Geographic Distribution and Incidence of Human Parasitic Diseases

*by Ernest Carroll Faust**

The recent world conflict intensified interest in all diseases, particularly those produced by parasitic organisms. Global operations necessitated that disease be examined on a world-wide scale. Parasitic infections are necessarily studied in relation to geography or climatology. Figure 1 shows the different climatic areas of the world. The principal warm regions are the Tropics, Subtropics, which includes a considerable part of the United States, and Temperate Zones. Some parasitic organisms are found practically throughout the world. More frequently the parasitic burden is greater in warm climates. In some instances, as in Africa and the eastern part of India, certain customs, habits, and religious practices of the people combine with climate and environmental conditions to create hyperendemic occurrence of certain animal parasite infection. A few parasite diseases are more common in temperate than in tropical areas.

This discussion of animal parasite diseases is arranged in accordance with the zoological classification of the causative organism. Table I indicates the taxonomic position of species considered here.

PHYLUM PROTOZOA

CLASS RHIZOPODA

Endamoeba histolytica, the etiological agent of amebiasis, is found throughout the world but is most prevalent in the Tropics and Subtropics. It has been found to occur significantly from the Strait of Magellan, into the northern part of Argentina, in Uraguay, the southern part of Brazil, Paraguay, and in the southern part of Peru. In these areas *Endamoeba histolytica* is not as important clinically as in the northern part of this continent where the disease is more severe, but is poorly surveyed, as indicated on the accompanying map (Figure 2, page 4). In general, amebiasis occurs from the Strait of Magellan to the Arctic Circle. A survey made in Saskatchewan a number of years ago indicated the presence of the parasite. Other workers have reported its existence in Sweden, Finland, the central and eastern parts of the USSR, South Africa, and southern Australia.

Col. Charles F. Craig estimated a number of years ago that 10% of the population of the United States was infected with *Endamoeba histolytica.* Without increasing this estimate, a safe assumption is that 300 million of the world's population have amebiasis and that at least 10% of this number are suffering from the disease at any one time. It is likely that a considerable proportion of the remaining 90% will, at some time in their lives, be attacked by amebic enteritis or possibly amebic liver abscess.

According to Colonel Craig's estimate of 10%, approximately 14.3 million people in the United States are hosts of *Endamoeba*

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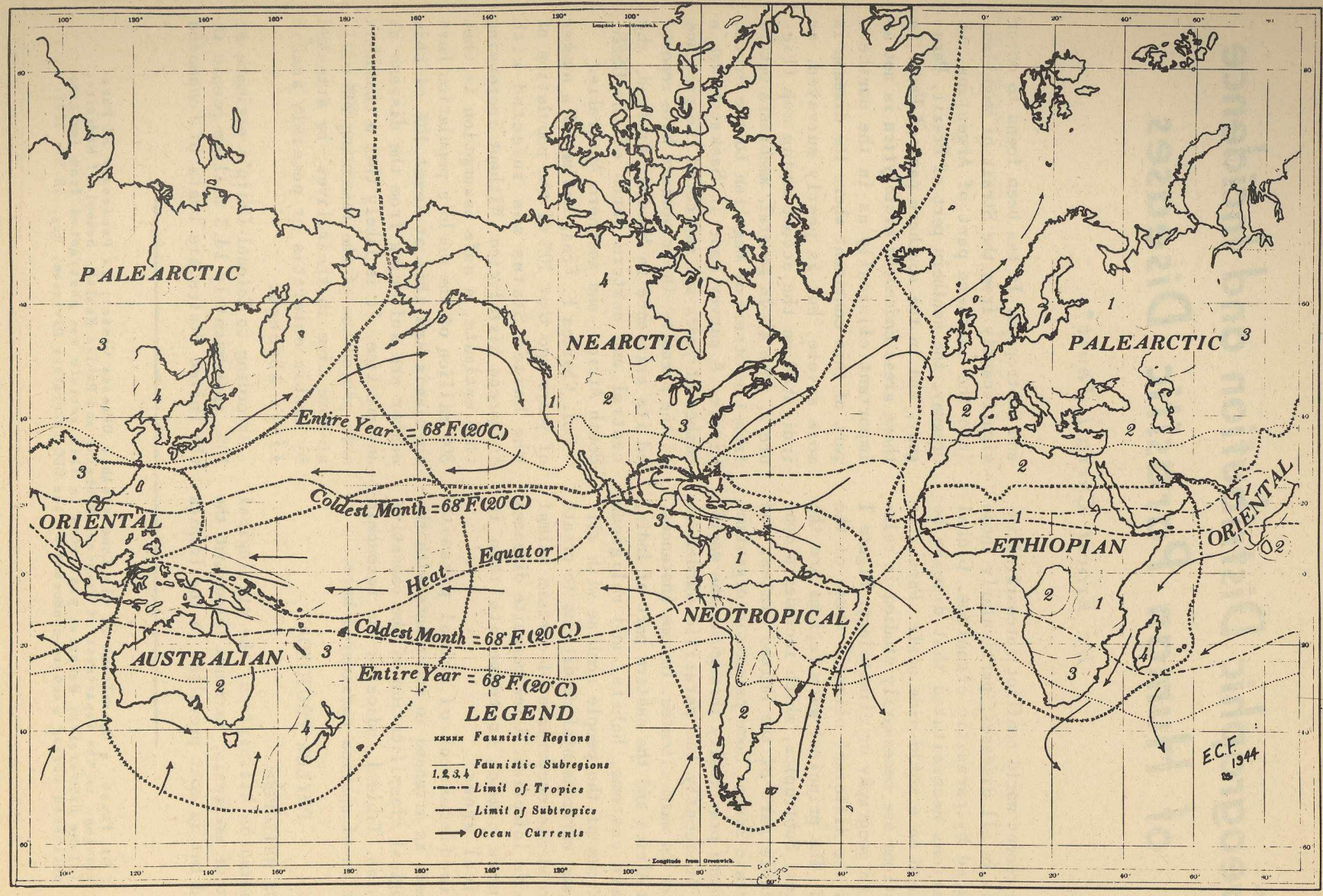

FIGURE 1. Climatic areas of the world. Equatorial isotherm, isothermic boundaries of the Tropics and Subtropics, principal ocean currents, and faunistic divisions are indicated.

Table I.

TAXONOMIC POSITION OF HUMAN PARASITIC ORGANISMS —ACTUAL OR POTENTIAL PATHOGENS

PHYLUM PROTOZOA

CLASS RHIZOPODA

Endamoeba histolytica

CLASS MASTIGOPHORA

Giardia lamblia
Chilomastix masnili
Trichomonas vaginalis
Leishmania donovani
Leishmania tropica
Leishmania brasiliensis
Trypanosoma gambiense
Trypanosoma rhodesiense
Trypanosoma cruzi

CLASS SPOROZOA

Isospora hominis
Plasmodium vivax
Plasmodium malariae
Plasmodium falciparum
Plasmodium ovale

CLASS CILIATA

Balantidium coli

PHYLUM NEMATODA

Trichinella spiralis
Trichocephalus trichiurus
Strongyloides stercoralis
Ancylostoma duodenale
Ancylostoma braziliense
Necator americanus
Trichostrangylus spp.
Enterobius vermicularis
Ascaris lumbricoides
Wuchereria bancrofti
Wuchereria malayi
Onchocerca volvulus
Loa loa
Dracunculus medinensis

PHYLUM PLATYHELMINTHES

CLASS TREMATODA

Schistosoma haematobium
Schistosoma mansoni
Schistosoma japonicum
Fasciola hepatica
Fasciolopsis buski
Clonorchis sinensis
Paragonimus westermani

CLASS CESTOIDEA

Diphyllobothrium latum
Sparganum spp.
Diphylidium caninum
Hymenolepis nana
Hymenolepis diminuta
Taenia saginata
Taenia solium
Echinococcus granulosus

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FIGURE 2.

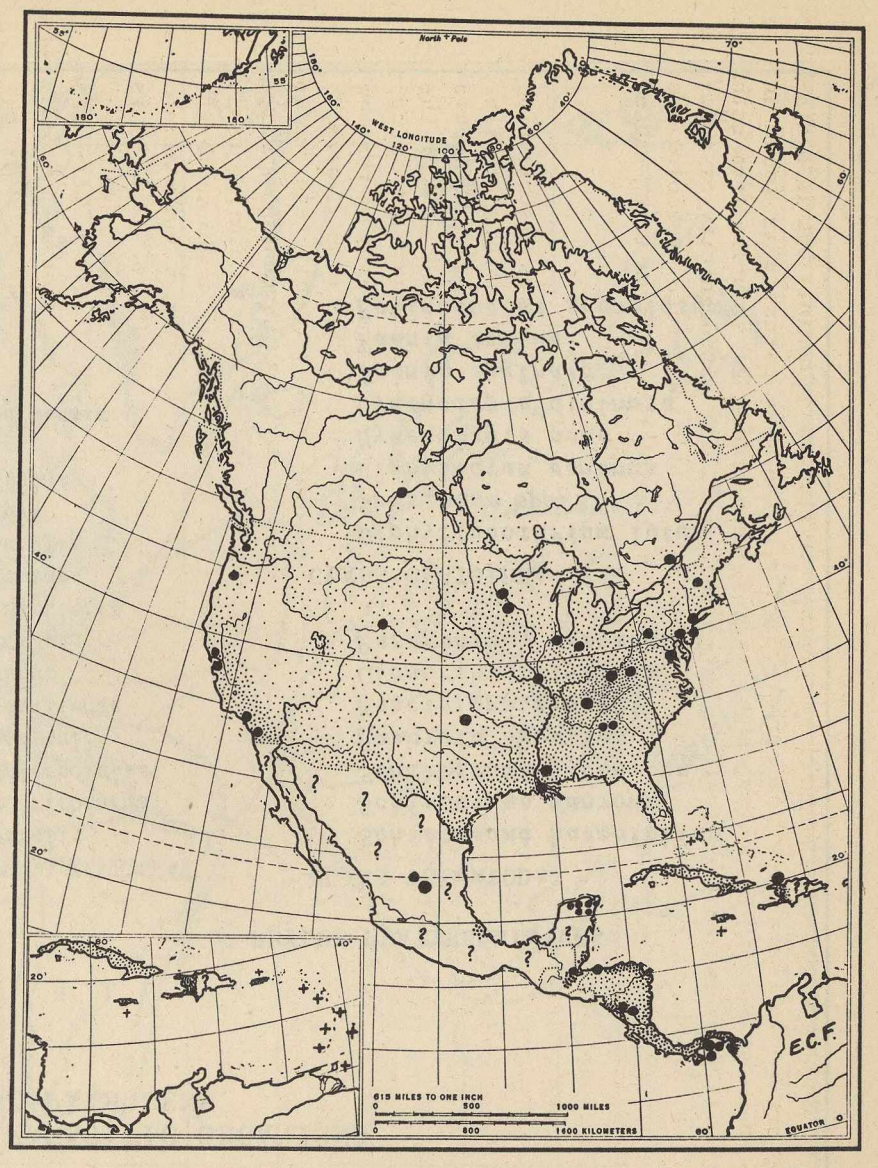

FIGURE 3.

Location of amebiasis surveys and estimated incidence in South America (Fig. 2) and in North America (Fig. 3). Large dots indicate known presence of clinical amebiasis, with or without survey data; question marks indicate unknown status of amebiasis.

histolytica. Figure 3 (page 4) indicates by solid circles the foci or areas where surveys have been made in this country, and by fine dots the estimated prevalence in North America. Although this map is four years old, it is essentially up-to-date, since very few surveys have been made of populations during the war years in extra-military groups. The map indicates that surveys have been fairly well distributed. The lack of information through the mountain states, the western and southwestern part of Texas, the Plain States, and in the Carolinas does not mean that amebiasis does not exist there, but that sufficient surveys have not been conducted in these areas.

As with many other diseases, reports of *Endamoeba histolytica* must be evaluated critically on the following basis: 1) the competency of the individual making the examination; 2) the extent of examination made, whether on a single stool or several stools, and 3) technics used, whether a direct examination or concentration technics were applied. For example, if the zinc sulfate technic is used in combination with direct fecal films, the yield of positives is practically doubled. The more stools examined, the greater the possibility of approximating the actual number of positives. In addition, data must be evaluated in respect to the population being surveyed.

CLASS MASTIGOPHORA

The Mastigophora or flagellate protozoa constitute a large group, of which several forms occur in the human body.

Giardia lamblia is a widely distributed infection, by far the most common parasite found in the human intestine. The infection is much more prevalent in children, to the period of adolescence, than in adults. *Giardia lamblia* is transmitted in food or drink contaminated by feces containing *Giardia* cysts. The infection is pathogenic only in a small minority of cases.

Chilomastix mesnili, Enteromonas hominis, and *Trichomonas hominis* are other non-pathogenic intestinal flagellates of world-wide distribution.

Trichomonas vaginalis is morphologically rather similar to *T. hominis* but is a distinct species. The parasite is found in vaginal secretions, and in urine from both men and women. The pathogenicity of *vaginalis* is unsettled although gynecologists regard a form of vaginitis as being caused by this parasite.

Genus *Leishmania*

Figure 4 (page 6) indicates distribution of the three types of leishmaniasis: visceral leishmaniasis caused by *Leishmania donovani*; cutaneous leishmaniasis of the Old World, caused by *Leishmania tropica*; and mucocutaneous leishmaniasis of the New World, caused by *Leishmania brasiliensis*.

The visceral type (commonly referred to as kala-azar) occurs in Manchuria, a large area of north and northwest China, a newly found area in west China, Assam where the parasite was first discovered, Calcutta and vicinity, and eastern India. It also is found in the Transcaucasian region and north of the Ural Mountains. There are numerous foci of the infection in the Mediterranean area. Several foci occur in the midcontinent of Africa. Areas in the Anglo-Egyptian Sudan are very important, for there the disease is more fulminating and has a higher mortality rate than anywhere else. We in the Western Hemisphere are not exempt from this disease. The first record in this part of the world was from a foci in northeastern Brazil when viscerotome surveys were being made for yellow fever. More recently it has been found in northern Argentina, in adjacent Bolivia, in Venezuela, and in Colombia. In all, probably about 300 million people or one-tenth of the world's population suffer from visceral leishmaniasis.

The cutaneous type, caused by *Leishmania tropica,* occurs in the drier areas of India, extending from the northwestern part toward Asia Minor, likewise in North Africa and tropical Africa but never exactly in the same foci as the visceral type. More than 200 million persons are infected with this parasite.

Mucocutaneous leishmaniasis, caused by *Leishmania brasiliensis,* is found in several foci in Brazil, Peru, Ecuador, and Colombia. *Brasiliensis* probably occurs

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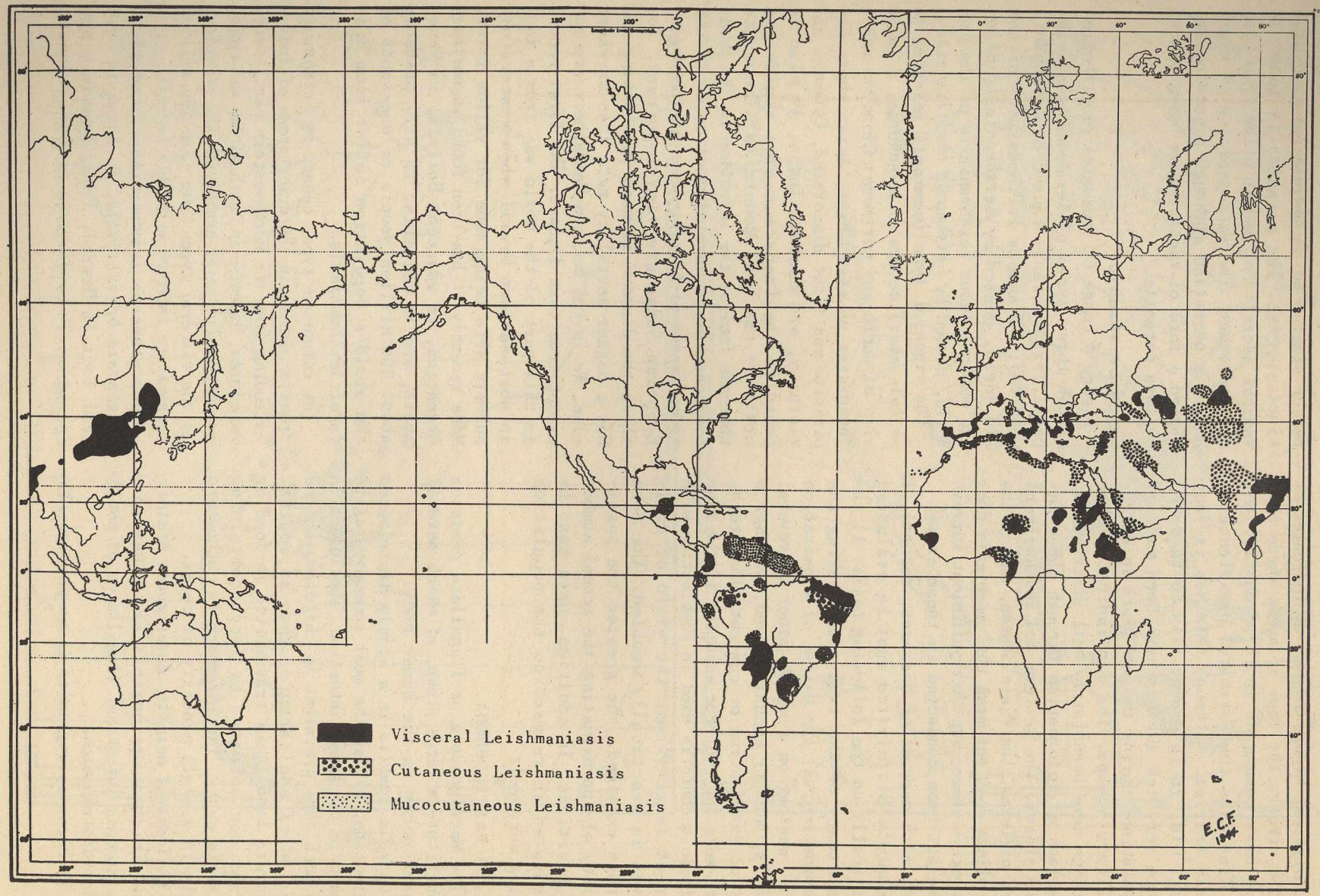

FIGURE 4. Distribution of the three different types of leishmaniasis.

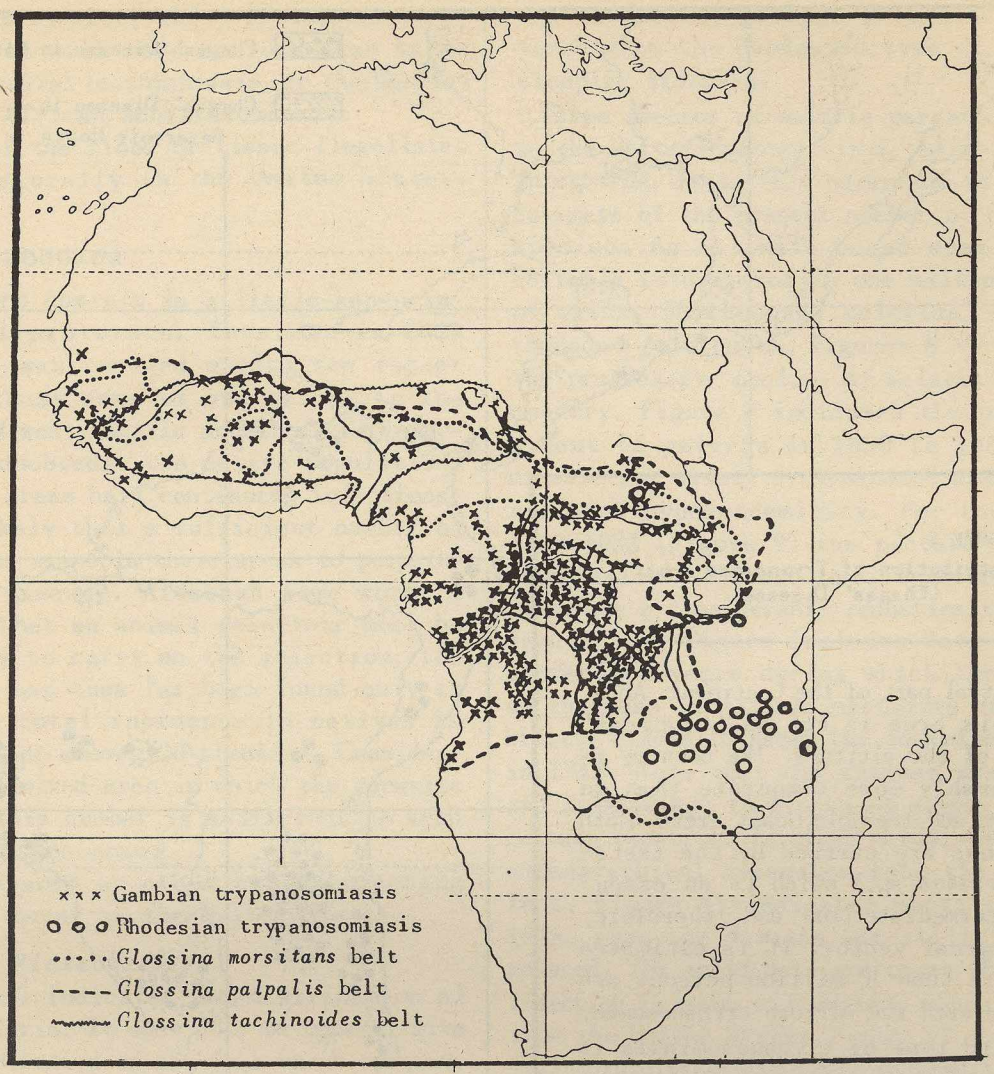

FIGURE 5. Distribution of *Trypanosoma gambiense, Trypanosoma rhodesiense,* and breeding area of tsetse flies in Africa.

throughout Central America although we know most about it in Yucatan and the adjacent portion of Guatamala where the disease is known as the Disease of the Chicle Gatherers, although it is just as common among individuals who work in the mahogany forests. In the southern part of Brazil and Paraguay the disease is found in the less tropical, deciduous forests. In Peru it is more commonly found in the inland mountain valleys.

All three species of *Leishmania* are transmitted by different species of the sand fly, *Phlebotomus*. There is almost no breeding of *Phlebotomus* in the United States. A few species have been described, but intensity and extent of breeding is much less than in areas where leishmaniasis is endemic. The American type of leishmaniasis is believed to infect five million or more people.

Genus *Trypanosoma*

Two trypanosomes occur in tropical Africa and are responsible for so-called "African sleeping sickness." Figure 5 shows the distribution of *Trypanosoma gambiense* and *Trypanosoma rhodesiense*. *Trypanosoma gambiense* has a very extensive distribution. *Trypanosoma rhodesiense* is found in the

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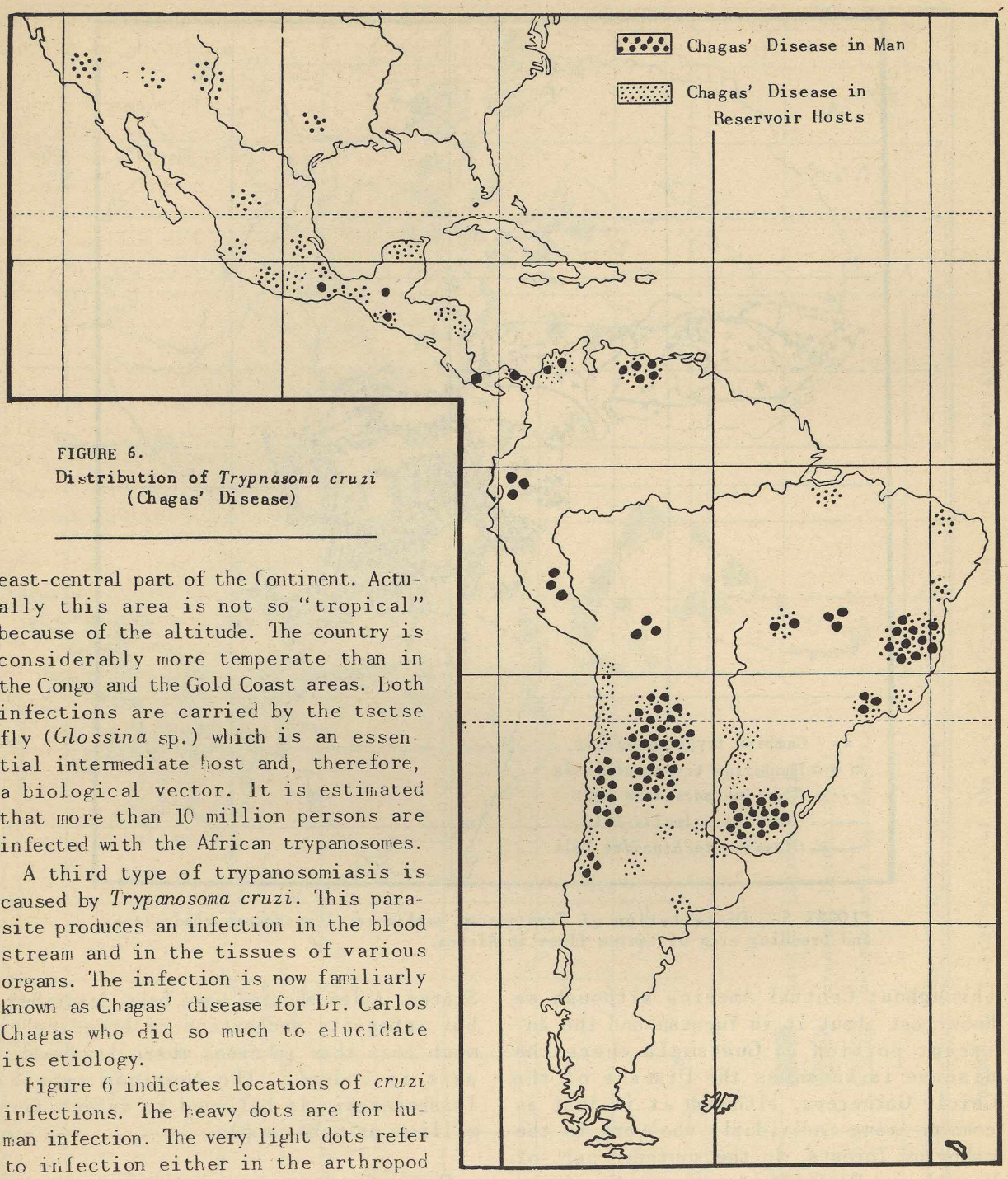

FIGURE 6.
Distribution of *Trypnasoma cruzi* (Chagas' Disease)

east-central part of the Continent. Actually this area is not so "tropical" because of the altitude. The country is considerably more temperate than in the Congo and the Gold Coast areas. Both infections are carried by the tsetse fly (*Glossina* sp.) which is an essential intermediate host and, therefore, a biological vector. It is estimated that more than 10 million persons are infected with the African trypanosomes.

A third type of trypanosomiasis is caused by *Trypanosoma cruzi*. This parasite produces an infection in the blood stream and in the tissues of various organs. The infection is now familiarly known as Chagas' disease for Dr. Carlos Chagas who did so much to elucidate its etiology.

Figure 6 indicates locations of *cruzi* infections. The heavy dots are for human infection. The very light dots refer to infection either in the arthropod host or in animal reservoirs of the infection. This parasite is most interesting in that practically any mammal is a good host. Armadillos, opossums, many kinds of rodents, bats, monkeys, and the domestic guinea pig of South America are all common reservoirs. *Cruzi* is transmitted by assassin bugs, of which there are many species.

Chagas' disease is found from central Chile and southern Brazil up to the southwestern part of the United States. The most northern record of human infection is in the state of Oaxaca in southern Mexico on the Pacific slope. Approximately 8 million people, and possibly more, are afflicted

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with this disease, which is considered by some to be much more serious than kala-azar, visceral leishmaniasis, or the Gambian type of African schistosomiasis.

None of the blood or tissue flagellates occur naturally in the United States.

CLASS SPOROZOA

Isospora hominis is a little-known intestinal protozoon. Interest in this parasite was renewed during the recent war, because some of our troops in the south and west Pacific acquired the infection. Undoubtedly the native populations in these areas have continuing infections. It is likely that a sufficient number of infections exist in these areas to perpetuate the disease. Although some workers believe that an animal reservoir must be necessary to carry on the infection, the organism has thus far been found only in man. The total incidence in natives is probably not above 100 thousand. Considering the limited area in which the parasite occurs, this number is sufficient to keep the infection going.

No *Isospora* or other human-infecting Coccidia occur in the United States.

Genus *Plasmodium*

Figure 7 indicates the distribution of human malaria. It does not, of course, give the distribution of the four known species, *Plasmodium vivax,* producing vivax malaria; *Plasmodium malariae,* producing the quartan type; *Plasmodium falciparum,* producing falciparum malaria, and *Plasmodium ovale,* producing the ovale type. It is practically impossible to determine the species of plasmodia in the billion persons in the world suffering from malaria. A reasonable assumption is that practically all of the malaria extending into the Temperate Zones is *vivax;* that both *vivax* and *falciparum* contribute to the hyperendemicity of malaria in the Tropics, and that quartan infections usually occur sporadically or in localized spots. An exception is a part of tropical Africa where quartan infection is widely distributed. *Ovale* malaria is found primarily in east-central Africa in about the same area, perhaps a little farther north than the Rhodesian type of African sleeping sickness.

Three species of malaria parasites occur in the United States: *vivax, malariae,* and *falciparum.* It is very hazardous to make an estimate of the present number of cases by species. An estimate based upon fairly reliable information is one million cases of *vivax,* 50 thousand *malariae,* and 500 thousand *falciparum.* Figures 8 to 10 show the progressive decline of malaria in this country. Figure 8 indicates the probable extent of malaria in 1850 to 1860. The disease was widely disseminated with dense areas of hyperendemicity. For the years 1929-1938 (Figure 9) the picture was not essentially different in distribution, but there was a considerable reduction in incidence. This figure includes data on the depression years during which there was an increase in malaria mortality and morbidity. Figure 10 shows the marked decrease in 1943. Note that the intense areas now are limited not to blocks of states but to certain counties. In other words, there was a geographical recession into the mother foci. Figure 11 indicates mortality for 1945, when the disease was still further reduced. The solid dots are cases where the infection is known to have been acquired outside the United States. Figure 12 shows the 1945 morbidity attributable to malaria. Note that quite a number of malaria cases were reported outside of known endemic areas, as in Minnesota, in the New England States, and in parts of Ohio. Actually these areas are less malarious today than they have ever been. The cases reported were almost exclusively infections acquired overseas or in the South during the war years. This map reflects the fact that in Mississippi, South Carolina, and in the eastern part of Texas case reporting was probably more accurate than in some other places.

A very great recession in malaria has taken place, particularly during this last decade. If this advantage is followed up, there is no reason why malaria in the United States cannot be almost completely under control within ten years.

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FIGURE 7. World Distribution of Malaria.

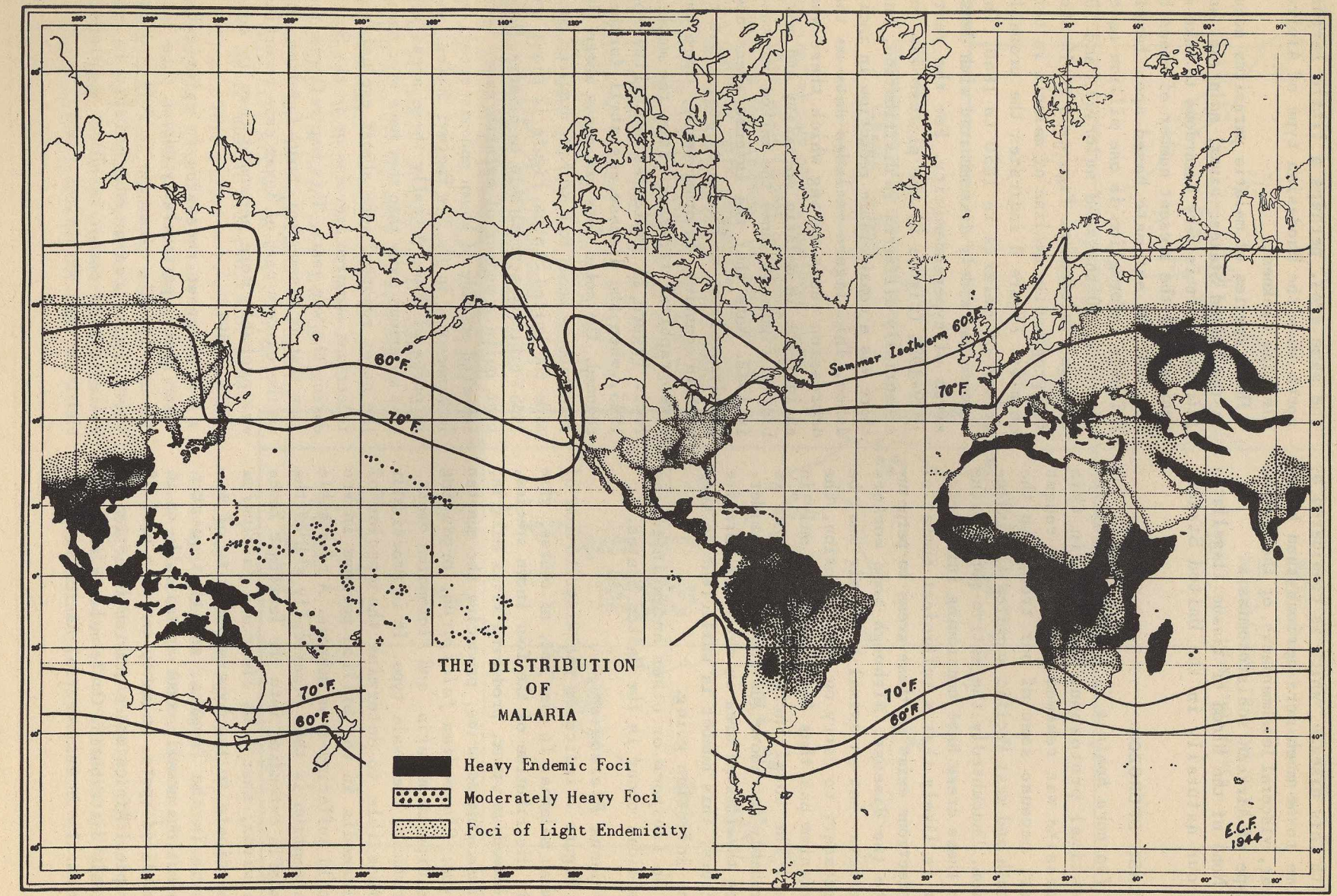

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FIGURE 8. Distribution of Malaria in the United States 1850 –1860.

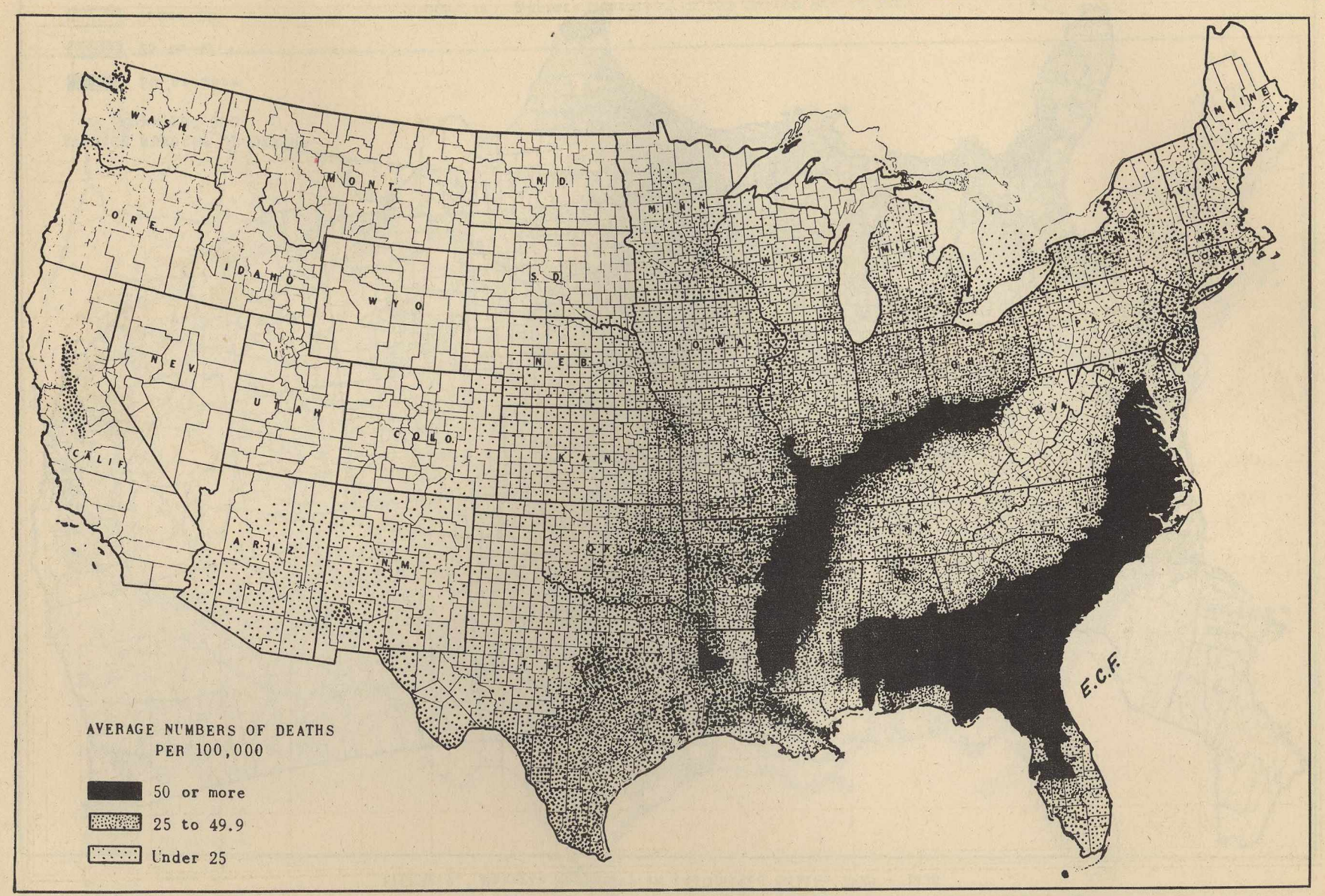

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FIGURE 9. Malaria Mortality in the United States 1929 — 1938.

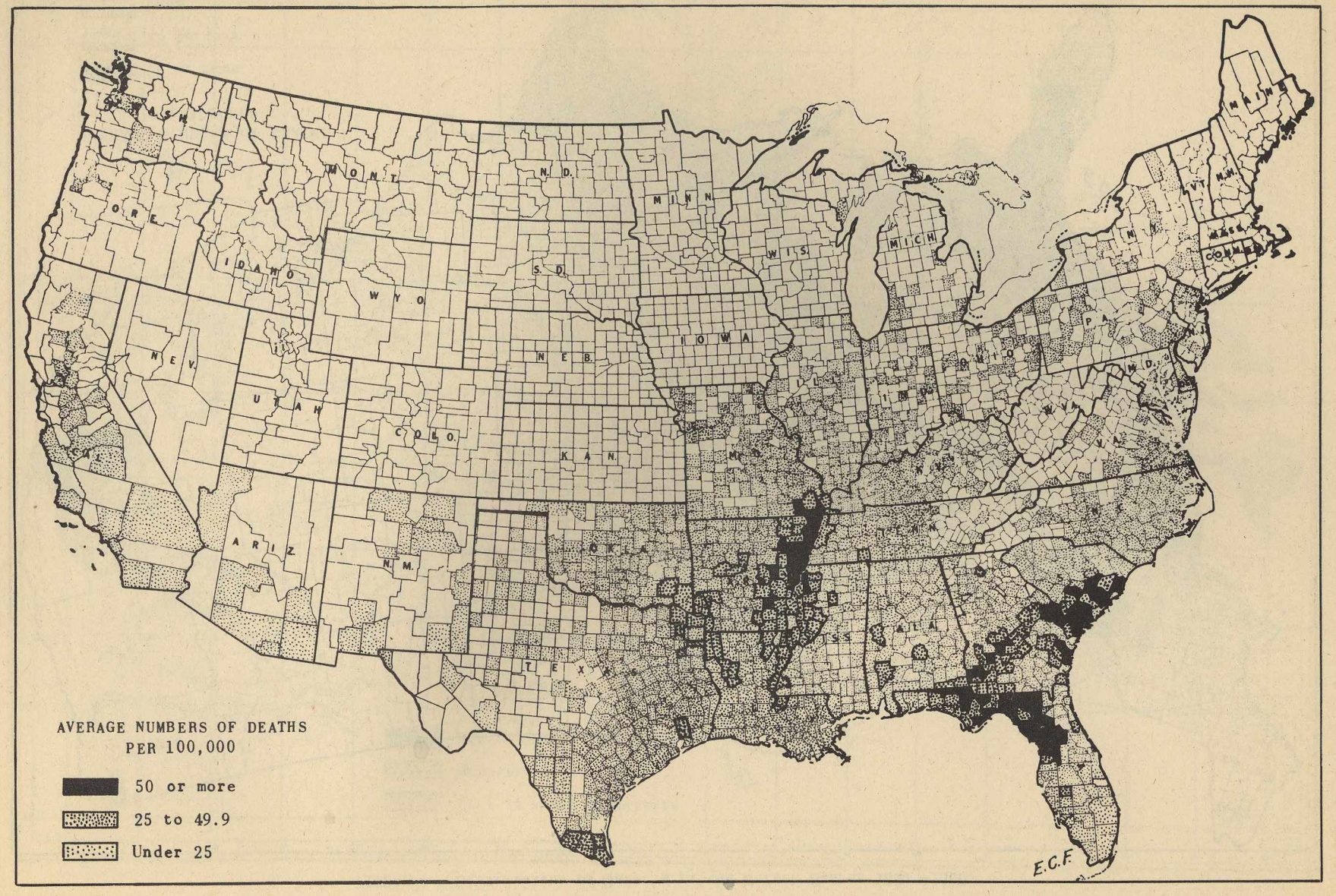

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FIGURE 10. Malaria Mortality in the United States 1943.

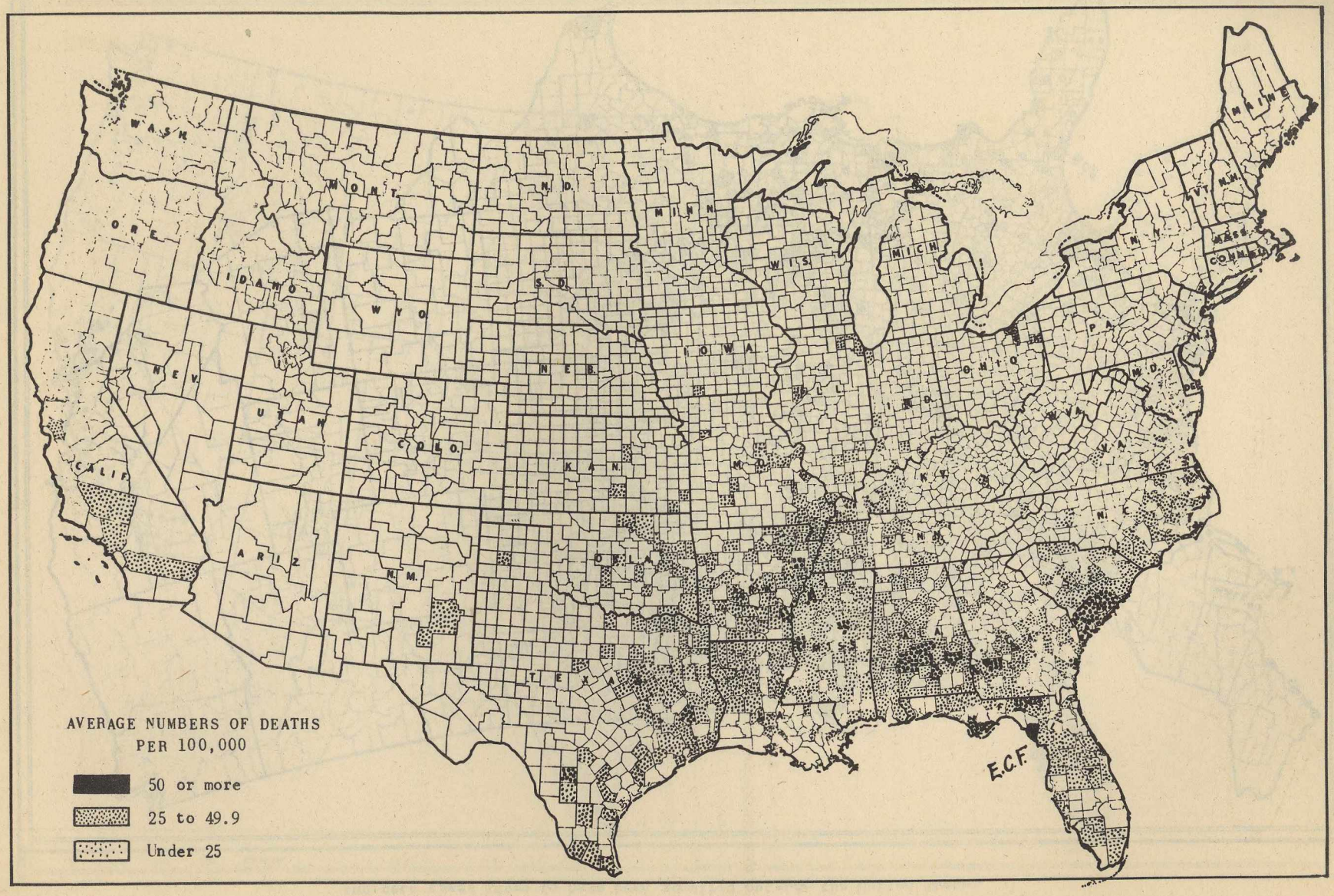

FIGURE 11. Malaria mortality in the United States 1945. The solid dots indicate cases known to have been acquired outside the United States.

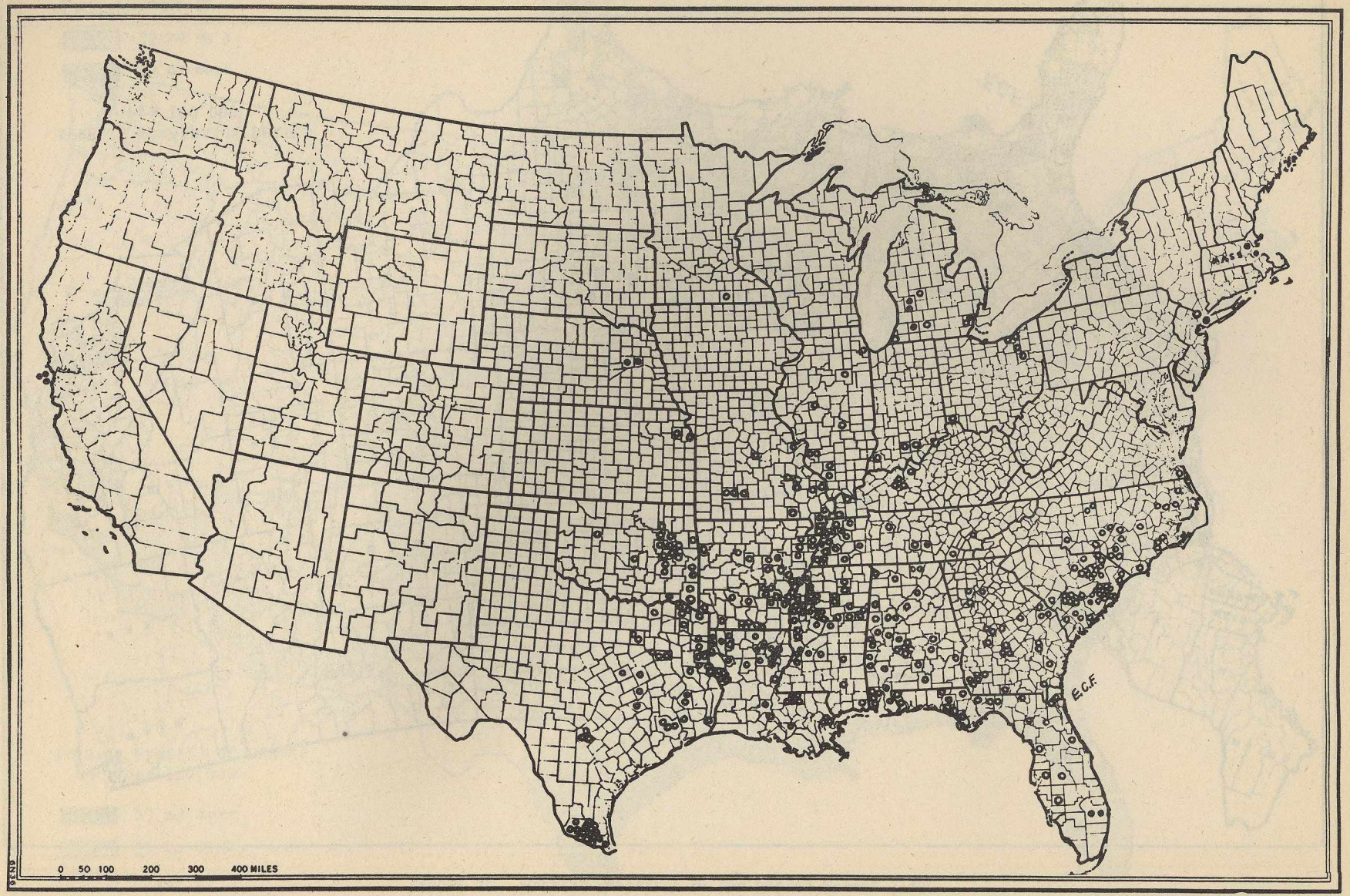

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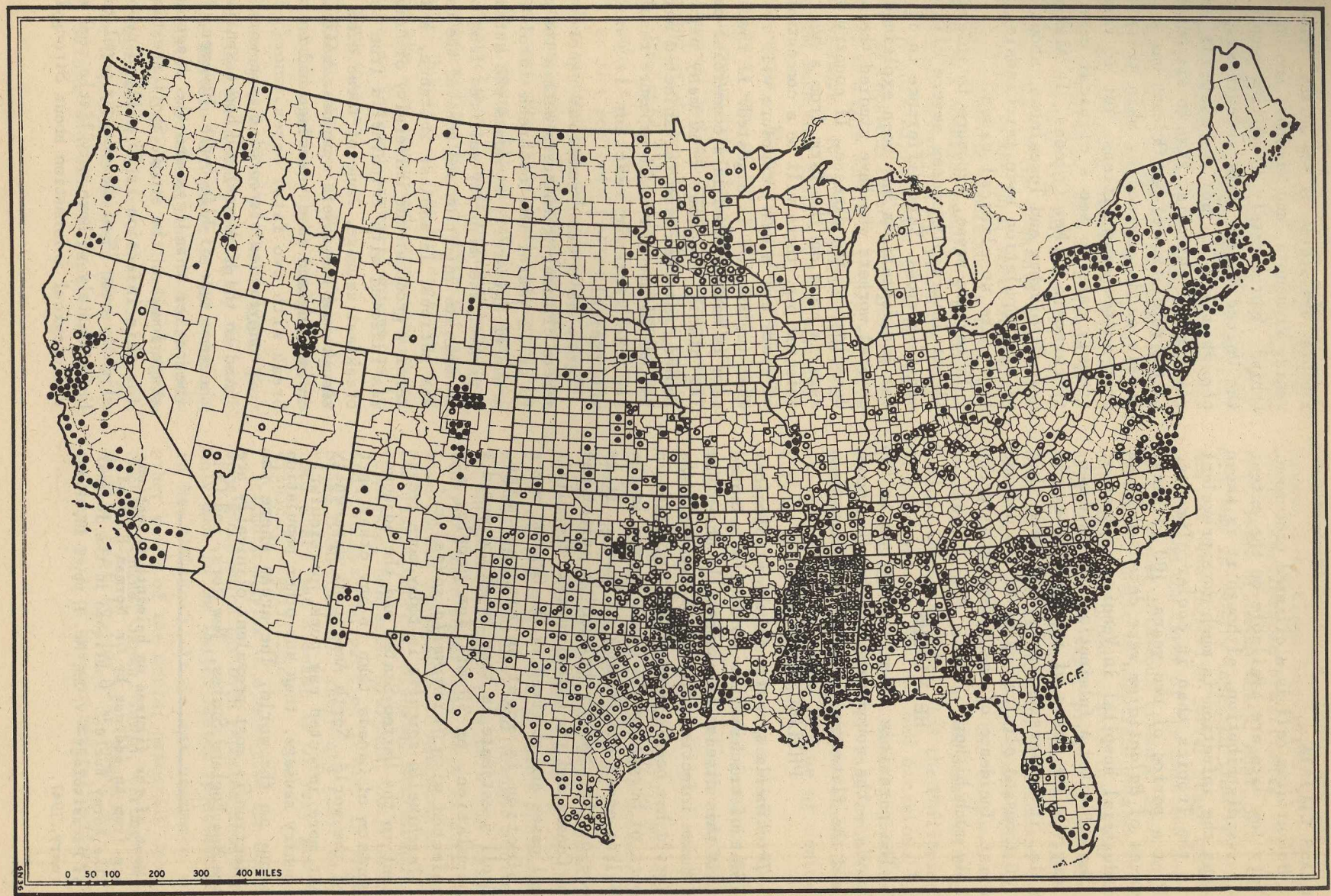
FIGURE 12. Malaria morbidity in the United States 1945. The solid dots indicate cases known to have been acquired outside the United States.



CLASS CILIATA

Balantidium coli is a ciliated protozoon. Very few data are available on the extent of its distribution, although it is known that the infection is much more prevalent in the Tropics than in cooler climates. Over a period of two years, 100 clinical cases of *Balantidium* were detected in an industrial hospital in Venezuela. Most of them exhibited a fulminating type of dysentery. On the basis of information available, it appears unlikely that more than 100 thousand clinical cases of the disease exist. Incidence of the infection is probably much higher.

HELMINTHS

The parasitic helminths belong to two phyla — the roundworms, phylum Nematoda, and the flatworms, phylum Platyhelminthes.

PHYLUM NEMATODA

Trichinella spiralis is the etiological agent of trichinosis. It should be noted that this disease is essentially absent as a human infection in tropical areas. *Trichinella* has been a very common infection in part of Europe and is still common in the Balkan areas and regions of Russia. It is one of the commoner helminthic infections of Canada and the United States. Few clinical cases are observed in the Orient, where infection is scant in rats and pigs. Stoll's estimate is that 1% of the world's population, or 30 million people, are infected with *Trichinella spiralis*.*

Trichinella spiralis is today more prevalent in the United States and the adjacent portion of Canada than in any other part of the world. North Americans apparently eat more infected raw pork, particularly country sausage, than any other population group in the world. The areas where the infection is most prevalent clinically are the New England States, New York, and California. The states of New Jersey, Pennsylvania, Minnesota, and Missouri are not far behind. Approximately 23 million people in the United States have trichinosis, although these do not necessarily have clinical trichinosis. Five to six percent of the population of New Orleans has trichinosis as determined by skin tests and post-mortem examinations. Yet it is extremely rare to see a clinical case of trichinosis in New Orleans. In Alabama, near Birmingham and Tuscaloosa, about 30% of the population have trichinosis, but there are no clinical cases.

In certain areas, exposure to infection almost invariably causes severe clinical manifestations. This difference in clinical manifestations has been explained by several workers who have studied the epidemiology of the disease. If country sausage is made on the farm from a heavily infected pig, there will be a concentration of cysts and a heavy exposure will result when the sausage is digested. If the sausage is manufactured in a commercial packing plant, the meat from many pigs is pooled, material from the infected animal is thus diluted, a light exposure results, and the systemic reaction is usually subclinical.

There have been numerous records of severe clinical trichinosis within the past 10 or 12 years. One outbreak involved a group of university students who attended a picnic. The majority suffered from mild to moderate infection and none of the cases was serious. In another instance, a fraternity group at the University of Arizona was infected with *Trichinella* from their breakfast sausage. None of these died although some had severe symptoms. A CCC Camp in New England some years ago had an outbreak with two fatal cases.

Strongyloides stercoralis is a worm related to the hookworm, and has essentially the same type of life cycle. However, larvae rather than eggs are the diagnostic stage found in the stool. Stoll's estimate for this infection is 35 million people, slightly over 1% of the world's population. Unfortunately we have very little real epidemiological information about *Strongyloi-*

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*Most of the figures on helminth infections are from an address by Dr. Norman R. Stoll, "The Wormy World." Published in the Journal of Parasitology— V. 33, No. 1, pp. 1-18, February, 1947.

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des. Many areas of the Tropics are not involved. In Panama and Venezuela, however, *Strongyloides* is found in 20-25% of all the stools examined. Specific microclimatic conditions are necessary for the survival of *Strongyloides.* In general, its occurrence in the United States is similar to the distribution of hookworm. Although infections have been found in central New York state, Kansas City, Tennessee, Kentucky, and the Carolinas, they are found more commonly around the Gulf Coast. Cases appear north of the hookworm belt only sporadically. In the rural areas of Louisiana about 4% of the population is infected. Perhaps 400 thousand people in the United States have *Strongyloides* infection. This is much more significant than an equal number of hookworm infections since *Strongyloides* is a more subtle, insidious parasite than hookworm. It is more difficult to diagnose and much more difficult to eradicate.

Whipworms. Whipworms *(Trichocephalus trichiurus)* are, on the whole, more tropical in their distribution than *Ascaris.* In tropical and sub-tropical areas, more than 10% of the population has this infection. Probably 355 million persons are involved. It is true that in many areas, such as the southern United States and similar subtropical and moderately temperate areas, cases of clinical whipworm diseases constitute but a small percent of the infected group. Yet almost every month of the year clinical cases of this infection are admitted to the pediatric service of Charity Hospital in New Orleans. In such cases the worm count indicates that there may be a thousand or more whipworms in the intestines.

Hookworms. Figure 13 (Page 18) shows the distribution of the three common species of hookworms.

Hookworm infection of the tropical part of the Old World and practically the whole of the Western Hemisphere is due primarily to *Necator americanus,* the "American hookworm." The infection of Europe and the northern part of Africa, which is outside of the Tropics, the northern parts of India and China, and all of Japan is due to *Ancylostoma duodenale.* These are the two common intestinal hookworms of man. A third, *Ancylostoma braziliense,* has at least three different hosts: dogs, cats, and man. Man is usually infected from the dog and cat. The infective larval stage bores through the top layer of the skin and down to the deeper cutaneous tissues. Since the larvae are unable to negotiate passage into the cutaneous blood vessels they keep on migrating in the skin, producing the so-called "creeping eruption." This manifestation is common in Florida, less common in other parts of the Gulf and South Atlantic Area, and is found on the beaches of southern Brazil, in west and east Africa, Ceylon, Calcutta, Malay, and the Philippine Archipelago. In Africa, and occasionally in the Philippines, *Ancylostoma braziliense* is found as an intestinal infection. In these cases, it is probably the human strain rather than the feline or canine strain which is involved.

Stoll's estimate of intestinal infection for all three of these worms is 457 million, or about 15% of the world's population.

According to Stoll's figures, 1.8 million people in the United States have hookworm. These are for the most part in the rural South. In the more isolated rural communities the infections are found up to the edge of the town, and genuine hookworm disease among children and younger adults is encountered. Surveys within the past ten years have shown that there is still a wide-spread prevalence of hookworm in the Carolinas, Georgia, Alabama, Mississippi, Tennessee, Kentucky, Arkansas, Louisiana, and the eastern part of Texas. In this broad hookworm belt, there are restricted foci where the disease is of very great clinical significance.

Trichostrongylus is a member of the hookworm group which has been reported from man only once in the United States (post-mortem in New Orleans). It is not uncommon in other parts of the world, primarily Java, Sumatra, China, Japan, India, through the Middle East to the Near East, and the southern part of Russia. Several different

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species are involved. Stoll estimates that 5.5 million people are infected with *Trichostrongylus*. This estimate is quite conservative. Species of this genus are common parasites of cattle, sheep, goats, and other ruminants throughout the world, including the United States. The infection is transmitted to man and other animals by ingesting grass or other green stuff on which the partly-encysted infective larvae are found. It differs from hookworm infection in that the larva is swallowed instead of entering through the skin.

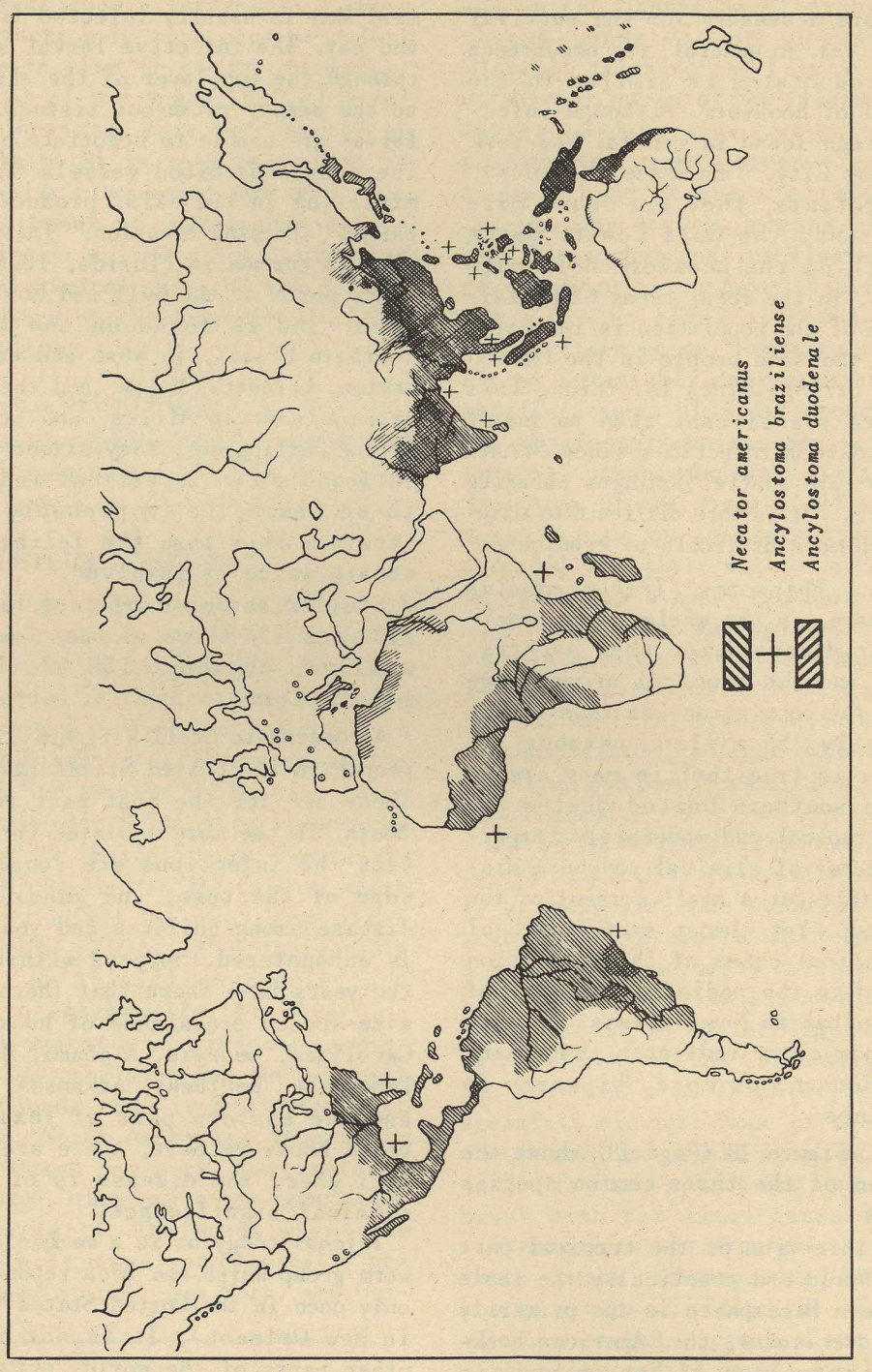

FIGURE 13. Distribution of hookworm infections. The symbol ⊙ indicates locations where hookworm infections have been acquired in mines.

Enterobius vermicularis is the seat worm

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or pinworm. Stoll's world estimate is 209 million infections. This is based on surveys probably not made primarily by swab examination but by ordinary stool examination. This latter method at best would disclose only 10% of the positive cases. The estimate can, therefore, be raised considerably. Possibly one-third of the world's population have pinworm infection.

By Stoll's estimate, 18 million persons in the United States are infected with *Enterobius vermicularis*. This figure is unquestionably very low. The infection is uniformly distributed over the country. It is about as prevalent in institutional groups and large families in one area as in another.

Ascaris lumbricoides infects from 750 million to one billion people throughout the world. This roundworm is very rarely found in strictly temperate areas. The *Ascaris* belt of the new world extends south from the Mason and Dixon line to southern Brazil. In the Old World it extends from central Europe to the southern part of Africa, while the tropical region farther to the east in the Eastern Hemisphere is hyperendemic for *Ascaris*. Ascariasis infection is much more common in childhood than it is in adults. Children are responsible not only for reinfecting themselves and their playmates but to a very considerable extent for the infection of adults.

Three million people in the United States harbor *Ascaris lumbricoides*. Most of these are children under 10 years of age. Ascariasis is most prevalent in the southern Piedmont section. The infected area extends into the Ozark region, including southern Indiana and Illinois, the southern third of Missouri, eastern Oklahoma, and northern Arkansas. It is not as common along the Gulf Coast as it is in the hilly areas. However, one survey in Tampa, Florida among Cuban cigar makers' families indicated that ascariasis is quite common in that area. New Orleans is interesting as an example of urban distribution of *Ascaris*. Some twelve years ago a comprehensive survey for *Ascaris* was made in the city. No five-block area was found where *Ascaris* families could not be located. The better residential districts were involved as well as all other sections. It is true, however, that more ascariasis was detected in the downtown area of the old city, around the river front and in the suburbs than in the uptown part of the city. If this survey is representative of our southern cities, ascariasis is an urban as well as a rural problem.

Figure 14 (page 20) shows areas of hyperendemicity of Bancroft's filaria, *Wuchereria bancrofti* and the Malayan filaria, *W. malayi*. These parasites are found in extensive areas throughout the Tropics and Subtropics. As far as is known filariasis is no longer present in the United States. *Wuchereria malayi* is found in areas of the southwest Pacific, extending into central Indo-China, parts of China, and Ceylon. The number of people infected with the two species of *Wuchereria*, according to Stoll, is 189 million. There is very little difference in the clinical manifestations of these two infections. *Microfilaria malayi* does not have as distinctive a nocturnal periodicity in the blood stream as does *Microfilaria bancrofti*. Moreover, there is a difference in the epidemiology. *Malayi* is frequently carried by mosquitoes of the genus *Mansonia*. Larvae of this genus are attached to the submerged roots of water plants which makes larvicidal control a much more serious problem than if *Culex* or *Aedes* mosquitoes are involved, as they commonly are in Bancroft's filariasis.

Onchocerca volvulus, the convoluted filaria, has a very extensive distribution throughout tropical Africa. It is also found on the Pacific slope of Guatamala and the adjacent portion of Mexico, where the disease was apparently imported in African slaves. The infection is transmitted by black gnats belonging to the genus *Simulium*. Stoll estimates that 19.8 million are infected with this worm, of whom 800 thousand are in the Western Hemisphere.

Loa loa, the "eye-worm," is confined to the tropical part of Africa. The infection is transmitted by tabanid flies (*Chrysops* spp.). Stoll estimates that 13 million people are infected.

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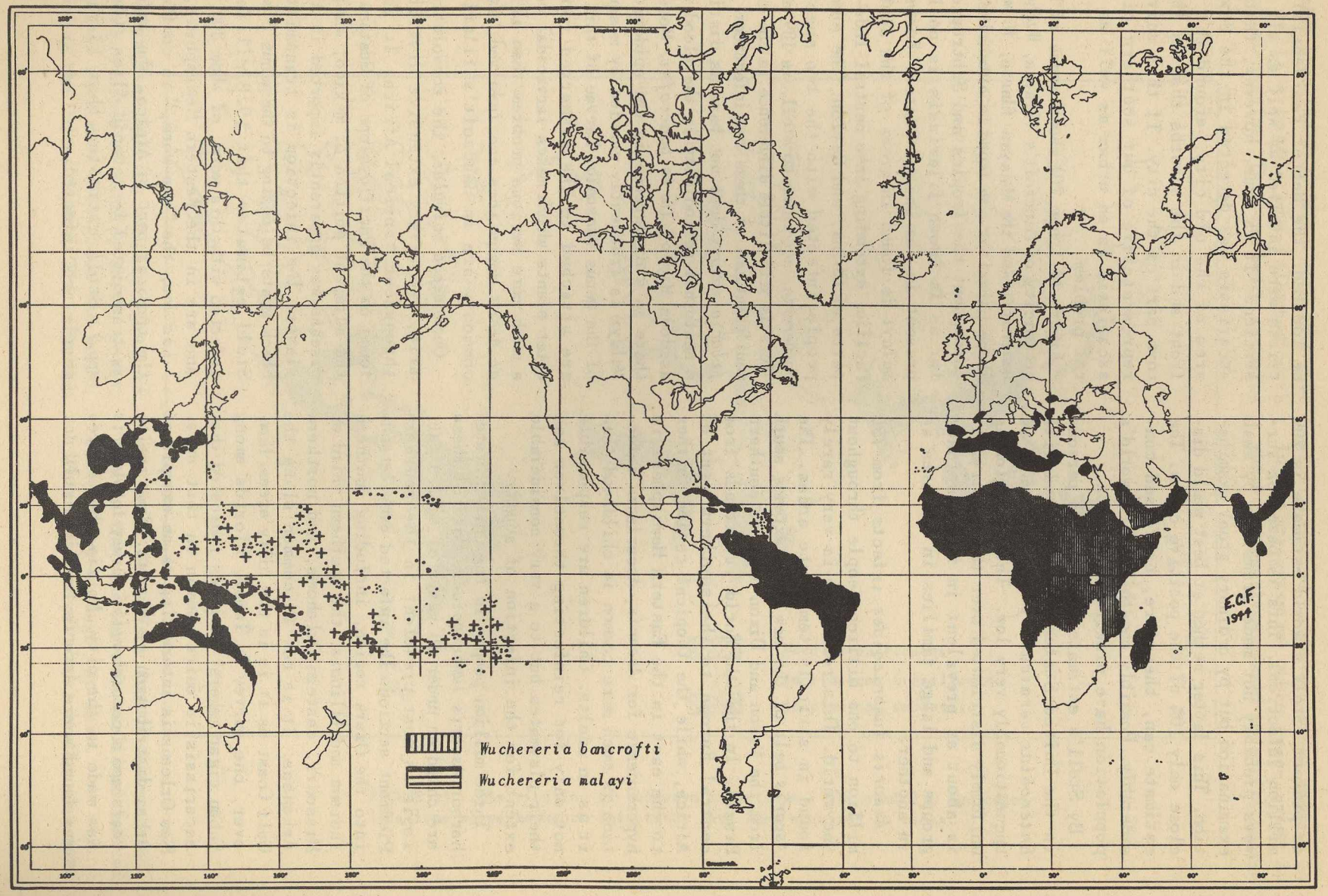
FIGURE 14. Distribution of Filariasis.



Courtesy of the David J. Sencer CDC Museum

Dracunculus medinensis, the dragon worm or guinea-worm, has various species of Cyclops as intermediate hosts. This infection in man is found extensively in India, the Middle East, parts of Africa, and in southern part of the USSR. It probably has now completely died out from the Brazilian and Guinean portions of the Western Hemisphere where it existed as late as a quarter of a century ago. Forty eight and three-tenths million persons are believed to be infected with this parasite.

PHYLUM PLATYHELMINTHES

CLASS TREMATODA (Flukes)

Schistosomes

Figure 15 (page 22) shows the distribution of the three schistosomes of man. *Schistosoma japonicum* is confined to areas in the Far East. Five small foci are in Japan. The whole Yangtze River basin is involved, four islands of the Philippines are infected, and one focus has been found in Celebes.

Schistosoma mansoni is found in the lower half of the Nile Delta, in many other foci of Africa, in Puerto Rico, Santo Domingo and some of the Lesser Antilles, Venezuela, Dutch Guiana, and in extensive areas in Brazil.

Schistosoma haematobium probably originated in the Nile Valley. Today extensive areas of infection exist in Africa, the southern tips of Europe, and in western Asia. Stoll estimates the human infections for these species as follows: *japonicum* 46 million, *mansoni* 29 million, and *haematobiam* 36 million.

Numerous cases of *Schistosoma mansoni* are being imported into the United States from Puerto Rico, and Puerto Rican students in this country occasionally have mild Manson's schistosomiasis. Based upon the rate of infection in Puerto Rico, at least 100 thousand Puerto Rico residents in New York have *Schistosoma mansoni* infection. Nevertheless, it is unlikely that this disease will become established in this country since suitable snail hosts are not present in the New York area. Recently some native snails from southern Louisiana have been experimentally infected so the possibility of the disease becoming established exists, even though it is remote.

Other Flukes

Fasciola hepatica is a common liver fluke of sheep. Not many persons are reported to be infected but human infection is known in the Orient, Africa, southern Europe, particularly the southern part of France, and various parts of the Latin America. Man usually contracts the infection by eating water cress to which the little encysted larvae are attached.

In the United States *Fasciola hepatica,* or the related *Fascioloides magna,* is found in Louisiana, eastern Texas, in irrigation areas in the Southwestern States, Oregon, Washington, and more recently in Wisconsin and Ohio. Sheep and cattle are the reservoir of the infection and they are responsible for the spread of the disease to uninfected areas.

Fasciolopsis buski is indigenous to central and south China, Formosa, French Indo-China, Siam, Assam, Bengal, and in the islands of the Southwest Pacific. This infection is contracted by eating certain water plants containing the encysted stage. Probably about 10 million persons have this infection.

Clonorchis sinensis, the Chinese liver fluke, is found in various parts of Japan, southern Korea, China, and French Indo-China. The infection is contracted by eating raw or inadequately cooked infected freshwater fish. Approximately 19 million people have the disease. In addition one million in eastern Europe and the USSR have a related infection, *Opisthorchis felineus.*

Paragonimus westermani, the lung fluke, has a distribution essentially the same as *Clonorchis sinensis.* This parasite is acquired from ingesting raw or inadequately cooked crawfish or freshwater crabs which are infected. This infection also occurs in the Western Hemisphere in Venezuela, in Ecuador, and probably in Peru. About 3 million people in the world are infected.

CLASS CESTOIDEA (Tapeworms)

Diphyllobothrium latum, the broad or fish tapeworm, is almost exclusively an infec-

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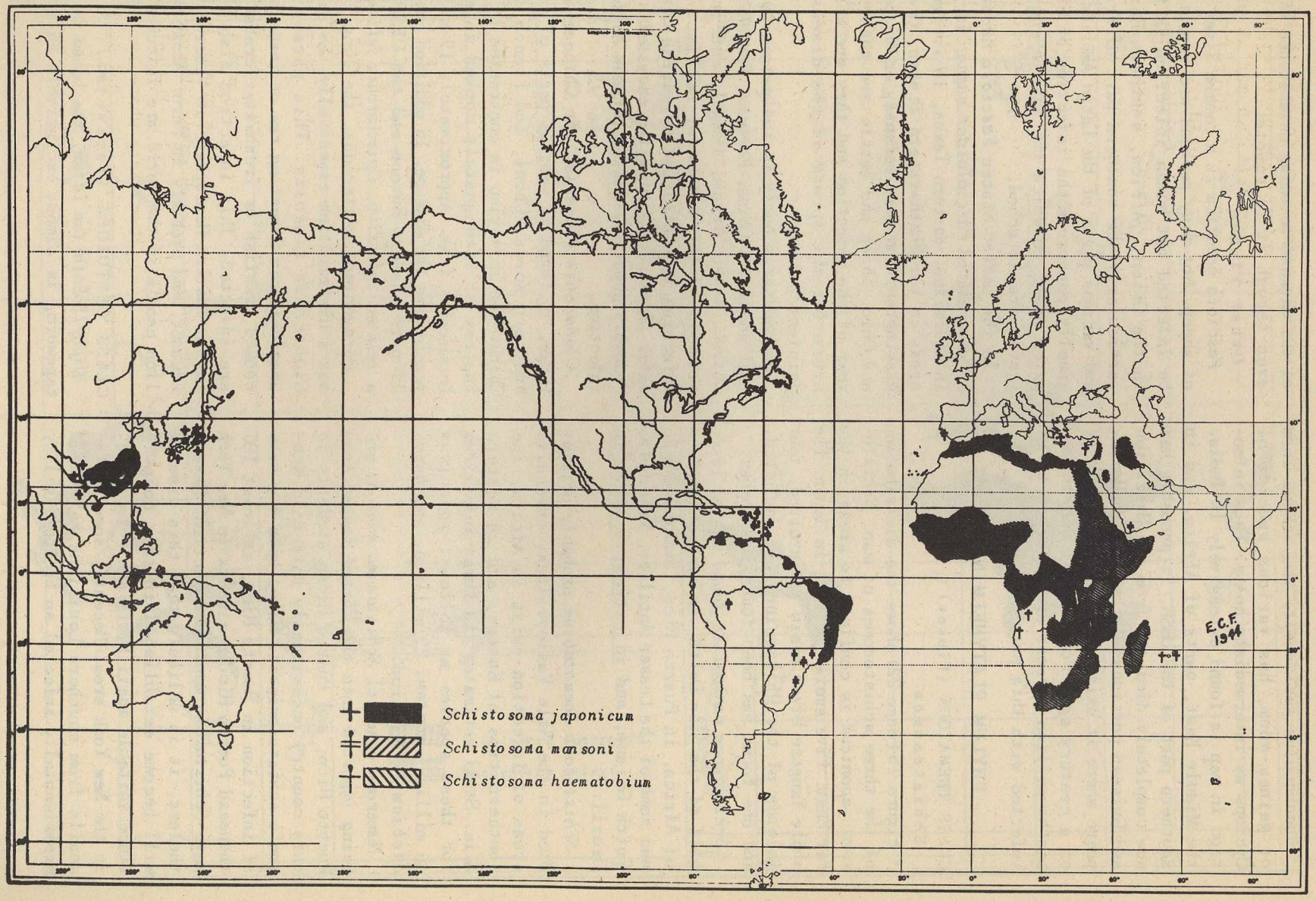
FIGURE 15. Distribution of Schistosomiasis.



tion of the North Temperate Zone. It has, however, been found in the Arctic. Very few other localities are involved. The infective larval stage (sparganum) is found only in fish living in cold water. Stoll estimates that about 10 million people are infected. A related species of *Diphyllobothrium* is found in the Orient in which the sparganum stage is at times found in man. Human infection is reported from Java, Sumatra, southern China, Formosa, and Japan. The sparganum stage of this *Diphyllobothrium* typically develops in the tissues of amphibia, reptiles, birds and mammals. Man becomes the second intermediate host when infected tadpoles are swallowed. Moreover, in China and French Indo-China the flesh of a bird, frog, or snake is sometimes applied to a festering lesion on the skin or to an inflamed eye. The warmth of the human tissues causes the worm to enter the human tissues. Probably 100 thousand people in the Orient have this infection.

In the United States, *Diphyllobothrium latum* occurs in northern Minnesota and the northern peninsula of Michigan. It is found much more extensively in adjacent portions of Canada from the Atlantic to the Pacific coasts. Cases of *Diphyllobothrium latum* occur beyond the boundary of the endemic areas. Fish from endemic areas are shipped as far south as St. Louis and Louisville and as far east as New York City. If infected fish is eaten uncooked or inadequately cooked after shipment, it is likely to produce infection. There are reports of cases from New York City in people who have not been outside the city area. These infections can be traced to shipped fish. It is relatively simple to control such exposure by prohibiting shipment of fish during the highly endemic season, the latter part of the summer and early fall months.

Dipylidium caninum, the dog tapeworm, is common in dogs and cats. Whenever these domestic animals have fleas, as they usually do, the infection may be occasionally transferred to man. Human infections are found only in children who have been fondling these pets, and accidentally swallow the infected fleas. Records from New Orleans indicate infections occur in children from under one year of age up to eight and ten years. The incidence in man is probably about the same in the United States as elsewhere in the world.

Hymenolepis nana, the dwarf tapeworm, is primarily a childhood parasite. It is found more in the Subtropics than in the Tropics, and is very uncommon in cooler climates. About 20 million children throughout the world are infected. In the United States *Hymenolepis nana* occurs principally in the South but may extend as far north as the Ohio River. The incidence is usually moderate. Probably not more than 100 thousand to 200 thousand children in this country are infected. In certain areas, however, infection rates may be as high as 5-10%. These areas are in north Georgia, east Tennessee, and east Kentucky. Ordinarily the number of worms present in the individual is few, but occasionally heavy infections are observed where the number of worms amount to several thousand.

Hymenolepis diminuta, the rat tapeworm, seldom produces human infection. It has been found sporadically in Texas, Louisiana, Mississippi, Arkansas, Tennessee, Kentucky, Alabama, Georgia, and the Carolinas. There are a very few records from farther north.

Taenia saginata, the beef tapeworm, is common particularly through the Mohammedan population of the world. In the United States about 1% of the beef in federally inspected slaughter houses which gets to the consumer has the viable larval stage. There are altogether close to 39 million people in the world who have this infection. At any one time at least 100 thousand people in the United States are infected with *Taenia saginata.*

Taenia solium, the pork tapeworm, has a very much lower incidence and a more limited distribution. It is primarily found in eastern and southeastern Europe, India, and in Mexico. Mexico is the only place in the Western Hemisphere where its incidence is high. Altogether about 2.5 million persons are infected.

Taenia solium is very rare today in the

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population in the United States. Formerly it was not uncommon to see so-called "measly" pork which contained the larvae stage. It is only in the last decade that practically all *Taenia solium* infections have died out. Nevertheless, the rare cases which now occur should be given very careful laboratory and clinical attention because of the grave possibility of human larval infection, that is human cysticercosis, occurring as a result of previously acquired intestinal infection.

Hydatid worm. *Echinococcus granulosus,* which causes hydatid disease, is greatly over-rated statistically, at least as of the present time. The disease is commonly found in hogs, sheep, cattle, and, from time to time, in man. Today human infection is of importance particularly in the very fertile Plata River Valley of Argentina. About one-third of all the cases which come to surgery in the hospitals in Buenos Aires, Argentina are hydatid cysts. Altogether, the infection throughout the world today in the human population is not much over 100 thousand, whereas 25 or 30 years ago it may have been as much as one million. This reduction has occurred as a result of certain preventive measures, and from care with reference to handling dogs around sheep, cattle and hog ranches. The latter entails the periodic deworming of dogs to get rid of the adult stage of the worm so that the eggs will not be passed in the dog's excreta and reach man, to be swallowed and produce hydatid cyst.

In the United States, *Echinococcus granulosus* was quite a problem before 1924. Then new immigration laws went into effect and a high percentage of the previous immigrants from eastern and southeastern Europe were excluded on a quota basis. However, this infection does exist naturally in the United States. It has been found in several western states among persons who have been associated with sheep. Moreover, there is a record of approximately 15 indigenous cases in Louisiana, individuals who had not been out of the deep south and the majority of whom had never been out of the state of Louisiana. The infection exists also in eastern Tennessee. Although this disease is not widely prevalent, whenever there is a suggestion in the clinic or the laboratory of abdominal cysts of any kind, the laboratory worker, as well as the internists and surgeons, should always think of the possibility of hydatid cysts.

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