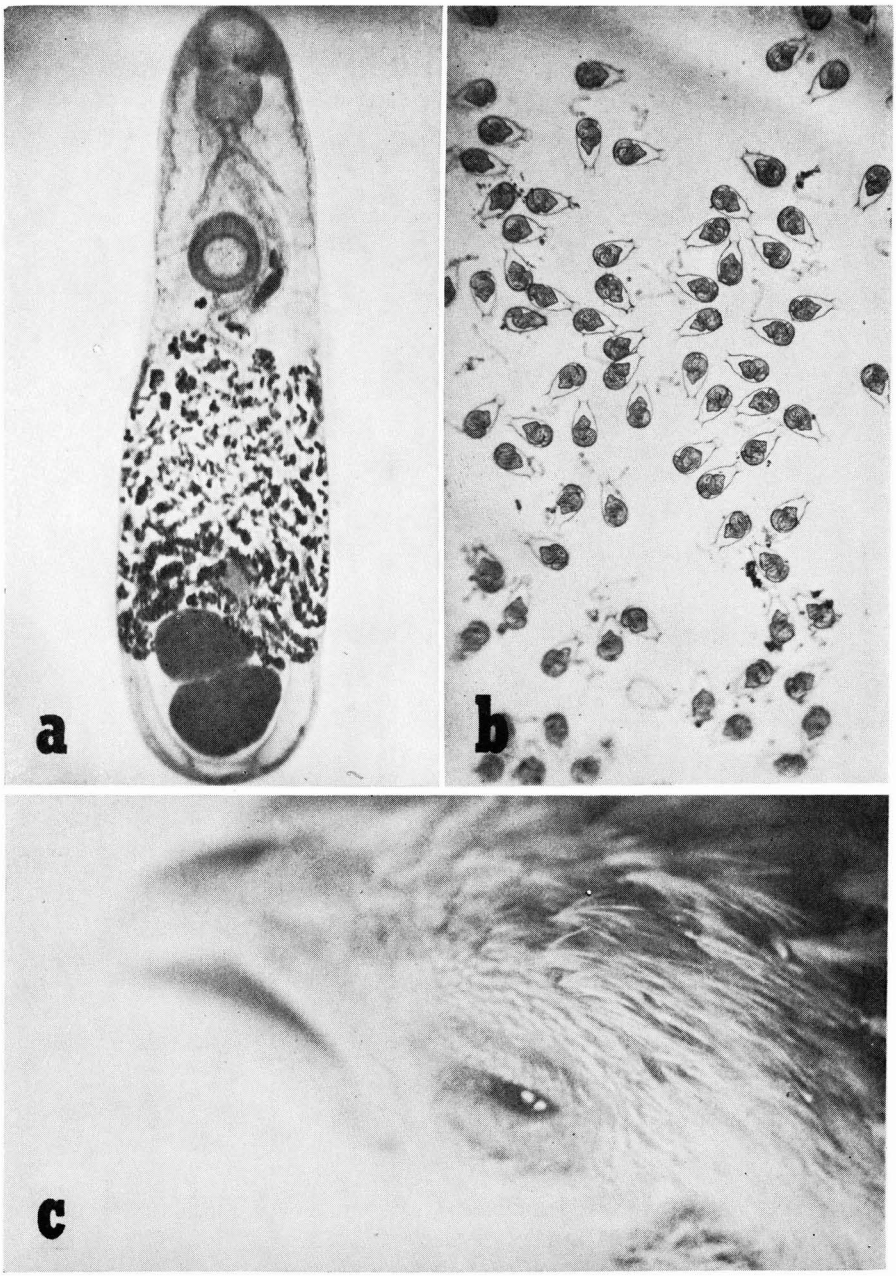

FIGURE 26. *a,* Adult eye-fluke, *Philophthalmus gralli,* ×20; *b,* encysted infective larval stage (metacercariae), ×20; *c,* head of chicken, experimentally infected with eye-flukes, showing congestion of the eyelids. (After Alicata, 1962, courtesy of *Journal of Parasitology.*)

Young chickens and ducks have been infected experimentally with the eye-fluke, *Philophthalmus gralli* (fig. 26*a*), by feeding the birds encysted cercariae (fig. 26*b*) derived from naturally infected melanid snails, *Thiara granifera* and *Stenomelania newcombi* (*see* Alicata and Noda, 1960; Ching, 1961*b;* Alicata, 1962*b*). Rabbits have been infected experimentally by placing the active cercariae on the surface of the eye. Heavily infected chickens and rabbits show considerable congestion and exudate (fig. 26*c*). Natural infections of this parasite occur among the Hawaiian coot, *Fulica americana alai* (*see* Alicata and Noda, 1960). This is a large bird inhabiting the emergent aquatic vegetation or heavy stands of grass of coastal areas. Accidental human infection with this parasite is possible (*see* Parasites of Man).

ARTHROPODS

Various species of biting lice infest poultry in the Islands. These include the following (Illingworth, 1928*a*): chicken body louse, *Menacanthus stramineus;* chicken head louse, *Cuclotogaster heterographa;* common hen louse, *Menopon gallinae,* also found on ducks, guinea fowl, pigeons, and turkeys; fluff louse of chickens and turkeys, *Goniocotes gallinae;* large chicken louse, *Goniodes gigas;* large turkey and chicken louse, *Chelopistes meleagridis;* peafowl and guinea fowl louse, *Menopon phaeostomum;* turkey louse, *Oxylipeurus polytrapezius;* and the chicken wing louse, *Lipeurus caponis.* Also, the biting lice of pigeons, *Columbicola columbae* and *Colpocephalum turbinatum,* and the chicken louse, *Goniodes dissimilis,* have been reported (Zimmerman, 1948).

Several species of biting lice and mites have been recorded by Schwartz and Schwartz (1949) from the following game birds: barred dove, (lice) *Goniocotes asterocephalus, Goniocotes chinensis,* and *Menopon* sp.; California quail, (lice) *Goniodes mammillatus, Lagopoecus docophoroides, Menopon fulvomaculatum,* (mites) *Xoloptes* sp.; Japanese quail, (lice) *Goniocotes asterocephalus;* jungle fowl, (lice) *Goniodes dissimilis, Lipeurus caponis,* and *Menopon gallinae;* pigeon, (lice) *Goniocotes bidentatus,* (mites) *Megninia columbae;* Chinese ring-necked pheasant, (lice) *Goniodes colchici, G. mammillatus, Lipeurus caponis, L. maculosus, Menopon fulvomaculatum, Uchida* sp., (mites) *Megninia columbae* and *Raphignathus* sp.

Several species of biting lice have been listed by Zimmerman (1948) from the following wild birds: "amakihi," *Philopterus macgregori* and *Machaerilaemus hawaiiensis;* "apapane," *Myrsidea cyrtostigma;* barred dove, *Columbicola columbae* and *Goniocotes chinensis;* "dove," *Goniodes lativentris;* English sparrow, *Bruelia vulgata;* California valley quail, *Goniodes mammillatus;* Chinese dove, *Myrsidea invadens, Columbicola columbae,* and *Goniocotes chinensis;* Chinese ring-necked pheasant, *Lipeurus caponis* and

Goniocotes hologaster; guinea fowl, *Goniodes gigas;* gray-backed tern, *Sacmundssonia snyderi* and *Quadraceps birostris;* Hawaiian coot, *Rallicola advena* and *Quadraceps oraria;* Hawaiian owl, *Colpocephalum brachysomum;* "iiwi," *Myrsidea cyrtostigma* and *Colpocephalum hilensis;* linnet, *Colpocephalum discrepans* and *Philopterus subflavescens;* mynah, *Myrsidea invadens;* noddy tern, *Colpocephalum discrepans, Actornithophilus epiphanes,* and *Quadraceps separata;* Pacific golden plover, *Colpocephalum brachysomum, Quadraceps birostris,* and *Saemundssonia conicus;* ricebird, *Philopterus subflavescens* and *Bruelia stenozona;* wandering tattler, *Saemundssonia conicus* and *Actornithophilus kilauensis.*

Several species of biting lice and mites have been reported from the following wild birds trapped on poultry farms (Alicata, Kartman, and Fisher, 1948): barred dove, (lice) *Columbicola columbae* and *Goniodes* sp., (mites) *Ornithonyssus bursa;* Brazilian cardinal, (lice) *Myrsidea incerta;* Chinese dove, (mites) *Pterolichus* sp.; English sparrow, (lice) *Myrsidea* sp., (mites) *Atricholaelaps megaventralis* (= *Haemolaelaps casalis*), *Neonyssus* sp., and *Proctophyllodes truncatus;* Japanese white-eye, (mites) *Dermoglyphus elongatus, Megninia* sp., *Pteronyssus* sp. (?), and *Trouessartia* sp.; mynah, (lice) *Menacanthus spinosus* and *Myrsidea invadens,* (mites) *Montesauria* sp., *Pteronyssus* sp., and *Trouessartia* sp.

Mites found on chickens include: the red mite, *Dermanyssus gallinae,* the wing mite, *Pterolichus obtusus,* and the body mite, *Megninia cubitalis* (*see* Alicata *et al.,* 1946). Also included is the tropical fowl mite, *Ornithonyssus bursa;* this has also been reported as common in nests of English sparrows and mynahs. It is known to invade houses, where it bites human beings and causes skin irritation (Zimmerman, 1944).

The following species of mites have been reported on the Chinese ring-necked pheasant in Hawaii (Schwartz and Schwartz, 1951): *Megninia ginglymura* and *M. columbae.* The latter was also recovered from pigeons. Two other species of mites include *Gabucinia* sp. (*see* Baker, 1956) and the feather mite, *Falculifer rostratus* (*see* Yager and Gleiser, 1946).

Other arthropods reported include: the sticktight flea, *Echidnophaga gallinacea,* on chickens (Illingworth, 1916) and on the California quail (Schwartz and Schwartz, 1951); the pigeon-fly, *Pseudolynchia canariensis,* generally widespread among pigeons (Bryan, 1934); the hippoboscid fly, *Ornithoica vicina,* on the Chinese ring-necked pheasant, the Japanese quail, the jungle fowl (Schwartz and Schwartz, 1951), the English sparrow (Alicata, Kartman, and Fisher, 1948), and on *Zosterops* sp. (*see* Hardy, 1952), presumably the Japanese white-eye; the soft-bodied tick, *Ornithodorus capensis,* which feeds on a variety of birds, has been found in crevices on Manana Island (Strandtmann, 1963). *O. capensis* has also been recorded from Laysan Island of the Hawaiian Archipelago (Butler, 1961).

DEER

PROTOZOA

No reports are available.

ROUNDWORMS

Cooperia punctata is the only roundworm recorded from axis deer in the Hawaiian Islands. The infection was noted in one deer each from the islands of Lanai and Molokai (Ash, 1961). *C. punctata* is a common parasite of calves in Hawaii (*see* Parasites of Cattle). It is likely that the deer acquired the infection from foraging in localities formerly grazed by cattle. This finding leads to the belief that, under field conditions, deer can serve as a reservoir host for this parasite.

TAPEWORMS AND FLUKES

No tapeworms or flukes have been reported. Swanson (1939) examined 8 deer, 14 wild cattle, and about 20 goats for the common cattle liver fluke, *Fasciola gigantica,* but none were found. He was of the opinion (1936) that since these animals do not usually range in fluke-infested areas, they are probably of little importance as reservoir hosts for the cattle liver fluke.

ARTHROPODS

No reports are available.

DOG

PROTOZOA

Canine coccidiosis occurs in dogs in Hawaii, but the species involved is unknown.

ROUNDWORMS

In a study of helminths from 96 dogs in Honolulu, the following species and percentages of roundworms were found (Ash, 1962*a*): hookworms, *Ancylostoma caninum,* 71.0 percent; subcutaneous tissue filarioids, *Dipetalonema* sp., 19.0 percent; heartworms, *Dirofilaria immitis* (fig. 27*a, b*), 23.0 percent; ascarids, *Toxocara canis* (fig. 28), 24.0 percent; whipworms, *Trichuris vulpis,* 3.0 percent. The ascarid, *Toxascaris leonina,* was reported by Hall (1936). In a check list of parasites of dogs and cats, Becklund (1964) lists the dog lungworm, *Filaroides osleri,* from Hawaii. *T. canis* is of public health interest since the infective (second-stage) larvae (fig. 28*d*) are one of the chief causes of visceral larva migrans in children (*see* Parasites of Man). At room

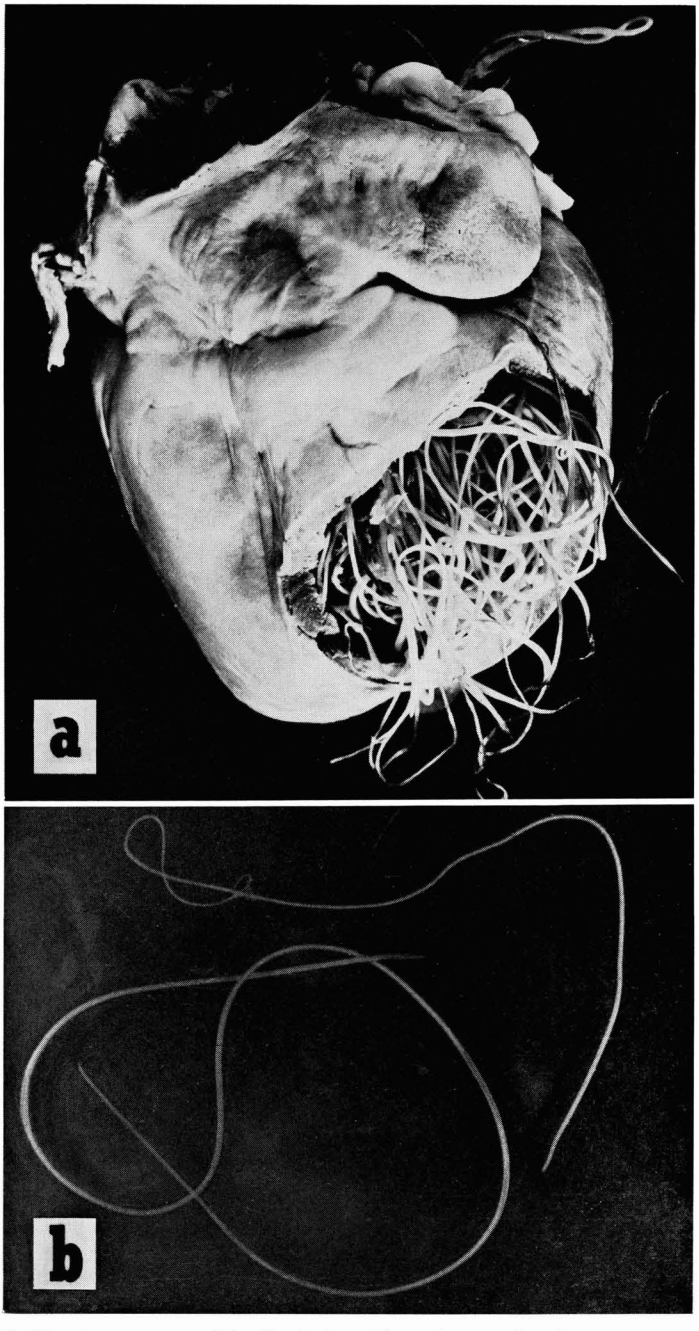

FIGURE 27. Dog heartworms, *Dirofilaria immitis: a,* heart of a dog, cut open to show a cluster of adult heartworms, slightly enlarged; *b,* adult male (*top*) and female worms, natural size. (*a,* Courtesy of U. S. Department of Agriculture; *b,* original.)

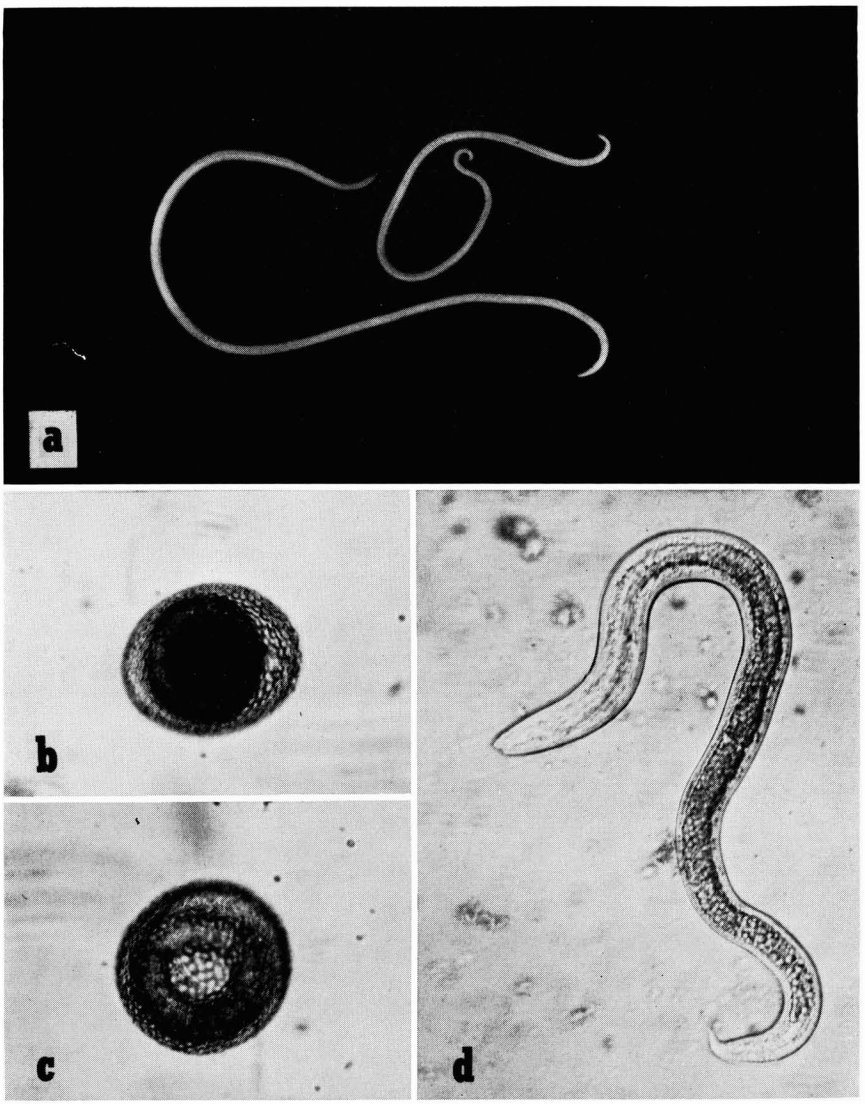

FIGURE 28. Intestinal roundworms, *Toxocara canis: a,* adults, natural size; *b,* egg, undeveloped, ×335; *c,* egg, embryonated, ×335; *d,* infective (second-stage) larva, ×400. (Original.)

temperature (26° C) the eggs of *T. canis* embryonate and contain infective larvae in about 9 days; these larvae are approximately 0.35–0.38 millimeter long by 0.02 millimeter wide (Alicata, 1964*c*).

Of the above roundworms, the heartworm, *D. immitis,* utilizes mosquitoes as intermediate hosts. Of the four species of mosquitoes known to be present in Hawaii, namely, *Culex pipiens quinquefasciatus, Aedes aegypti, A. albopictus,* and *A. vexans nocturnus,* all have been incriminated as intermediate hosts of heartworms (Hall, 1929; Kartman, 1953; Yen, 1938). In recent years, *A. aegypti* has not been found present on the islands of Oahu and Kauai (Nakagawa and Hirst, 1959). The filarioid nematode, *Dipetalonema* sp. (possibly *D. reconditum*), is known to utilize the fleas, *Ctenocephalides canis* and *C. felis,* as intermediate hosts (Newton and Wright, 1956). Of these fleas, *C. felis* occurs in Hawaii. The life history of *Filaroides osleri* is unknown; it is probable that it utilizes mollusks as intermediate hosts, as does the related species, *F. martis* (*see* Dubnitski, 1955, cited by Yamaguti, 1961*a*).

TAPEWORMS

Dipylidium caninum is the only tapeworm recorded from dogs in Hawaii. Of 82 dogs examined in Honolulu, 85.0 percent were infected (Ash, 1962*a*). This tapeworm utilizes fleas and lice as intermediate hosts (Hall, 1929). *Ctenocephalides felis* (*see* Pemberton, 1926) and *Trichodectes latus* (*see* Swezey, 1931), which could serve as hosts, are found on dogs in Hawaii. *D. caninum* also occurs in man. The infective larval stage (cysticercus) of *Taenia hydatigena* has been observed on several occasions attached to the liver and omentum of swine (fig. 40*b*) and sheep in the Islands; from this finding it may be inferred that the adult stage of this parasite is present in dogs.

FLUKES

Two species of heterophyid flukes, *Stellantchasmus falcatus* and *Phagicola longus,* were found in 5 and 3 percent, respectively, of 96 dogs examined by Ash (1962*a*). Dogs, as well as cats, may, therefore, serve as an important reservoir for human infection in this area.

S. falcatus utilizes melanid snails as the first intermediate host and mullet as the second intermediate host (see Parasites of Man). *P. longus* also requires a fresh-water snail and fish as first and second intermediate hosts, respectively, but the species of these hosts have not been determined in Hawaii.

ARTHROPODS

Arthropods present on dogs in Hawaii include the following: fleas, *Ctenocephalides felis* (*see* Pemberton, 1926) and *Echidnophaga gallinacea;* biting

lice, *Trichodectes canis* (*see* Swezey, 1931); species of kangaroo lice, *Heterodoxus longitarsus,* collected from a dog in Honolulu (Pemberton, 1934); sucking lice, *Linognathus setosus* (*see* Zimmerman, 1948); and ticks, *Rhipicephalus sanguineus* (*see* Van Zwaluwenburg, 1934).

GOAT

PROTOZOA

No reports are available.

ROUNDWORMS

The following species of roundworms, collected by Lyman Nichols, wildlife biologist, Hawaii Department of Agriculture, and identified by the writer, were found in wild goats in Hawaii: stomach worms, *Haemonchus contortus;* stomach and intestinal worms, *Ostertagia circumcincta* and *Trichostrongylus colubriformis;* and whipworms, *Trichuris ovis.*

TAPEWORMS AND FLUKES

No tapeworms or flukes have been reported from goats in the Islands. Swanson (1939) examined about 20 goats for the common cattle liver fluke, *Fasciola gigantica,* but none were found.

ARTHROPODS

The sucking louse, *Linognathus africanus,* and the biting louse, *Bovicola caprae,* have been reported from goats (Zimmerman, 1944).

HORSE

PROTOZOA

No reports are available.

ROUNDWORMS

According to a survey (Foster and Alicata, 1939), horses in Hawaii harbor at least 25 species of roundworms as follows: *Alfortia edentata, Cyathostomum asymmetricum, C. bicoronatum, C. calicatum, C. catinatum, C. coronatum, C. euproctum, C. goldi, C. leptostomum, C. longibursatum, C. nassatum, C. pateratum, Delafondia vulgaris, Gyalocephalus capitatus, Habronema microstoma, H. muscae, Oxyuris equi, Parascaris equorum, Poteriostomum imparidentatum, Probstmayria vivipara, Strongylus equinus, Trichostrongylus axei, Triodontophorus brevicauda,* and *T. serratus. Cyathostomum insigne* has also been recorded (Swanson, 1939).

Of the above parasites, *D. vulgaris* (fig. 29*a*) is of somewhat common occurrence. This fact suggests that verminous arthritis and aneurysm, believed to be caused by the larval stages of this roundworm (Lapage, 1956), may not be infrequent among horses in the Islands.

The roundworms of the genus *Habronema* listed above utilize various species of flies as intermediate hosts (Hall, 1929). In Hawaii, the house fly, *Musca domestica,* may transmit *H. muscae* and *H. microstoma,* and the stable fly, *Stomoxys calcitrans,* may transmit *H. microstoma.*

TAPEWORMS

Two species of tapeworms, *Anoplocephala perfoliata* (*see* Foster and Alicata, 1939) and *A. magna* (fig. 29*b*) (Swanson, 1939), have been reported from horses in the Islands. In Russia, under laboratory conditions, free-living oribatid mites of the genus *Scheloribates* have been found to serve as intermediate hosts for these two species of tapeworms. In Russia, experimentally, mites of the genera *Galumna* and *Achipteria* have been found to serve as intermediate hosts for *A. perfoliata* (*see* Kates and Runkle, 1948; Kates, 1965). Oribatid mites of the genera *Galumna* and *Scheloribates,* which are known to occur in Hawaii (Jacot, 1934), may possibly serve as vectors under local conditions.

FLUKES

According to a report by Hall (1936), liver flukes collected in 1894 from a horse in Honolulu were sent to the United States Bureau of Animal Industry. These flukes were originally diagnosed as *Fasciola hepatica,* but a more recent re-examination by McIntosh (1935) revealed that they are *F. gigantica.* Moreover, veterinarians on the island of Kauai have verbally reported to the writer the finding of fasciolid flukes in livers of horses. In recent years, examination by the writer of the livers of five horses pastured in areas known to be fluke-infested failed to reveal liver fluke infection. In addition, a horse and a mule experimentally fed 650 to 2,300 infective liver fluke cysts, respectively, failed to show evidence of flukes or fluke lesions when autopsied a few months later (Alicata and Swanson, 1938). It appears that horses only rarely become infected with liver flukes.

ARTHROPODS

The larvae of the botflies, *Gasterophilus intestinalis* and *G. nasalis,* are commonly found attached to the stomach wall (fig. 30) of horses in the Islands (Foster and Alicata, 1939). The adult stable fly, *Stomoxys calcitrans,* is also pestiferous on horses. The biting horse-louse, *Bovicola equi,* and the sucking louse, *Haematopinus asini,* have been seen on U. S. Army horses brought to the Islands (Zimmerman, 1948).

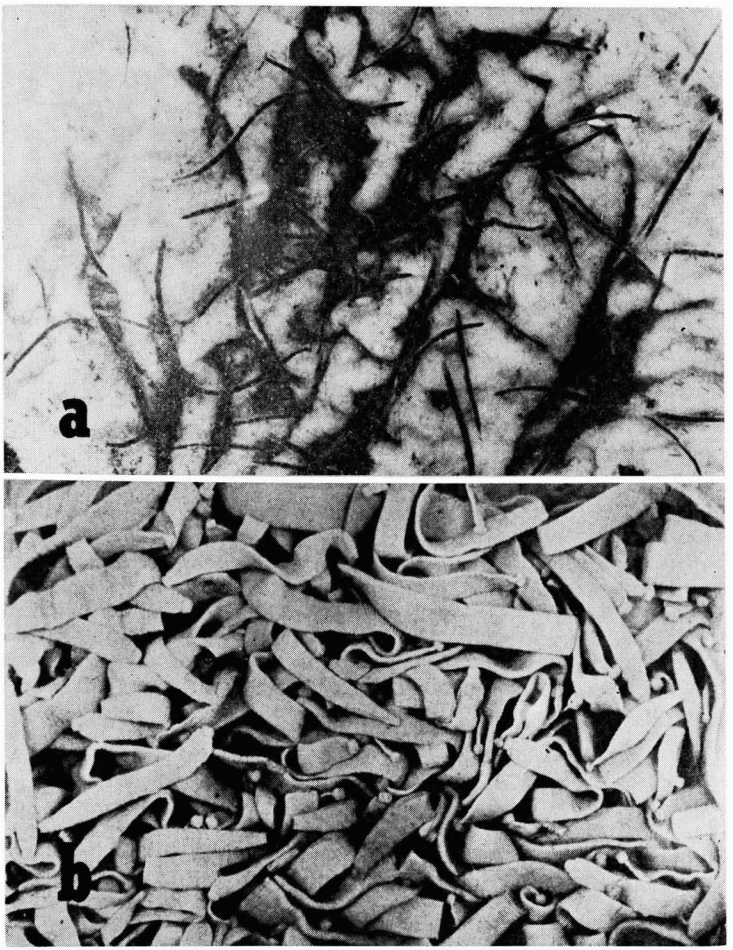

FIGURE 29. *a,* Portion of cecum of a horse showing a mixed infection of *Strongylus equinus* and *Delafondia vulgaris,* natural size; *b,* adult tapeworms, *Anoplocephala magna,* from a horse, about one-half natural size. (After Schwartz *et al.,* 1948, U. S. Department of Agriculture, Circular 148.)

MONGOOSE

PROTOZOA

No reports are available.

ROUNDWORMS

The infective stage of *Trichinella spiralis* was found in 21.4 percent and 9.1 percent of the mongooses examined on the islands of Hawaii and Maui, respectively (Alicata, 1938*e*).

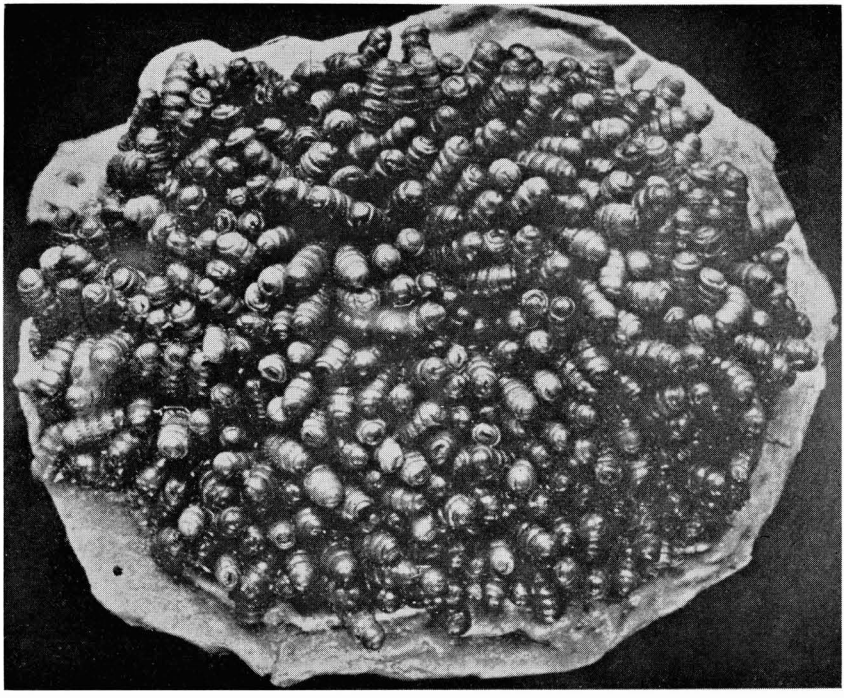

FIGURE 30. Larvae of the botfly, *Gasterophilus intestinalis,* attached to the wall of the stomach of a horse. (After Lapage, *Veterinary Parasitology,* courtesy of Mr. H. Bastin, Reading.)

TAPEWORMS AND FLUKES

No reports are available.

ARTHROPODS

The following species of fleas have been reported from the mongoose in Hawaii (Pemberton, 1945): *Ctenocephalides felis, Echidnophaga gallinacea, Leptopsylla segnis, Nosopsyllus fasciatus, Xenopsylla cheopsis,* and *X. vexabilis hawaiiensis.* The mange mite, *Notoedres cati,* has also been collected from the mongoose (Haramoto, 1964).

MOUSE

PROTOZOA

No reports are available on protozoan parasites of mice in Hawaii. *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 experimentally grown in mice and rats and propagated in culture media (Johnson, 1947).

ROUNDWORMS

Of 343 mice examined from various islands of Hawaii, none showed infection with trichina larvae (Alicata, 1938*c*).

TAPEWORMS

The liver of mice in Hawaii has been found to be commonly infected with the infective stage (strobilocercus) of the cat tapeworm, *Hydatigera taeniaeformis.*

FLUKES

No reports are available.

ARTHROPODS

The following fleas have been reported from mice in Hawaii (Pemberton, 1945): *Ctenocephalides felis, Leptopsylla segnis, Nosopsyllus fasciatus, Xenopsylla cheopis,* and *X. vexabilis hawaiiensis.* Mites reported from mice in Hawaii include: *Myobia musculi* (*see* Baker, 1956), *Myocoptes musculinus, Radfordia affinis* (*see* Joyce, 1957), and *Listrophorus* sp. (Joyce, 1959).

RABBIT

PROTOZOA

Encephalitozoon cuniculi has been found in the apparently normal tissue of the brain of local rabbits (Shoho, 1964). This microsporidian parasite, though frequently innocuous, is able to produce paralysis and death to rabbits. The mode of transmission is not well understood.

Liver coccidiosis caused by *Eimeria stiedae* is of common occurrence in domestic rabbits in Hawaii. Infected animals frequently show whitish spots on the surface of the liver. These spots contain masses of coccidial oocysts. The parasite is usually transmitted either in feed or water contaminated with droppings of infected rabbits.

ROUNDWORMS

Pinworms, *Passalurus ambiguus,* have occasionally been noted in the cecum and large intestine of domestic rabbits in the Islands (Alicata, 1964*c*).

TAPEWORMS AND FLUKES

No reports are available.

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, 1964). 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*e*). 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).

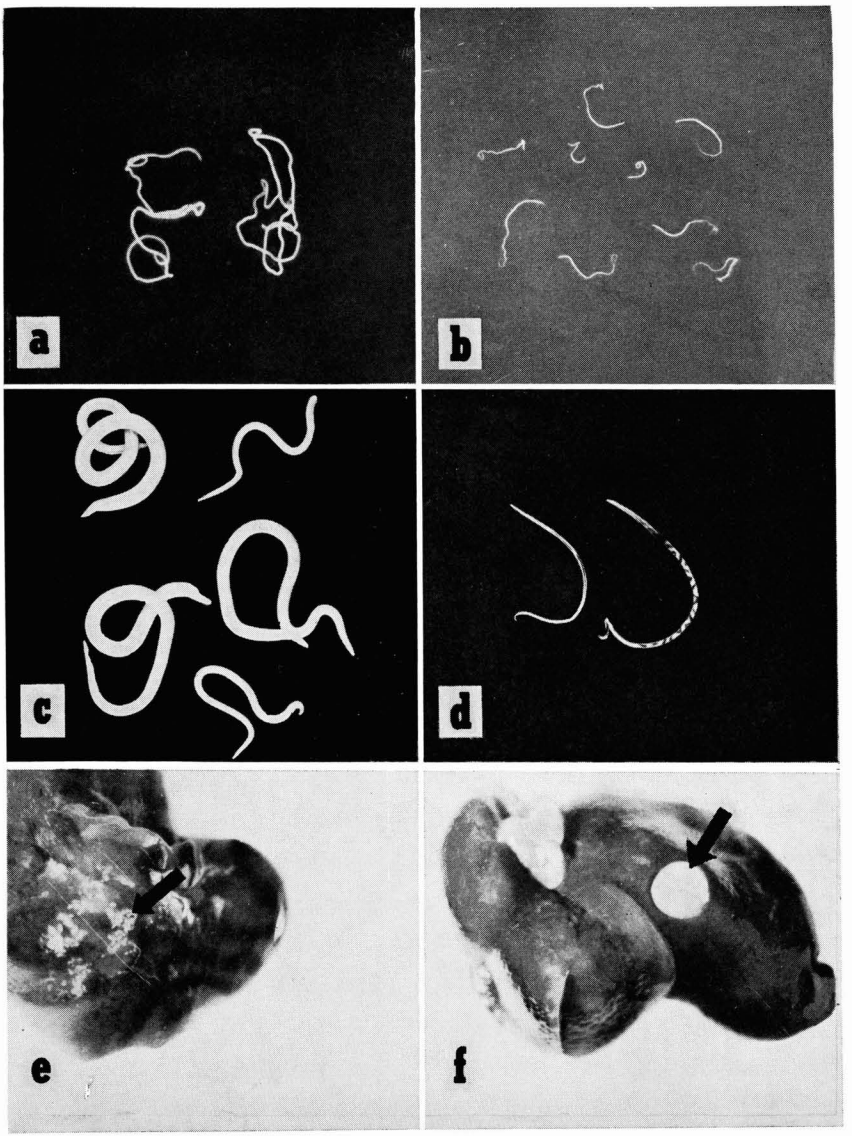

FIGURE 31. Parasites of the rat: *a,* adult *Gongylonema neoplasticum; b,* adult bladderworms, *Trichosomoides crassicauda; c,* adult stomach worms, *Physaloptera muris-brasiliensis; d,* adult lungworms, *Angiostrongylus cantonensis; e,* liver showing clusters (*arrow*) of eggs and adults of *Capillaria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

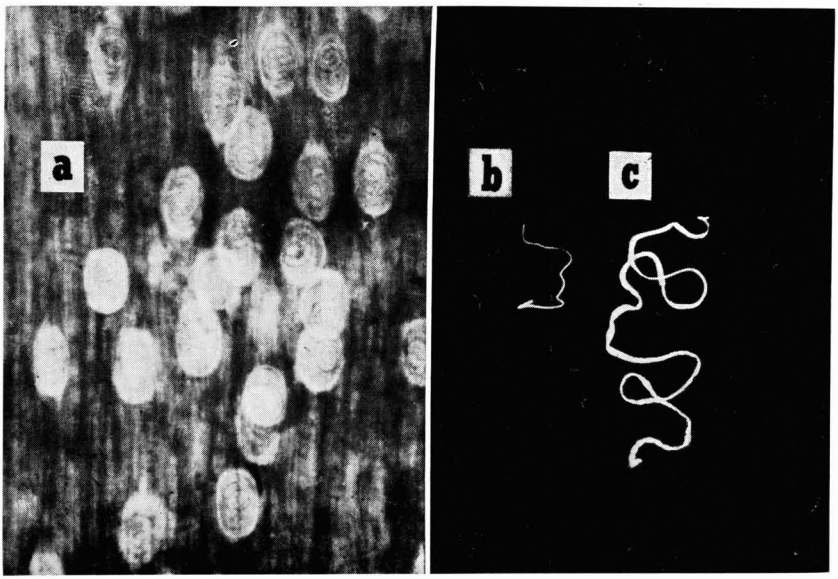

FIGURE 32. *a,* Infective larvae of *Trichinella spiralis* encysted in the diaphragm of rat, highly magnified; *b,* adult tapeworm, *Hymenolepis nana,* natural size; *c,* adult tapeworm, *Hymenolepis diminuta,* natural size. (Original.)

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-

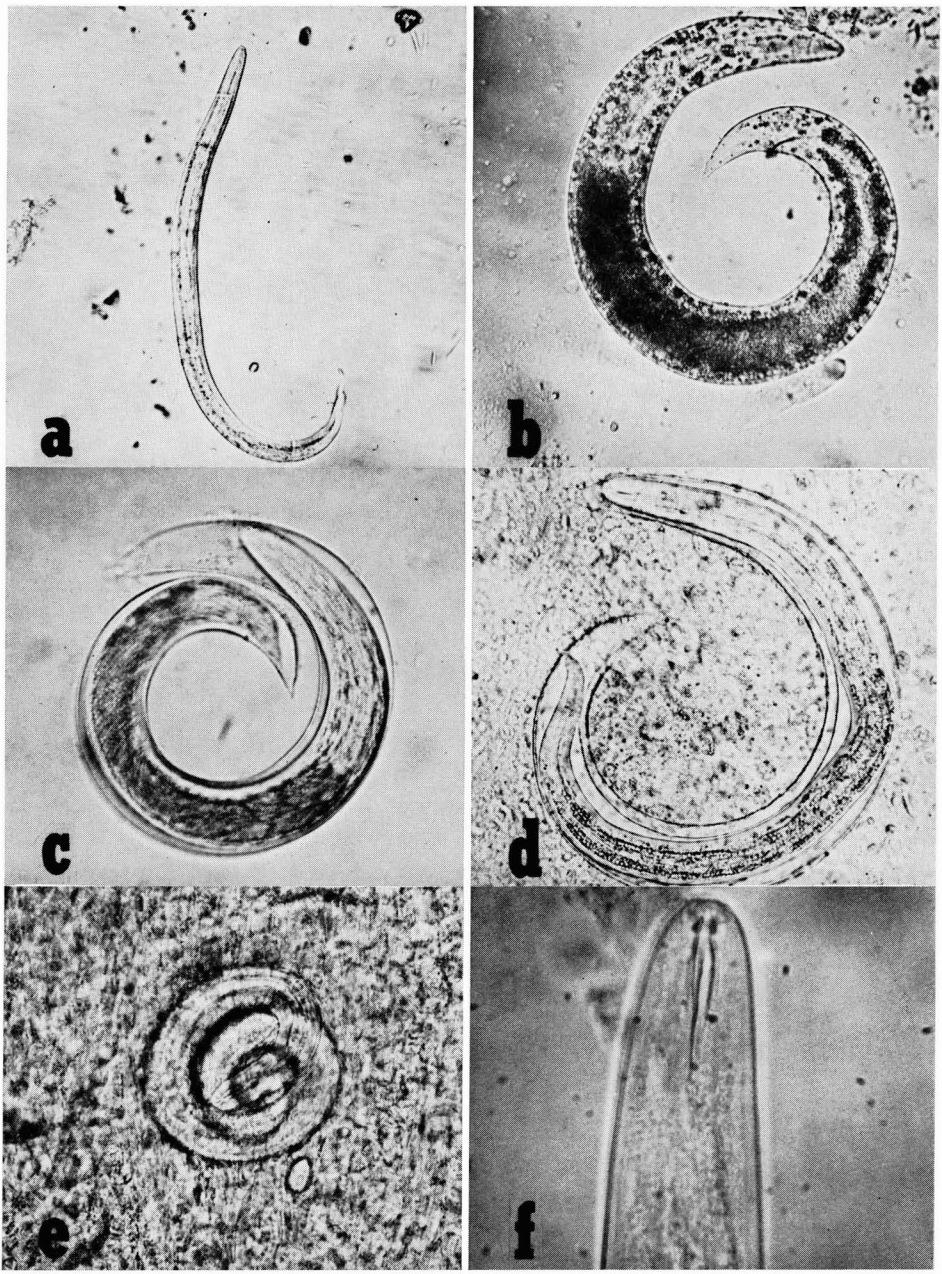

FIGURE 33. Larvae of *Angiostrongylus cantonensis: a,* first-stage larva recovered from feces of rat, ×300; *b,* full-grown first-stage larva from snail, ×300; *c,* second-stage larva enclosed within cuticle of first molt from snail, ×300; *d,* third-stage larva enclosed within cast cuticles of the first 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, ×640. (*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 40 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

intestine and develop into sexually mature adults. In the indirect cycle, species of fleas such as *Nosopsyllus fasciatus* and *Xenopsylla cheopis,* or the grain beetle, *Tenebrio molitor,* serve as intermediate hosts (Hall, 1929). Voge and Heyneman (1957) studied the development of *H. nana* and *H. diminuta* in experimentally infected beetles, *Tribolium confusum.*

H. diminuta utilizes a large number of arthropods as intermediate hosts, including certain species of beetles, dermapterans, fleas, lepidopterans, and myriapods (Hall, 1929).

FLUKES

Plagiorchis muris was found by Ash (1962*b*) in 1 out of 75 rats he examined in Honolulu. Unpublished data by Noda (1958) stated that rats obtained from rural areas, particularly near bodies of water, were frequently infected with the heterophyid fluke, *Stellantchasmus falcatus* (fig. 6*a*). It appears that rats, as well as cats and dogs, serve as reservoir hosts for *S. falcatus* infection of man in Hawaii. Martin (1958) reported rats as natural hosts for *Centrocestus formosanus* in Hawaii.

An adult echinostomid fluke, identified as *Echinostoma* sp. and closely resembling *E. ilocanum,* was recovered from the small intestine of a white rat experimentally fed encysted metacercariae found in naturally infected fresh-water snails, *Fossaria ollula,* collected by the writer in the Kailua district of the island of Oahu. The metacercariae possessed about 47 uninterrupted collar spines, and the eggs of the adult worm measured 0.093 to 0.108 millimeter long by 0.070 to 0.074 millimeter wide (Alicata, 1964*c*).

Of the above flukes, the life history of *P. muris* in Hawaii has not as yet been determined. The first intermediate host of this parasite in the continental United States is the snail, *Stagnicola emarginata angulata* (*see* McMullen, 1937*a*); and in Japan, *Lymnaea viridis* (*see* Tanabe, 1922). The metacercariae encyst either in the snail host or in various species of aquatic insect larvae, which serve as secondary intermediate hosts. The final hosts reported in other areas include birds, man, mice, and rats (McMullen, 1937*a, b*). *S. falcatus* and *C. formosanus* utilize melanid snails and mullet as first and second intermediate hosts, respectively (*see* Parasites of Man).

ARTHROPODS

Seven species of fleas are known to occur on rats in Hawaii (Pemberton, 1945). These include the following: *Ctenocephalides felis,* rarely found on rats and mice, but common on cats, dogs, and mongooses; *Echidnophaga gallinacea,* also found on poultry, dogs, and mongooses; *Leptopsylla segnis,* uncommon on rats, but common on cats, dogs, and mice; *Nosopsyllus fasciatus,* found mostly at about 2,500 feet elevation on the islands of Maui and

Hawaii and also rarely found on mice and mongooses; *Pulex irritans,* rare on rats, and also found on cats, dogs, and man; *Xenopsylla cheopis* and *X. vexabilis hawaiiensis,* also rarely found on mice and mongooses.

Mites found on rats include *Laelaps echidninus* and *L. hawaiiensis* (= *L. nuttalli*) (*see* Pemberton, 1943), *Radfordia ensifera* (*see* Joyce, 1958), and *Ornithonyssus bacoti* (*see* Haramoto, 1964), which are also capable of biting man.

Species of sucking lice found on rats include the spinulose rat louse, *Polyplax spinulosa,* and the Pacific rat louse, *Hoplopleura oenomydis* (*see* Zimmerman, 1948).

Of the above fleas, *X. cheopis* and *X. vexabilis hawaiiensis* are the principal vectors of bubonic plague (Eskey, 1934). *X. cheopis* and *N. fasciatus* are believed to be the principal vectors of endemic typhus (Doolittle, 1941); *E. gallinacea* also serves in the same capacity (Alicata, 1942*a*). The flea, *C. felis,* is an intermediate host for the tapeworm, *Dipylidium caninum* (*see* Hall, 1929), and for the subcutaneous tissue filarioid, *Dipetalonema* sp., of dogs (Newton and Wright, 1956).

SHEEP

PROTOZOA

No reports are available.

ROUNDWORMS

An examination of a group of sheep from the island of Kahoolawe revealed the following incidence of roundworms (Cuckler, 1943): stomach worms, *Haemonchus contortus,* in 6 of 15 examined, and *Trichostrongylus colubriformis,* in 3 of 10 examined; intestinal worms, *Cooperia punctata,* in 3 of 10 examined, and *Nematodirus spathiger,* in 1 of 10 examined.

TAPEWORMS

Tapeworms identified by the writer as *Moniezia expansa* have been found in the intestines of wild sheep. In the continental United States, this tapeworm is known to utilize several species of free-living oribatid mites of the genera *Galumna, Peloribates, Protoschelobates,* and *Oribatula* as intermediate hosts (Kates and Runkel, 1948). Members of the genera *Galumna* and *Protoschelobates* are known to occur in Hawaii (Jacot, 1934), and may serve as vectors under local conditions.

Unidentified larval tapeworms (cysticerci), probably those of *Taenia hydatigena,* attached to the liver and peritoneum of sheep, were noted by Julien (1947), federal meat inspector. The larvae of *T. hydatigena* reach maturity in the intestinal tract of dogs.

FLUKES

Specimens of liver flukes collected from sheep in Honolulu were submitted to the United States Bureau of Animal Industry in 1892 (Hall, 1936). These specimens, which originally were identified as *Fasciola hepatica,* are probably those of *F. gigantica,* since the former is only rarely found in the Islands.

ARTHROPODS

In the examination by Cuckler (1943) of 60 sheep from the island of Kahoolawe, 43 harbored the spinose ear tick, *Otobius megnini.* Reports also indicate the occurrence of the "sheep tick," *Melophagus ovinus* (*see* Bryan, 1934; Muir, 1928); the "head maggot," *Oestrus ovis* (*see* Bryan, 1934); and the "Oriental blowfly," *Chrysomyia megacephala* (*see* Bryan, 1934). The sheep scab mite, *Psoroptes equi ovis,* has been reported from sheep in the Islands (Hawaii Dept. Agr. and Cons., 1960).

SWINE

PROTOZOA

At least four species of protozoa occur in swine in the Islands (Alicata, 1947). They are frequently the cause of dysentery, especially among young animals (fig. 34). Included are the coccidia, *Eimeria debliecki, E. scabra* (fig. 35), and *E. spinosa,* and the ciliate, *Balantidium coli.* Various forms of unidentified amoebae and flagellates of unknown pathogenicity are also frequently found in the feces of swine.

ROUNDWORMS

In 1938, an examination of the feces of 103 grown pigs from the islands of Oahu and Hawaii (Alicata, 1939*b*) revealed the following incidence of parasite eggs: *Ascaris lumbricoides,* 21 percent; *Oesophagostomum dentatum,* 32 percent; *Strongyloides ransomi,* 43 percent; *Trichuris trichiura,* 7 percent.

Adult roundworms which have been recovered at necropsy from swine include the following (Alicata, 1938*d*): stomach worms, *Ascarops strongylina* and *Hyostrongylus rubidus;* intestinal worms, *A. lumbricoides* (fig. 36), *T. trichiura* (fig. 37*b*), and *O. dentatum* (fig. 37*a*); kidney worms, *Stephanurus dentatus* (fig. 38*b*); lungworms (fig. 40*a*), *Choerostrongylus pudendotectus* and *Metastrongylus elongatus.* Larvae of *Trichinella spiralis* (fig. 32*a*) also have been found encysted in the musculature of a domestic pig (Alicata, 1938*e*).

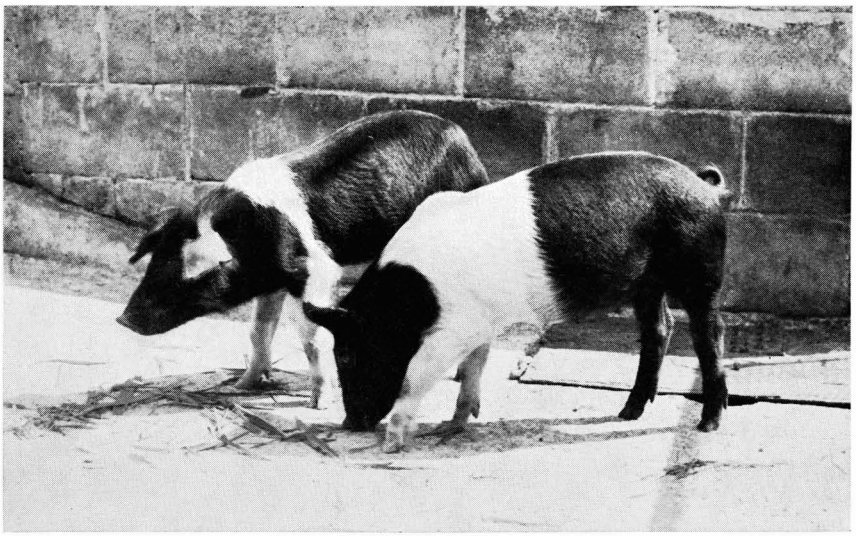

FIGURE 34. Two pigs of the same litter. *Left,* pig which had suffered from a severe case of experimental coccidiosis; *right,* control normal pig. (Original.)

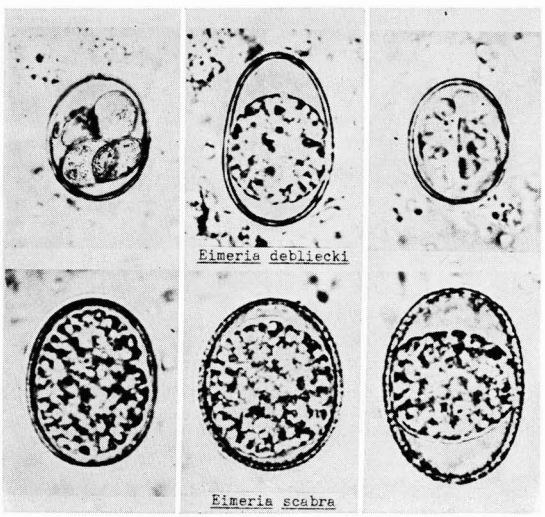

FIGURE 35. Intestinal coccidia of swine. (After Henry, 1931, courtesy of University of California Press.)

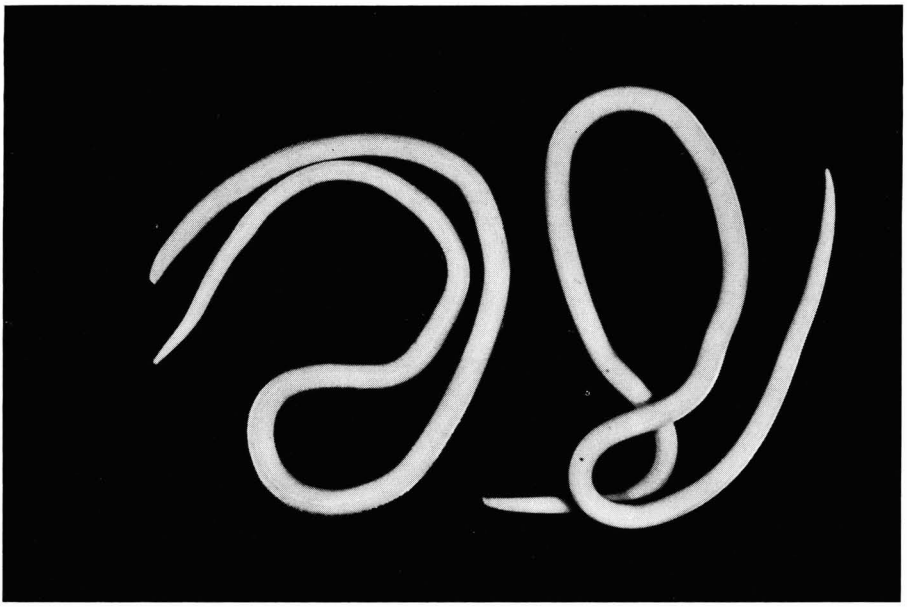

FIGURE 36. Intestinal roundworms, *Ascaris lumbricoides*, natural size.

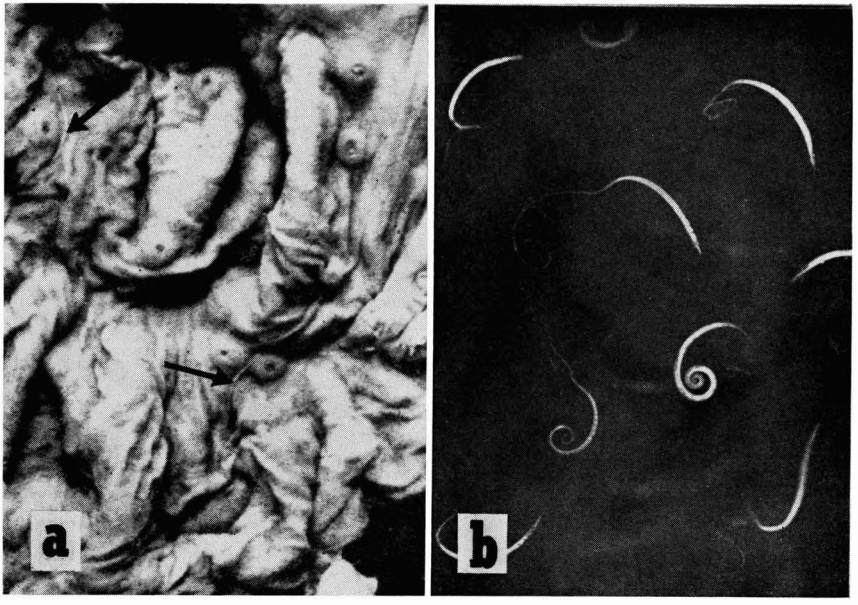

FIGURE 37. *a*, Large intestine of pig showing adult nodular worms, *Oesophagostomum dentatum* (*arrows*) and nodules caused by them; *b*, adult whipworms, *Trichuris trichiura*, natural size. (After Schwartz, 1952, U. S. Department of Agriculture, Farmers' Bulletin 1787.)

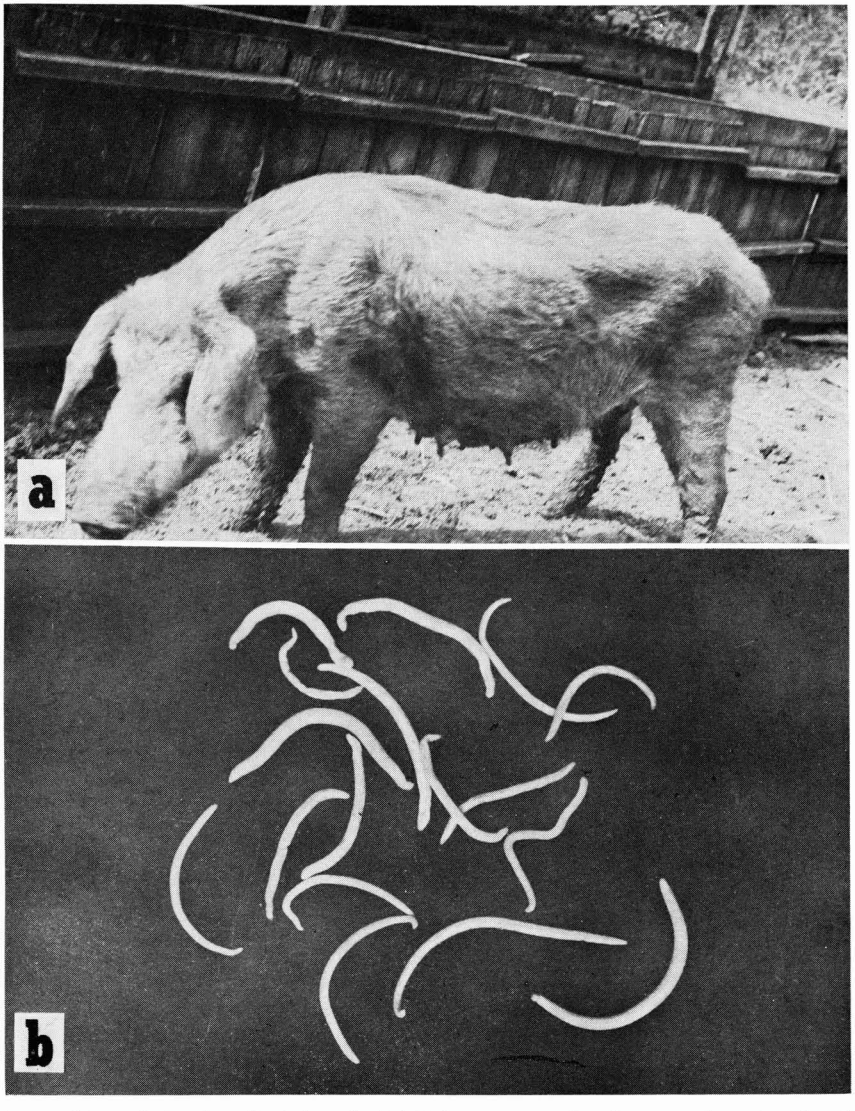

FIGURE 38. *a,* Swine heavily infected with kidney worms, *Stephanurus dentatus; b,* adult kidney worms, natural size. (*a,* After Alicata, 1953, courtesy of *American Journal of Veterinary Research; b,* original.)

The following species of roundworms collected by Lyman Nichols, wildlife biologist, Hawaii Department of Agriculture, and identified by the writer, have been found among wild pigs in Hawaii: lungworms, *Metastrongylus elongatus* and *Choerostrongylus pudendotectus;* stomach worms, *Ascarops strongylina* and *Physocephalus sexalatus;* intestinal worms, *Globocephalus urosubulatus* and *Oesophagostomum dentatum;* kidney worms, *Stephanurus dentatus.* Wild pigs are descendants of domestic stock which escaped and now roam wild in the mountains, swamps, and wastelands of the Islands.

Kidney worms and lungworms are most frequently present among hogs raised in open hog lots. According to Gooch (1952), veterinarian, Hawaii Department of Health, of 16,323 hogs slaughtered between January and April, 1952, on the island of Oahu, 3,466 (21.2 percent) harbored kidney worms. Furthermore, one of the slaughterhouses in Honolulu indicated that during 1947, hog livers valued at about $13,000 were condemned because of parasitism due largely to kidney worms (fig. 39) (Kartman and Alicata, 1948). A method of protecting swine against kidney worm infection by the use of polyborate as a larvicide was suggested by Alicata (1954).

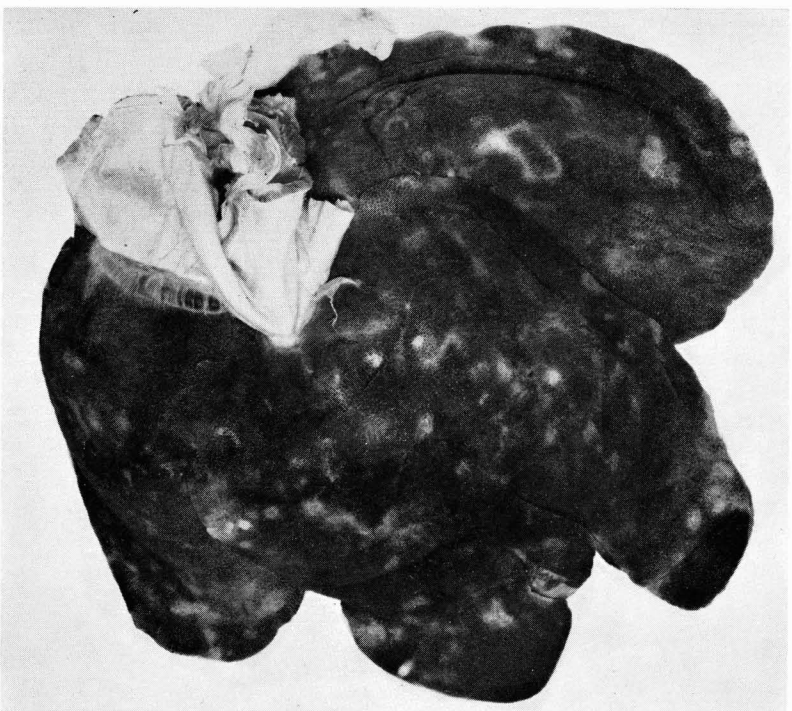

FIGURE 39. Liver of swine showing lesions produced by the migratory, immature stages of the kidney worm, *Stephanurus dentatus.* (Original.)

Of the above roundworms, lungworms require earthworms as intermediate hosts. At least two species of unidentified earthworms recovered from hog lots around Honolulu were found by the writer to harbor infective lungworm larvae. It was reported (Williams, 1931) that in Hawaii there were about a dozen species of earthworms of the genus *Pheretima*. The stomach worms, *A. strongylina* and *P. sexalatus*, utilize one of various coprophagous beetles as intermediate hosts in the continental United States (Alicata, 1935); in Hawaii, coprophagous beetles possibly serve in this capacity.

Because of the occurrence of the first laboratory-proved case of human trichinosis in Hawaii in 1936, the writer, under the auspices of the Hawaii Department of Health, conducted a survey to determine the prevalence of trichina infection in nature. This survey revealed the following information: of 47 domestic hogs and 40 wild hogs examined from the island of Hawaii, 1 (2.1 percent) and 6 (15.0 percent), respectively, were found infected; of 2,130 rats and 70 mongooses examined, 57 (2.7 percent) and 15 (21.4 percent), respectively, harbored trichinae. No trichinae were observed in 92, 130, and 30 domestic hogs examined from the islands of Maui, Oahu, and Kauai, respectively. Of 1,904 rats and 22 mongooses examined on Maui, 1 (0.05 percent) and 2 (9.1 percent), respectively, were found infected. Of 352 and 601 rats examined from Oahu and Kauai, respectively, none were infected (Alicata, 1938*e*).

It is of interest to point out that, from 1936 to 1964, the Hawaii Department of Health reported 112 cases of human trichinosis in Hawaii. Most of the infected persons had eaten, or were suspected of having eaten, improperly cooked wild pork or products made from wild pork (Alicata, 1938*e*). According to records of the Hawaii Board of Agriculture and Forestry, during the 8-year period from 1933 through 1940 inclusive (Tinker, 1941), 32,724 wild hogs, or an average of 4,090 a year, were killed on five of the larger islands. Because of the moderately high incidence of trichinosis in wild hogs, meat from these animals constitutes a health menace unless proper precautions are taken in cooking, preservation, and refrigeration. Of 133 human diaphragms examined at autopsy in Honolulu, 7.4 percent harbored trichina larvae (Alicata, 1942*b*) (*see* Parasites of Man).

TAPEWORMS

No adult tapeworms are present in swine. However, the infective larval stage (cysticercus) of *Taenia hydatigena* (fig. 40*b*) has been observed attached to the liver and omentum of domestic swine (Alicata, 1938*d*) and wild pigs. These larvae are known to reach maturity in the intestinal tract of dogs.

In 1954, a case of human cysticercosis (infection with the larval stage of *Taenia solium*) of unknown origin was reported in Honolulu in a person

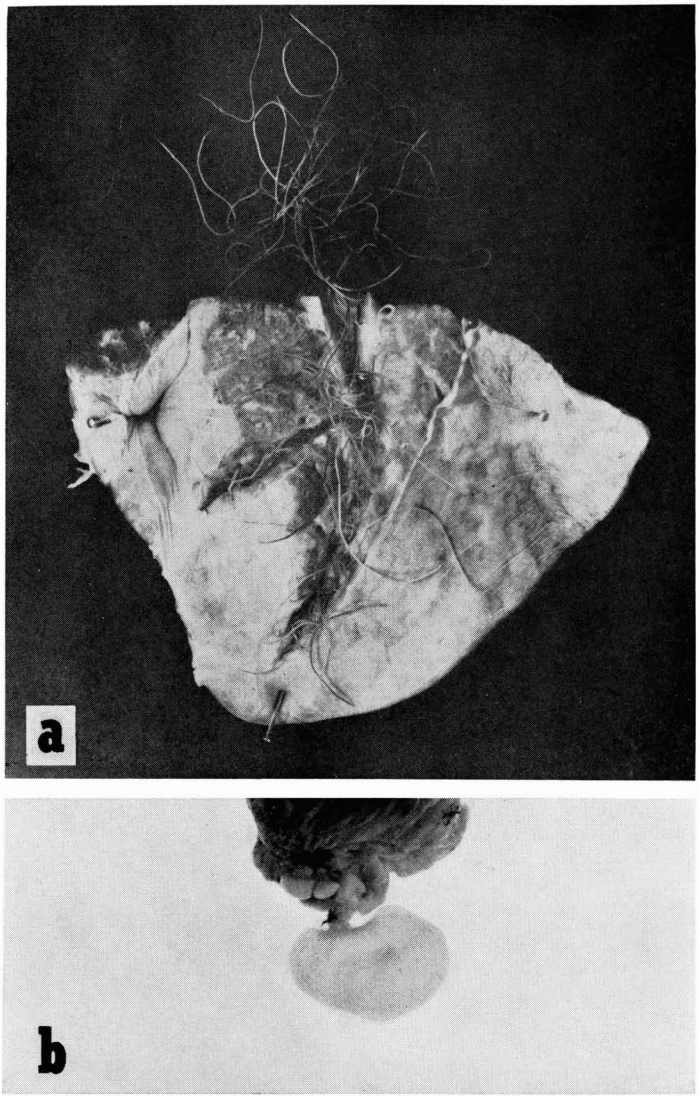

FIGURE 40. Parasites of swine: *a,* adult lungworms in lower portion of lung, natural size; *b,* infective bladderworm stage of the dog tapeworm, *Taenia hydatigena,* attached to omentum of swine, natural size. (*a,* After Schwartz, 1952, U. S. Department of Agriculture, Farmers' Bulletin 1787; *b,* original.)

who had never resided away from the Islands (*see* Parasites of Man). Since this form of infection usually results from the ingestion of food or water contaminated with the eggs of the parasite, it implies that the adult parasite occurs in man in Hawaii. Man acquires the adult parasite from eating raw or undercooked pork containing the infective bladderworm stage. No record is available of the occurrence of porcine cysticercosis in Hawaii.

FLUKES

Flukes are not known to occur in domestic hogs in Hawaii. However, the liver fluke of cattle, presumably *Fasciola gigantica,* has been reported from wild pigs (Shipley, 1913).

ARTHROPODS

The hog mange mite, *Sarcoptes scabiei suis,* is present among domestic and wild pigs in the Islands (fig. 41). The sucking louse, *Haematopinus suis,* is also present (Illingworth, 1928*b*). Infestation with these ectoparasites is very often associated with malnutrition and unhygienic surroundings.

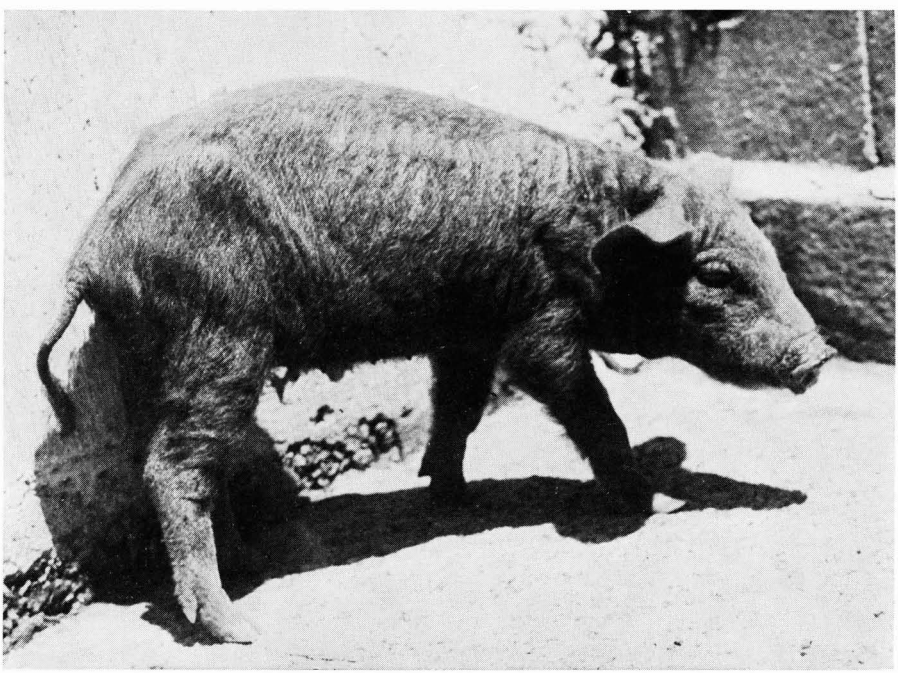

FIGURE 41. Pig showing lesions of sarcoptic mange. (Original.)

HOST LIST OF PARASITES AND INTERMEDIATE HOSTS RECORDED FROM HAWAII

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
"AMAKIHI" (*Chlorodrepanis virens*)		
Arthropods:		
Machaerilaemus hawaiiensis	External	
Philopterus macgregori	External	
"APAPANE" (*Himatione sanguinea*)		
Arthropods:		
Myrsidea cyrtostigma	External	
BARRED DOVE (*Geopelia striata striata*)		
(*See* DOVE, BARRED)		
BRAZILIAN CARDINAL (*Paroaria cucullata*)		
(*See* CARDINAL, BRAZILIAN)		
CALIFORNIA VALLEY QUAIL (*Lophortyx californica vallicola*)		
(*See* QUAIL, CALIFORNIA VALLEY)		
CARDINAL, BRAZILIAN (*Paroaria cucullata*)		
Arthropods:		
Myrsidea incerta	External	
CAT (*Felis domestica*)		
Roundworms:		
Aelurostrongylus abstrusus	Lungs	Gastropoda: *Subulina octona*,[2] *Bradybaena similaris*[2] (rodents serve as paratenic hosts)
Anafilaroides rostratus	Lungs	Gastropoda: *Subulina octona*,[2] *Bradybaena similaris*[2] (rodents serve as paratenic hosts)
Ancylostoma tubaeforme	Small intestine	
Dirofilaria immitis	Heart and pulmonary artery	(*See* Parasites of Dog, p. 101)

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Physaloptera praeputialis	Stomach	Orthoptera: *Blatella germanica*[3]
Toxocara canis	Small intestine	
Tapeworms:		
Dipylidium caninum	Small intestine	(*See* Parasites of Dog, p. 101)
Hydatigera taeniaeformis	Small intestine	Rodentia: *Mus musculus*,[1] *Rattus norvegicus*,[1] *Rattus rattus*[1]
Flukes:		
Phagicola longus	Small intestine	Gastropoda (first intermediate host): unknown in Hawaii Teleostei (second intermediate host): unknown in Hawaii
Platynosomum fastosum	Liver	Gastropoda (first intermediate host): *Subulina octona*,[2] *Bradybaena similaris*[2] Squamata (second intermediate host): unknown in Hawaii
Stellantchasmus falcatus	Small intestine	(*See* Parasites of Man, p. 107)
Arthropods:		
Ctenocephalides felis	External	
Echidnophaga gallinacea	External	
Felicola subrostrata	External	
Notoedres cati	External	

CATTLE (*Bos taurus*)

Protozoa:		
Eimeria bovis	Small intestine and cecum	
Eimeria bukidnonensis	Intestine	
Eimeria cylindrica	Intestine	
Eimeria zurnii	Small and large intestines	

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Roundworms:		
Bunostomum phlebotomum	Small intestine	
Cooperia pectinata	Small intestine	
Cooperia punctata	Small intestine	
Cooperia spatulata	Small intestine	
Dictyocaulus viviparus	Lungs	
Gongylonema pulchrum	Esophagus	Coleoptera: *Aphodius lividus*,[3] *Dermestes vulpinus*[3] Orthoptera: *Blatella germanica*[3]
Haemonchus contortus	Fourth stomach	
Oesophagostomum radiatum	Cecum and colon	
Ostertagia ostertagi	Small intestine	
Stephanofilaria stilesi	Skin	Diptera: *Haematobia irritans*[3]
Strongyloides papillosus	Small intestine	
Trichostrongylus axei	Fourth stomach	
Trichuris ovis	Cecum	
Tapeworms:		
Moniezia benedeni	Small intestine	Acarina: Species of oribatid mites
Taenia saginata (cysticercus)	Muscles	Artiodactyla: *Bos taurus*[1] (cattle serve as intermediate host; man is the final host)
Flukes:		
Fasciola gigantica	Liver	Gastropoda: *Fossaria ollula*,[1] *Pseudosuccinea columella*[2]
Fasciola hepatica	Liver	Gastropoda: *Fossaria ollula*[2]
(Rumen fluke)	Rumen	(Unknown)
Arthropods:		
Bovicola bovis	External	
Chrysomyia megacephala (larvae)	In wounds and external	

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Chrysomyia rufifacies (larvae)	In wounds and external	
Fannia sp. (larvae)	External	
Haematobia irritans	External	
Haematopinus eurysternus	External	
Hypoderma bovis (larvae)	Under skin	
Hypoderma lineatum (larvae)	Under skin	
Lucilia sericata (?) (*see* p. 55) (larvae)	External	
Otobius megnini (larvae and nymphs)	Ear canal	
Stomoxys calcitrans	External	

CHICKEN (*Gallus gallus*)

Protozoa:

Eimeria tenella	Cecum	
Histomonas meleagridis	Cecum and liver	

Roundworms:

Acuaria hamulosa	Gizzard	Amphipoda: *Orchestia platensis*[1] Coleoptera: *Carpophilus dimidiatus*,[2] *Dactylosternum abdominale*,[2] *Dermestes vulpinus*,[2] *Epitragus diremptus*,[1] *Euxestus* sp.,[2] *Gonocephalum seriatum*,[2] *Litargus balteatus*,[2] *Oxydema fusiforme*,[2] *Palorus ratzeburgi*,[2] *Sitophilus oryzae*,[2] *Tenebroides nana*,[1] *Tribolium castaneum*,[2] *Typhaea stercorea*[2] Orthoptera: *Atractomorpha ambigua*,[2] *Conocephalus saltator*,[2] *Oxya chinensis*[2]
Ascaridia galli	Small intestine	
Dispharynx nasuta	Proventriculus	Isopoda: *Porcellio laevis*[1]

* Legend: (1) = infection found in nature; (2) = determined experimentally; (3) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Gongylonema ingluvicola	Crop	(Unknown; probably coprophagous beetles)
Heterakis gallinarum	Cecum	
Oxyspirura mansoni	Conjunctival sac	Orthoptera: *Pycnoscelus surinamensis*[1]
Subulura brumpti	Cecum	Coleoptera: *Alphitobius diaperinus*,[1] *Ammophorus insularis*,[1] *Dermestes vulpinus*,[1] *Gonocephalum seriatum*,[1] *Tribolium castaneum*[2] Orthoptera: *Conocephalus saltator*,[2] *Oxya chinensis*[2] Dermaptera: *Euborellia annulipes*[1]
Tropisurus americanus	Proventriculus	Coleoptera: *Dendrophilus* sp.,[1] *Dermestes vulpinus*,[1] *Epitragus diremptus*,[1] *Gonocephalum seriatum*[1] Orthoptera: *Blatella germanica*,[1] *Conocephalus saltator*[2] Dermaptera: *Euborellia annulipes*[1] Amphipoda: *Orchestia platensis*[1]
Tapeworms:		
Choanotaenia infundibulum	Small intestine	Coleoptera: *Dermestes vulpinus*,[1] *Epitragus diremptus*,[1] *Gonocephalum seriatum*[1] Diptera: *Musca domestica*[3]
Echinolepis carioca	Small intestine	Coleoptera: *Aphodius granarius*[3] Diptera: *Stomoxys calcitrans*[3]
Hymenosphenacanthus exiguus	Small intestine	Amphipoda: *Orchestia platensis*[1]
Raillietina cesticillus	Small intestine	Coleoptera: *Dermestes vulpinus*,[1] *Gonocephalum seriatum*[1]

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Raillietina tetragona	Small intestine	(Probably ants of the genera *Pheidole* and *Tetramorium*)[3]
Flukes:		
Postharmostomum gallinum	Cecum	Gastropoda: *Bradybaena similaris*,[1] *Subulina octona*[1]
Arthropods:		
Chelopistes meleagridis	External	
Cuclotogaster heterographa	External	
Dermanyssus gallinae	External	
Echidnophaga gallinacea	External	
Goniocotes gallinae	External	
Goniodes dissimilis	External	
Goniodes gigas	External	
Lipeurus caponis	External	
Megninia cubitalis	External	
Menacanthus stramineus	External	
Menopon gallinae	External	
Ornithonyssus bursa	External	
Pterolichus obtusus	External	

CHINESE DOVE (*Streptopelia chinensis*)
(*See* DOVE, CHINESE)

CHINESE RING-NECKED PHEASANT (*Phasianus colchicus torquatus*)
(*See* PHEASANT, CHINESE RING-NECKED)

COOT, HAWAIIAN (*Fulica americana alai*)

Flukes:		
Philophthalmus gralli	Eye	Gastropoda: *Stenomelania newcombi*,[1] *Thiara granifera*[1]
Arthropods:		
Quadraceps oraria	External	
Rallicola advena	External	

* Legend: (1) = infection found in nature; (2) = determined experimentally; (3) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
DEER (*Cervus axis*)		
Roundworms:		
Cooperia punctata	Small intestine	
DOG (*Canis familiaris*)		
Protozoa:		
(Coccidia of undetermined species)	Small intestine	
Roundworms:		
Ancylostoma caninum	Small intestine	
Dipetalonema sp.	Subcutaneous tissue	Siphonaptera: *Ctenocephalides felis*[3]
Dirofilaria immitis	Heart and pulmonary artery	Diptera: *Aedes aegypti*,[3] *Culex pipiens quinquefasciatus*[3]
Filaroides osleri (*see* p. 71)	Lungs	(Unknown; *see* p. 74)
Toxascaris leonina	Small intestine	
Toxocara canis	Small intestine	
Trichuris vulpis	Cecum	
Tapeworms:		
Dipylidium caninum	Small intestine	Siphonaptera: *Ctenocephalides felis*,[3] *Pulex irritans*[3] Anoplura: *Trichodectes latus*[3]
Taenia hydatigena (*see* p. 74)	Small intestine	(*See* Parasites of Swine, p. 117)
Flukes:		
Phagicola longus	Small intestine	(*See* Parasites of Cat, p. 96)
Stellantchasmus falcatus	Small intestine	(*See* Parasites of Man, p. 107)
Arthropods:		
Ctenocephalides felis	External	
Echidnophaga gallinacea	External	
Heterodoxus longitarsus	External	
Linognathus setosus	External	
Rhipicephalus sanguineus	External	
Trichodectes canis	External	

* Legend: (1) = infection found in nature; (2) = determined experimentally; (3) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)

DOVE (Species unrecorded)

Arthropods:

Goniodes lativentris	External	

DOVE, BARRED (*Geopelia striata striata*)

Arthropods:

Columbicola columbae	External	
Goniocotes asterocephalus	External	
Goniocotes chinensis	External	
Goniodes sp.	External	
Menopon sp.	External	
Ornithonyssus bursa	External	

DOVE, CHINESE (*Streptopelia chinensis*)

Roundworms:

Oxyspirura mansoni	Eye	(*See* Parasites of Chicken, p. 99)

Arthropods:

Columbicola columbae	External	
Goniocotes chinensis	External	
Myrsidea invadens	External	
Pterolichus sp.	External	

DUCK (*Anas boschas domestica*)

Arthropods:

Menopon gallinae	External	

DUCK, HAWAIIAN (*Anas wyvilliana wyvilliana*)

Tapeworms:

Cloacotaenia megalops	Cloaca	(Unknown)

ENGLISH SPARROW (*Passer domesticus*)
(*See* SPARROW, ENGLISH)

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)

FOWL, GUINEA (*Numida meleagris galeata*)

Arthropods:

Goniodes gigas	External
Menopon gallinae	External
Menopon phaeostomum	External

FOWL, JUNGLE (*Gallus gallus*)

Arthropods:

Goniodes dissimilis	External
Lipeurus caponis	External
Menopon gallinae	External
Ornithoica vicina	External

GOAT (*Capra hircus*)

Roundworms:

Haemonchus contortus	Stomach
Ostertagia circumcincta	Small intestine
Trichostrongylus colubriformis	Stomach and small intestine
Trichuris ovis	Cecum

Arthropods:

Bovicola caprae	External
Linognathus africanus	External

GRAY-BACKED TERN (*Sterna lunata*)
(*See* TERN, GRAY-BACKED)

GUINEA FOWL (*Numida meleagris galeata*)
(*See* FOWL, GUINEA)

HAWAIIAN COOT (*Fulica americana alai*)
(*See* COOT, HAWAIIAN)

HAWAIIAN DUCK (*Anas wyvilliana wyvilliana*)
(*See* DUCK, HAWAIIAN)

HAWAIIAN OWL (*Asio flammeus sandwichensis*)
(*See* OWL, HAWAIIAN)

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
HERON, NIGHT (*Nycticorax nycticorax*)		
Flukes:		
Centrocestus formosanus	Small intestine	(*See* Parasites of Rat, p. 113)
Haplorchis taichui	Small intestine	Gastropoda (first intermediate host): *Thiara granifera*[1] Teleostei (second intermediate host): *Gambusia affinis*,[1] *Mugil cephalus*,[1] *Xiphophorus helleri*[1]
Haplorchis yokogawai	Small intestine	Gastropoda (first intermediate host): *Stenomelania newcombi*,[1] *Thiara granifera*[1] Teleostei (second intermediate host): *Clarias fuscus*[2]
HORSE (*Equus caballus*)		
Roundworms:		
Alfortia edentata	Large intestine	
Cyathostomum asymmetricum	Large intestine	
Cyathostomum bicoronatum	Large intestine	
Cyathostomum calicatum	Large intestine	
Cyathostomum catinatum	Large intestine	
Cyathostomum coronatum	Large intestine	
Cyathostomum euproctum	Large intestine	
Cyathostomum goldi	Large intestine	
Cyathostomum insigne	Large intestine	
Cyathostomum leptostomum	Large intestine	
Cyathostomum longibursatum	Large intestine	
Cyathostomum nassatum	Large intestine	
Cyathostomum pateratum	Large intestine	
Delafondia vulgaris	Large intestine	
Gyalocephalus capitatus	Large intestine	

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Habronema microstoma	Stomach	Diptera: *Musca domestica*,[3] *Stomoxys calcitrans*[3]
Habronema muscae	Stomach	Diptera: *Musca domestica*[3]
Oxyuris equi	Colon	
Parascaris equorum	Small intestine	
Poteriostomum imparidentatum	Large intestine	
Probstmayria vivipara	Colon	
Strongylus equinus	Large intestine	
Trichostrongylus axei	Stomach	
Triodontophorus brevicauda	Large intestine	
Triodontophorus serratus	Large intestine	
Tapeworms:		
Anoplocephala magna	Small intestine	Acarina: species of oribatid mites
Anoplocephala perfoliata	Cecum and near ileocecal valve	Acarina: species of oribatid mites
Flukes:		
Fasciola gigantica (*see* p. 76)	Liver	(*See* Parasites of Cattle, p. 97)
Arthropods:		
Bovicola equi	External	
Gasterophilus intestinalis (larvae)	Stomach	
Gasterophilus nasalis (larvae)	Stomach	
Haematopinus asini	External	
Stomoxys calcitrans	External	

"IIWI" (*Vestiaria coccinea*)

Arthropods:		
Colpocephalum hilensis	External	
Myrsidea cyrtostigma	External	

JAPANESE QUAIL (*Coturnix coturnix japonica*)

(*See* QUAIL, JAPANESE)

JAPANESE WHITE-EYE (*Zosterops palpebrosus japonicus*)

(*See* WHITE-EYE, JAPANESE)

* Legend: (1) = infection found in nature; (2) = determined experimentally; (3) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)

JUNGLE FOWL (*Gallus gallus*)
(*See* FOWL, JUNGLE)

LINNET (*Carpodacus mexicanus obscurus*)

Arthropods:		
Colpocephalum discrepans	External	
Philopterus subflavescens	External	

MAN (*Homo sapiens*)

Protozoa:		
Dientamoeba fragilis	Large intestine	
Endolimax nana	Large intestine	
Entamoeba hartmanni	Large intestine	
Entamoeba histolytica	Large intestine	
Giardia lamblia	Small intestine	
Pentatrichomonas hominis	Cecum and colon	
Roundworms:		
Angiostrongylus cantonensis (developmental stages)	Brain	(*See* Parasites of Rat, p. 112)
Ascaris lumbricoides	Small intestine	
Capillaria hepatica	Liver	
Enterobius vermicularis	Cecum and adjacent portions	
Strongyloides stercoralis	Small intestine	
Toxocara canis (larvae)	In tissues	
Trichinella spiralis	Adults in small intestine, larvae in muscles	(Same as final host)
Trichostrongylus colubriformis	Small intestine	
Trichuris trichiura	Cecum	
Tapeworms:		
Dipylidium caninum	Small intestine	(*See* Parasites of Dog, p. 101)
Hymenolepis nana	Small intestine	(*See* Parasites of Rat, p. 113)
Taenia saginata	Small intestine	Artiodactyla: *Bos taurus*[1]
Taenia solium (larvae)	Brain and viscera	Artiodactyla: *Sus scrofa domestica*[3] Primate: *Homo sapiens*[1]

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Flukes:		
Fasciola gigantica	Liver	(*See* Parasites of Cattle, p. 97)
Stellantchasmus falcatus	Small intestine	Gastropoda (first intermediate host): *Stenomelania newcombi*,[1] *Thiara granifera*[1] Teleostei (second intermediate host): *Mugil cephalus*[1]
Arthropods:		
Aedes aegypti	External	
Aedes albopictus	External	
Aedes vexans nocturnus	External	
Cimex lectularius	External	
Ctenocephalides felis	External	
Culex pipiens quinquefasciatus	External	
Demodex folliculorum	External	
Dermanyssus gallinae	External	
Echidnophaga gallinacea	External	
Laelaps echidninus	External	
Laelaps nuttalli	External	
Leptopsylla segnis	External	
Nosopsyllus fasciatus	External	
Oestrus ovis (larvae)	Body openings	
Ornithonyssus bacoti	External	
Ornithonyssus bursa	External	
Pediculus humanus capitis	External	
Pediculus humanus humanus	External	
Phthirus pubis	External	
Pulex irritans	External	
Pyemotes boylei	External	
Rhipicephalus sanguineus	External	
Stomoxys calcitrans	External	
Triatoma rubrofasciata	External	
Xenopsylla cheopis	External	
Xenopsylla vexabilis hawaiiensis	External	

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
MONGOOSE (*Herpestes javanicus auropunctatus*)		
Nematodes:		
Trichinella spiralis	Adults in small intestine, larvae in muscles	(Same as final host)
Arthropods:		
Ctenocephalides felis	External	
Echidnophaga gallinacea	External	
Leptopsylla segnis	External	
Nosopsyllus fasciatus	External	
Notoedres cati	External	
Xenopsylla cheopis	External	
Xenopsylla vexabilis hawaiiensis	External	
MOUSE (*Mus musculus*)		
Protozoa:		
Trypanosoma conorhini (*see* p. 78)	Blood	Heteroptera: *Triatoma rubrofasciata*[1]
Tapeworms:		
Hydatigera taeniaeformis (larvae)	Liver	(*See* Parasites of Cat, p. 96)
Arthropods:		
Ctenocephalides felis	External	
Leptopsylla segnis	External	
Listrophorus sp.	External	
Myobia musculi	External	
Myocoptes musculinus	External	
Nosopsyllus fasciatus	External	
Radfordia affinis	External	
Xenopsylla cheopis	External	
Xenopsylla vexabilis hawaiiensis	External	
MYNAH (*Acridotheres tristis*)		
Roundworms:		
Microtetrameres sp.	Proventriculus	(Unknown)
Oxyspirura mansoni	Eye	(*See* Parasites of Chicken, p. 99)

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Arthropods:		
Menacanthus spinosus	External	
Montesauria sp.	External	
Myrsidea invadens	External	
Ornithonyssus bursa	External	
Pteronyssus sp.	External	
Trouessartia sp.	External	

NIGHT HERON (*Nycticorax nycticorax*)
(*See* HERON, NIGHT)

NIGHTINGALE, PEKIN (*Liothrix lutea*)

Protozoa:		
Plasmodium vaughani	Blood	Passeriformes: *Liothrix lutea* (parasites probably transmitted by mosquitoes)

NODDY TERN (*Anous stolidus pileatus*)
(*See* TERN, NODDY)

OWL, HAWAIIAN (*Asio flammeus sandwichensis*)

Arthropods:		
Colpocephalum brachysomum	External	

PACIFIC GOLDEN PLOVER (*Pluvialis dominica fulva*)
(*See* PLOVER, PACIFIC GOLDEN)

PEAFOWL (*Pavo cristatus*)

Arthropods:		
Menopon phaeostomum	External	

PEKIN NIGHTINGALE (*Liothrix lutea*)
(*See* NIGHTINGALE, PEKIN)

* Legend: (1) = infection found in nature; (2) = determined experimentally; (3) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
PHEASANT (*Phasianus* sp.)		
Roundworms:		
Cyrnea graphophasiani	Gizzard	(Unknown in Hawaii; probably transmitted by several species of arthropods)
PHEASANT, CHINESE RING-NECKED (*Phasianus colchicus torquatus*)		
Roundworms:		
Acuaria hamulosa	Gizzard	(*See* Parasites of Chicken, p. 98)
Ascaridia sp. (*galli*?) (*see* p. 63)	Small intestine	
Heterakis gallinarum	Cecum	
Oxyspirura mansoni	Eye	(*See* Parasites of Chicken, p. 99)
Subulura brumpti	Cecum	(*See* Parasites of Chicken, p. 99)
Arthropods:		
Falculifer rostratus	External	
Gabucinia sp.	External	
Goniocotes hologaster	External	
Goniodes colchici	External	
Goniodes mammillatus	External	
Lipeurus caponis	External	
Lipeurus maculosus	External	
Megninia columbae	External	
Megninia ginglymura	External	
Menopon fulvomaculatum	External	
Ornithoica vicina	External	
Raphignathus sp.	External	
Uchida sp.	External	
PIGEON (*Columba livia domestica*)		
Protozoa:		
Haemoproteus columbae	Blood	Columbiformes: *Columba livia domestica* (parasites transmitted by the pigeon-fly, *Pseudolynchia canariensis*[1])

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Trichomonas gallinae	Upper digestive tract	
Roundworms:		
Ornithostrongylus quadriradiatus	Small intestine	
Tapeworms:		
Raillietina sp.	Small intestine	(Unknown; probably species of arthropods)
Arthropods:		
Colpocephalum turbinatum	External	
Columbicola columbae	External	
Goniocotes bidentatus	External	
Megninia columbae	External	
Menopon gallinae	External	
Pseudolynchia canariensis	External	

PLOVER, PACIFIC GOLDEN (*Pluvialis dominica fulva*)

Arthropods:		
Colpocephalum brachysomum	External	
Quadraceps birostris	External	
Saemundssonia conicus	External	

QUAIL, CALIFORNIA VALLEY (*Lophortyx californica vallicola*)

Arthropods:		
Echidnophaga gallinacea	Attached to skin	
Goniodes mammillatus	External	
Lagopoecus docophoroides	External	
Menopon fulvomaculatum	External	
Xoloptes sp.	External	

* Legend: (1) = infection found in nature; (2) = determined experimentally; (3) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
QUAIL, JAPANESE (*Coturnix coturnix japonica*)		
Roundworms:		
Microtetrameres sp.	Proventriculus	(Unknown)
Oxyspirura mansoni	Eye	(*See* Parasites of Chicken, p. 99)
Arthropods:		
Goniocotes asterocephalus	External	
Ornithoica vicina	External	
RABBIT (*Oryctolagus cuniculus*)		
Protozoa:		
Eimeria stiedae	Liver	
Encephalitozoon cuniculi	Brain	
Roundworms:		
Passalurus ambiguus	Cecum and large intestine	
Arthropods:		
Notoedres cati cuniculi	External	
Psoroptes equi cuniculi	External	
RAT (*Rattus exulans, R. norvegicus, R. rattus*)		
Protozoa:		
Trypanosoma conorhini (*see* p. 80)	Blood	Heteroptera: *Triatoma rubrofasciata*[1]
Trypanosoma lewisi	Blood	Siphonaptera: *Xenopsylla vexabilis hawaiiensis*[1]
Nematodes:		
Angiostrongylus cantonensis	Lungs	Gastropoda: *Achatina fulica*,[1] *Bradybaena similaris*,[1] *Fossaria ollula*,[2] *Subulina octona*,[1] *Deroceras laeve*,[1] *Opeas javanicum*,[1] *Veronicella alte*[1] (land planarians, *Geoplana septemlineata*,[1] calves,[2] and swine,[2] serve as paratenic hosts)

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Capillaria hepatica	Liver	
Capillaria traverae	Small intestine	
Gongylonema neoplasticum	Stomach	Orthoptera: *Blatella germanica*,[3] *Periplaneta americana*,[3] *Tenebrio molitor*[3]
Heterakis spumosa	Large intestine	
Nippostrongylus brasiliensis	Small intestine	
Physaloptera muris-brasiliensis	Stomach	Coleoptera: *Dermestes vulpinus*,[2] *Tenebroides nana*,[2] *Tribolium castaneum*[2] Orthoptera: *Nauphoeta cinerea*,[2] *Periplaneta americana*[2]
Strongyloides ratti	Small intestine	
Syphacia obvelata	Large intestine	
Trichinella spiralis	Adults in small intestine, larvae in muscles	(Same as final host)
Trichosomoides crassicauda	Urinary bladder	
Tapeworms:		
Hydatigera taeniaeformis (larvae)	Liver	(*See* Parasites of Cat, p. 96)
Hymenolepis diminuta	Small intestine	Coleoptera: *Tenebrio molitor*,[3] *Tribolium ferrugineum*[3] Siphonaptera: *Myobia musculi*,[3] *Pulex irritans*,[3] *Xenopsylla cheopis*[3]
Hymenolepis nana	Small intestine	Coleoptera: *Tenebrio molitor*[3] Siphonaptera: *Nosopsyllus fasciatus*,[3] *Xenopsylla cheopis*[3]
Flukes:		
Centrocestus formosanus	Small intestine	Gastropoda (first intermediate host): *Stenomelania newcombi*,[1] *Thiara granifera*[1]

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
		Teleostei (second intermediate host): *Gambusia affinis*,[1] *Mugil cephalus*,[1] *Xiphophorus helleri*,[1] *Kuhlia sandvicensis*[2]
Echinostoma sp. (*see* p. 85)	Small intestine	Gastropoda (first and second intermediate hosts): *Fossaria ollula*[1]
Plagiorchis muris	Small intestine	(Unknown in Hawaii; but possibly fresh-water snails as first and second intermediate hosts, and aquatic larvae of midges also as second intermediate hosts)
Stellantchasmus falcatus	Small intestine	(*See* Parasites of Man, p. 107)
Arthropods:		
Ctenocephalides felis	External	
Echidnophaga gallinacea	External	
Hoplopleura oenomydis	External	
Laelaps echidninus	External	
Laelaps nuttalli	External	
Leptopsylla segnis	External	
Nosopsyllus fasciatus	External	
Ornithonyssus bacoti	External	
Polyplax spinulosa	External	
Pulex irritans	External	
Radfordia ensifera	External	
Xenopsylla cheopis	External	
Xenopsylla vexabilis hawaiiensis	External	

RICEBIRD (*Munia nisoria*)

Arthropods:		
Bruelia stenozona	External	
Philopterus subflavescens	External	

RUDDY TURNSTONE (*Arenaria interpres interpres*)
(*See* TURNSTONE, RUDDY)

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
SHEEP (*Ovis aries*)		
Roundworms:		
Cooperia punctata	Small intestine	
Haemonchus contortus	Fourth stomach	
Nematodirus spathiger	Small intestine	
Trichostrongylus colubriformis	Stomach and small intestine	
Tapeworms:		
Moniezia expansa	Small intestine	Acarina: species of oribatid mites
Taenia hydatigena	Larval stage attached to liver, mesentery, and omentum	(*See* Parasites of Swine, p. 117)
Flukes:		
Fasciola sp. (*gigantica*?) (*see* p. 87)	Liver	(*See* Parasites of Cattle, p. 97)
Arthropods:		
Chrysomyia megacephala	In wounds and external	
Melophagus ovinus	External	
Oestrus ovis (larvae)	Nasal cavities and sinuses of head	
Otobius megnini (larvae and nymphs)	Ear canal	
Psoroptes equi ovis	Skin	
SPARROW, ENGLISH (*Passer domesticus*)		
Roundworms:		
Oxyspirura mansoni	Eye	(*See* Parasites of Chicken, p. 99)
Tropisurus sp.	Proventriculus	Orthoptera: *Conocephalus saltator*,[2] *Oxya chinensis*[2]

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Arthropods:		
Bruelia vulgata	External	
Haemolaelaps casalis	External	
Myrsidea sp.	External	
Neonyssus sp.	External	
Ornithoica vicina	External	
Ornithonyssus bursa	External	
Proctophyllodes truncatus	External	

SWINE (*Sus scrofa domestica*)

Protozoa:		
Balantidium coli	Large intestine	
Eimeria debliecki	Small and large intestines	
Eimeria scabra	Intestine	
Eimeria spinosa	Large intestine	
Roundworms:		
Ascaris lumbricoides	Small intestine	
Ascarops strongylina	Stomach	Coleoptera: (probably coprophagous beetles)
Choerostrongylus pudendotectus	Lungs	Oligochaeta: (earthworms, probably of the genus *Pheretima*)
Globocephalus urosubulatus (*see* p. 91)	Small intestine	
Hyostrongylus rubidus	Stomach	
Metastrongylus elongatus	Lungs	Oligochaeta: (earthworms, probably of the genus *Pheretima*)
Oesophagostomum dentatum	Large intestine	
Physocephalus sexalatus	Stomach	Coleoptera: (probably coprophagous beetles)
Stephanurus dentatus	Adults in kidneys and kidney fat; immature forms in liver and other internal organs	

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NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Strongyloides ransomi	Small intestine	
Trichinella spiralis	Adults in small intestine; larvae in muscles	(Same as final host)
Trichuris trichiura	Cecum	
Tapeworms:		
Taenia hydatigena (cysticercus)	Attached to liver, mesentery, and omentum	Artiodactyla: *Sus scrofa domestica*,[1] *Ovis aries*[1]
Taenia solium (cysticercus, *see* p. 37)	Larvae in musculature and viscera	Artiodactyla: *Sus scrofa domestica*[3] Primate: *Homo sapiens*[1]
Flukes:		
Fasciola sp. (*gigantica?*) (*see* p. 94)	Liver	(*See* Parasites of Cattle, p. 97)
Arthropods:		
Haematopinus suis	External	
Sarcoptes scabiei suis	External	
TATTLER, WANDERING (*Heteroscelus incanus*)		
Arthropods:		
Actornithophilus kilauensis	External	
Saemundssonia conicus	External	
TERN, GRAY-BACKED (*Sterna lunata*)		
Arthropods:		
Quadraceps birostris	External	
Saemundssonia snyderi	External	
TERN, NODDY (*Anous stolidus pileatus*)		
Arthropods:		
Actornithophilus epiphanes	External	
Colpocephalum discrepans	External	

* Legend: (1) = infection found in nature; (2) = determined experimentally; (3) = reported elsewhere for animals similar to those occurring in Hawaii.

NAME OF PARASITE	LOCATION IN HOST	INTERMEDIATE HOST* (IF ANY)
Quadraceps separata	External	

TURKEY (*Meleagris gallopavo*)

Protozoa:

Histomonas meleagridis	Cecum and liver	

Roundworms:

Acuaria hamulosa	Gizzard	(*See* Parasites of Chicken, p. 98)
Heterakis gallinarum	Cecum	

Arthropods:

Chelopistes meleagridis	External	
Goniocotes hologaster	External	
Menopon gallinae	External	
Oxylipeurus polytrapezius	External	

TURNSTONE, RUDDY (*Arenaria interpres interpres*)

Flukes:

Austrobilharzia variglandis	Mesenteric veins	Gastropoda: *Littorina pintado*[1]

WANDERING TATTLER (*Heteroscelus incanus*)
(*See* TATTLER, WANDERING)

WHITE-EYE, JAPANESE (*Zosterops palpebrosus japonicus*)

Arthropods:

Dermoglyphus elongatus	External
Megninia sp.	External
Ornithoica vicina	External
Pteronyssus sp. (?)	External
Trouessartia sp.	External

* Legend: ([1]) = infection found in nature; ([2]) = determined experimentally; ([3]) = reported elsewhere for animals similar to those occurring in Hawaii.

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