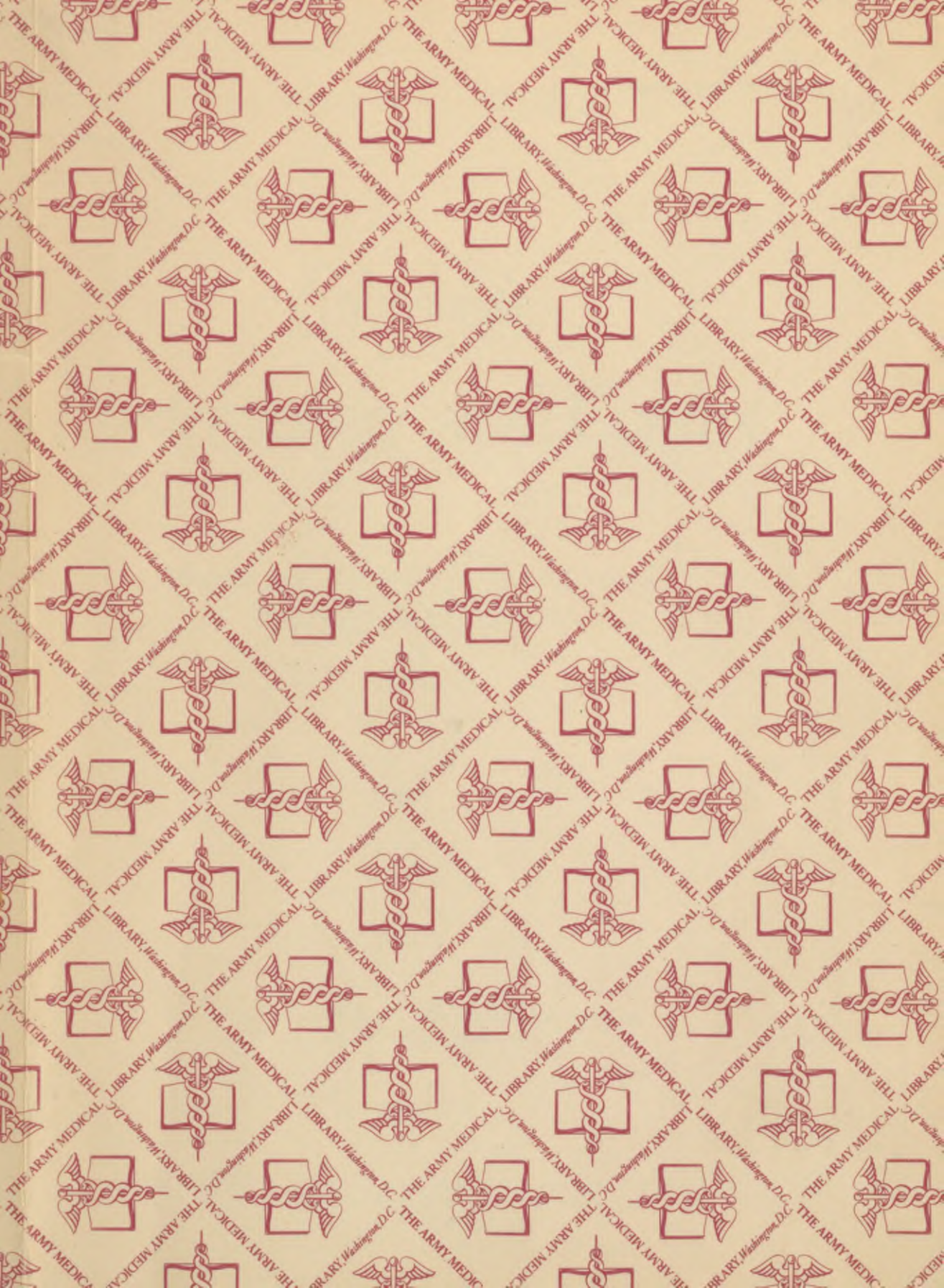


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MALARIA AND EPIDEMIC DISEASE CONTROL



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Malaria and Epidemic Disease  
Control

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# Filariasis

## Epidemiology and Control

Malaria and Epidemic Disease Control  
Training Manual No. 6.



**For Medical and Epidemic Disease Control Officers  
South Pacific Area**

**November 1944**

The Information in This Manual is not to be Communicated Either  
Directly or Indirectly to the Press nor to any Person  
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Malays and Epidemic Disease Control  
Training Manual No. 6



For Medical and Epidemic Disease Control Officers  
South Pacific Area

November 1944

The Government of the United Kingdom is pleased to supply this manual to the Government of the South Pacific Area.

JAN 10 1949

**SOUTH PACIFIC AREA AND FORCE**  
**HEADQUARTERS OF THE COMMANDER**

From: Commander South Pacific Area and South Pacific Force.  
To : South Pacific Area and South Pacific Force.  
Subject: Filariasis, Epidemiology and Control.  
Enclosure: (A) Training Manual Number 6.

1. The accompanying Manual on Filariasis, its Epidemiology and Control in Military and Naval forces in the South Pacific Area is published for the information of all forces operating under the South Pacific Command.

2. The information contained herein will be widely published and used as a guide in the survey and control of filariasis in the areas occupied by our forces.

J. H. NEWTON

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# Filariasis, Epidemiology and Control

## I. INTRODUCTION

For many centuries a disease commonly referred to as elephantiasis has been known to be endemic throughout the tropical regions of the world. It was not until comparatively recent times (approximately fifty years ago) that the condition known as elephantiasis was determined to be of filarial origin. Since the discovery of this fact and the demonstration of its transmission by mosquitoes considerable knowledge of medical and epidemiological importance has accumulated.

Prior to the outbreak of the present war the disease of filariasis (elephantiasis) was considered to be confined to individuals residing within the known limits of its distribution and was considered to be more specifically a disease of certain races and types. Many people who spent considerable time within endemic areas or who migrated to this region are known to have contracted the disease after a short or longer residency there. Even with this knowledge at hand the disease of filariasis was generally believed to be more or less specific in its selection of host subjects and that the white race suffered attacks of the disease so infrequently that it could be regarded as being of minor medical importance in so far as whites were concerned.

With the introduction of large numbers of service personnel into certain filarioid areas in the South Pacific zone, perhaps for the first time filariasis has broken the bounds of its endemic status and has reached near epidemic proportions, especially among the white service personnel stationed or staged within certain endemic centers within this zone. For the present at least this threatened epidemic has been checked, and the disease once more is reduced to its smoldering endemic status.

It is the purpose of this manual to outline the medical and epidemiological aspects of the disease of filariasis. Such an outline of necessity must be brief, omitting many of the more interesting details, but stressing the main points in the distribution, transmission, prevalence, endemicity and control of the disease. Particular emphasis is placed on recently acquired epidemiological facts which will enable all officers to better understand the filarial problem. The manual will serve as a guide for the determination and elimination of any possible future threatening recurrence of mass filarial infections such as has occurred in the past. The organization and functions of a suggested filaria survey-control program are outlined.

## II. FILARIASIS.

### A. Definition.

Filariasis is a disease caused by the presence of a specific worm parasite in the body of man, the toxic effects of which are usually expressed in physiological disturbances of the lymphatic system.

### B. The parasite.

*Wuchereria bancrofti*, the causative agent of Bancroft's filariasis, and *Wuchereria malayi*, the causative agent of Malayan filariasis, will be the two species of filaria worms most frequently encountered in the Asiatic-Pacific zone. For the purpose of this manual

only the parasitologist needs be familiar with the differences between the two parasites. In many locations both organisms are present in endemic proportions while in others one or the other may be entirely absent or will be present only in the imported portion of the population. For all practical purposes the disease produced by one of these worms is identical to that produced by the other in so far as the clinical manifestations and ultimate effects on the human body are concerned.

The sex are separate in the filaria parasite, there being a true female and male worm. It is necessary for the infected individual to be parasitized by a sufficient number of both male and female worms for these to find each other within the human body before viable larvae can be produced. The individual may harbor one or the other or both sex of the parasite. The production of symptoms in the human host is not dependent upon the presence of both sex. There is no increase in the number of adult worms within either the human or the transmitting mosquito host. To increase the number of parasites within the human body, it is essential that these be acquired through the bite of the infected mosquito.

### **C. Diagnosis.**

#### **1. Clinical symptoms.**

As in the case with so many diseases there is no set series of symptoms which in themselves would enable the clinician to diagnose filariasis. There are certain symptoms, however, which strongly suggest filariasis. In the absence of other attributable causes such symptoms as (1) lymphadenitis, with or without lymphangitis, (2) retrograde lymphangitis of an extremity, (3) funiculitis, with or without epididymitis, orchitis, acute hydrocoele, and edema of the scrotal skin, and (4) the recurrence of one or more or all of these, should be regarded as being of filarial origin. To substantiate the clinical picture, the history given by the patient should be of value in making the diagnosis. This history should include (1) length of service in a filarious area, (2) the proximity of residence to native habitation, and (3) exposure to transmitting mosquitoes.

#### **2. Laboratory aids in making the diagnosis.**

The only way to definitely establish a diagnosis of filariasis is to demonstrate (1) the actual presence of the adult or adolescent filaria parasite in the tissues of the body or (2) the presence of the microfilariae in the blood or lymph stream.

In regard to the demonstration of the adult or adolescent parasite in the lymph tissue, it must be borne in mind that often the disturbance produced in the lymph system through surgical removal of such tissue results in complications out of proportion to the value of the procedure. Experience has shown that the actual presence of the parasite can be demonstrated in only a small per cent of the tissues removed through biopsy. Even then the worms may be found only when serial sections are made of the excised material.

Regarding the demonstration of microfilariae in the blood or lymph of the newly infected service personnel, it must be remembered that even when large volumes of blood or lymph are withdrawn a special technique is required for the demonstration of the larvae. Experience gained through a survey of many hundreds of individuals having filariasis shows that service personnel do not harbor the larvae in sufficient numbers for these to be detected by routine laboratory methods (see Incubation Period, page 3).

Thus, due to the medical inadvisability of confirming the diagnosis of filariasis by tissue biopsy, together with the improbability of being able to detect the presence of microfilariae in the blood stream, the diagnosis in service personnel should be based on the findings of the clinician and the history of exposure to the infection.

#### D. Incubation period.

The incubation period in filariasis ranges from three months to many years, this period being defined as the length of time elapsing between initial exposure and the first appearance of clinical symptoms and/or the appearance of microfilariae in the blood stream. Undoubtedly a few individuals will develop symptoms earlier than the three months minimum, although the vast majority of the cases will not show symptoms of the disease until after a much longer period of time. As yet we do not know how long the parasite must reside in the body before larvae appear in the blood stream. In the native population microfilariae have been demonstrated in the blood by the end of the first eighteen months of life; however, the larvae are already encountered in the blood of children under five years of age. By the same token it might be assumed that at least five years of continuous exposure to the infection are necessary before filaria larvae can be expected to appear in the blood in appreciable numbers. It is extremely doubtful, therefore, if service personnel ever will show a sufficient number of microfilariae in the blood stream for these to be detected by ordinary laboratory methods. The shorter period of residency in the uncontrolled endemic areas and the fact that service personnel were never exposed to the infection to the same degree as was observed to be the case with the native population argue strongly in favor of this assumption.

#### E. Prognosis.

The disease of filariasis is rarely given as a cause of death, although it may be a contributing factor. Within the endemic area recurrent attacks of clinical filariasis ("Mumu") may occur at frequent intervals throughout life, or the attacks may be intermittent with the periods of apparent normal health of longer duration. In a small per cent (usually less than 5) of those infected the affected part of the body becomes permanently enlarged and continues to enlarge for an indefinite period. Such a permanent enlargement is referred to as elephantiasis. In certain local areas of Southeast Asia and the Netherlands Indies it is reported that as many as eighty per cent of those individuals having the disease develop elephantiasis. The worm involved is *Wuchereria malayi*.

In the absence of reinfection, the filaria parasite is known to live within the human body for as long as ten years and may continue to cause recurrent attacks of clinical filariasis throughout the entire period. From this fact it must be assumed that a certain per cent of the infected personnel will continue to show clinical attacks of filariasis for many years after leaving the endemic area. It is questionable whether or not noticeable elephantitic manifestations will ever develop unless the infected personnel prove to be more reactionary to the infection than is observed for the permanent inhabitants of endemic areas.

The question of sterility often arises among those troops in which the genitals are involved. There is no foundation for assuming sterility to be a result of filariasis. The reproductive tissue itself is not affected.

#### F. Treatment.

At the present time there is no known treatment for filariasis which will effect a complete cure. Attempts to alleviate the pain and congestion experienced locally at the time of the attack may be made through the applications of any suitable remedy. The attack may last from a few to many days, and the patient should be under the supervision of the Medical Officer throughout the duration of the attack. Surgical intervention may be found to be of value in draining deep abscesses, or in removing the excess tissues after elephantiasis has developed.

### G. Transmission of Filariasis.

The disease of filariasis is transmitted from one individual to another by mosquitoes. The mosquito is **absolutely** essential to the transmission of the filaria parasite. There is no increase in the number of worms within the mosquito host, i. e., if the mosquito draws up ten microfilariae from the blood of the infected individual, ten is the maximum number of larvae it can pass on to the next individual.

From eleven to seventeen or more days (average being fourteen) are required for the filaria larvae to develop to the infective stage within the mosquito host (see figures). During this period of time the larva passes through two moults and grows from the microfilaria stage (about 200 microns in length) to the infective stage (about 2 millimeters in length). In the case of the human filaria worm, this development takes place in the thoracic muscles of the mosquito. The infective stage larva leaves the muscles and is usually found in the head or labium of the mosquito host. This larva is deposited on the surface of the skin during the time the mosquito is feeding, and from this location it works its way into the body, entering the body through the puncture made by the mosquito. Nothing is known concerning the activity of the worm from the time it enters the body until the first appearance of symptoms.

### 111. MILITARY IMPORTANCE OF FILARIASIS.

Up to the present time the disease of filariasis has been one of the leading causes of medical evacuation of troops from this area. The majority of the troops evacuated from the area came from those troops which were stationed or staged in the Samoan Defense Area and adjacent islands (inclusive of American and British Samoa, Wallis Island, Ellice Islands, Cook Islands, Tonga Islands, Society Islands and Fiji). Many troops were evacuated from other areas although the majority of these had been quartered at one time or another in the Samoan Defense Area (or adjacent islands) and, hence, it is claimed that they contracted the disease while in that area.

There is no way whereby the actual number of days lost to the war effort through illness resulting from filariasis can be determined. Although the attack of filariasis may be too light to necessitate hospitalization, the patient is unable to perform his duties in a manner commensurate with his importance to the teamwork of the unit to which he belongs. Under combat conditions this part incapacitation together with the actual loss of members of the unit due to hospitalization may mean the delay of action, defeat and even death to comrades. A majority of the filarial patients will require hospitalization from a few to many days, and, depending on the severity and number of attacks, evacuation from this area. An inestimable loss in both manpower and money has resulted directly from the disease of filariasis. The end of this loss of manpower is not yet in sight. Even after leaving endemic areas troops continue to develop filariasis and require hospitalization and/or evacuation. Many of those troops returned to the United States continue to have recurrent attacks of the disease.

The general morale of troops within an endemic area as well as of those having been staged in such areas is greatly influenced by the disease of filariasis. Aside from the general attitude which develops in troops because of any illness that may be current within their organization, there is the added mental stress which is brought on by the unsightly after effects of filariasis as is evident in the elephantitic developments (see figure 20) in the native population. Of equal importance is the dread of impotency and sterility which are erroneously believed by troops to be effected through the involvement

of the genital organs. In all organizations there will be a few individuals who will utilize the opportunity filariasis presents for malingering and who will attempt to use the disease as a means of evacuation to the United States.

#### IV. CERTAIN EPIDEMIOLOGICAL FACTS APPLICABLE TO FILARIASIS.

##### A. Distribution and prevalence of filariasis.

###### 1. Distribution.

The disease of filariasis is endemic throughout the more moist and warm regions of the world between 30°N. and 32°S. latitude. In general, the disease can be said to occur in the populations of all major island groups in the Pacific Ocean from a latitude which would bisect the home islands of Japan in the north to one in the south that would cross the continent of Australia somewhere just south of the city of Brisbane (New Zealand and the Hawaiian Islands being the only major exceptions). The disease is endemic along a narrow coastal area on the east, northeast and north coast of Australia. In Asia it is present along the coast and inland waterways throughout China, French Indo-China, the Malay States, Thailand, Burma, India and Arabia. In Africa the disease is confined to Central Africa and the Mediterranean coastal area. Areas of low endemicity occur throughout southern Europe. In the Americas filariasis is prevalent from about central Mexico to Argentina, being confined on the mainland to coastal areas and river valleys. The West Indies and adjacent islands are endemic centers. Charleston, South Carolina, is the only known endemic center of the disease within the continental United States.

###### 2. Prevalence.

Throughout the filarial belt the prevalence of the disease varies from area to area, with the incidence of infection in the population ranging from a fraction of one per cent to practically one hundred per cent. In many areas considerable survey work has been done both from the incidence and transmission points of view as well as from the view to ascertaining a general concept of the clinical aspects of the disease. Many of the areas have been only partially studied or have been neglected altogether. In general, the extent of the distribution of the disease is so vast that knowledge concerning the filarious conditions existing in many areas will not be known for many years to come.

##### B. Vectors of Filariasis.

Throughout the filarial belt of the world fifty or more species of mosquitoes are reported to be transmitters of filariasis. Approximately one-half of this number of mosquitoes is known to transmit the disease naturally, while the remainder are included in the list of transmitters because of their ability to serve as hosts to the parasite experimentally. Both the natural and experimentally proved transmitters are about equally divided between the anopheline and culicine mosquitoes. A partial list of the principal vectors of filariasis and their geographic sphere of activity follows:

1. *Culex quinquefasciatus* (*fatigans*) South China, Formosa, Celebes, India, Egypt, Australia, West Indies, Brazil, East Indies, Philippine Islands, Pacific Islands, and United States).
2. *Culex habitator* West Indies).
3. *Culex pipiens* (China, Japan and Egypt).
4. *Culex fuscocephalus* (East Indies).
5. *Culex whitmorei* (East Indies).
6. *Culex annulirostris* (East Indies).

7. *Culex alis* (East Indies).
8. *Culex vishnui* (East Indies).
9. *Culex sitiens* (East Indies).
10. *Culex bitaeniorhynchus* (East Indies).
11. *Culex tritaeniorhynchus* (East Indies).
12. *Aedes scutellaris pseudoscutellaris* (Central and South Central Pacific Islands).
13. *Aedes scutellaris tongae* (Central and South Central Pacific Islands).
14. *Aedes scutellaris hebrideus* (South Pacific Islands).
15. *Aedes aegypti* (West Africa, West Indies and Australia).
16. *Aedes togoi* (Japan).
17. *Aedes taeniorhynchus* (West Indies).
18. *Aedes vigilax* (East Indies and Australia).
19. *Mansonia (Mansonoides) uniformis* (Central Africa, East Indies and South Pacific Islands).
20. *Mansonia (Mansonoides) annulata* (East Indies).
21. *Mansonia (Mansonoides) indiana* (East Indies and New Guinea).
22. *Mansonia (Mansonoides) annulifera* (Dutch Indies).
23. *Mansonia (Mansonoides) longipalpis* (East Indies).
24. *Mansonia (Mansonoides) pseudotitillans* (Malay States).
25. *Mansonia (Mansonoides) juxtamansonia* (Brazil).
26. *Anopheles maculatus* (East Indies).
27. *Anopheles aconitus* (New Guinea and Celebes).
28. *Anopheles barbirostris* (East Indies and India).
29. *Anopheles bancrofti* (East Indies).
30. *Anopheles amictus* (Australia).
31. *Anopheles ludlowi* (India).
32. *Anopheles stephensi* (India).
33. *Anopheles fuliginosus* (India).
34. *Anopheles pallidus* (India).
35. *Anopheles philippinensis* (India).
36. *Anopheles varuna* (India).
37. *Anopheles pseudojamesi* (India).
38. *Anopheles subpictus* (India and East Indies).
39. *Anopheles costalis* (Africa).
40. *Anopheles funestus* (Africa).
41. *Anopheles rhodesiensis* (Africa).
42. *Anopheles squamosus* (Africa).
43. *Anopheles rossi* (India).
44. *Anopheles albitarsis* (Brazil).
45. *Anopheles albimanus* (West Indies).
46. *Anopheles algeriensis* (North Africa).
47. *Anopheles hyrcanus nigerrimus* (South China and Malay).
48. *Anopheles hyrcanus sinensis* (East China and East Indies).
49. *Anopheles hyrcanus x* (East Indies).
50. *Anopheles sundaicus* (East Indies).
51. *Anopheles annularis* (East Indies).
52. *Anopheles vagus* (East Indies).

53. *Anopheles tessellatus* (East Indies).
54. *Anopheles punctulatus moluccensis* (East Indies).
55. *Anopheles punctulatus farauti* (East Indies and South Pacific Islands).
56. *Anopheles punctulatus punctulatus* (East Indies).
57. *Anopheles punctulatus* var. ? (South Pacific Islands).

Since the greater majority of the transmitting mosquitoes, included in the above list, are more active in their feeding habits at night, it can be said that in general the transmission of filariasis occurs during the hours of darkness. On the other hand, one must not lose sight of the fact that day feeding varieties of mosquitoes are involved in the transmission of filariasis. In certain areas the transmission of the disease is due entirely to the activities of the day feeding mosquito. Undoubtedly this one factor is as much responsible for the large number of filariasis cases which developed in troops within the Samoan Defense Area as can be attributed to any other single cause. Troops in this area were instructed in preventive measures and were provided with the means of preventing disease contraction due to the activities of night feeding varieties of mosquitoes. Unfortunately the importance of the day feeding mosquito, so common to that area, was unknown and, hence, no preventive measures were considered necessary against the species. Undoubtedly day feeding mosquitoes which are capable of transmitting filariasis will be encountered in other areas.

A great many of the night feeding varieties of mosquitoes will actively feed during dark days, in dense jungle or within quarters, with the feeding activities increasing in intensity at dusk and dawn. Other night feeding varieties are extremely shy in their feeding habits and will confine this activity to the hours of total darkness.

From the control point of view it is just as important to know how accessible are troops to the transmitting host as it is to know which species of mosquito is responsible for the transmission of filariasis within a given area. The accessibility of service personnel to the vector will depend on (1) the proximity of the personnel to a focus of infection and (2) the flight range of the transmitting mosquito. In cases involving transmission of filariasis by anopheline mosquitoes, it will be necessary to observe the standard proved to be effective in the control of malaria: At least one mile should be considered the minimum distance camps should be located away from native habitation. The actual distances mosquitoes will fly in search of a blood meal have been demonstrated only for a very few species. Such mosquitoes as *Culex quinquefasciatus* (*fatigans*) and *Aedes aegypti*, for example, are known to breed and rest only in the immediate vicinity of a constant food supply: they do not fly great distances in search of a blood meal. Such mosquitoes are considered to be domesticated species and, hence, do not breed or rest at great distances away from human habitation. *Aedes scutellaris pseudoscutellaris*, on the other hand, breeds extensively throughout the area of its distribution and obtains its food from whatever source of blood that chances to be available in the immediate vicinity of its breeding place. In undisturbed conditions this species will not fly more than two hundred yards in search of the blood meal. It is to be remembered that the flight range will have to be determined for the vast majority of the transmitting mosquitoes which are met with throughout the filarial belt. In situations in which the principal vector or its normal flight range is unknown, the camp site should be located far enough away from native habitation to insure against all possible transmission.

### C. The Transmission Efficiency of the Vectors of Filariasis.

*Culex quinquefasciatus* (*fatigans*) is the only mosquito common to all major areas of filaria endemicity throughout the world. The species has the distinction of being

the one in which the mosquito phase of the life cycle of the filaria was first demonstrated. The ability of the mosquito to develop the larvae to infectivity experimentally, together with the low incidence of natural infections which can be determined for it in endemic areas, have led many investigators to assume that the species plays a major role in the transmission of filariasis. In many areas this species is listed as being the only important transmitter present; however, from investigations in South Pacific and Netherlands Indies areas it is strongly indicated that the species plays a very minor role in the transmission of filariasis within these areas. Considerable doubt, therefore, is cast on the importance of the species as a vector in other endemic areas of the world. In Samoa, for example, only 29 per cent of *Culex quinquefasciatus* could be infected from a single blood meal whereas 90 per cent of *Aedes scutellaris pseudoscutellaris*, the vector in that area, became infected. In a like manner only one per cent of *quinquefasciatus* developed the larvae to the infective stage experimentally in contrast to 18 per cent of the *Aedes* mosquito. Although early developmental stages of the filaria larvae were found in naturally infected *Culex quinquefasciatus*, no specimen of the species was taken in the field in which infective stage larvae were encountered. This is to be contrasted with an eight per cent incidence for the infective stage larvae in *Aedes scutellaris pseudoscutellaris*. It is obvious, therefore, that *C. quinquefasciatus* plays a very minor role in the transmission of filariasis within the Samoan area. In a like manner the role this mosquito plays in the transmission of the disease has been demonstrated to be of little importance or secondary to other species in all areas where sufficient data have been accumulated to give a true picture of this factor.

In regard to *anopheles punctulatus farauti*, the principal vector of filariasis in the New Hebrides and Solomon Islands, it has been possible to demonstrate a higher incidence of infection in this species than was possible for *Aedes scutellaris pseudoscutellaris* in Samoa. Despite this higher incidence of infection in the anopheline mosquito, a slightly higher per cent of the *Aedes* mosquito developed the larvae to the infective stage (14 days) than did the anopheline, indicating, perhaps, that the *Aedes* host is slightly more efficient as a transmitter of the disease. Within the spheres of their activity both species are considered to be exceptionally good transmitters, far outweighing the importance of *Culex quinquefasciatus* as a vector of filariasis.

In the Solomon Islands two other species of mosquitoes have been incriminated in the transmission of Bancroft's filaria, an undetermined variety of *Anopheles punctulatus* and *Mansonia (Mansonioides) uniformis*. Neither of these species is considered to be as important in the transmission of filariasis as *A. punctulatus farauti*, although both must be considered to be more important transmitters than can be claimed for *Culex quinquefasciatus*.

In order to determine the transmission efficiency of the vector or vectors within a given area, a great deal of incidence data must be accumulated before the determination can be made. In such areas where more than a single species of mosquitoes is involved in the transmission of the disease, it is important to know the efficiency rate of those species which are shown to harbor the developing larvae. A method for determining this efficiency rate, along with reason for its importance to the problem, is given in another section of the manual (see The Mosquito Survey, page 19).

#### D. Endemicity.

Throughout this manual the term endemicity is used to describe an area in which there is an incidence of the disease in both the native population and the mosquito vector. The disease of filariasis is said to be endemic in a given area because of the facts that (1) the disease is present in a definite and measurable per cent of the population, and (2)



this per cent incidence of the infection shows no marked variation from year to year.

Typical endemic centers can be illustrated by giving the per cent incidence of infection in both the native and mosquito populations in three specific island groups within this general area.

#### 1. Samoan Defense Area.

a. Filariasis (*Wuchereria bancrofti*) is present in this area in approximately 24 per cent of all natives surveyed.

b. The disease is transmitted by *Aedes scutellaris pseudo-scutellaris*, a day feeding culicine mosquito. Within the area this mosquito shows an incidence of infection up to 45 per cent.

#### 2. New Hebrides Islands.

a. Approximately 22 per cent of all Melanese surveyed were infected with *Wuchereria bancrofti* and 9 per cent of all Tonkinese harbored *Wuchereria malayi*.

b. The filaria worm (*Wuchereria bancrofti*) is transmitted by *Anopheles punctulatus farauti*. The incidence of infection in this mosquito ranged up to 45 per cent. Because of an absence of known vectors of *W. malayi* in the area and since additional vectors could not be demonstrated, it is believed that no transmission of the species occurs. Undoubtedly the disease is present in the area only because it was brought into the area by imported laborers.

#### 3. Solomon Islands.

a. *Wuchereria bancrofti* is present in 22 per cent of all natives surveyed from this area. No other filaria worm was encountered.

b. The three species of mosquitoes which are involved in the transmission of filariasis in this island group, together with the incidence of infection in each, are: (1) *Anopheles punctulatus farauti*, 52 per cent, (2) *A. punctulatus* var. (unknown) 5 per cent, and (3) *Mansonia (Mansonoides) uniformis*, 23 per cent.

*Mansonia (Mansonoides) uniformis* is listed here because of its probable role in the transmission of filariasis in this area. In no individual was it possible to demonstrate infective stage larvae, although a few of the specimens carried well advanced (10 to 12 day old) developmental stages.

From the filarious condition demonstrated for the three areas listed above it must be concluded that each constitutes a typical endemic filarious area. A similar condition of filariasis will be found to exist in all endemic areas throughout the filarial belt of the world.

#### E. Hyperendemicity.

1. Within the endemic area the disease of filariasis will be found to be spotty in its distribution. Certain areas will constitute the foci from which all transmission occurs while other areas will be entirely free of the disease. For all practical purposes, therefore, those centers from which the disease is transmitted may be considered as the hyperendemic foci. It is to be understood that certain of the foci can be determined to have a higher incidence of infection in both the native and mosquito population than can be shown for other foci. By all ordinary standards such areas of high incidence in the native and mosquito population would be considered as the hyperendemic focus, and, hence, the area most dangerous from the transmission point of view. On the other hand, areas

having a low incidence of infection in both types of hosts might just as readily be considered as being of minor importance to the transmission of the disease. This, however, is not always the case. **The filarial danger within a given area is dependent upon the volume of transmission.** The high incidence of infection within the mosquito host is not the only factor governing the rate of transmission. **The index of the transmission rate within any given area is the product of the per cent incidence of infection in the vector times the density of that mosquito.** The rate of transmission within three hypothetical areas will illustrate this point as follows: (1) In area A the vector shows a density of 100 mosquitoes per man per hour. Fifty per cent of these are infected. It is obvious then that an individual entering this area would receive 100 bites per hour and that 50 of these would be by an infected mosquito. (2) In a second area, B, the density of the transmitter is 100 mosquitoes per man per hour and 10 per cent of these are infected. Thus, an individual would obtain 100 bites per hour while in the area. Of these only 10 bites would be by an infected mosquito. (3) In area C the density of the vector is only 10 mosquitoes per man per hour, but 50 per cent of these are infected. Within one hour an individual would be bitten only 10 times and of these only 5 bites would be by infected mosquitoes. When it is remembered that the incidence of infection in the mosquito host is always higher than can be shown for the native population from a single smear method, it becomes obvious that the native population in Areas A and C shows a higher incidence of infection than can be shown for that in area B. With this in mind, area A must be considered as a hyperendemic focus while areas B and C may be considered as endemic by the same standard. Certainly as they are set up area B is at least twice as dangerous as area C even though the incidence of infection in both the native and the mosquito population is much higher in C than in B. It then becomes apparent that the transmission of filariasis is directly dependent upon the density of the transmitting mosquito within the given area when all other factors are stable.

One must not lose sight of the fact that seasonal changes may greatly affect the density of the mosquito population. Mosquito densities always fluctuate with the creation or destruction of breeding and resting places as well as when variations in the available food supply occur. Thus, areas B and C must be considered as potential hyperendemic foci: they may become hyperendemic within a very short period of time. In a like manner the importance of area A may be reduced to the status of area C through a lowering of the density of the vectors. Because of the extremely slow development of filariasis in the human host, it should be pointed out that a fluctuation in the incidence of blood infection in the native, or the incidence of infection in the mosquito population, would occur only over an extended period of time. Thus, for all practical purposes the incidence of infection in a given area may be considered stable. The only factor, therefore, which would change the rate of transmission of the disease is a change in the density of the vector. Thus, it is obvious that all centers in which transmission can occur must be considered as danger spots from the standpoint of filariasis, and attempts to control the transmission within such centers as are located an unsafe distance from personnel camps are demanded.

#### **F. Epidemiological Precepts.**

1. From epidemiological investigations of the disease of filariasis, especially those studies made in the Samoan Defense Area, the New Hebrides and Solomon Islands, the following general factual statements can be predicated:

- a. Regardless of how highly endemic an area may be, the disease of filariasis

will be found to be spotty in its distribution within that area. Certain locations within the area must be considered as filarious while other locations may be entirely free of the disease.

b. Those factors favoring the creation and maintenance of a hyperendemic focus are a stable group of highly infected natives and a high density of the specific vector. All villages and semi-permanent gathering places of natives should be considered as hyperendemic or potential hyperendemic foci.

c. The size of any given center of transmission is directly dependent upon the flight range of the vector or vectors. In cases where *Aedes scutellaris pseudoscutellaris*, the vector in the Samoan Area, is determined to be the transmitter the radius of a focus may be as little as two hundred yards. In areas where other mosquitoes are found to be the vector a certain amount of investigation will be necessary before the flight range of the host and, hence, the size of the focus can be determined.

d. In general, a single species of mosquito will be found to be the principal vector within a given area. It is, therefore, highly important that the main vector or vectors be determined through a thorough study of all mosquitoes showing evidence of being transmitters before suitable control measures can be put into effect. To determine the main vector or vectors, one must determine which mosquitoes show a significant incidence of infection with infective stage larvae (see pages 19 to 24). The flight range and feeding habits of the vector or vectors should be determined as quickly as possible so that troops can be instructed in the proper protective measures against these specific mosquitoes.

e. In addition to the spotted distribution of the disease in endemic areas, two factors make possible a more complete and stable control of the disease of filariasis than can ever be hoped for in cases involving malaria or dengue:

(1) Unlike malaria or dengue, a single bite from an infected mosquito is much less likely to result in a clinical case filariasis. This is true because the filarial worm cannot reproduce itself asexually within the human body as is the case with the malaria organism. It requires repeated reinfections to build up a worm density in the individual sufficient to bring about serious clinical manifestations. The importance of this fact cannot be overemphasized. The majority of the clinical cases, therefore, must come from an area where repeated reinfections can occur in a relatively short time, the hyperendemic focus.

(2) The slow development of the filaria parasite in man, even when mass transmission occurs, results in the fact that service personnel rarely, if ever, harbor microfilariae in the blood in sufficient numbers for these to be demonstrated or for them to be picked up by the transmitting mosquito host (see paragraph C, page 2, and paragraph D, page 3). This fact almost assuredly eliminates the possibility of large units of troops becoming seeded and thereby endangering the health of other personnel. This being true, the native population is the only source of the infection for the transmitting agent.

f. With these facts in mind, it becomes obvious that the control of filariasis is dependent upon determining and delimiting all centers of transmission. Once this is done, proper steps can be taken to eliminate or isolate these foci. Since the source of the disease is confined to the native population, the centers of transmission of necessity must be confined to the areas of their habitation. Therefore, if the flight range of the vector proves to be limited and the topography of the area lends itself to the location of camp sites in non-filarious areas, a sufficient distance from the centers of transmission, all that is necessary for complete control of the disease is to prevent promiscuous visiting of

## EXPLANATION OF FIGURES

The following series of photomicrographs portrays the relative differential growth changes which occur from day to day in the filaria larva during its developmental cycle (from microfilaria, figure 1, to infective stage larva, figure 16) in the mosquito host. The photomicrographs were made with the aid of the Speed Graphic Camera, using Super Pancropress film. A prefocused ribbon filament lamp was used as a source of light and this was filtered through blue and ground glass plates. All photomicrographs, except figures 2, 18, 19, and 20, were made by using a 7.5x ocular and a 10x objective and the final prints were enlarged approximately 1.5 times to give uniform pictures with a magnification of 115 diameters.

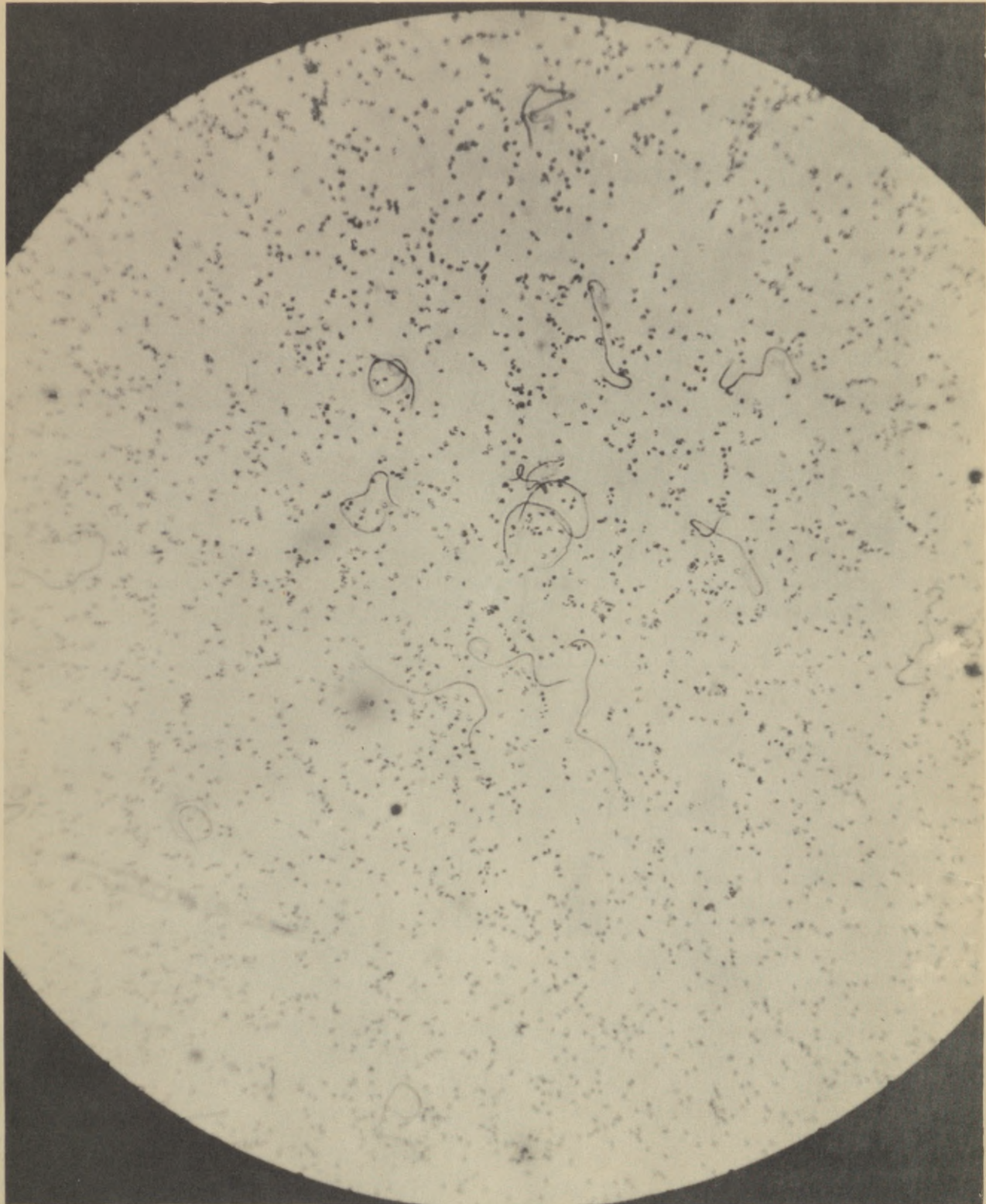
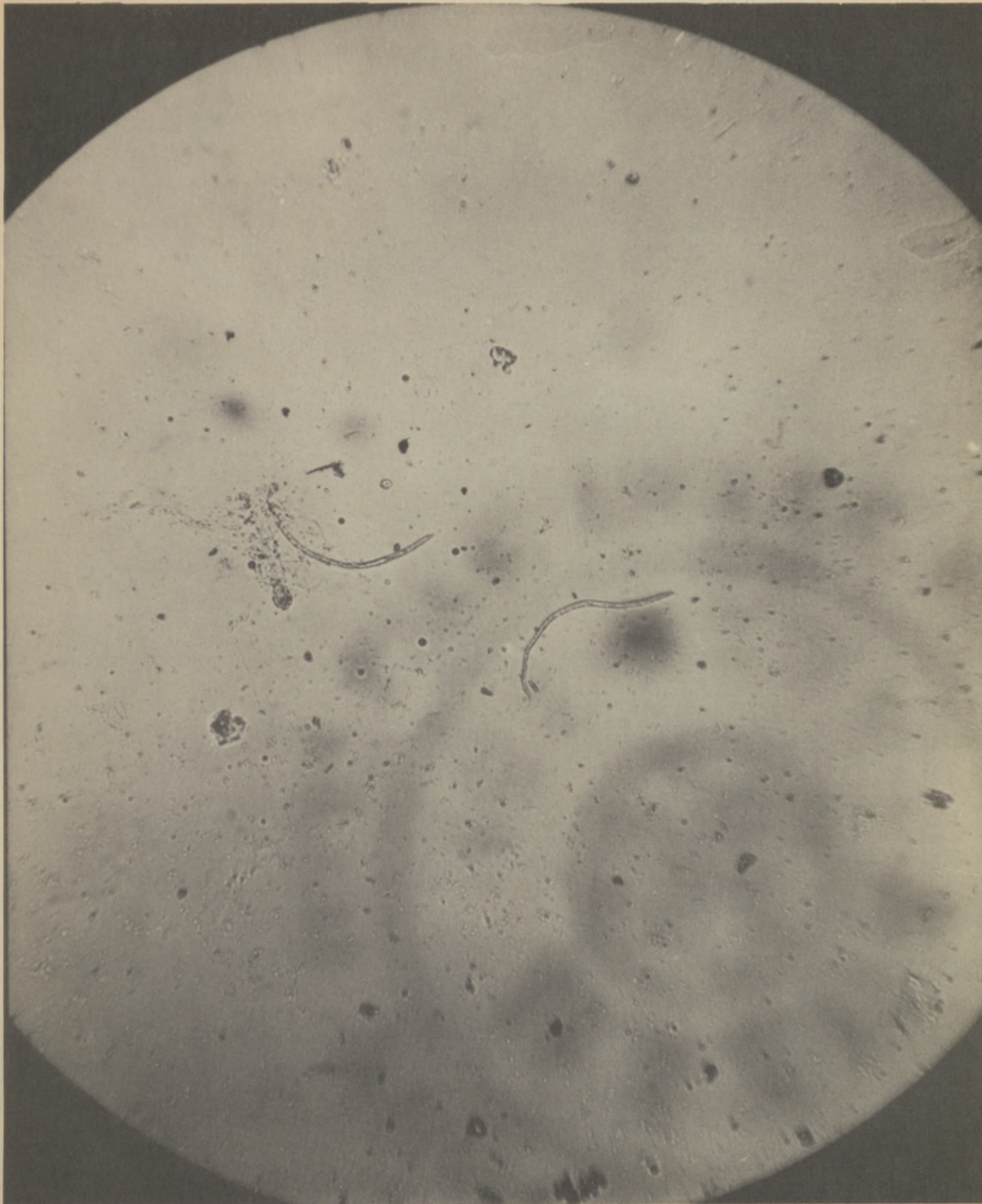


Figure 1. Photomicrograph of microfilariae (x 115). Note presence of sheath and the size of the microfilariae in comparison to white blood cell. Dehaemaglobinized blood, Harris' hematoxylin-eosin.



Figure 2. Photomicrograph of single microfilaria (x 530) to show sheath. Same as Figure 1.



**Figure 3.** Photomicrograph of two developing filaria larvae (x 115) at the end of the first day of the developmental cycle in the mosquito vector. Note shortening and thickening of the worm, and appearance of spike-like tail. Living specimens.

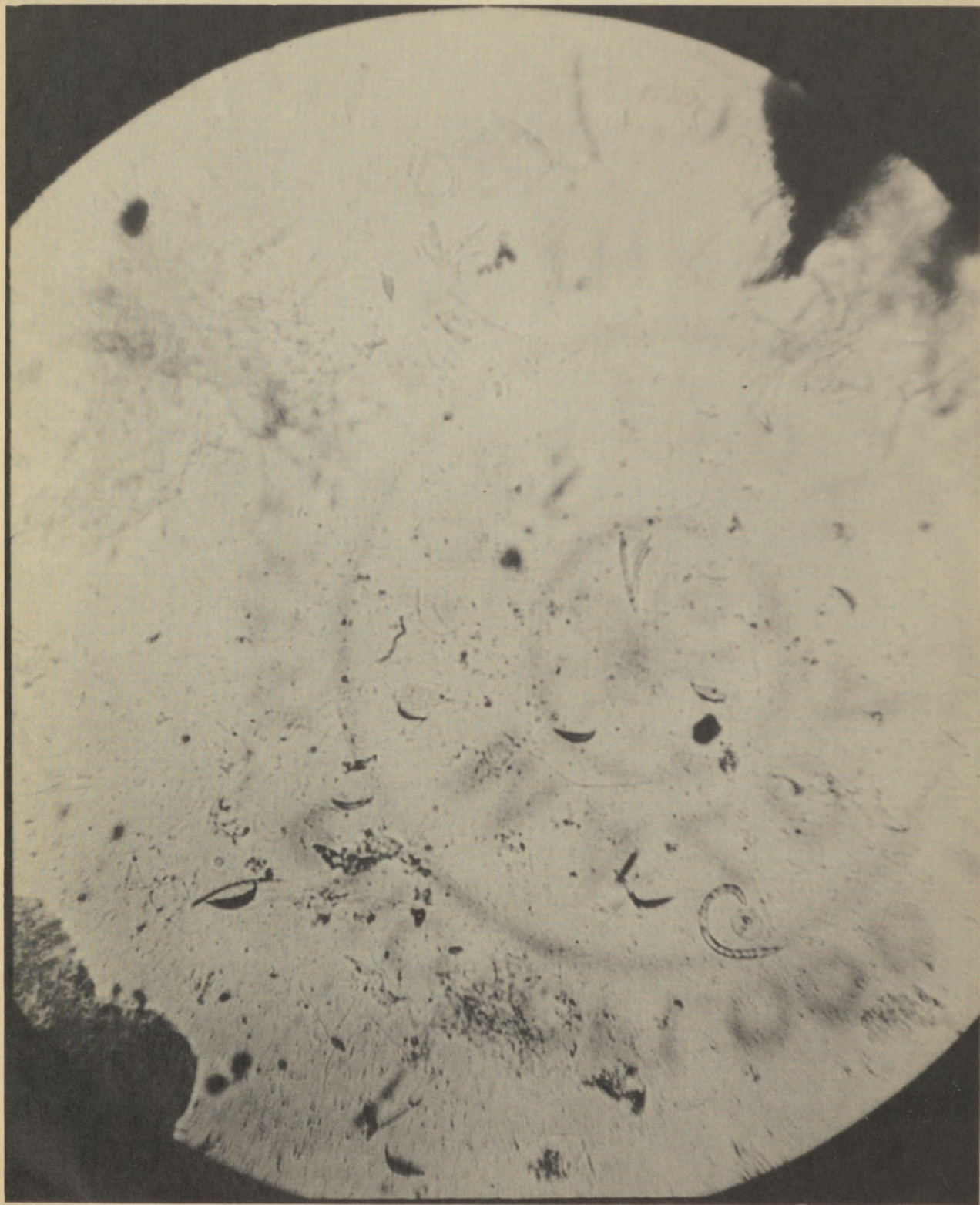


Figure 4. Photomicrograph of two developing filaria larvae (x 115) at end of second day of developmental cycle in mosquito host. Note thickened, curved body and tail spike. Living specimens.



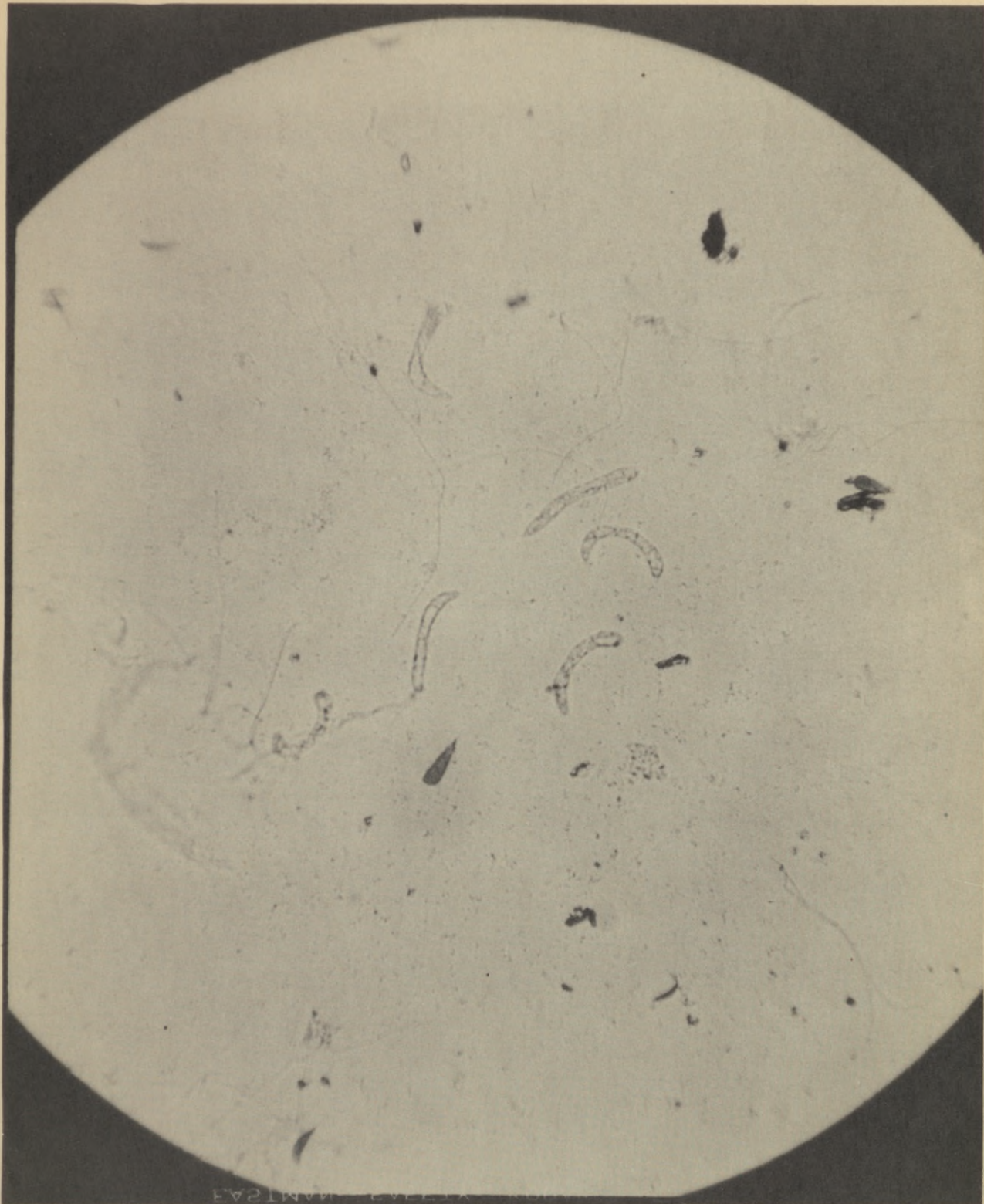


Figure 5. Photomicrograph of six developing filaria larvae (x 115) at end of third day of developmental cycle in mosquito host. Note size of internal cells, excretory and anal vesicle, and tail spike. Living specimens.

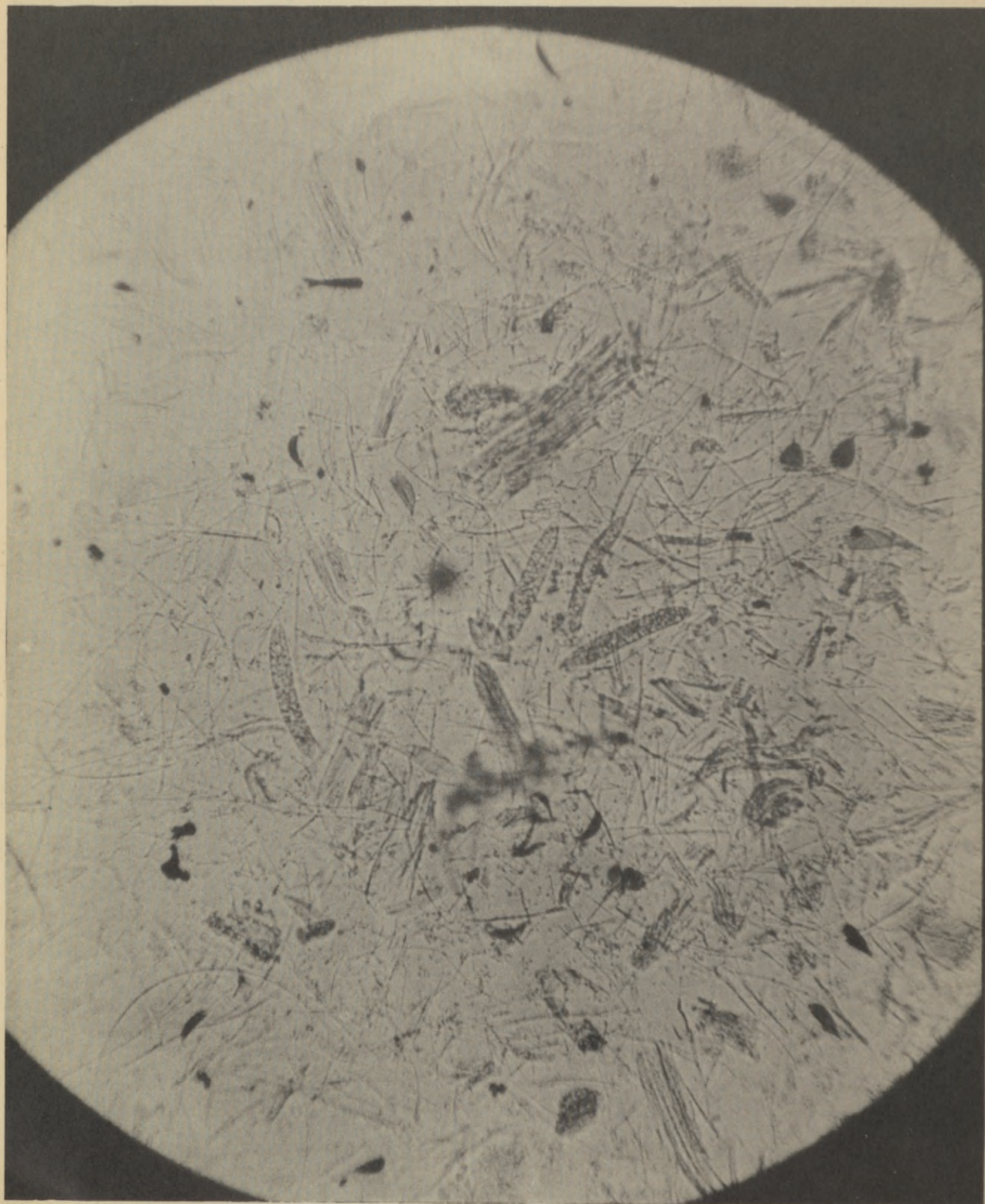


Figure 6. Photomicrograph of four developing filaria larvae (x 115) at end of fourth day of developmental cycle in mosquito host. Note sausage-shape of body and arrangement of internal structure. Living specimens.

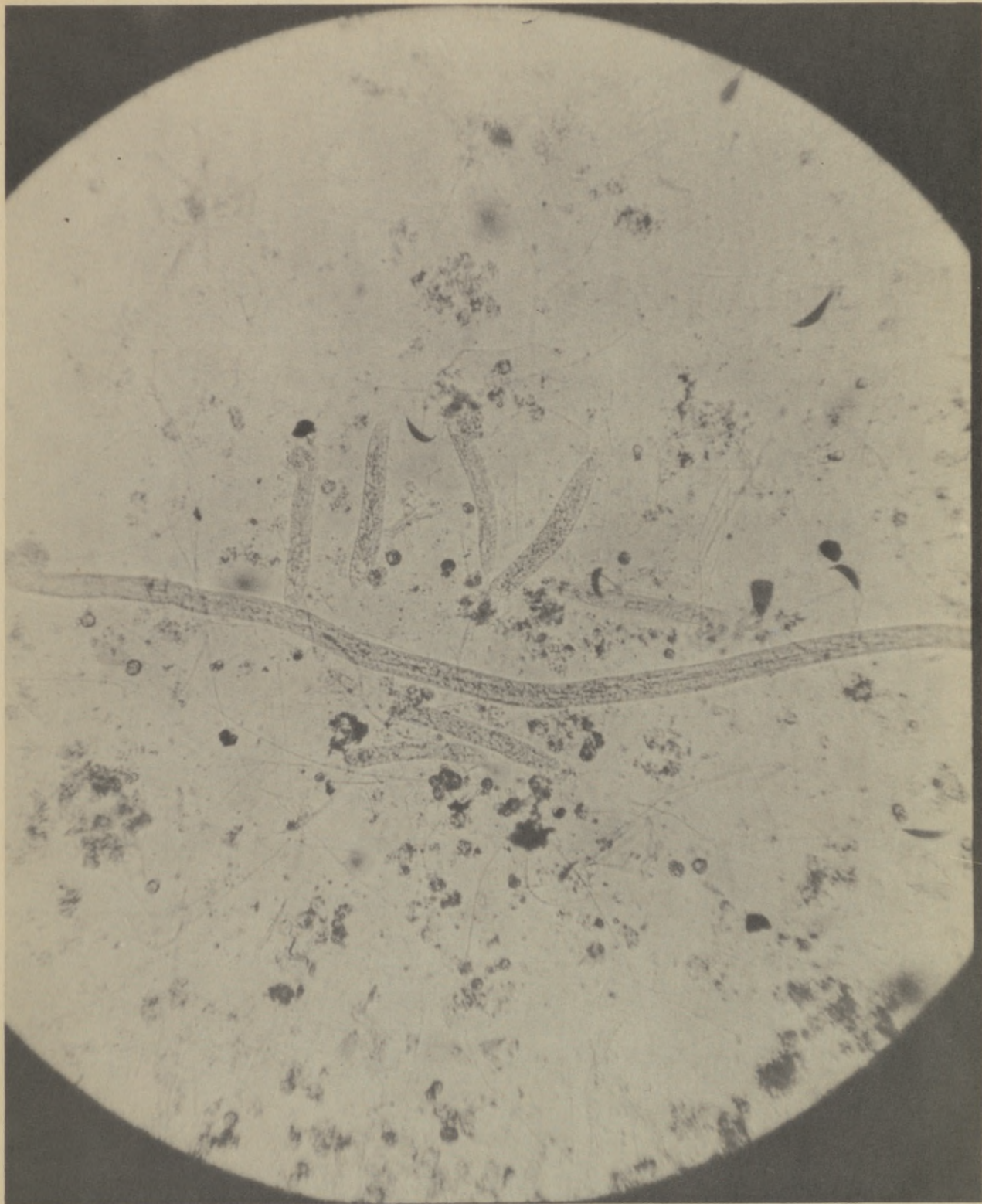


Figure 7. Photomicrograph of seven developing filaria larvae (x 115) at end of fifth day of developmental cycle in mosquito host. Note prominent excretory and anal vesicle and tail spike. Large worm is twelve day old larva. Compare. Living specimens.

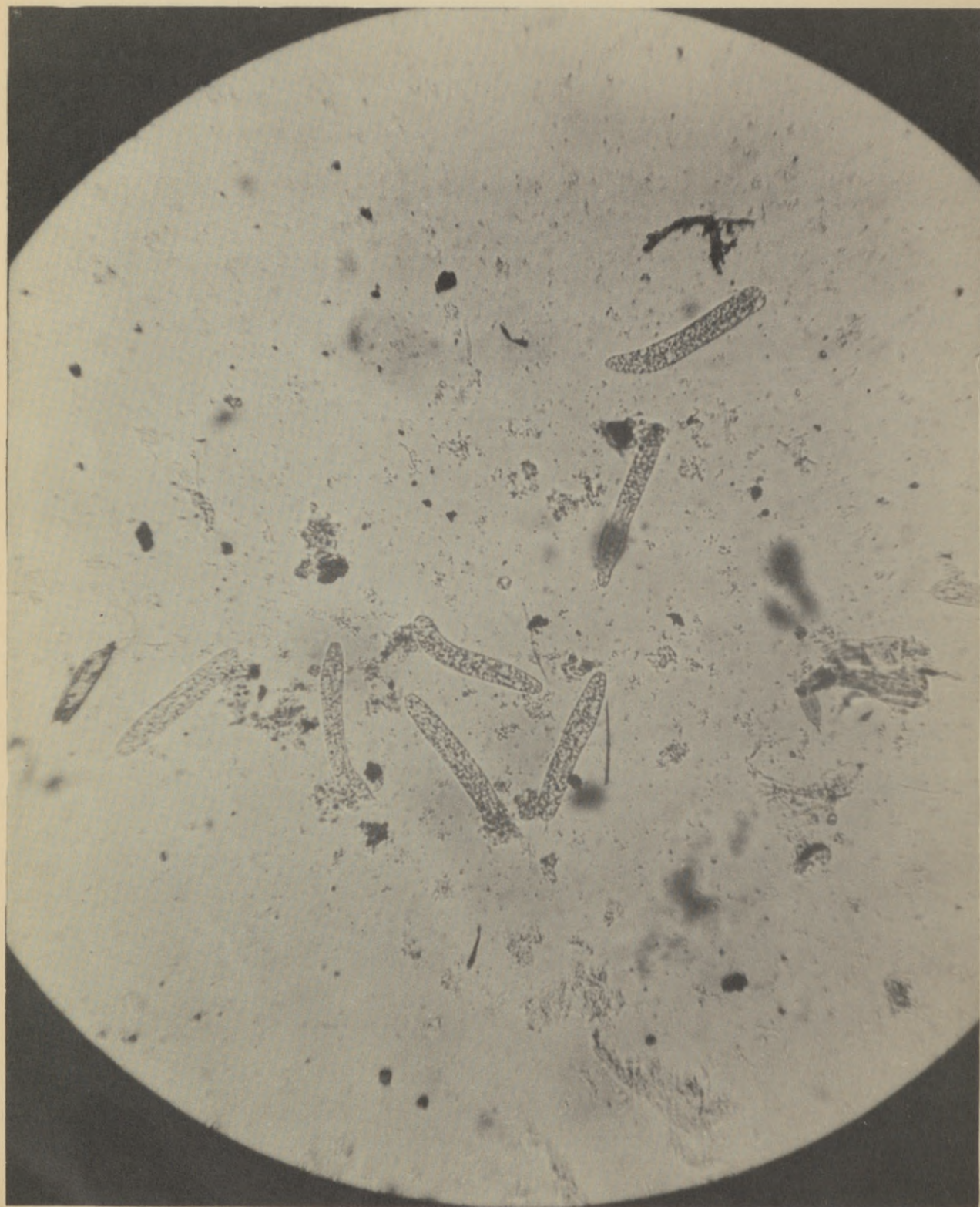


Figure 8. Photomicrograph of seven developing filaria larvae (x 115) at end of sixth day of developmental cycle in mosquito host. Living specimens.

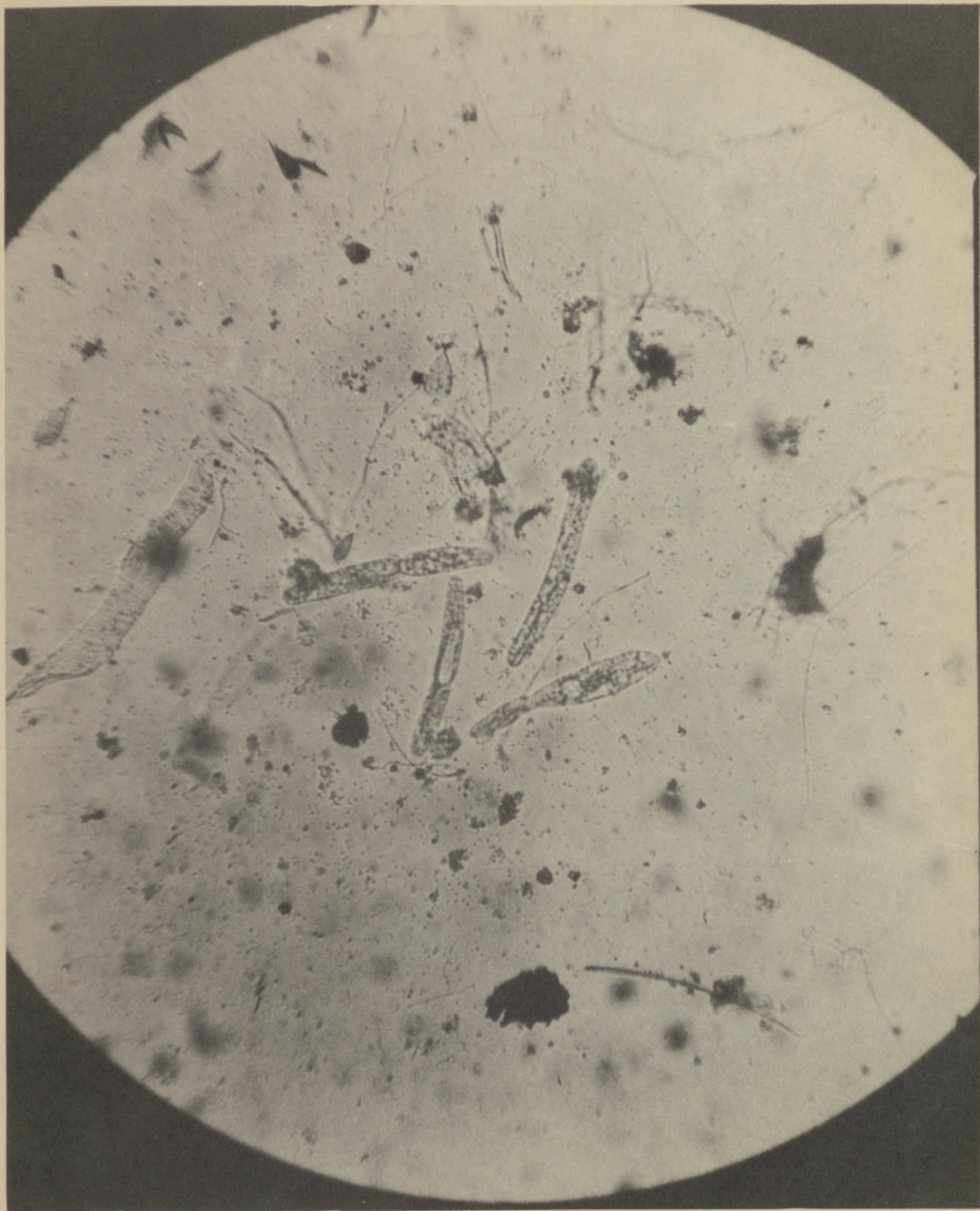


Figure 9. Photomicrograph of four developing filaria larvae (x 115) at end of seventh day of developmental cycle in mosquito host. Note evidence of moulting and reorganization of internal structures. Living specimens.

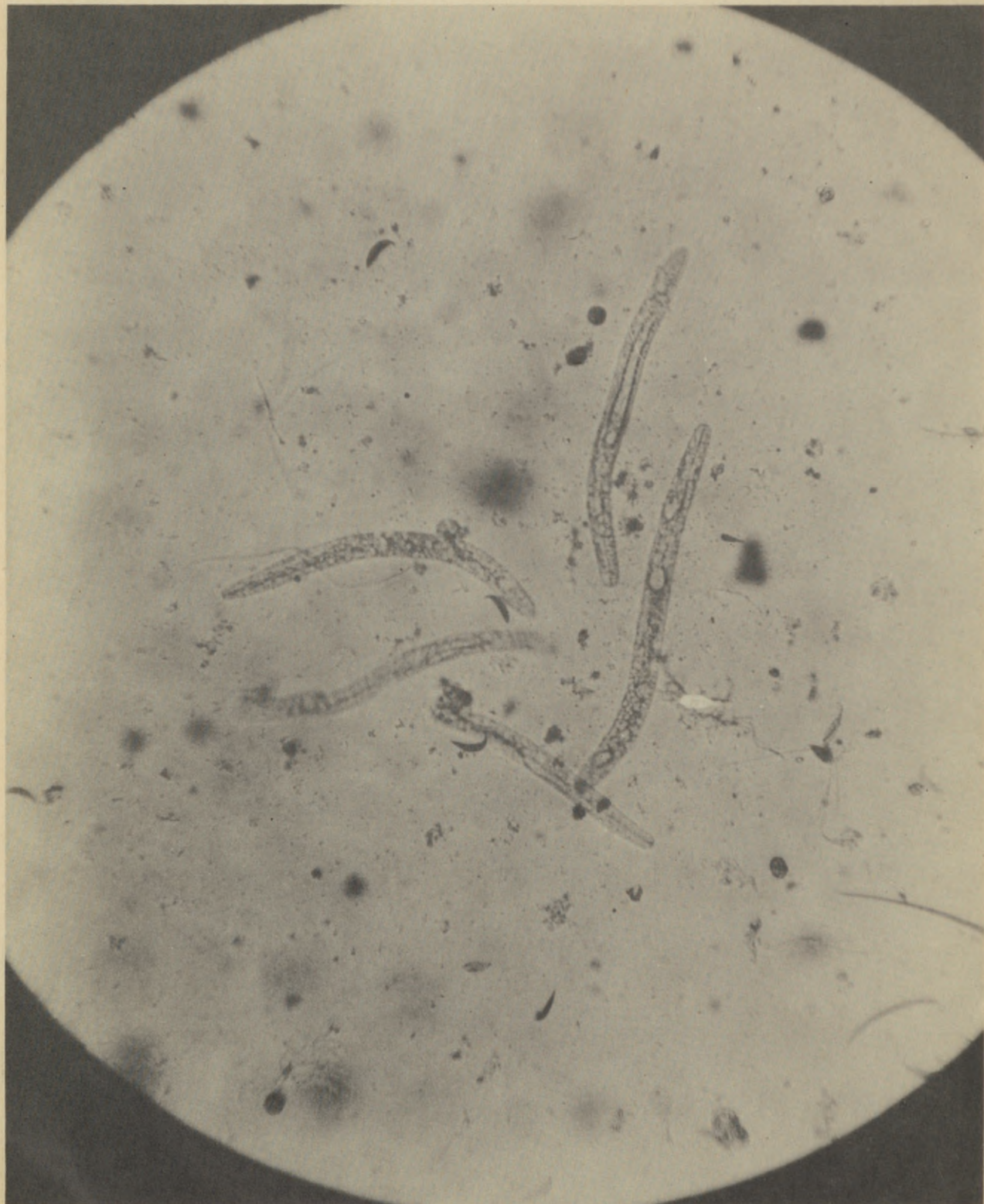
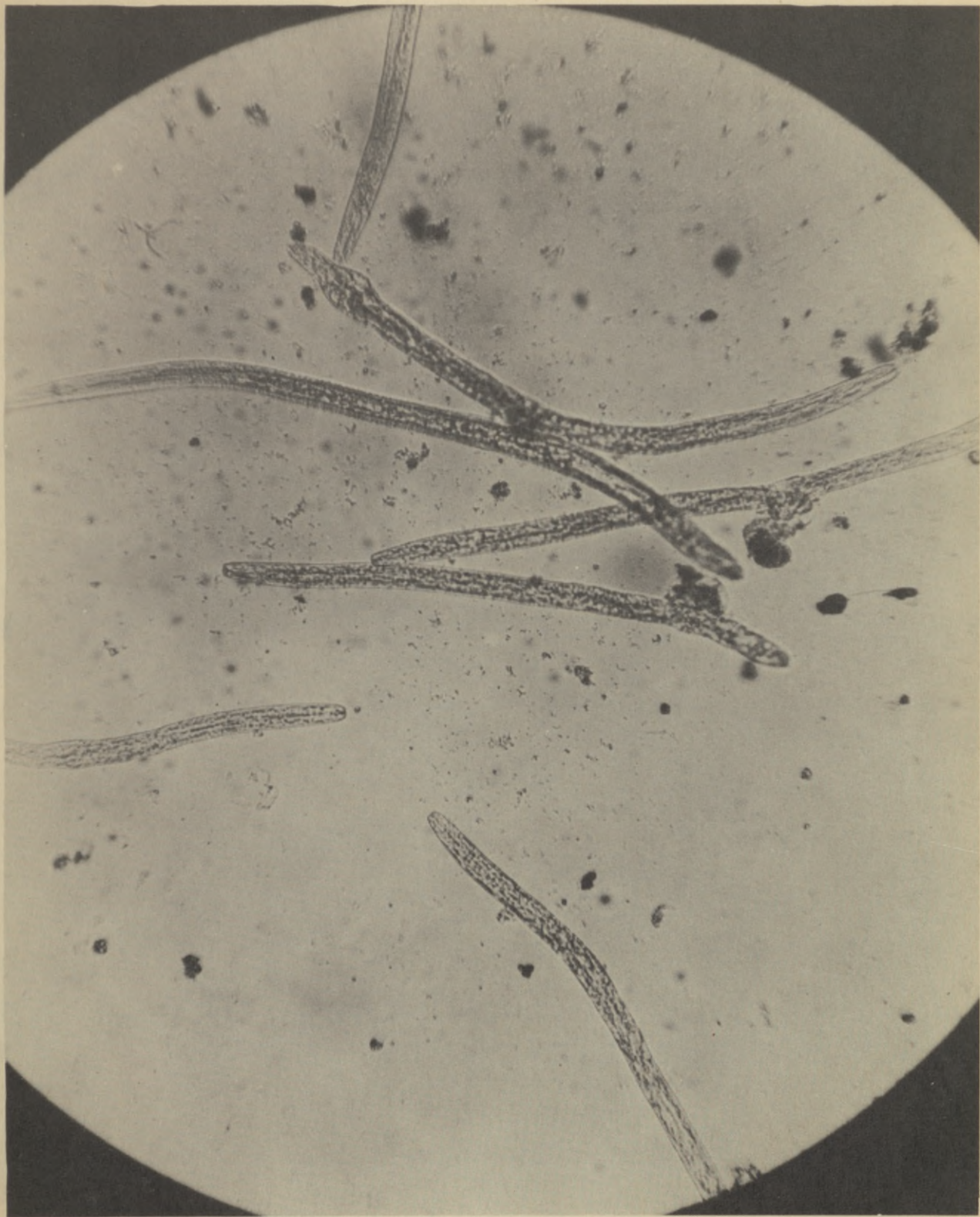


Figure 10. Photomicrograph of five developing filaria larvae (x 115) at end of eighth day of developmental cycle in mosquito host. Note increase in length of body, development of digestive tract, and loss of tail spike. Living specimens.



**Figure 11.** Photomicrograph of seven developing filaria larvae (x 115) at end of ninth day of developmental cycle in mosquito host. Note marked increase in length of body and complete digestive tract. Living specimens.



Figure 12. Photomicrograph of eight developing filaria larvae (x 115) at end of tenth day of developmental cycle in mosquito host. Living specimens.





Figure 13. Photomicrograph of five developing filaria larvae (x 115) at end of eleventh day of developmental cycle in mosquito host. Note differentiation in digestive tract. Living specimens.



Figure 14. Photomicrograph of two developing filaria larvae (x 115) at end of twelfth day of developmental cycle in mosquito host. Note elongation and thinning of body, and differentiation in digestive tract. Living specimens.



Figure 15. Photomicrograph of four developing filaria larvae (x 115) at end of thirteenth day of developmental cycle in mosquito host. Note elongation and thinning of body. Living specimens.

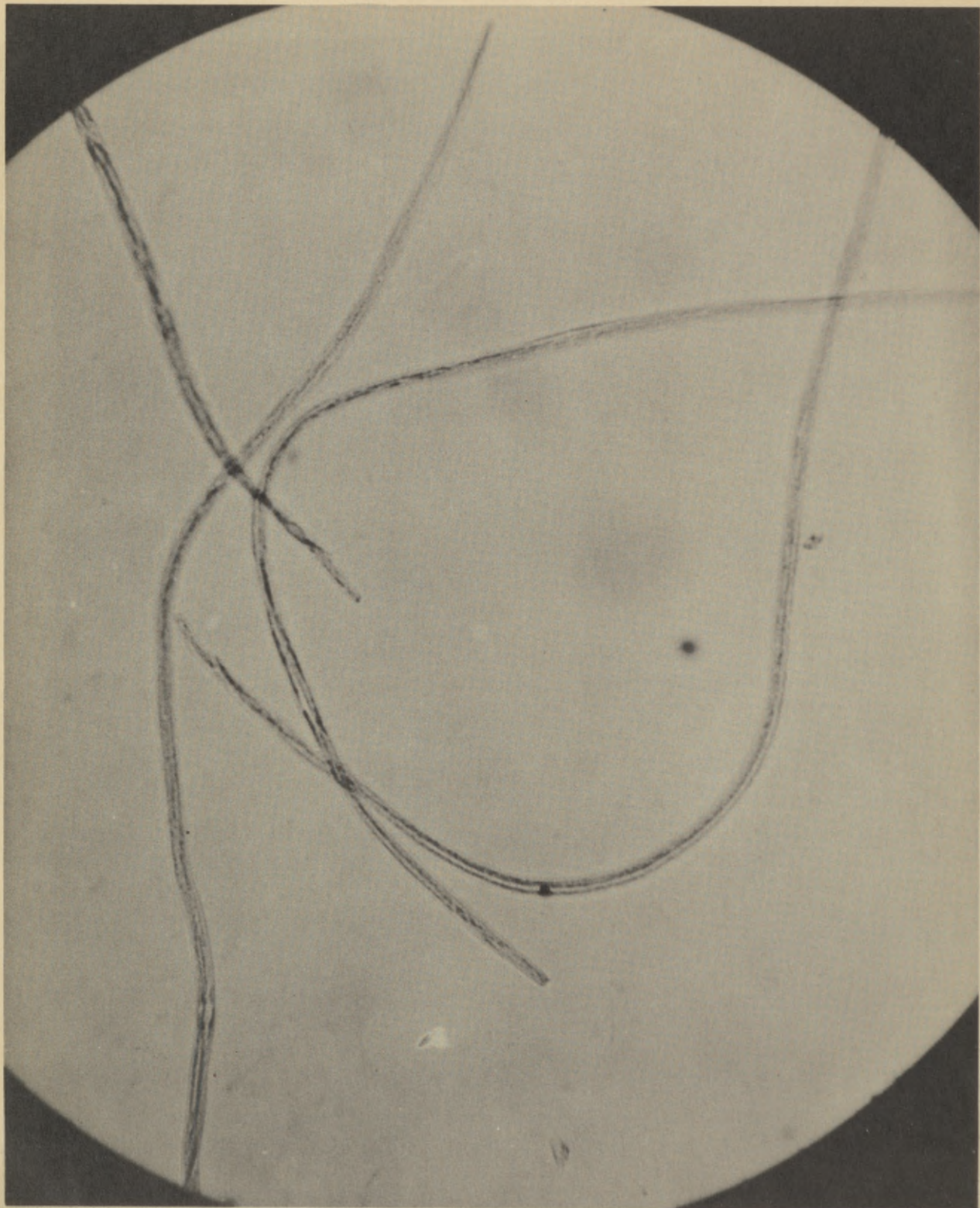


Figure 16. Photomicrograph of four infective stage filaria larvae (x 115) fourteen days after mosquito host ingested infective blood meal. Note extreme elongation and slenderness of body. Living specimens.

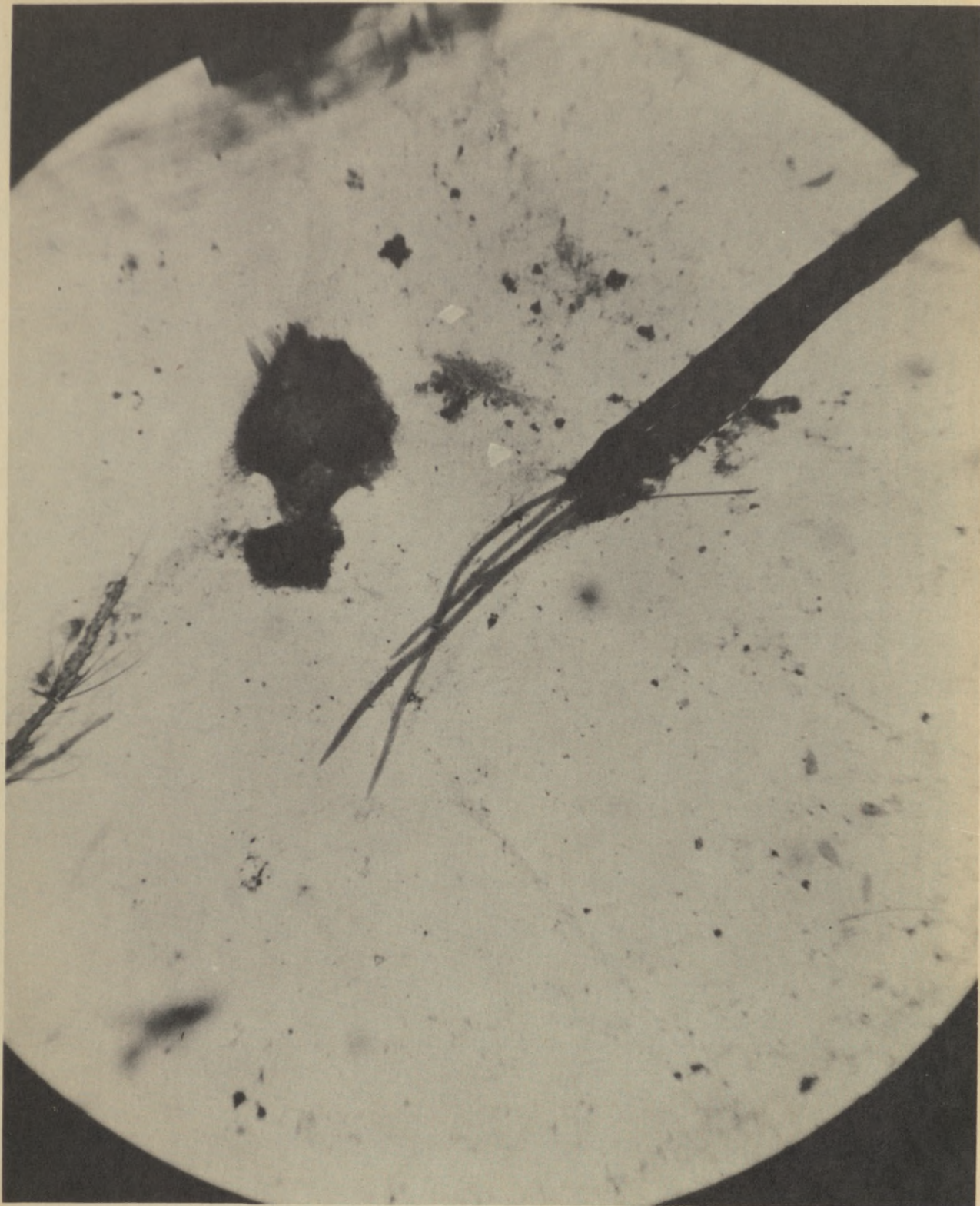


Figure 17. Photomicrograph of four infective stage filaria larvae (x 115) leaving labium of mosquito. Fixed specimens.

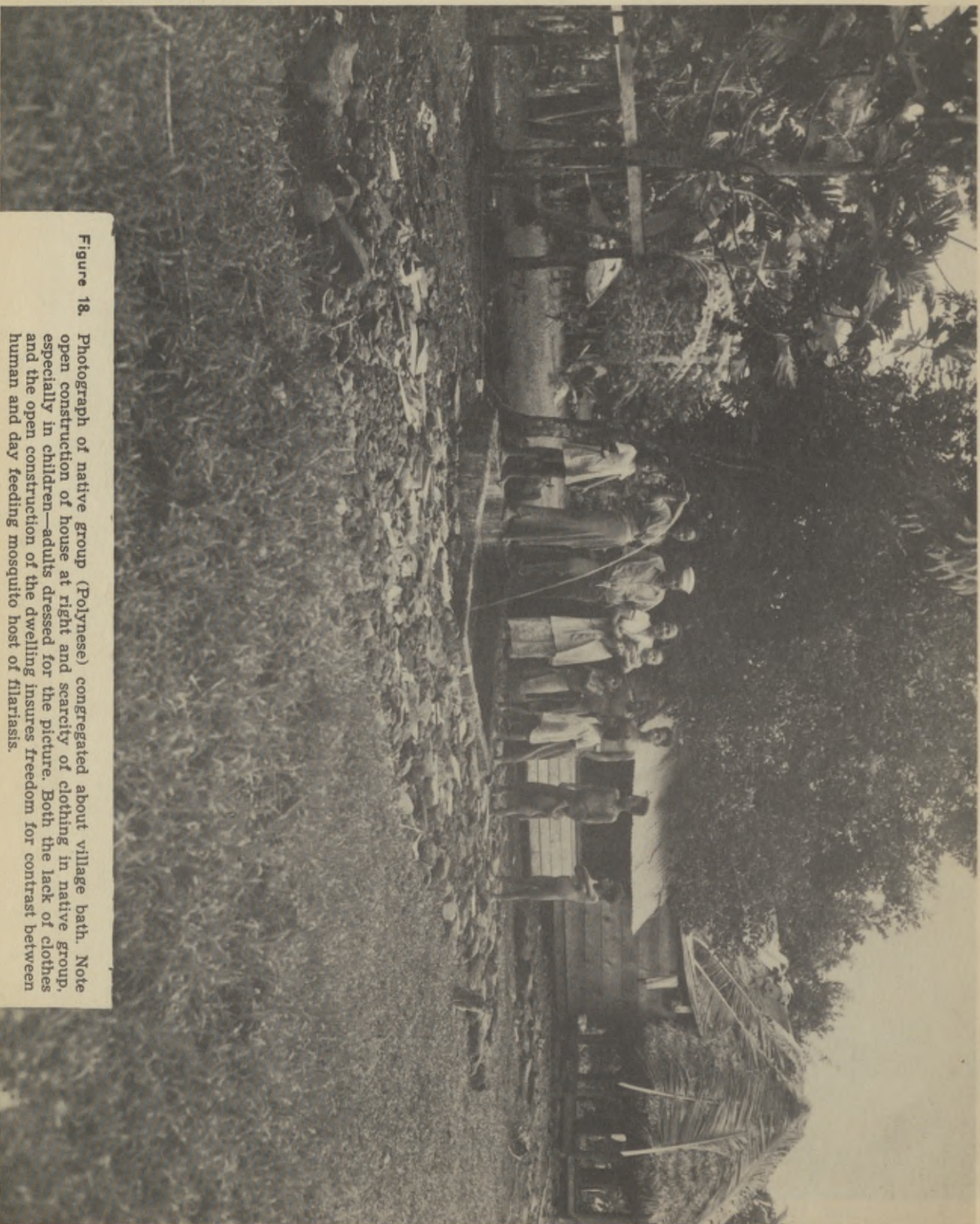


Figure 18. Photograph of native group (Polynesian) congregated about village bath. Note open construction of house at right and scarcity of clothing in native group, especially in children—adults dressed for the picture. Both the lack of clothes and the open construction of the dwelling insures freedom for contrast between human and day feeding mosquito host of filariasis.



Figure 19. Collecting day feeding mosquitoes from exposed body of native volunteer. Note small screened cage (on ground just to the right of the group) which is used for transporting live mosquitoes to the laboratory.



Figure 20. Photograph of Polynesian male. Note the advanced elephantiasis of the left arm and hand, both feet and legs, and the scrotum.



personnel to areas of native habitations during periods when the vector is likely to be actively feeding. On the other hand, when military expediency or the topographical features of the area necessitate the location of camp sites adjacent to or within the centers of transmission, a lowering of the density of the vector by suitable control measures together with as much segregation of natives and troops as is possible will prevent mass infections and, hence, the appearance of clinical manifestations and disability among the troops.

2. The above listed facts concerning the epidemiology of filariasis will be considered to be more or less general in nature and to apply to most areas where the disease occurs. In comparing those conditions of filariasis found to exist in Samoa with that determined for other South Pacific Areas, however, certain outstanding differences are noted. The enumeration of these will serve to indicate the necessity for field and laboratory investigations in all endemic areas where military personnel are likely to be stationed.

a. The larvae (microfilariae) of that strain of **Wuchereria bancrofti** which occurs in Samoa and adjacent islands of the South Central Pacific zone is non-periodic whereas in those islands to the west of this zone, beginning with the New Hebrides and Solomon Islands, a nocturnal periodicity is observed to be the case.

b. The principle vector of filariasis in the Samoan, Wallis and Ellice Islands is **Aedes scutellaris pseudoscutellaris**, a widely and heavily distributed day-biting culicine mosquito. Verbal communications, together with a limited investigation, indicate that this mosquito is the principal vector in the Society, Cook, Penhryn, Gilbert, and Marshall Islands. In those islands which lie to the west of this area, by contrast, the principal vector is the night-biting **Anopheles punctulatus farauti (moluccensis)** whose breeding and breeding habits, as well as its flight range, make necessary an entirely different approach to the control problem and to the education of troops in protective measures.

c. The introduction of **Wuchereria malayi** through the importation of Tonkinese laborers into the area further complicates the filarial problem. Where the importation of these laborers is of recent date or in areas where the transmitting host of this filaria is not found, the presence of the parasite is of academic interest only. In such areas, however, one must be constantly alert to the fact that new vectors may be acquired or that known ones may be introduced. In many areas away from the known endemic center of the infection there is evidence which strongly indicates the disease is being introduced into both the local native and mosquito populations.

d. In areas where the same mosquito transmits both malaria and filariasis, the malaria control program should amply provide the needed control against filariasis. In such areas it is of utmost importance for the control personnel to be assured that the malaria transmitting mosquito alone is responsible for the transmission of filariasis.

e. In many areas the filarial picture will be found to be greatly complicated because of the presence of both anopheline and culicine mosquitoes which will share the responsibility for filaria transmission (see list of mosquito hosts, pages 5 & 6).

Such striking differences between the details of the filarial picture in two adjacent areas indicate that only general epidemiological facts will be found applicable in all endemic areas and that an intensive investigation is urgently demanded when such areas are occupied by military personnel. To forego such investigations might well lead to heavy filarial infections in the personnel, resulting in a mass evacuation of badly needed troops from the area.

3. The erroneous conception held by some that the Samoan Area is the only area

where filariasis occurs or that it is the only area in which the white man can contract this disease is without facts and can no longer be held. Wherever endemic areas occur whites as well as natives can and will contract the disease provided conditions are suitable. One can be assured there are reasonable answers to such questions as to why Colonials have failed to contract filariasis after long residence in endemic areas and why so few cases of the disease have developed in troops in other areas of the Pacific in contrast to the large number of such cases which developed in troops stationed in the Samoan area.

a. Colonials, for example, for the most part live in ideal tropical quarters and remain segregated from the natives as much as possible. This plus the fact that many of the early cases developing in the white population were not recognized or reported led many to believe that the white man was not susceptible to the disease. A great many Colonials are known to have the disease of filariasis.

b. The large number of filarial cases which developed in troops in the Samoan Area was due principally to:

(1) Too free an association with the natives in hyperendemic areas prior to the time preventive measures were made known.

(2) The topography of the island made it more practical to quarter troops in the area of the native village, the hyperendemic focus.

(3) The extremely high density of and incidence of infection in the host mosquito within the hyperendemic areas.

c. By contrast, the low rate of initial infections reported for other South Pacific areas where filariasis is even more prevalent in the native population is due to the effective work of the malaria control organizations in controlling the vector, *Anopheles punctulatus farauti (mollucensis)* or related species. To this we must add the fact that those infections developing in the original combat troops stationed in New Hebrides and Solomon Islands were attributed to Samoa since it was here that most of these troops had staged. No doubt a large percentage of these early combat troops did acquire their initial infections in Samoa. On the other hand, there is little doubt that repeated reinfections, aggravating the disease, and new infections were acquired by these combat troops in the new location before malaria control became effective. It should be kept constantly in mind that a situation such as unfortunately occurred in the Samoan Area may occur anywhere in the endemic filarial belt unless the proper preventive steps are taken.

## V. THE STATUS OF FILARIASIS IN OTHER AREAS WITH SPECIAL REFERENCE TO THE MAIN POINTS THAT SHOULD BE INVESTIGATED.

By considering some of the more probable places in which the armed forces may be expected to operate, certain suggestions may be of aid in developing a proper outlook toward the filarial question.

### A. East Indies.

Dutch investigators have furnished us with relatively recent and accurate information on the filarial conditions in western New Guinea and the Netherlands Indies. These investigators have shown the native population to have a filarial incidence ranging up to 73 per cent throughout the entire area. The problem here is further complicated

by the fact that west of longitude 130° E. both *Wuchereria bancrofti* and *W. malayi* are prevalent. Throughout this area fifteen (15) species of anopheline and culicine mosquitoes have been demonstrated to be natural filaria vectors and nineteen (19) more are listed as being probable vectors. These facts indicate the extreme necessity for investigations in any of these areas which might be occupied by the armed forces.

The problem in New Guinea and the Moluccas Islands seems to be similar to that outlined for the New Hebrides and Solomon Islands. *Wuchereria bancrofti* is the only type of filaria believed to be endemic in these areas. It is believed that the principal vector of the worm in this area is one of the *punctulatus* complex of the anophelines. This being the case, the regular malaria control programs already established in the area will automatically control filarial transmissions. Undoubtedly this hypothesis is substantiated in part by the fact that a very few initial cases of filariasis have been reported in troops from this area.

West of the Moluccas and 130°E. longitude the picture is more obscure and complex. The filarioid condition is unknown in many places. In other areas both *Wuchereria malayi* and *W. bancrofti* are reported to be prevalent and natural vectors are said to be numerous. Concrete knowledge concerning the vectors of *W. bancrofti* in this area is limited, although five (5) species of anophelines and two (2) culicines are listed as being probable vectors. Five (5) species of *Mansonia*, all of the subgenus *Mansoniodes*, and one species of anopheline have been implicated as vectors or probable vectors of *Wuchereria malayi*. It becomes most essential that the principal vector or vectors of both species of the filaria parasite be determined for this area before proper control measures can be initiated.

#### B. Philippine Islands.

Knowledge concerning the occurrence of filariasis in the Philippine Islands is very limited. Reports claim a low incidence of filariasis is found in the natives and that the disease is no problem to the white man. A similar claim for Samoa prior to 1943 is recalled! It seems quite probable that the little investigated central and southern Philippines might be a highly endemic area. Further complications might develop from the fact that a non-periodic strain of *Wuchereria bancrofti* is reported to occur within this area. The presence of such a strain of the parasite could easily involve both day and night-biting vectors in its transmission. Little is known concerning the vectors of the disease in the Philippine Islands. The time worn implication that *Culex quinquefasciatus* (*fatigans*) transmits the infection persists. The existence of twenty-nine (29) species of *Anopheles*, thirty five (35) species of *Aedes* and seventeen (17) species of *Culex* within the island group creates a none too pleasant a prospect for the rapid determination of the epidemiological picture.

#### C. Formosa.

Filariasis is said to be rare on the island of Formosa. The extreme prevalence (29 per cent) of the disease in the Nansei Islands (Loochoo Islands) to the north and the 16 per cent incidence recently reported for the Pescadores Islands just off its western coast leave grave doubts as to the accuracy of the reports from Formosa Island proper. It would be much safer to consider Formosa endemic for filariasis and to act accordingly. Japanese investigators implicate nine (9) species of mosquitoes as vectors of the disease in this general area. One (1) species of *Anopheles*, six (6) species of *Culex*, one (1) species of *Aedes*, and one (1) of *Mansonia* are implicated. Fourteen (14) species of anopheline

and twenty-one (21) species of culicine mosquitoes are known to occur in the area, and many of these have been found to be vectors in other areas. It will be necessary to determine the principal vector or vectors from this location before control and preventive measures can be instigated.

#### D. Eastern Asia.

Little is known of the filarial situation in China, Indo-China, and the Malay States. *Wuchereria bancrofti* and *W. malayi* are coexistent in practically all coastal areas and along inland waterways. Except for the implication that *Culex quinquefasciatus* (*fatigans*), *Culex pipiens*, *Mansonia* (*Mansonoides*) *pseudotitillans*, and *Anopheles hyrcanus sinensis* are vectors nothing is known concerning transmission in this area. Epidemiological investigations will be of the utmost importance before full protection of the armed forces can be expected.

## VI. A SUGGESTED ORGANIZATION FOR THE PREVENTION AND CONTROL OF FILARIASIS IN THE ARMED FORCES.

From experience and considering the facts about filariasis outlined in the above sections of this manual, the following organization to work in conjunction with the Malaria Control Organization in preventing and controlling the disease of filariasis in the armed personnel is proposed. The proposed organization is offered with the view of expending the minimum of manpower and man hours. However, because of the needed flexibility to cover differences in areas and sizes of areas the plan should not be considered a fixed one. In reality each area will prove to have certain peculiarities which will necessitate individual attention. For this reason an outline of methods for making the filarial survey is included in another section of this manual. This outline of methods is included as an aid to the Malaria Control Organization in setting up filarial survey units when and where the need for these may arise.

#### A. Organization and Function.

1. The key to the prevention and control of filariasis in any given area is having accurate data and knowledge concerning (1) the prevalence of filariasis, (2) the hyperendemic areas, (3) the specific vector or vectors, and (4) the habits of the vector in that area. Since all previous literature on filariasis offers only fragmentary information on the practical epidemiological aspects of the disease and since filarial conditions in many areas have not been investigated, it is absolutely necessary that a specially trained and experienced filarial survey unit investigate each area as soon as possible after it has been occupied by the armed forces.

2. Such a survey unit should consist of not less than one parasitologist and one entomologist or preferably two officers specially trained for this type of work and from three to five hospital corpsmen. The unit should be provided with the necessary laboratory equipment and transportation with which to perform the duties ascribed within a minimum length of time.

3. The unit should have a high degree of mobility not only within a given area but also in moving into another area once the general survey of one area is completed. To insure this mobility, it will be necessary for the unit to function at the discretion of the

Bureau of Medicine and Surgery and/or Army Surgeon General as directed through the Commanding Officer of the larger theaters of war. The unit should be attached only temporarily to the command of a smaller area and then only for the purpose of making filarial surveys within that specific area.

4. The main functions of the filaria survey unit would be as follows:

a. To make or aid in the initial filarial survey for any area coming under its jurisdiction.

b. To analyze and report all data obtained through the survey.

c. To cooperate with the Area Malaria Control Organization in outlining and coordinating a plan by which the control of filariasis will become a function of that organization.

d. To train the necessary personnel in the Area Malaria Control Organization who will be used for filarial survey and control work within that area.

e. To procure and report to the Bureau of Medicine and Surgery and/or Army Surgeon General through the area commands all data on filariasis obtained from those areas occupied by the armed forces.

f. To aid in the dissemination of knowledge and the organization of all material pertaining to filariasis for educational purposes.

5. The status and functions of the filaria survey unit while temporarily attached to area commands are as follows:

a. The filaria survey unit will be temporarily attached to the Area Malaria Control Headquarters to facilitate the closest cooperation, to allow for complete freedom of movement within the area, and for procuring the necessary transportation and expendable supplies.

b. All reports of findings and discussions pertinent to filariasis in that area will be made available to the Area Malaria Control Headquarters for its use within that area.

c. The initial survey of the area will be carried out by or under the guidance of the filaria survey unit. To facilitate making as rapid a survey as possible and at the same time to train the necessary local malaria survey personnel who will later constitute the permanent filaria sub-unit for that area, certain personnel will be attached to the filaria unit by Malaria Control Headquarters. The number of personnel to be attached to the filaria survey unit for this purpose will depend on the size of the area and the prevalence of filariasis. It is suggested that a minimum of one officer (parasitologist) and from two to four hospital corpsmen be assigned.

d. During the time of or after the initial survey is completed, the filaria survey unit will work in close cooperation with the Area Malaria Control Officer to organize a plan by which the control of filariasis can be included in or become part of the malaria control system of the area.

e. When the survey is complete, the area filaria sub-unit is trained and functioning, and a plan for the control of filariasis coordinated with and functioning under the supervision of the Area Malaria Control Organization, the filaria survey unit is free to move to other areas.

## **B. The Organization of Individual Area Filaria Sub-Unit.**

### **1. Personnel.**

a. The filaria sub-unit should consist of one parasitologist or entomologist or both and three to four hospital corpsmen.

b. The Officer personnel of the filaria sub-unit should be specially trained in or familiar with (1) making of blood surveys, (2) dissection and examination of mosquitoes, (3) taxonomy of the mosquito fauna, (4) rearing and maintenance of the mosquito colony, (5) transporting of living mosquitoes, and (6) methods of collecting both adult and larval mosquitoes in the field.

c. The enlisted personnel of the filaria sub-unit should consist of (1) one hospital corpsman who is qualified to take and stain blood smears and to do general laboratory technique and (2) one to three general duty hospital corpsmen who have had some experience in field collection and survey methods.

d. Additional personnel or even complete sub-units may be added in accordance to the size and requirements of the area.

## **2. Equipment.**

a. The following equipment will be necessary for the filaria sub-unit to function most efficiently:

(1) Sufficient transportation to move all members of the sub-unit at one time throughout the area in which it works.

(2) Complete laboratory equipment and supplies essential for the making of blood surveys, the rearing, maintenance and handling of live mosquitoes and the collection and dissection of the adult mosquito.

The differences in the size of various areas, the manner in which the Malaria control Organization is set up, and the possible lack of flexibility in the Malaria Control complements will for the most part govern the use and mobility of the filaria sub-units within the area. Because these differences will exist from area to area the following methods for handling the sub-unit is suggested. However, any efficient method suitable to all concerned should be the aim.

1. It is to be preferred that the personnel of the sub-unit be permanently assigned to filaria work. The sub-unit should be highly mobile and free to move in all parts of the area for temporary duty but should remain permanently attached to the Area Malaria Control Headquarters, to which office all reports will be made. This method utilizes a minimum of manpower and allows for a standardized survey of the entire area.

2. An alternate method is to have small sub-units on full or part time filaria work at each base within the area. Each sub-unit would be responsible to the local Malaria Control Officer for its locality. Reports reaching Area Headquarters would be included in the general malaria report. This method seems less advisable because of the greater use of manpower, the loss of standardized data, and for the fact that the experience and training of the sub-unit is curtailed by being confined to a small locality.

## **VII. AN OUTLINE OF PROCEDURE TO BE FOLLOWED BY FILARIA SUB-UNITS AS A PART OF THE MALARIA CONTROL ORGANIZATION IN DETERMINING THE STATUS OF FILARIASIS.**

In presenting this outline it is assumed that the personnel of those sub-units assigned to a filarial survey meet the qualifications outlined above. The actual laboratory technique and details of procedure are left to the choice of the officer in charge. Emphasis here is placed on how and where to obtain all necessary data pertinent to the filarial situation as well as to the evaluation and organization of such data so that concise and standardized reports may be made.

A complete survey of any area should include the results of a blood survey of the native population, a survey of all of the more common mosquitoes with the view to determine the principal vector or vectors, and other species that may be involved in the transmission of the disease. It should also include data pertaining to centers of hyperendemicity, the limits of these, and recommendations for the control and prevention of filariasis in the armed personnel. An outline of procedure for determining these facts is given below.

### **A. The Blood Survey.**

#### **1. General procedure.**

a. The number of natives examined should be sufficient to be representative of the area. In small populations all individuals should be surveyed. In larger populations 1000-2000 individuals representing a cross section of the area should be sufficient.

b. Where several types of natives (Melanese, Tonkinese, Polynese, etc.) inhabit the same area, a representative number of each type should be examined and the data on each type kept separately for comparison purposes.

c. When the natives are of the same type but come from different islands or localities within the area the data should be kept separately for purposes of determining prevalence in these localities.

Usually it will be necessary to obtain permission from proper authorities before the blood survey of natives can be made. This is done best by working through the medical officer of the government within the area in which the survey is desired.

#### **2. Technical procedure.**

a. A single 20 cmm sample of blood in the form of a thick smear is taken from each individual. The method may vary, but good results may be had by using a graduated glass pipette to pick up the blood. Such pipettes can be made by drawing a short tip on 1 mm glass tubings and then graduated by using 20 cmm of mercury.

b. Any stain that will demonstrate the microfilariae clearly enough for counting may be used, but for permanent slides and when necessary to distinguish between *Wuchereria bancrofti* and *W. malayi* Bullard's or Harris' hematoxylin and eosin are recommended.

c. Because of the probable nocturnal periodic nature of the parasite no smears should be taken before 1900. Once an individual is determined to harbor the larvae, a second survey may be made at some convenient daylight hour so that an answer to the question of periodicity can be obtained.

d. The following data should be recorded for each native surveyed: (1) date and hour of survey, (2) race, (3) sex, (4) approximate age, (5) home island or village, (6) clinical manifestations of the disease, if any, (7) the number of microfilariae per unit of blood taken, and (8) species of parasite involved. Record name or number of each native surveyed.

#### **3. Report.**

a. The report on the blood survey should include the following information:

(1) The total number of each type (race) of native surveyed with the incidence of infection in each type as well as the total incidence for the area.

(2) The species of filariae present in the area and which of these parasitize the various types of natives within the area.

(3) The incidence of infection for the various islands within the area, if more than one island is covered.

(4) The incidence of infection in children is contrasted with this in adults as well as in regard to sex.

(5) The periodic or non-periodic nature of the microfilariae. This can be determined by noting the difference in the number of microfilariae between the sample of blood taken during daylight hours and the one taken after nightfall.

## **B. The Mosquito Survey.**

### **1. General procedure.**

a. Determine which are the more common anthropophilic species of mosquitoes in the area and as nearly as possible the exact taxonomic status of each.

b. Make collections of adult females of all the more common day and night feeding species in and around native habitation. By dissection, determine all species that show any evidence of being vectors (presence of newly ingested or developing larvae).

### **2. Details of the survey.**

#### **a. Collection of mosquitoes.**

(1) Mosquitoes can be taken by any convenient capturing method from in and about native habitation. Care should be taken in catching and handling so as to insure a maximum of living mosquitoes for dissection.

(2) In transporting living mosquitoes to the laboratory for dissection, it is suggested that the recently captured specimens be transferred to a screen-cage (8 to 10 inches square) and this kept covered with wet toweling or burlap. Care must be taken to prevent ants from having free access to the caged mosquitoes.

#### **b. Dissection of mosquitoes.**

(1) To obtain the best results, only those mosquitoes should be dissected which are freshly killed. Should a large number of the recently captured mosquitoes die before dissections can be made, they may be kept for a short time in fairly good condition on moist blotting paper.

(2) The following steps may be followed in the dissection of mosquitoes:

(a) Kill several mosquitoes and record the identification.

(b) Remove wings and legs and separate the abdomen from the thorax.

(c) Place abdomen and thorax in separate drops of Locke's or other suitable solution on the same or separate slides.

(d) Dissect abdomen and examine the macerated material under the low power of a compound microscope for presence of exsheathed microfilariae. If worms are found, the number of these and their condition are recorded.

(e) Dissect the head and thorax (tease and macerate with fine needles) and examine this carefully for the presence of microfilariae and advanced developmental stages of the parasite.

(f) If worms are determined to be present, an accurate count of these should be made and the age of the worms noted. If double or triple infection occurs, record the number of worms in each larval age group.

(g) For permanent record all positive preparations may be fixed with Schaudins' or other fixation and stained with haematoxylin and eosin.

### **3. Determination of larval ages.**

To determine the principle vector or vectors within a given area, it is necessary that the personnel of the unit be able to determine the age of the developing larvae



within the mosquito host. Especially is this true in so far as the infective or near infective stage larvae are concerned. The development of the ingested microfilariae to infective stage larvae requires approximately 14 days, during which time the microfilariae grow from a worm only 0.2 mm long by 0.01 mm wide into a nelongated, filiform larvae that measures from 1.5 to 2.0 mm long and 0.03 mm wide. During this growth process several distinct developmental stages occur. These may be used as an index by which to estimate the age the larvae have attained at the time the mosquito is dissected. These are:

a. **1—2 day old larvae.**—Exsheathed, motile microfilariae in recently ingested blood or enroute to thoracic muscles; size 200 by 10 microns (Figs. 3-4).

b. **3—7 day old larvae.**—Pre-moult sausage stages, characterized by slightly curved sausage shape, pin tail, little or no motility, presence of excretory and anal vesicles; size 165—650 by 35 microns (Figs. 5-9).

c. **12 day old larvae.**—Post-moult elongated stage, characterized by lengthening of body, increase in motility with age, well differentiated digestive tract; sizes 0.5—1.0 mm by 30—40 microns (Figs. 10-14).

d. **12—14 day old larvae.**—Near infective to infective stage, characterized by extreme elongated filiform body, high motility, already in head or labium of host or wandering in all parts of body; size 1.5—2.0 mm by 25 microns (Figs. 14-17).

It will require considerable experience and familiarity on the part of the observer before the age of the developing filaria larvae can be determined accurately to a given day of age. The quickest way by which this experience and familiarity with the larvae can be acquired is through an experimental test in which a large number of mosquitoes are infected. Once the mosquitoes are infected the larvae can be studied and the age noted, through the dissection of a number of the infected mosquitoes each day during the developmental cycle. Until this necessary experience and familiarity with the developing larvae can be acquired, the accompanying photomicrographs (figures 3 to 17) should be of aid in making the age determinations.

#### 4. The evaluation and presentation of data.

To realize any value from the tedious undertaking of a complete mosquito survey, it is absolutely essential that the proper data be recorded and that it be analyzed correctly. The following outline and examples are given as a guide and will be adhered to in recording and presenting this data:

a. When the mosquito survey is complete, the following information should be available:

(1) The accurate determination of all mosquito species collected and dissected.

(2) The number of each species of mosquitoes collected from each locality and the date of collection.

(3) The relative density of all species of mosquitoes collected as determined by man-hour catch records.

(4) The number of each species dissected and the date of dissection.

(5) The number of each species of mosquito proved to be infected by the filaria, the number of negatives, and the per cent incidence of infection for each.

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**NOTE:** Attention should be called to the fact that the larvae of the human species of the filaria parasite undergo their developmental cycle in the thoracic muscles of the mosquito. This is in contrast to the larvae of the dog heartworm, *Dirofilaria immitis*, which undergo this cycle in the Malpighian tubules of the mosquito host. Often the same mosquito will serve as the host for both types of worms.

- (6) The number and age of the developing larvae for each dissection.  
 (7) The number of multiple infections, the number of age groups in each infection, and the number of larvae in each age group.

b. From the above data the principle vector or vectors may be determined and the presence of the hyperendemic focus established. In determining the principle vector, it is important to establish which species of mosquitoes nurture the worm to the infective stage and which are capable of transmitting it. This cannot be determined solely from the per cent of positive individuals in each species but must be determined on the basis of the larval age groups present in the "positive" individuals.

Table I shows the per cent incidence of infection in a representative group of probable vectors.

**TABLE I.**

Dissection record on a representative group of mosquitoes.

Species of mosquitoes	Total No. dissected	No positive for filaria larvae	Per cent of infection
<i>Anopheles punctulatus farauti</i>	1239	170	13.72
<i>Aedes scutellaris hebrideus</i>	414	12	2.90
<i>Aedes vexans</i>	127	14	11.02
<i>Aedes funereus ornatus</i>	91	6	6.60
<i>Aedes aegypti</i>	75	15	20.00
<i>Culex quinquefasciatus</i>	69	8	11.60
<i>Culex annulirostris</i>	115	7	6.10
<i>Culex sitiens</i>	76	0	0.00
<i>Culex pacificus</i>	61	0	0.00

TABLE II.

The distribution in days of age \* for developing filaria larvae recorded from all naturally infected mosquitoes listed in Table I.

Species of mosquitoes	Number of mosquitoes harboring filaria larvae for the indicated day of age.														
	1 day		2	3	4	5	6	7	8	9	10	11	12	13	14
	Abdomen	Thorax	days	days	days	days	days	days	days	days	days	days	days	days	days
<i>Anopheles punctulatus farauti</i>	34	72	23	18	16	12	5	5	6	3	3	1	6	1	2
<i>Culex quinquefasciatus</i>	3	4	4	1					1						
<i>Aedes scutellaris hebrideus</i>	7	1	2	1	1										
<i>Aedes vexans</i>	12	4													
<i>Aedes funereus ornatus</i>	6														
<i>Culex annulirostris</i>	5														
<i>Aedes aegypti</i>	15														

\* Fourteen days being the time required for the larvae to reach the infective stage.

From the data presented in Table I all but two of the species listed must be considered to be vectors or potential vectors, as can be adjudged by the per cent infection in each. The high per cent of infection given for four of the species might lead one to assume that each of these is an excellent vector. This, however, is far from being the case. On the other hand, Table II presents the correct method of determining the principal vector. The data in this table are based on the number of infections for the various larval age groups in each of the species of mosquitoes indicated to be a vector in Table I. This per cent incidence of infection is determined from the information required by subparagraphs (6) and (7), page 21.

From Table II it becomes clear that even though several of the mosquitoes listed (Table I) showed a high incidence of infection, *Anopheles punctulatus farauti* alone carries the larvae through to infectivity and, therefore, must be considered the vector in this case. *Culex quinquefasciatus* and *Aedes scutellaris hebrideus* must be considered as probable minor vectors on the strength of the fact that some larval development did occur. It is likely that an occasional infective larva will be produced by each of these two mosquitoes. *Aedes aegypti*, *A. vexans*, *A. funereus ornatus*, which seemed to be important (Table I), may be ruled out because the ingested microfilariae failed to show any development within these mosquitoes.

To arrange data as in Table II, only the recorded "positive" mosquitoes need be considered. In the arrangement of the data it is correct to record a triple infection in one mosquito as a positive infection in the three different age groups concerned.

In considering the data given in Table I, it is to be pointed out that (1) the number of mosquitoes dissected for each of the listed species represents a fair index to the relative density of the species within the area, provided equal attention has been given to collecting all species, and (2) only a small number of mosquitoes will be found to be infected with the filaria worm. The necessity for computing the per cent infection (Table I) from the greatest number of specimens of each species obtainable from a given area cannot be overemphasized.

The importance of this method of handling incidence data cannot be overemphasized. It is the only way to determine the true vector and thereby prevent the possibility of controlling those mosquitoes which play only a minor if any role in the transmission of filariasis. The relative density of the various species also should be taken into consideration in designating the principal vector or vectors. When two or more species prove to be efficient vectors, their importance in transmission is directly proportional to their densities.

c. For control purposes these centers showing a per cent incidence of infection in the proved principal vector should be considered as hyperendemic foci and, therefore, of danger to troop concentrations. **The per cent incidence of infection in the vector is dependent upon the incidence of the infection in the native population and never upon the density of the vector. The higher density of the mosquito host increases the probability of filaria transmission but does not change the relative per cent incidence of the infective stage larvae at any one time.** It follows, therefore, that under certain conditions an area showing a lower incidence of infection in the mosquito host but a higher density of the mosquito will be more dangerous than an area having a high incidence rate and a low density of the transmitting mosquito (see paragraph E, page 9).

d. The limits of a given hyperendemic focus or any area of transmission is governed by the flight range of the mosquito host. In cases where the vector has a short flight range and where its density is high enough to afford catches some distance from

the center of infection, the limits of the hyperendemic focus may be established accurately. This may be done by collecting and determining the incidence of infection in the vector at stations moving progressively away from the center of the focus. The limits will be reached when the per cent of infection in the mosquito host drops to zero. The effects of wind, natural barriers, etc., also should be considered in delimiting the area involved. When the vector has a long flight range, the establishment of the limits of the area is made difficult. This is true because (1) the overlapping of flight ranges from contiguous centers of infection and (2) the lower densities of the vector at various distances from its source of food.

e. For the information obtained by the filaria survey to be reliable it will be necessary for it to be based on data embracing a significant number of collections and dissections. The size of the area to be covered, the density of the mosquito species, their availability, and the time devoted to the survey are factors which will determine the total number of each species of mosquito covered by the survey. In general, the survey should strive to capture every mosquito, regardless of the species or the time of its feeding, which it is possible to take at each collection. If this is done, it will not be long before the records of collections and dissections will show a preponderance of two or three species in contrast to a proportional smaller number for the less common species. After a time a careful study of the records will give some indication as to the number of species and the per cent infection in those which show evidence of being transmitters of filariasis. This, then, should be taken as the index of future studies: an attempt should be made to build up the data pertaining to those species of mosquitoes which give promise of being of filarial importance. Where possible all data on the principal and probable vectors should be based on at least 500 to 1000 or more specimens of each species. It is essential that density counts be made. The data obtained from this can be recorded as number of mosquitoes per man per hour. The density counts together with the collection and dissection data will form the basis for (1) determining the number and kind of the more common mosquitoes within a given area, (2) their relative densities, (3) their importance to the transmission of filariasis, and (4) the relative transmitting efficiency of those mosquitoes which prove to be infected.

f. Field results may be substantiated by laboratory experimentation. Parasite-free mosquitoes may be obtained by allowing field collected larvae to emerge as adults in the laboratory. These can be infected by permitting them to take a single blood meal from a suitable native (having 2 to 5 microfilariae per cmm of blood). From such experimentation many aspects of the problem may be worked out that cannot be elucidated by field work.

### **C. The Mosquito Survey Report.**

1. The report of the mosquito survey should bring out the following points:
  - a. The principal vector or vectors of filariasis in the area.
  - b. The relative transmitting efficiency of the vector or vectors.
  - c. The incidence of infection in the general mosquito population in the area.
  - d. The number, size and location of the hyperendemic centers of transmission.
- e. Recommendation for the control of the vector or vectors and the protective measures to be employed by the service personnel against the transmitting host.

## VIII. RELATIONSHIP OF FILARIA CONTROL TO MALARIA CONTROL.

Since both filariasis and malaria are mosquito-borne diseases, often involving the same or related mosquitoes as their transmitters, the control of filariasis can be most efficiently accomplished by being incorporated as one of the duties of the Malaria and Epidemic Disease Control Organization, an organization which is already set up and functioning in the control of malaria. The Malaria Control Officer should familiarize himself with all aspects of filariasis which will be of aid in the performance of his control duties. The following outline of duties is offered as a guide to the Malaria Control Officer in the performance of his additional duties of controlling filariasis in his area.

**A.** The Malaria Control Officer should become familiar with the cause and effects of filariasis on the patient, all known epidemiological facts concerning the disease and the more important differences between filariasis and malaria from both the disease and the epidemiological points of view (see pages 1-15, this Manual and Reference List, pages 25 & 26).

**B.** The Malaria Control Officer will be expected to make the following decisions (decisions to be based on the report of the Survey Unit):

1. Which centers of transmission within the area warrant immediate attention from the control point of view.
2. What control measures are necessary for specific areas as well as for the area as a whole.
3. When both malaria and filariasis are present in the same area but are transmitted by different mosquitoes, the control officer shall decide what measures are needed for the control of each type of the host as well as the extent of the control effort against each and which shall take precedence over the other.
4. The Malaria Control Officer will outline and instigate filariasis discipline, to include both preventive and protective measures, within his area.
5. The Malaria Control Officer will give his opinion on the location of all new camp sites within his area.
6. The Malaria Control Officer shall make decisions concerning (1) location of native labor camps, (2) the dangers of native laborers to personnel areas, and (3) the control of filariasis within the area of the native labor camp.
7. The Malaria Control Officer will decide on the nature of the educational information on filariasis and its dissemination within his area.

## IX. REFERENCE LIST OF RECENT REPORTS ON AND SUMMARIES OF INFORMATION CONCERNING FILARIASIS

**A. Epidemiology of Diseases of Military Importance in the Netherlands. Indies.** Bureau of Medicine and Surgery, Navy Department, NavMed 133. August 20, 1943.

**B. Epidemiology of Diseases of Naval Importance in Formosa.** Bureau of Medicine and Surgery, Navy Department, NavMed 266. 1944.

**C. Medical and Sanitary Data on Philippine Islands.** War Department Technical Bulletin. TB Med. 68, July, 1944.

**D. Filariasis.** BuMed Letters, Navy Department. September 3, 1943 and July 7, 1944.

**E. Filariasis.** News Letters, Headquarters Malaria and Epidemic Disease Control, South Pacific Area. May, 1944; June, 1944; August, 1944; and October, 1944.

**F. Reports of the Navy Filaria Survey Unit.**

**(a) Preliminary Epidemiological Report of Filariasis Among Marines on Tutuila, Samoa.** July 1, 1943.

**(b) Filariasis on Tutuila, Samoa,** August 20, 1943.

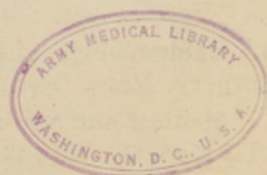
**(c) Filariasis on Wallis Island.** October, 1943.

**(d) Studies on Filariasis in the Samoan Area.** February, 1944.

**(e) Studies on Filariasis in the New Hebrides.** July 11, 1944.

**(f) Studies on the Problem of Filarial Transmission from Infected to Uninfected Members of the Armed forces.** July 11, 1944.

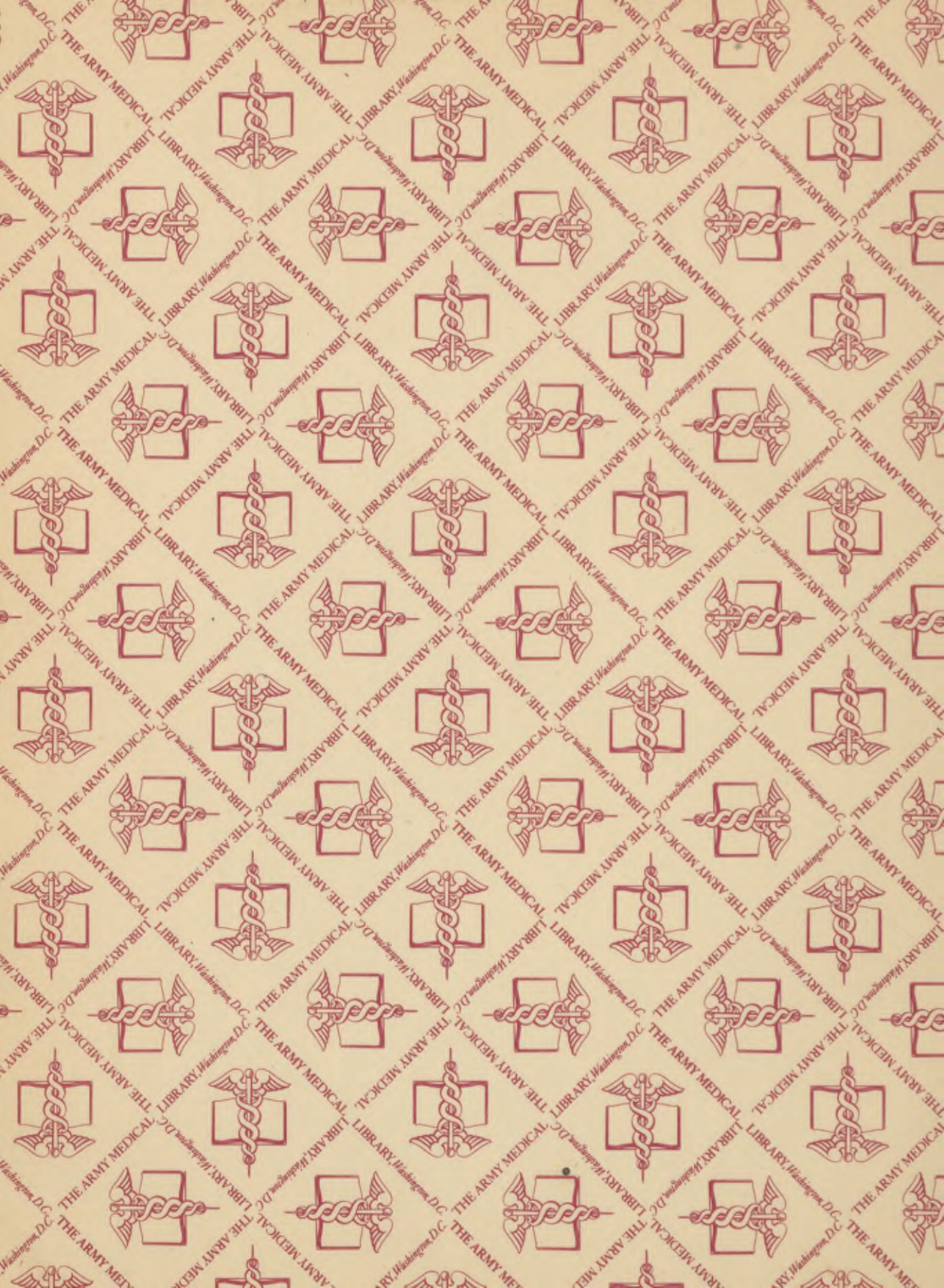
**(g) Studies on Filariasis in the Solomon Islands.** October 4, 1944.











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