MALARIA — CAUSE AND CONTROL

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MALARIA

CAUSE AND CONTROL

BY

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ITS RELATION TO PUBLIC HEALTH"; ETC., ETC.

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Dedicated

TO

MY WIFE

LILLIE MAGLY HERMS

WHOSE KINDLY CRITICISM HAS BEEN
INVALUABLE IN THE
PREPARATION OF THIS WORK

PREFACE

THE material presented in this volume is based on nearly four years of practical study of Malaria in California, during which time virtually every part of the state has been reached. The extent of the infested area is limited to a comparatively few counties, and here the problem is shown to be a controllable one, as demonstrated by several successful anti malaria campaigns. Concerted action backed by sufficient funds to carry on a scientific and systematic crusade against the *Anopheles* mosquito is all that is needed to free California of malaria, and thus eliminate the one glaring defect of this splendid state.

A seven-years siege in his earlier experience with malaria in the southern part of Ohio has given the writer an interest in this malady which is of more than scientific birth.

This extensive study in California could not have been possible but for the painstaking and loyal assistance of graduate students who have given time and energy, often under very trying conditions, and often for little or no compensation. Much credit is due Mr. Harold F. Gray, who, through his excellent equipment and efficiency, has given indispensable assistance in the preparation of this work. His careful reports

are embodied in this book. Other field assistants whose work deserves commendation are Mr. Ben Bairos, Mr. E. H. Cornell, Mr. E. O. McGregor, Mr. Herbert Leak, Mr. W. M. Davidson, Mr. Edward Barber, and Mr. Arnold Weber. To these and to my laboratory assistant, Mr. A. B. Shaw, Jr., I wish to extend heartiest thanks.

W. B. HERMS.

BERKELEY, CALIFORNIA,
April 4, 1912.

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INTRODUCTION

THE awakening of the general public to the necessity and possibility of the control of malaria, indicated by the incessant demand for information on this subject, is sufficient reason for the appearance of this publication. Though many books and pamphlets on malaria have been written by many authors, the situation as found in the state of California has received little or no attention by others. The contents of this book are based mainly on the conditions as the writer has found and studied them in this State during the past few years, and the suggestions for control are made as they have been applied by him and have been found successful.

The subject of malaria control deserves the most careful attention of the best scientifically equipped men of this time, and to enter into this work no one, not even the most dignified scientist, needs to suffer abasement. There are still some few scientists who, under the shadow of scholasticism, disdain to give to mankind the facts in their hands to relieve suffering, who in their laboratories concern themselves with the microscopical structure of disease bearing and disease causing organisms and scorn the man who has the courage to step out of his laboratory and apply these facts for the welfare of humanity. All honor to the man who

searches in his laboratory for the unknown mysteries of living things, but twice honor to the scientist who does this for the purpose of serving his fellow men.

The great imperative call now going forth for young men and women to go back to the soil brings with it the responsibility to make life on the farm worth living. Malaria is notably a disease of rural districts. Many are responding to the call of ranch life and many are the colonists who are pouring into our fair valleys, and many are there who leave again after a very short time. Those who are familiar with the situation know very well that malaria is too often responsible for the departure.

California is noted for its healthful climate, and its natural resources in this respect are tremendous. Careful study and extensive travel in this vast empire of the Pacific have impressed me with its wonderful natural conditions conducive to good health, and the conservation and protection of these health resources is a problem of great moment. Malaria is a disease not indigenous to our soil, nor to our sunshine, nor to our luscious fruit, nor to the clear, cool waters that flow from the Sierras; it is an alien that has crept in stealthily and has occupied the length and breadth of these fair valleys. California is not the only state that is suffering from this disease, but it is destined to be foremost in the great crusade to banish malaria from its boundaries. Natural conditions are favorable for control, and the people once alive to the situation will

act vigorously. The time when real estate men and chambers of commerce denounce anti-malaria efforts for fear of exposure is rapidly drawing to an end. As one editor has wisely said : "There are two kinds of boosting, both of which are good. There is the boosting that brings good things here, and the boosting that boosts bad things away."

ECONOMIC CONSIDERATIONS

Mortality.— While malaria is not a highly fatal disease (the mortality being comparatively low, as will be seen), it is one of the most expensive diseases extant, owing to its continued weakening effect on the victim and its harmful influence on labor and real estate valuation.

The following table and quotations after Howard (1907) give a fair estimate of the mortality in the United States due to malaria. The table is based on the registration area.

TABLE I
DEATHS DUE TO MALARIA IN THE REGISTRATION STATES, 1900
TO 1907. (After Howard.)

YEAR	NO. OF DEATHS FROM MALARIA PER 100,000 POPULATION	TOTAL NO. OF DEATHS FROM MALARIA
1900	7.9	2434
1901	6.3	1791
1902	5.4	1738
1903	4.3	1410
1904	4.2	1391
1905	3.9	1321
1906	3.5	1415
1907	2.8	1166
Total deaths		12,666

Howard comments on this table as follows : "Estimating from the preceding table, the average annual death rate due to malaria is 4.8 per 100,000 population, and considering that the registration area includes only sixteen of the northern states (assuming fairly, however, that the death rate in the other northern states is the same), it seems reasonably safe to conclude that the death rate from malaria for the whole United States must surely amount to 45 per 100,000. It is probably greater than this, since the statistics from the south are city statistics, — and malaria is really a country disease. Yet this will give an annual death rate from malaria of nearly 12,000 and a total number of deaths for the same period (1900-1907) of approximately 96,000."

Expensive to the State. — The best available statistics to set forth the economic importance of malaria for any one state are given us by the California State Board of Health. In 1909 there were 112 deaths from malaria in this State, with an average age of forty-four years at death. The table given us by the State Board of Health is based on these facts and the economic significance is shown in the various losses due directly or indirectly to the disease.

No doubt, a similar table of expenses for any one of the more malarious central and southern states would show a correspondingly great loss, but nowhere in the Union are the possibilities for eradication so good as in California, owing to the long, dry summers.

TABLE II

ANNUAL LOSSES FROM MALARIA ESTIMATED TO ILLUSTRATE THE ECONOMIC SIGNIFICANCE OF THIS DISEASE TO THE STATE OF CALIFORNIA. (After California State Board of Health.)

Death of 112 citizens at \$1700, average economic value	\$190,400
Six thousand acute cases of malaria at average of \$20 per year for drugs, etc.	120,000
Six thousand citizens' earning power reduced 25 per cent by malaria, estimated average income \$800 .	1,200,000
Loss of life, wages, illness from other diseases given opportunity through lowered resistance brought about by malaria, estimating 50 deaths at \$1700, and 1000 persons ill at \$100 each	185,000
Loss through sacrifice sales of farms and moving expenses of families leaving malarial districts, estimating 250 families at \$500	125,000
Loss through depreciation in land values, estimating \$1 per acre only on 1,000,000 acres under irrigation in the Sacramento and San Joaquin Valleys . . .	1,000,000
	<u>\$2,820,400</u>

Expensive to Community. — The following itemized expense account (Table III) applies to the town of ——— in the northern Sacramento Valley. In this town deaths due to malaria have been increasing, while the population in the same time has not increased materially; in 1909 there was one death, in 1910 there were three deaths, and in 1911 there were five, all reported due directly to malaria. The itemized account is based on a careful investigation of data furnished by reputable druggists, physicians, and city officials, and is figured in a conservative manner.

TABLE III

Showing the expense incurred in the year 1911 through the existence of malaria in the town of ———, situated in the northern Sacramento valley, population about 4000.

Quinine, 1100 oz. at 75 cents	\$822.50
Quinine, 30,000 gr., 24 gr. at 10 cents	120.00
Cocoa quinine, 40 pts. at 75 cents	30.00
Patent medicines, estimated by druggists	1800.00
Add 20 per cent for sales from drug store not included in above	<u>554.50</u>
	\$3327.00
500 estimated cases of malaria attended by physicians (200 cases simultaneously) at \$5	2500.00
5 deaths due to malaria at \$1700	8500.00
500 cases earning capacity reduced for a period of six months by 30 per cent, average annual income \$800	<u>60,000.00</u>
Total annual loss due to malaria to the town of ———	\$74,327.00

This does not include depreciation of real estate valuation, which may safely be estimated at 5 cents per \$100 assessed valuation.

The loss inflicted on this town can without exaggeration be placed at \$75,000 annually, with every prospect of being increased proportionately unless an active anti-malaria campaign brings a stop to this great municipal leakage. As is shown later in this work, the number of malaria cases in any given protected area can be reduced at least 50 per cent in one year through the agency of an efficient malaria-mosquito campaign, followed by a reduction of 80 per cent in the second and pretty surely by 95 per cent in the third

year through continuous systematic effort; it can thus be seen what this community could save annually at an expenditure of about \$2000 each year.

Estimating the loss for 1909 at \$15,000, for 1910 at \$45,000, and 1911 at \$75,000, the total loss for the three years just past amounts to \$135,000. Had an efficient crusade been in operation in 1909, the loss would only have been \$7500, for 1910¹ it would have been \$3000, for 1911¹ the loss would have been \$750, a total of \$11,250, to which must be added the probable cost of three years anti-malaria work, \$6000, — giving a sum total loss of \$17,250 against a sustained loss of \$135,000. Thus the community would have saved in the past three years the sum of \$117,750, which amount, if expended in beautifying the town, building streets, and otherwise improving things, would have made it one of the most beautiful towns in the whole state, with a healthy and happy citizenship thrown in. Surely things will not improve by standing still; malaria will continue to increase. It is none too early to begin operations at once and stop the wasteful leakage all due to this most wasteful of diseases.

¹ Applying the percentage above (namely 50, 80, and 95 per cent) to the sustained loss for the year 1909, *i.e.* \$15,000.

MALARIA AND ITS TRANSMISSION

Historical. — Though there is even at this late date much popular and even some professional (medical) aversion and faithlessness in the so-called “mosquito-malaria theory,” notwithstanding the great mass of evidence in its favor, it is shown by such writers as Nuttall (1899) that this theory has existed for many years among the Italian and Tyrolese peasants and the natives of German East Africa, and in the United States as early as the beginning of the nineteenth century. The same writer states, viz.: “It is curious to look over the more recent literature on the subject to see how writers have rediscovered the mosquito-malaria theory. In France the theory is ascribed to Laveran, in Germany to Koch and Pfeiffer, in England to Manson, whilst in Italy the names of Bignami, Mendini, and, lastly, Grassi are identified with it. By far the most masterly exposition of the theory was written by King (an American, in 1883).¹ It is first mentioned by Laveran in 1891, by Manson in 1894, whilst Pfeiffer makes the first published statement of Koch’s views in 1892. As far as I can gather, Bignami and Mendini refer to it in 1896 and Grassi in 1898.”

The credit for the discovery of the causative organism

¹ Author’s words in parenthesis.

belongs entirely to Dr. C. L. A. Laveran, a French army surgeon in Algeria, who made the discovery in 1880. The fact that certain kinds of mosquitoes are the transmitters of this causative organism was discovered by the Englishman, Major Ronald Ross, while stationed in India. This discovery was made in 1898, and mankind owes no greater debt to a fellow man than this.

Circumstantial Evidence. — A several years' residence in a notoriously malarial district, during the 80's and early 90's, has given the author much circumstantial evidence at least to incriminate the mosquito, though this was looked upon then as an incidental matter. Immediately following the great floods, when the valleys were inundated during late February and March and the receding water left behind it innumerable pools and filled cellars and cesspools, there was much more malaria than usual, a fact always predicted. Coincidentally mosquitoes were unusually abundant, and especially the noiseless kind. Exceedingly warm, moist seasons always brought more malaria, while a prolonged drought was said to kill the disease, as did the approach of cold weather. The connection between the weather and relative abundance of mosquitoes can easily be made.

Furthermore, observations covering several years' residence in California, during which time the state has been carefully traversed several times, bring home the fact that the southern part of the state is

practically devoid of malaria, while the central and northern counties, except those parts directly bordering the Pacific Ocean, all have more or less of the disease. This condition is directly associated with the relative abundance of fresh water and consequently with the relative facility for the breeding of mosquitoes. The relation to irrigation will be touched upon later.

A very common suggestion to escape malaria is to keep out of the "night air," closing the windows and all openings that might possibly permit the "night air" to enter. This again relates to the night-flying habits of the mosquito.

In districts in which anti-mosquito campaigns have been waged with vigor there has quickly followed a decrease in malaria, no other precaution having been taken. Thus in the village of Penryn (California) the malaria absences in the public schools during the months of September to December were reduced by 45 per cent in only one season's work.

The circumstantial evidence against the mosquito (in a broad sense) may be summed up as follows:—

(1) Malaria exists endemically in districts where mosquitoes are present (all species except the Anophelines are eliminated experimentally); (2) malaria does not exist endemically where there are no mosquitoes; existing cases are without exception traced to a visit on the part of the patient to some part in which mosquitoes of the Anopheline type are found; (3) persons protecting themselves from mosquito

bites while dwelling in malarial districts (otherwise living as do the natives) do not contract malaria; (4) communities previously noted for malaria have been practically freed from this disease when efficient sewer systems have been installed; (5) properly conducted mosquito crusades result in the elimination of nearly 50 per cent of the cases of malaria within the district in the same season (the occurring cases can be accounted for through relapses and exposure to mosquito bites outside the protected districts).

It should furthermore be said that malaria may be wholly absent even when there is an abundance of mosquitoes. In answer to this it should be explained that there are several hundred species of mosquitoes, of which number only two or three for any one locality are capable of transmitting malaria. Hence, first, the mosquitoes in such localities are probably all non-malaria bearing or Culicine, with entire absence of the malaria bearing species (Anopheline); or, secondly, if Anopheline mosquitoes are present, they have not become infected by the importation of persons affected with malaria, *i.e.* malaria must first be introduced before the Anopheline mosquitoes can carry it from person to person.

Experimental Evidence. — As is noted under the next head, malaria is a parasitic disease caused by a blood-inhabiting unicellular animal organism discovered by Laveran in 1880. This parasite, as far as is known, perishes very quickly when taken from the human

body with extracted blood. Manifestly, then, malaria cannot exist in water, nor in air, nor in overripe fruit, or the like.

Water used for drinking purposes that was suspected of being responsible for malaria in a given district was used continuously in two communities (Penryn and Oroville, California) during their anti-mosquito crusades while malaria was on a steady decrease. The sanitary inspectors drank this water, ate freely of the ripest fruit during this time, exposed themselves to the severest heat of the day, and yet remained free from malaria, exercising, of course, the proper night precautions.

It is well known that malarial blood taken directly from a patient suffering from malaria shows flagellated parasites. Ross, in 1895, in his observations in India found these flagellated bodies in the intestine of mosquitoes which had fed on the blood of malarial patients. Many experiments were made and hundreds of mosquitoes examined during the next few years by Ross. The most striking condition found in some of these mosquitoes was the development of pigmented cells in the stomach wall, the pigment corresponding to malaria pigment. Some of this number gave positive results, while the majority gave negative results. Those that furnished the positive results were of a particular species, and this gave the clue that the malaria parasite required a particular species of mosquito to serve as intermediary host. The connection between the flagel-

lated bodies and the pigmented cells was furnished by MacCallum in 1898. He found that the function of the flagellated cells was that of an impregnating body; that each flagellum, of which there were several to each cell, impregnated the spherical parasite. MacCallum's observations were made on the Proteosoma of birds, also known as "bird malaria." Using the Proteosoma as a basis for his further observations, Ross found that the pigmented cells migrating through the stomach wall of the mosquito,¹ and encysting just beneath the peritoneal lining, grew steadily for three or four days, forming spindle-shaped bodies, which were shed into the body cavity and in six or seven days after feeding were found in vast numbers in the salivary glands.

Grassi's experiments and observations in the Roman Campagna and Sicily proved that human malaria was carried solely by Anopheline mosquitoes (*Anopheles claviger*). Nuttall describes one of the early experiments of Grassi and Bignami as follows: "Mosquitoes comprising the three species, *Culex penicillaris*, *Culex malariae*, and *Anopheles claviger* were collected at Maccarese, a malarial foyer 22 miles from Rome on the Civita Vecchia Road. The insects were brought to Rome, where they were allowed to bite a patient (who consented to the experiment) in the Santo

¹ It should be noted here that Culicine mosquitoes (*Culex pipiens*) are the transmitters of Proteosoma, though inefficient as transmitters of Plasmodium or human malaria.

Spirito Hospital. The patient, a man who had been an inmate of the hospital for six years, had never had malaria. He was confined at night in a room in which vessels containing mosquito larvæ were placed, and a new supply of these was placed in the room every four to six days. The patient was severely bitten by the mosquitoes which developed from the larvæ. The result was that the man acquired malaria, with æstivo-autumnal parasites in the blood. The details of this experiment were published by Bignami; Grassi believed that infection was due to the agency of the first species above named, as it was the most numerous. *A. claviger* was only present in exceedingly small numbers, and perhaps none of this species bit the patient. (It has since been proved that it could only have been *A. claviger* that caused infection.)”

The above description might lead one to believe that the parasite of malaria is transmitted from the adult mosquito to its larva, since the patient was bitten by the mosquitoes developing from the larvæ, but it does not say that he was not bitten by the originally infected mosquitoes.

The following quotation from Manson¹ concludes the experimental evidence. “Finally, on behalf of the Colonial Office and the London School of Tropical Medicine, with the assistance of Drs. Sambon and Low, I instituted two experiments which dispose for good and all of any objections that otherwise might

¹ Manson, Sir Patrick, 1909. “Tropical Diseases.”

have been advanced against the theory. Drs. Sambon and Low, Mr. Terzi, their servants and visitors, lived for the three most malarial months of 1900 in one of the most malarial localities of the Roman Campagna, Ostia, in a hut from which mosquitoes were excluded by a simple arrangement of wire gauze on the doors and windows. They moved freely about in the neighborhood during the day, exposed themselves in all weathers, drank the water of the place, often did manual work, and beyond retiring from sunset to sunrise to their mosquito-protected hut observed no precautions whatever against malaria. They took no quinine. Although their neighbors, the Italian peasants, were each and all of them attacked with malaria, the dwellers in the mosquito-proof hut enjoyed absolute immunity from the disease. Whilst this experiment was in progress mosquitoes fed in Rome on patients suffering from tertian malaria were forwarded in suitable cages to the London School of Tropical Medicine, and on their arrival were set to bite my son, the late Dr. P. Thurburn Manson, and Mr. George Warren. Shortly afterwards both of these gentlemen, neither of whom had been abroad or otherwise exposed to malarial influences, developed characteristic malarial fever, and malarial parasites were found in abundance in their blood, both at that time and on the occurrence of the several relapses of malarial fever from which they subsequently suffered.

“The mosquito-malaria theory has now, therefore,

passed from the region of conjecture to that of fact."

Malaria. — Malaria is a widely distributed disease prevalent to a greater or less degree on every continent, in parts where there is an average summer

FIG. 1. To illustrate detection of malaria parasite. *a*, normal, unparasitized red blood corpuscle; *b*, young intracorporeal parasite; *c*, signet ring; *d*, intracorporeal crescent; *e*, free female crescent; *f*, free male or hyaline crescent; *g*, female oval.

temperature of not less than 60° F., and while not restricted to the lowlands, does not occur abundantly in high altitudes. The disease is known to occur endemically in Java, Madagascar, and elsewhere at an elevation of 3000 feet.

Malaria symptoms, even though very slight, are usually manifested in the form of a paroxysm con-

sisting of three well-defined stages, viz.: the *cold stage* (the chill), in which the skin becomes pale and appears as "goose skin," the patient's teeth chatter, and he shivers more or less violently; the next stage is the *hot stage*, or fever (the temperature rises during the chill), the skin being now hot and flushed; the third stage is manifested by the appearance of perspiration, which becomes general all over the body; the fever falls, and the patient becomes normal. In many cases the stages are not easily distinguishable.

The term "malarial fever" is quite commonly applied to many conditions of *malaise* associated with fever. It is not safe to conclude that the case is malaria until a microscopical examination of the blood indicates the presence of the intracorpuseular parasites or crescents (Fig. 1).

The Parasite. — The malarial parasites (*Plasmodia*) belong to the lowest forms of animal life, the *Protozoa* (Subphylum Sporozoa, Class Telosporida, Sub-class Hæmosporida). The pigment of these blood-corpuscle-inhabiting parasites is black and characteristic, and their presence usually gives rise to a periodic fever, due to their asexual reproduction (sporulation) in the human blood at regular intervals.

To detect the presence of the parasite a drop of blood is drawn from the lobe of the patient's ear or finger tip, after proper cleansing, the droplet of blood being lightly touched with a glass microscopical slide, upon which the film (smear) is made by gently and

evenly spreading the droplet by means of a needle. The film is fixed and stained with a good malarial stain. If parasites are present in the blood, they should be visible after careful microscopical examination as pigmented intracorpuscular bodies, or as crescents in æstivo-autumnal fever of ten or more days' duration. Microscopic examination under an oil-immersion lens is desirable, though crescents can easily be seen under lower powers.

The ease with which parasites can be discovered in a blood smear depends on several important factors, — first, on the length of time that the patient has had malaria, *i.e.* the parasites may be so few that they will be hard to find. Ross states that the parasites "will not generally be numerous enough to cause illness unless there is at least one parasite to 100,000 hæmatids; that is, 50 parasites in 1 c.mm. of blood; or 150,000,000 in a man 64 kilograms in weight. . . . Such calculations demonstrate the absurdity of supposing that there are no plasmodia present in a person because we fail in finding one after a few minutes' search. As a matter of fact, even if as many as 150,000,000 plasmodia are present in an average man, the chances are that ten to fifteen minutes' search will be required for each plasmodium found; while if we are careless or unfortunate, we may have to look much longer."

In the second place, if the patient has recently taken quinine, the chances for the discovery of parasites are virtually reduced to nil.

The various types of malaria are due to the fact that there are several species of parasitic plasmodia, each of which produces specific symptoms. Three distinct types are usually recognized: (1) *Æstivo-autumnal* or Malignant Tertian, (2) *Tertian* or Benign Tertian, and (3) *Quartan*.

FIG. 2. Diagram to show species of malaria parasites with reference to red corpuscles, pigmentation, and sporulation. *abc*, benign tertian parasite (*Plasmodium vivax*); *a'b'c'*, malignant tertian parasite of æstivo-autumnal fever (*Plasmodium præcox*); *a''b''c''*, quartan parasite (*Laverania malariae*); *a*, *a'*, *a''*, normal unparasitized corpuscles; *b*, nearly full-grown *Plasmodium vivax* in enlarged corpuscle; *c*, sporulating specimen of the same; *b'*, young *Plasmodium præcox*; *c'*, sporulating specimen of the same; *b''*, young specimen of *Plasmodium malariae*; *c''* sporulating specimen of the same. (Redrawn and adapted after Deaderick.)

a. Plasmodium præcox (*Hæmamæba præcox*, *Plasmodium falciparum*, *Plasmodium immaculatum*) is the cause of æstivo-autumnal fever (malignant tertian fever) of the tropics, with the paroxysm recurring every forty-eight hours. The pigment granules in this species are relatively few and very coarse (Fig.

2, *b'*). The segmenting stage (Fig. 2, *c'*), which is rarely seen in the blood, is said to produce only from eight to ten merozoites, according to Stephens and Christophers, while Deaderick states that the number varies from five to twenty-five and over. Characteristic crescents (Fig. 1) or gametocytes (sexual forms) are commonly observed in cases of ten or more days' duration. Crescents occur in this species only. The female crescents show the chromatin material well concentrated in the mid-region, with slight stippling at both ends, while the male crescents present a thinly scattered chromatin with both ends hyaline (these are also called hyaline bodies or hyaline crescents). Certain relapses after some months' latency are said to be traceable to a parthenogenetic cycle in the female crescents, which produce merozoites, and these attack the red blood corpuscles, as do the ordinary sporulated forms.

Enlarged parasitized corpuscles occur in this species, but merely as a coincident, since enlarged corpuscles commonly occur in anæmia, and these may be entered by the sporozoites.

b. Plasmodium vivax (*Hæmamaeba vivax*) is the cause of tertian fever or benign tertian malaria of temperate climates, also the tropics and subtropics, with recurrent paroxysms regularly every forty-eight hours. In these parasites the pigment granules (Fig. 2, *b*) are very fine and are distributed throughout the red corpuscle as Schüffner's dots. The parasitized

corpuscles are distinctly enlarged and are quite pale. There are no crescents in this species, and the gametes are not easily distinguishable from the asexual parasites. The number of elements in the sporulating or segmentation stage (Fig. 2, *c*) is larger than in the former, and their arrangement is irregular (fifteen or more, according to Stephens and Christophers).

c. Laverania malariae (*Plasmodium malariae*, *Hæmameba malariae*) is the cause of quartan fever, with recurrent paroxysms every seventy-two hours. This form of malaria is comparatively rare, and coincides in distribution with æstivo-autumnal fever. In the parasites the pigment is coarse and generally occurs in a streak along the margin (Fig. 2, *b''*). The parasitized corpuscles are commonly shrunken and may appear as "brassy bodies." The gametes are rarely seen. The segmenting stage gives rise to the typical "daisy" form, each sporulated body radiating from the center (Fig. 2, *c''*). The number of bodies varies from six to twelve, oftenest eight (Deaderick).

The *signet ring* (Fig. 3) is a young stage in the development of the intracorpuseular parasite of all species, and is characterized by a broken ring, whose ends are connected more or less loosely by a chromatin dot, which in the æstivo-autumnal parasite may be double. The chromatin dot is often inside the ring, but ordinarily nearest the thin segment of the ring.

Life History of the Parasite. — Only one phase of the life history (the asexual), or cycle of Golgi (repeated

sporulation every forty-eight or seventy-two hours, as the case may be) (Fig. 4, 1-6), is passed within the human body; therefore if a human were only once infected with malaria and were to undergo no treatment, the parasites would probably eventually disappear, even in the absence of treatment, owing to their senescence after repeated asexual sporulation,

FIG. 3. Signet ring stage of malaria parasite.

and what is probably more important, the production of a toxin which is destructive to the parasites. There is apparently, however, parthenogenesis, in which female crescents give rise to new blood-cell attacking parasites, which may give rise to a recurrence of the malaria paroxysm even after a long latency. Therefore in order to continue the race, *i.e.* to provide for sexual rejuvenation, these parasites must find their

FIG. 4. Diagram to show life history of parasite (*Plasmodium vivax*) of æstivo-autumnal malaria. 1-6, asexual or schizogonic cycle in human blood, requiring 48 hours to complete (72 hours in quartan); 1 represents a malarial vermicle or sporozoite, either in salivary gland of mosquito or newly injected into human circulation; 2 represents a red blood corpuscle about to be parasitized by a sporozoite; 3 shows a young parasite in signet ring form; 4, fully grown parasite with dividing nuclei; 5 shows parasite sporulated, but still intracorporeal; 6, sporulation, each body a merozoite ready to enter a new corpuscle; some are sexual and may develop into gametes; 7a, female gametocyte, still intracorporeal; 7b, male gametocyte, also intracorporeal; 8a, free female crescent, which may sporulate, producing a parthenogenetic cycle (w, x, y, z); 8b, male gametocyte or hyaline crescent (crescents do not ordinarily appear in the blood until ten days or more after infection); 9-20 illustrates the sporogonic or sexual cycle of the parasite within the body of a female Anopheline mosquito, requiring six to ten days and over to complete; 9a, 9b, female and male gametocytes in stomach cavity of mosquito; 10a, female gamete (macrogamete); 10b, exflagellated male gametocyte; 11, deflagellated male gamete (microgamete); 12, fertilization; (9-13 requires about 24 hours); 13, ookinete or zygote ready to penetrate stomach; 14, ookinete burrowing through stomach wall; 15, ookinete lying outside of stomach wall and inside peritoneal lining, forming characteristic cysts, growing progressively larger; (16-19) in which the parasite sporulates, forming the sporozoites; 20 shows sporozoites (vermicules) escaping from cyst and migrating forward to salivary glands (21); (14-20 requires 5 days or more); 21, salivary glands of female mosquito; 22, head of female Anophelis. (Original, with suggestions from Grassi and Schaudin in Mense's Handbuch.)

way out of the human body, and in this connection it is interesting to note that the early phases of the sexual cycle may be undergone on a glass slide, in a blood smear, but owing to temperature conditions and most particularly lack of proper chemical conditions, the organisms die in a few minutes. Any blood-sucking insect or mechanical means of drawing blood may produce the same result; but if this blood, however much parasitized it may be, is swallowed by any other insect than the Anopheline mosquito, both blood and parasites are digested as food. But in the Anopheline mosquito the sexual cycle is completed; therefore this insect is the definitive host.

In the asexual stage there are present the gametes (sexual parasites) which are distinguishable from the asexual forms by "(1) their larger size, (2) by more abundant pigment, (3) by the fact that there is only one fairly large chromatin mass, whereas in an asexual form of nearly equal size the chromatin has already begun to divide into several portions (presegmenting stage)." ¹ The æstivo-autumnal gametes (crescents) have already been described.

If, now, a malarial patient with gametes (sexual parasites) present in the peripheral circulation is bitten by an Anopheline mosquito, the conditions are right for the completion of the sexual cycle in that insect (Fig. 4, 9-20). The male gametocyte undergoes

¹ Stephens and Christophers. "Practical Study of Malaria." Liverpool Univ. Press, 1908.

marked changes, extruding from three to six flagella often in a few minutes; each of these flagella breaks loose from the parent body, forming the male gamete (spermatozoön), which in the stomach of the mosquito fertilizes the female gamete, forming the oökinet (also called vermicule), in which stage the wall of the stomach

FIG. 5. Showing mid-gut (stomach) of *Anopheles* mosquito, with cysts of malaria parasites. (Redrawn from Smith after Berkeley's "Laboratory Manual.")

the membrane forming the outer stomach lining. In this position the parasites grow enormously, forming cysts (Fig. 5) in which many nuclei appear in four or five days; these give rise to myriads (thousands) of spindle-shaped bodies (sporozoites) which are in from twenty-four to forty-eight hours more

shed into the body cavity of the mosquito. The sporozoites eventually collect in the salivary glands and are injected with the saliva into the circulation of the next person bitten. The time required for the sexual cycle is from seven to ten days under favorable temperature conditions.

With the introduction of the sporozoites into the blood of a human being the asexual cycle begins, and the victim may show clinical symptoms of malaria in ten to twelve days in æstivo-autumnal fever after being bitten, and in five or six days in benign tertian. The red blood corpuscles are at once attacked, the parasites gaining entrance and growing, full asexual growth

being reached in forty-eight or seventy-two hours, according to the variety of the parasite. At the termination of growth sporulation occurs, and the paroxysm takes place, corresponding to the liberation of the new generation of parasites (merozoites) in the blood plasma. Again the red corpuscles are attacked and the asexual round continues.

The malaria pigmented spleen and liver give evidence of the enormous activities of the leucocytes in capturing the parasites as they are set free in the blood plasma.

Time Factor. — Although there are some localities in which the inhabitants are all infected with malaria, newcomers or visitors may or may not soon fall a prey to the disease, for the reason that not more than 25 to 35 per cent of the *Anopheles* mosquitoes are infected during the height of the season, and correspondingly less early in the spring. This is dependent upon both the time when the infected person and the next victim are bitten. Obviously the mosquito cannot transmit malaria when there is none present to be transmitted; again, the sexual parasites (gametes) must be in the peripheral circulation when the mosquito bites the infected individual; and again after the mosquito becomes infected a period of not less than six days (possibly five in benign tertian, and twelve days in æstivo-autumnal) must elapse before a new victim can be inoculated, *i.e.* the time required for sexual development of the parasite. This incubation period may be prolonged through reduced temperature, with

apparently no development in low temperatures (according to Manson this phase of the malaria parasite requires a "sustained average temperature of at least 60° F."). Thus it will be seen very readily that the time factor plays an important rôle in the transmission of malaria.

Is Malaria inherited by Mosquitoes? — For the reason that malaria is said at times to be contracted by explorers who have entered uninhabited territory, it is believed by some that the mosquitoes of the said territory had become infected perhaps years ago and that the parasite has been handed down from generation to generation from the female to the ovum, ovum to larva, and thus through the mosquito cycle. The fact that Texas cattle fever is thus inherited and infection is secured through the young seed tick seems to lend some weight to the argument. Explorers and others who have malaria in uninhabited regions have pretty surely become infected before entering such territory, and the disease is merely brought on by fatigue or even in due time after infection, corresponding to the incubation period.

Knowing the life history of the parasite, it would be more reasonable to suspect that other warm-blooded animals besides man may harbor the protozoan during its asexual cycle, a matter not, however, as yet proved.

Furthermore, specimens of *Anopheles maculipennis* larvæ were transported by the writer from an intensely malarial district to Berkeley and the adults reared from

these were permitted to bite healthy students, and in no case was the disease produced.

Anopheline Species Concerned.—Although no Anopheline mosquito should be trusted, there are comparatively few species that have been proved experimentally to be carriers of malaria. *Anopheles maculipennis* is for California the most dangerous species, since it is most common in midsummer and late autumn, while *Anopheles punctipennis* is most numerous in the spring.

Several other genera of exotic Anopheline mosquitoes (India and Africa) include malaria-bearing species, among them *Cellia*, *Nyssorhynchus*, *Myzorhynchus*, and *Myzomyia*.

The following key will be found useful in classifying adult *Anopheles* occurring in California.

KEY TO SUBFAMILY ANOPHELINÆ FOR SPECIES OCCURRING IN CALIFORNIA. (As suggested by Mitchell.)

- Palpi nearly as long as proboscis in both sexes. Wings distinctly spotted Subfam. Anophelinæ.
- I. With usually four, sometimes five or three, black spots on each wing *Anopheles maculipennis* Meigen.
- II. With more than five black spots on each wing.
- a. Last vein of wing with three black spots. Thorax not distinctly marked . *Anopheles crucians* Wiedemann.
- aa. Last vein of wing with not more than two black spots. Thorax with distinct, broad, light median stripe.
- b. Scales at base and tip of last vein black, remainder white *Anopheles punctipennis* Say.
- bb. Scales on basal half of last vein white, remainder black *Anopheles franciscanus* McCracken.

MOSQUITOES IN GENERAL

Mosquitoes and their Allies. — As members of the insect order Diptera the mosquitoes partake of the

FIG. 6. A shows portion of wing of *Anopheles* mosquito, illustrating characteristic scales of the family Culicidae and spots of *Anopheles*. B, Diagram of the wing of a mosquito with names of cells and veins useful in classification. (Adapted after Coquillett.)

general characters of the order, namely, reduction of the posterior pair of wings which are represented by a pair of small, knobbed organs known as the halteres,

or balancers, most distinctly seen in the crane flies (Fig. 7). The family Culicidæ belongs to the first subdivision of the Diptera, *i.e.* the Nematocera, by virtue of the filamentous antennæ (the second sub-

FIG. 7. A crane fly (Fam. Tipulidæ), often wrongly called a giant mosquito. A characteristic Dipterous (two-winged) insect showing halteres.

division is the Brachycera represented by the horse-flies (Tabanidæ) and house flies (Muscidæ).

The Culicidæ are distinguished from all other Nematoceran Diptera by the presence of scales on the wings and body (Fig. 7). The proboscis (Fig. 8) is long and suited for piercing, though not all of the Culicidæ are

blood sucking, and even the sexes differ in this respect, *i.e.* the males of all species are said to lack this habit.

There are many Dipterous insects which may be mistaken for mosquitoes without more careful examination. The most commonly mistaken forms are mem-

bers of the family *Chironomidae* (Midges) (Fig. 9), which will be found to lack the long, piercing proboscis of the mosquitoes, and also lack the scales on the wings and the body. Oftentimes there appear indoors on the windows rather large mosquito-like insects, the crane flies, of the family *Tipulidae* (Fig. 7). This group of Diptera is also devoid of the Culicid characteristics and further distinguished by the presence of a V-shaped suture situated dorsally on the thorax. The *Dixidae* (Dixa midges) also resemble the mosquitoes.

FIG. 8. Head and mouth parts of a mosquito with piercing bristles exposed. 1, threadlike antennæ; 2, compound eyes; 3, clypeus; 4, labium; 5, labella; 6, mandibles; 7, maxillæ; 8, maxillary palpi; 9, labrum; 10, labrum-epipharynx.

More closely allied to the mosquitoes and belonging to the same family are the members of the genera *Corethra* (Fig. 10) and *Mochlonyx*, but these have a short, blunt proboscis not well adapted for anything but lapping up liquids freely exposed, therefore not of the piercing type.

Structural Characters of Systematic Value.—The *Culicidæ* are subdivided into two subfamilies on the basis of relative length of *palpi* and *proboscis*, viz. *Culicinæ* (Fig. 11, *a*), in which the palpi of the female are shorter than half the length of the proboscis, and in *Anophe- linæ* (Fig. 11, *c*) the palpi of the female are nearly or quite as long as the proboscis. The males (Fig. 11, *b*) in both subfamilies are provided with somewhat hairy palpi as long as or longer than the proboscis. The determina- tion of the genera and species

FIG. 9. A midge (*Chironomus*), often mistaken for a mosquito. (After Osborn.)

rests quite largely on the character of the scales and the tarsal claws (ungues) (Fig. 12). The scales on the wings and body are of several varieties, as shown in Fig. 13. The occurrence and arrangement of these scales upon the head, thorax, abdomen, and

wings provides a basis for distinguishing the genera, as illustrated by Fig. 14. Stephens and Christophers state, viz.: "The genus *Anopheles* . . . has upright

FIG. 10. *Corethra*, often mistaken for a mosquito. (After Smith.)

forked scales only on the head. . . . All mosquitoes belonging to the genus *Culex* have on the head (1) narrow curved and (2) upright forked, but only (3) a few flat scales laterally; whereas all mosquitoes belonging to the genus *Stegomyia* have on the head (1) no narrow curved scales,

(2) a few upright forked, and (3) flat scales covering the whole of the head."

The *ungues* or tarsal claws are also useful characters in classification locally considered. In some species

the claws are toothed (Fig. 12, *b*) and in others the claws are not toothed (Fig. 12, *a*).

FIG. 11. Heads of mosquitoes, showing relative length of palpi and proboscis. (*a*) Culicine female; (*b*) male of either subclass; (*c*) Anopheline (malaria-bearing) female.

The spotting of the wings is not a safe means for dividing the Culicinæ from the Anophelinæ, although

FIG. 12. Ungues or tarsal claws of mosquitoes. (*a*) *Theobaldia*, (*b*) *Anopheles*, (*c*) *Culex*.

all species except two or three species of Culicines have clear wings, and all but a few Anopheline mosquitoes

FIG. 13. Varieties of Culicid scales. *a*, *b*, *c*, head scales: (*a*) narrow curved; (*b*) upright forked; (*c*) flat; (*d*–*h*) thoracic scales. (Redrawn after Stephens and Christophers.)

have spotted wings. A Culicine mosquito, *Theobaldia incidens*, very commonly found in California, has conspicuously spotted wings.

Sexual Differences. — The males of all species of mosquitoes, as far as known, are provided with *plumose antennæ* (Fig. 11, *b*), while in the female these organs are slender, thread-like, and covered only with short lateral hairs. In the males the palpi are long (as long as or longer than the beak) conspicuous, jointed organs, and quite hairy (Fig. 11, *b*). In habit the sexes differ

FIG. 14. Occurrence and arrangement of scales on the head. (*a*) *Stegomyia*; (*b*) *Anopheles*; (*c*) *Culex*. (Redrawn in part after Stephens and Christophers.)

quite markedly; the males do not feed upon blood, and are consequently less frequently found around human habitations. Sweeping with the insect net through

low grass, or other low vegetation, will usually result in the capture of males if there is a breeding place near and it is the proper season.

Internal Anatomy. — To be prepared to study technically the relation of mosquitoes to such diseases as malaria and filariasis, the student must be familiar with the internal structure of these insects, which possess specializations of importance.

The alimentary canal is separable into three regions, the *fore*, *mid*, and *hind gut*, each of which is again subdivided into distinct parts. Thus the fore-gut consists of the sucking tube of the proboscis and the *pharynx*, including pumping organ and the *oesophagus* with its diverticulæ; the mid-gut consists of a narrower anterior portion (*proventriculus*) and a wider posterior portion (*stomach*), the entire structure occupying the thorax and much of the abdomen, being limited by the origin of the five *malpighian tubules* which indicate the beginning of the intestine or hind-gut; the hind-gut is bent on itself several times and consists of the *ileum*, *colon*, and *rectum*, and marked anteriorly by a slight constriction (Fig. 15).

The *salivary system* consists of two sets (right and left) of salivary glands, three glands to each set. These organs are situated ventrally in the anterior portion of the thorax. The three central ducts meet to form a single tubule, which again meets the one from the opposite set of glands, uniting to produce the common salivary duct. This common duct empties its contents

into the œsophagus through the salivary receptacle close to the base of the proboscis.

The *reproductive system* of the female mosquito occupies the posterior portion of the abdomen and comprises a pair of ovaries joined by a pair of oviducts terminating in the vagina and ovipositors; one to three (depending on the species) spermathecæ are also pres-

FIG. 15. Internal anatomy, in part, of a mosquito. *a*, head; *b*, thorax; *c*, abdomen; *ant.*, antenna; *plp.*, palpus; *prb.*, proboscis; *br.*, brain; *sbbt.*, subœsophageal ganglion; *nch.*, ventral nerve chord; *ph.*, pharynx; *oes.*, œsophagus; *res.*, food reservoir (cæcum), of which there are three; *prov.*, proventriculus; *st.*, stomach or mid-gut; *il.*, ileum; *col.*, colon; *rect.*, rectum; *mpgt.*, malpighian tubules; *sal.*, salivary gland; *salrsr.*, salivary reservoir; *sald.*, salivary duct. (As suggested by various authors.)

ent. The spermathecæ of an impregnated female contain myriads of spermatozoa, and the ovaries when mature occupy the larger part of the abdomen.

Life History of Mosquitoes. — A general statement of life history as found in mosquitoes is not possible if the time for the transformation is desired, because this factor varies considerably for the genera and even

for the species. However, it may be said with certainty that all the species pass through a complex metamorphosis represented by the usual stages, egg, larva, pupa, and adult (Fig. 20). The larvæ are commonly called "wrigglers" and the pupæ "tumblers." Water in which to pass the early stages is absolutely essential. The eggs may be deposited on wet mud and the larvæ may exist for some hours in similar situations. The experiments recorded by Dr. Howard are of considerable interest, and he reports thus:—

"In no case, however, were we able to revive larvæ in mud from which the water had been drawn off for more than forty-eight hours, and after twenty-four hours only a small proportion of the larvæ revived."

The eggs of mosquitoes are deposited from early spring to early autumn, and in warmer parts of the country active "wrigglers" may be found throughout the year. The writer has found nearly full-grown larvæ in parts of California in January and pupæ from which occasional adults emerged during the month of February. These overwintering larvæ are quite certainly from eggs deposited late in the autumn, and the growth is comparatively slow. The adult mosquitoes which make their appearance the earliest in the spring are, as a rule, individuals which have been in hibernation during the winter. Probably about ten days is the shortest time required for any of the commoner species of mosquitoes to pass through the various stages. Howard gives the time for *Culex pungens* as "sixteen

to twenty-four hours for the egg, seven days for the larva, and two days for the pupa." From this rather short life-history period the time required to pass through the same transformations may be two or three weeks under average temperature conditions, and under lower temperature conditions may be several months.

ANOPHELINE OR MALARIA MOSQUITOES

Anopheline Characteristics. — As already stated, the subfamily Anophelinae is distinguished from the Culi-

cinæ by the presence of long palpi in both males and females (Fig. 11, *b, c*). The proboscis is always straight and the scutellum is simple, never trilobed (Stephens and Christophers). The commoner Anopheline species of North

America have also a characteristic resting attitude, *i.e.* the body is usually thrown up at an angle with the surface upon which the insect is resting; this angle is the greatest when the individual is resting on the ceiling, for the reason that gravity acts on the heavy abdomen. When resting on a table or other horizontal surface, this angle is not so great. In all cases the proboscis is nearly

FIG. 16. Characteristic attitude of adult mosquitoes. (*a*) *Anopheles* (malaria bearing), with body normally at an angle of from 25° to 55° with the surface; (*b*) *Culex* (body parallel).

FIG. 17. Mosquito eggs. (a) Culicine eggs from 250 to 750 in boats; (b) Anopheline eggs (after Howard) singly from 25 to 75.

or quite on a line with the body, whereas in the Culicine species the beak and body form a distinct angle (Fig. 16).

The “song” of *Anopheles* is also less audible; where the Culicine mosquito produces a high-pitched, tantalizing tone and is quickly brushed away, the *Anopheles* may alight and actually proceed to pierce the skin of the victim before it is detected.

The Eggs.—The Anopheline female deposits from 25 to 125 eggs, while the Culicines lay from 250 to 750. In the former (including *Stegomyia calopus*) the individual eggs lie flat on the surface of the water and often form geometrical figures with each other, owing to their peculiar form; in the latter (Culicine) (except *Stegomyia calopus*) the eggs are placed on end, forming a boat-shaped pack or raft (Fig. 17).

FIG. 18. Individual mosquito eggs. (a) Anopheline; (b) Culicine. (After Howard.)

On examination it will be seen that the individual Anopheline egg is provided on the upper surface with a pair of floats midway upon either side, together with

corrugated edges extending nearly the length of the egg. The individual *Culex* egg tapers decidedly at the upper end and terminates at the base in a globular organ called the "micropilar apparatus" (Fig. 18).

The Larvæ. — The larvæ of Culicine mosquitoes are always suspended from the surface of the water at

FIG. 19. Mosquito larvæ in natural position in the water. (a) larva or wriggler, of Culicine mosquito; (b) larva of the Anopheline or malaria bearing mosquito.

a decided angle, with only one portion (the anal siphon) touching the surface film, while in *Anophelinæ* the larvæ lie horizontal, with at least several body segments coming dorsally

in contact with the film (Fig. 19). At the points of contact will be seen prominent fan-shaped hairs. The eighth abdominal segment in both groups is provided with a specialized organ through which the trachea (breathing organs) come in contact with the outer air. In the *Culicinæ* this apparatus is prolonged into a definite breathing tube (siphon), while in the *Anophelinæ* this tube is absent, or only slightly protuberant, and not chitinous, as in the *Culicinæ*.

The movements of Anopheline larvæ are very much more jerky than the Culicine, the wriggling motion of the latter being wormlike. The former are also not so easily seen as the latter, probably due to their horizontal position in the water. On wading into a swamp there may be no larvæ visible, but on turning around and looking into the muddy water caused by wading, the larvæ are plainly seen, *i.e.* distinctly outlined against the now yellowish background.

A close examination of the feeding Anopheline larvæ will show that the head is turned dorsally and the smaller organisms (animal and vegetable) near the surface form the main objects of diet. The Culicine larvæ usually feed on organisms deeper down and in the edges of the pools, after going down in search of these objects.

The Pupæ. — The pupæ, or nymphs (Fig. 20, *c*), of all mosquitoes are very similar. In all cases, instead of the single posterior breathing apparatus of the larva, there are present a pair of breathing *trumpets* located on the thorax, *i.e.* anteriorly. The position of these trumpets in the two groups of mosquitoes is different and fairly distinctive, *i.e.* they are located farther forward on the thorax in Anophelinæ, near the middle, and open broadly in this group, being more slender and relatively longer in the Culicinæ.

In position also the two groups differ somewhat, *i.e.* the Anopheline pupæ hang more horizontally and the heavier head end is relatively longer.

Life History. — As in all other mosquitoes and insects in general, the life history (Fig. 20) depends greatly upon temperature and moisture. In early spring and late autumn the development is retarded, owing to the lower average temperature. Again, if not sufficient moisture is present, the eggs will not hatch readily.

In midsummer the egg stage is rarely longer than

FIG. 20. Showing the life history of the malaria mosquito (*Anopheles*). (a) egg (after Howard); (b) larva or wriggler; (c) pupa or tumbler; (d) adult mosquito. Time required from egg to the adult is about twelve days in midsummer.

twenty-four hours' and often nearer twelve hours' duration. The larva emerges by pushing the cap from the egg, and begins its existence in the water, usually clinging close to débris or scum. The larval stage is most easily affected by temperature changes, but lasts usually from twelve to fifteen days, during which period the skin is shed several times. The change into the nymphal or pupal stage is undergone very rapidly and usually occurs overnight; often great numbers undergo this change in the early part of the

night between nine o'clock and midnight. This stage is comparatively short, seldom lasting over thirty-six hours. At the end of this time the pupal skin bursts longitudinally along the dorsal side, the pupa in the meantime having straightened out. In a few minutes the adult has pulled itself out of the old skin, and quietly balancing itself remains on top of its cast skin until its wings are sufficiently dry to permit it to fly off to a near-by resting-place.

It can thus be seen that the process of emerging requires a very quiet body of water; otherwise the mosquito would be submerged and perish.

Duration of Adult Life. — As a rule, the newly emerged females will suck blood after about twenty-four hours. Numerous experiments tried on the male mosquito, as well as extensive field observations, seem to give conclusive evidence that these individuals do not possess the blood-sucking habit and live exclusively on the juices of plants and "plain" water. However well one may care for the males, they usually die within two or three days; exceptional individuals may live seven or eight days, and it is quite probable that very little nourishment is taken, as a rule, during this time.

In captivity the mosquito mortality is very high and it is not a satisfactory plan to estimate the average length of life on the basis of laboratory observations. Basing an estimate on the relative abundance of *Anopheline* mosquitoes in a given district after careful con-

trol measures are inaugurated, it seems safe to say that the average life of the adult female mosquito is between thirty and forty days, perhaps nearer thirty. This does not, of course, refer to hibernation.

FIG. 21. A typical *Anopheles* breeding place. The water is shallow and clear. The Inspector ready to oil the surface. Such pools can usually be drained.

Flight. — A very common observation is that the Anopheline mosquitoes are not as strong fliers as most Culicine species. If Anophelines are found, one can rest assured that their breeding place is somewhere very near, usually within two hundred yards.

Unlike certain other species of mosquitoes, notably

salt-marsh mosquitoes, the *Anopheles* are not readily carried by the wind, inasmuch as they cling to vegetation as soon as a moderate breeze begins to blow.

If the breeding place of these insects is connected with human habitations by means of low herbage at

FIG. 22. Receding streams leave pools of standing water along the banks, in which mosquitoes breed plentifully.

close intervals, this will afford a ready means of advance. On the other hand it seems that a belt of trees tends to act as a barrier.

Hibernation. — The writer has been bitten by *Anopheles* mosquitoes as early as February 12, and at noonday at that, and many have been reported as early as February 2d and 3d. A specimen was caught

actively flying about in a church on the 1st of January. Since all breeding had ceased in late October, it must be assumed that these were hibernated individuals that had been induced to leave their shelters, owing to the appearance of balmy days between the

FIG. 23. A prospecting hole, — often a convenient breeding place for mosquitoes.

heavy California rains. In the colder Eastern states there are seldom days in winter during which it is balmy enough to induce mosquitoes to come forth from their places of hibernation.

The first cases mentioned are normal responses to the usually early spring days in California, when breed-

ing begins correspondingly early. On February 11th *Anopheles* mosquitoes were seen emerging in numbers from under a schoolhouse which had afforded a safe hiding place against the rains, which place had probably been sought early in November.

The above and other observations give evidence that the *Anopheles* mosquitoes which have been in hibernation on coming out of their shelters are active for a

FIG. 24. Tin cans, tubs, and barrels in which water may stand. Other places in which mosquitoes breed.

few days even by daylight (noonday) and bite fiercely during that time. In a few days, apparently, the insects revert to their normal habit, *i.e.* flying and biting at night only, although both *Anopheline* and *Culicine* mosquitoes will bite in shady places during the day if given the opportunity.

Breeding Places for *Anopheles*. — Unquestionably the most attractive situations for *Anopheline* mosquitoes to breed in are marshy meadows (pasture land), where the water is just shallow enough to allow grass and other low herbage to protrude above the surface (Fig.

21). Such conditions are commonly produced along smaller creeks flowing sluggishly through meadows, or by lateral seepage from irrigation ditches. Often land that is soaked without actually forming open pools is made to produce many mosquitoes through the hoof prints of cattle and horses, *i.e.* these animals leave indentations behind which fill in with water, and proper conditions for mosquito breeding are produced.

Receding streams frequently leave chains of pools, rich in algæ, along the edges, especially if city wastes are involved; in these pools the

FIG. 25. *Anopheles* (malaria bearing) mosquitoes were found breeding in stagnant water in the gutters of a main thoroughfare.

Anopheles wrigglers are usually found in great abundance (Fig. 22).

As a rule, the least suspected places (as far as the average person is concerned) are the most dangerous. Large open ponds and larger streams are not, as a rule, directly concerned, though each individual case needs careful inspection before allowing it to pass. Such seemingly small matters as a little spring in a pasture, a hoof print, a leaky faucet, a bad kitchen drain, waste water from a laundry, notwithstanding its soap and lye content, a leaky irrigation ditch, — these are the greater nuisances that the inspector has to meet. Prospecting holes (Fig. 23), tin cans, water barrels, tubs, etc. (Fig. 24) must not be overlooked. Very often the water in the street gutters (Fig. 25) is a prolific source of *Anopheles* mosquitoes, notwithstanding other observations to the contrary.

ESSENTIALS OF CONTROL

THE essentials of control are indicated very clearly by the study of the life history (development) and habits of the mosquito, and rest on the application of two general methods; namely, temporary and permanent. Temporary control consists in oiling the breeding places or adding a poison, such as nicotine, Phinotas oil, or salt (in the case of fresh-water species) to the water. Manifestly this method requires constant repetition, but is extremely useful and really essential during the time that the permanent work is being advanced.

For the control of mosquitoes, especially the *Anophles*, the best method by all odds is drainage, improvement of irrigation methods, cutting deeper channels where the water spreads, etc. Thirty minutes' labor in cutting a ditch deeper, or digging a new one for a short distance, has very often absolutely eliminated a nuisance that has bred malaria mosquitoes season after season. It is highly important that control efforts should be systematic and thorough. Haphazard, slipshod work only results in dissatisfaction and new crops of mosquitoes.

OILING METHODS

Kinds of Oil. — Oil forms a perfect film over the surface of the water, which prevents the mosquito larvæ and pupæ from breathing and thus results in suffocation. The most desirable oil for the purpose is one that will spread most readily without breaking up into patches and that will remain on the water in an effective condition. Crude oil breaks up in patches between which the water is not affected, so that the *wrigglers* have been found by the writer developing in such places where this oil has been liberally used. Crude oil, furthermore, cannot be used as such in ordinary spray pumps. Therefore this material is not to be recommended in this form for mosquito control. Its lasting qualities are very good, however. Kerosene spreads most satisfactorily and does its work quickly, but evaporates in a comparatively short time, thus requiring frequent repetition. A combination can very well be made of the two which will bring about more nearly the desired results. Our best results have been obtained with a mixture of equal parts of crude oil and kerosene, though the proportion may perhaps safely range to three parts of the former to one of the latter. We have also used successfully a treated stove oil of about 32° Beaumé gravity.

Oil purchased on the market as “crude oil” varies

from 12° to 18° Beaumé, while “stove distillate” varies from 28° to 32°, and water-white kerosene from 40° to 42°. Knowing the specific gravity of the oil purchased, it can easily be calculated how to mix with lighter or heavier oil in order to obtain the required consistency. Thus if kerosene (42°) is at hand and crude oil (15°), use about ten gallons of the former to twelve gallons of the latter. For spring and autumn use 28°–30° Beaumé is to be recommended, while for summer use a heavier oil at about 26° is preferable.

How Applied. — Simply pouring on the oil with a dipper is wasteful and requires some little time if all the smaller adjacent pools of water to a given central area are to be treated. Experience has taught that the small, apparently insignificant, pools of water are in reality the greatest menace and are commonly overlooked. The use of a knapsack spray pump (Figs. 21 and 26) of five-gallon capacity is highly recommended. This can be strapped on the back and will provide enough oil for three or four hours of ordinary oiling on foot. Where it is out of the question to use a horse and cart to carry the oil, the field man can save himself many steps and some embarrassment if he will make it a habit to carry a small quantity of oil with him at all times in a pint or quart tin to which is attached a rubber bulb and a spray spout.

The inspector usually devotes a day or two to inspection and follows this with an entire day of oiling and he may then need to use a good many gallons of

oil in a few hours. A good-sized wad of cotton waste soaked in oil and placed in a pool of stagnant water

FIG. 26. Field Agent in working "togs." Showing use of knapsack spray pump.

will continue to give off oil for some time and is often very serviceable.

When Applied and How Often. — Oil should be applied whenever and wherever the *wrigglers* or *tumblers* are found, even though permanent correction is planned. This will prevent them from being washed out into some other situation where they would be liable to complete their transformation. The frequency with which oil must be applied depends on the rate of development of the *wrigglers* and the evaporation of the oil, — both conditions being dependent on the temperature. Therefore, more frequent applications are necessary during midsummer, when with the oil mentioned above, spraying should be repeated at least every twelve days, and under cooler conditions (averaging 50° to 60° F.) every three weeks. If it requires only ten days for some mosquitoes to pass through their entire transformation, one might think that applications of oil every twelve days would not be often enough, but it must be remembered that the oil kills all wrigglers and tumblers at the time of contact and the film remains on the water for two or three days, sometimes longer, during which time any adult mosquito, intending to lay eggs, is killed on coming in contact with the oil. After the oil has evaporated quite largely, the breeding may begin again, but the next application of oil will catch the oncoming brood before the ten days necessary for complete development have expired.

Certain conditions are unfavorable to the effective use of oil, such as abundant vegetation, e.g. tule and

algæ or soap and alkali in the water. This can be remedied by the addition of copper sulphate previous to oiling.

Tobacco Decoctions. — The writer has thoroughly tested the efficiency of tobacco decoction, both in the laboratory and in the field, and has found it very effective, but the expense is prohibitive when used on a large scale. Sulphate of nicotine (black leaf 40), made by the Kentucky Tobacco Product Company, was found to effectively destroy all wigglers and tumblers when used in the ratio of 1 part to 750 parts of water. Greater dilution proved uncertain for the pupæ, but 1 to 1000 is still effective for the larvæ. In field work this material was used for smaller pools and experimentally on a good-sized quarry hole pond effectively, but proved too expensive. Ordinary "black leaf" tobacco decoction cannot be used successfully in a greater dilution than 1 part to 20 of water. It must be remembered in all cases that a material in weaker strengths would be just as useful and less expensive, provided it killed the insect, even after a day or two, and this factor was borne in mind during the progress of experimentation.

Larvicide. — A larvicide generally used in the Panama Canal Zone is prepared from crude carbolic acid. Its manufacture and method of application are fully described in an article by G. T. Darling in the *American Journal of Public Health* for February, 1912. From this the following is quoted:—

“One hundred and fifty gallons of crude carbolic acid are heated in an iron tank having a steam coil with steam at 50 pounds pressure. Two hundred pounds of finely crushed and sifted common rosin are dissolved in the heated acid and then 30 pounds of caustic soda dissolved in six gallons of water are added. There is a mechanical stirring rod attached to the tank. The product is ready in a few minutes, yielding about $3\frac{1}{2}$ barrels. . . . As a mosquito larvicide it is used by spraying an aqueous emulsion (one part of larvicide to five of water) over the surface and along the margin of pools and ponds or other mosquito-breeding places so that the resulting dilution of the larvicide has a thin, milky opalescence representing approximately a dilution of 1 to 5000.”

NATURAL ENEMIES

ONE often hears others say that there is a natural "balance" in nature which should not be disturbed, and this argument is frequently advanced against the efforts of those engaged in mosquito control. It may be balm to such individuals to know that mosquitoes have also their natural enemies, if man can indeed be considered an unnatural enemy.

Among the less efficient enemies, owing to small numbers, are the dragon flies (Odonata), or mosquito hawks, also called "snake doctors" and "devil's darning needles." These insects may be seen in the evening darting hither and thither capturing mosquitoes and midges on the wing.

The more effective enemies are found among the surface-feeding fishes, which are practically all of small size. Unfortunately, where mosquito larvæ are found there are also abundant other aquatic insects, so that the stock of fish must be correspondingly large in order to hold in check the insects aimed at. In such places where it is desirable to apply oil and the water is not too shallow throughout its entire extent fishes may play an important rôle; indeed the same thing may hold true in bodies of water where it is possible to apply oil. It can readily be seen that to transplant fish into anything but permanent bodies of water would be very poor policy. Ornamental

ponds, reservoirs, springs, cisterns, tanks, and the like are among the instances in which surface-feeding minnows may be found useful.

The common goldfish (*Carassius auratus*) is at the same time one of the most ornamental as well as efficient fishes in this respect. The following quotation is apropos taken from Howard, after Underwood, referring to an ornamental aquatic garden near Boston, in which the mosquitoes were kept in check by goldfish: "I took from the pond a small goldfish about three inches long and placed it in an aquarium where it could, if it would, feed upon mosquito larvæ and still be under careful observation. . . . In the first day, owing perhaps to being rather easily disturbed in its new quarters, this goldfish ate eleven larvæ only in three hours, but the next day twenty-three were devoured in one hour; and as the fish became more at home the 'wrigglers' disappeared in short order whenever they were dropped into the water. On one occasion twenty were eaten in one minute, and forty-eight within five minutes. This experiment was frequently repeated and to see if this partiality for insect food was characteristic of those goldfish only which were indigenous to this locality experimented with, some said to have been reared in carp ponds near Baltimore, Maryland, were secured. The result was the same. . . ." Similar results have been attained in a number of places both on the Atlantic and Pacific coasts.

One of the most valuable articles touching the control of mosquitoes by fish is that of Seal¹ for the *Scientific American*, in which he makes the following statements : "The goldfish is somewhat lethargic in habit, and is also omnivorous, but there is no doubt that it will devour any mosquito larvæ that may come in its way or that may attract its attention. The one great objection is that they grow too large, and the larger will eat the smaller of them." The same observer concludes that "a combination of the goldfish, roach, and top minnows would probably prove to be more generally effective in preventing mosquito breeding than any other." The top minnows mentioned are *Gambusia affinis* and *Heterandria formosa*. In those bodies of water kept free from mosquito larvæ in California, Mr. McGregor has observed that the following three species are primarily concerned, viz. the Sacramento chub, *Leuciscus crassicauda*; the Sacramento pike, *Ptychocheilus grandis*; and the Shiner, *Lavinia exilicauda*. The Barbados "Millions" (*Cyprinodon dispar*) has been found useful as a mosquito destroyer in that country and elsewhere.

In salt marshes the tiny killifishes (*Fundulus*) should be given every opportunity to reach all parts of the marsh. Where found they are, as a rule, very abundant and are efficient as destroyers of mosquito larvæ.

¹ Seal, William P., 1908 (May 30). *Scien. Amer. Suppl.* Vol. 65, No. 1691, pp. 351-352.

PERMANENT CORRECTIONS

IF a useless pond of water can be drained easily, which is often the case, it is a foolish waste of time, energy, and money to repeatedly oil it. Marshy land, otherwise useless for agricultural purposes, can in most

FIG. 27. A big pond alongside the railroad caused by obstructing the natural drainage. This was a source of many mosquitoes every year. The Field Agent is oiling the pond. A source of constant danger, requiring repeated expenditure of time, labor, and money until permanently corrected.

cases be made useful and also free from mosquitoes by digging a ditch of necessary depth with connecting laterals. The dry summers of California, for example, favor permanent corrective work, because areas from which standing water is drained off at the termination of the rains in spring will remain dry for the rest of the

summer. The Southern Pacific Railroad Company responded readily to requests made for the correction of drainage along the right of way in lower Placer County, deeming it wiser to expend a larger sum for

FIG. 28. A permanent correction. No longer a prolific source of mosquitoes. Same spot as seen in Fig. 27.

this permanent work than to apply oil, although this was done in some places (Figs. 27, 28). The writer mentions the fact because the wisdom of this procedure is recognized by large corporations.

IRRIGATION

It is quite commonly asserted that malaria makes its appearance together with irrigation. This is evidently true, but it need not be so if proper attention

FIG. 29. Breaks in the irrigation ditch are responsible for considerable inundation, producing favorable breeding places for *Anopheles* mosquitoes. The rapidly running water in the ditch is unfavorable for mosquitoes.

were paid to the best methods of irrigation. Certainly southern California is necessarily the scene of much irrigation, yet malaria is virtually unknown, so

it cannot be irrigation as such. The matter simply resolves itself to relative abundance of water; where this is abundant, it is used unsparingly and without regard to leaky ditches (Fig. 29) and great waste, thus forming the ideal swamp areas (Fig. 30) for the propagation of the *Anopheles* mosquito. On the other

FIG. 30. Showing the results of a "leaky" irrigation ditch. Field Agent placing flag in position to mark place where *Anopheles* mosquito larvæ were found.

hand, where there is little rainfall and water is expensive, with greater evaporation throughout the year, the water is husbanded, with the result that leaky ditches, and consequent swamps, are practically unknown, and therefore the *Anopheles* mosquito has not obtained a foothold.

The farmers of northern California in general must pay more attention to the improvement of their irrigation methods. In irrigating, the water should not

be allowed to remain in pools for long periods, say not over several days. Water which has stood ten days or over is dangerous. The use of metal, cement, or tile irrigation ditches, which prevent lateral flow except where wanted, will greatly help in lessening the vast number of mosquitoes now produced in or by poorly

FIG. 31. Showing overflow or drain ditch ordered dug to prevent large standing pools. The pool in the foreground was due to drainage water from irrigation.

kept ditches. The running water in the ditches need not be feared, — mosquitoes do not breed in running water. The current in ditches with little slope may be sluggish and further retarded by weeds, and under such conditions mosquitoes may breed. The ditch must be kept free from weeds and the edges should be smooth. It is suggested that borrow pits in the construction of ditches should be at some distance from the ditch and from higher ground if possible; otherwise they may fill with seepage water and breed mosquitoes.

SUMMER RESORTS

AN ideal summer resort is one in which mosquitoes do not take a prominent part. The *Anopheles* may not have to be contended with in all parts, but the *Culicine* species are found more or less abundantly everywhere unless measures are taken to control them, and some of our summer resorts are far from ideal in this respect. Imagine the comfort on a fine summer evening under otherwise favorable circumstances, when it is possible to sit on the veranda without having to fight mosquitoes all the time. The ease with which these pests can be controlled and the advertisement that a mosquito-free resort deservedly secures should set managers working in this direction.

MEASURES USEFUL IN COMBATING ADULT MOSQUITOES

Screening. — Far too little attention has been paid to the proper screening of sleeping apartments. The time will come, no doubt, when screens will no longer be needed against intruding mosquitoes and flies, — indeed that day has already dawned for a few (a very few) thoroughly enlightened communities which have discovered that these noxious creatures can be controlled with proper care.

Against mosquitoes nothing larger than the best one-millimeter mesh screen should be used, because the mosquito is persistent and will work its way through a large mesh. In malaria-ridden districts it is time well spent to hunt down and destroy all mosquitoes that may have secured entrance despite the screens. It is furthermore wise to carefully screen in all malaria cases so that *Anopheles* mosquitoes cannot become infected through the blood of such patients.

For campers, prospectors, soldiers, and others required to sleep out of doors special folding frames covered with mosquito netting can be secured. These are light and can be folded to convenient size for portage when not in use.

Cisterns, fire buckets, and other water receptacles need to be kept properly screened or securely covered.

Repellents. — Night laborers, watchmen, pickets, and others compelled to be on duty at night are, of course, exposed to the bites of mosquitoes and should exercise some precaution at least against these pests. Repellents of several kinds have been used with more or less success. The writer has found oil of citronella to be one of the most reliable deterrents when simply rubbed on the hands and face, a dozen drops or thereabouts being placed in the hollow of the palm and thus applied.

To this oil may be added various other ingredients; for example, Howard has found the following mixture most effective, viz.: 1 ounce of citronella, 1 ounce spirits of camphor, and $\frac{1}{2}$ ounce oil of cedar. This Howard found very satisfactory against *Culex pipiens* by applying a few drops on a bath towel hung on the head of the bed. He, however, adds that it is not effective against the yellow fever mosquito, which begins biting at daybreak when the oil has lost most of its strength.

Other deterrents used and recommended by various authors are a mixture of castor oil, alcohol, and oil of lavender, equal parts; or a few drops of peppermint or pennyroyal, oil of tar, oil of cassia, or simply pure kerosene.

Repellent Plants. — Much has been written about deterrent trees and plants, but few if any have stood the test of accurate observation. The writer's own

experience, together with that of other observers, does not credit the castor-oil plant nor the Eucalyptus tree with deterrent properties; the same seems to hold true of the chinaberry tree.

Fumigants. — Knowing that mosquitoes often hibernate in great swarms in basements of buildings and other favorable situations, it becomes necessary to destroy them in order to prevent them from propagating in the spring of the year. A number of very satisfactory fumigating agents may be mentioned, such as pyrethrum powder, sulphur dioxide, “jimson” weed, and pyrofume (a turpentine by-product).

Mosquito Bites. — Mosquito bites, while perhaps never serious in themselves, may lead to blood poisoning through scratching with the finger nails in the attempt to relieve the irritation, often intense. To relieve this irritation any one of the following may be applied, viz.: ammonia, glycerine, alcohol, or iodine, and according to Howard the most satisfactory remedy known to him is the application of moist toilet soap. The latter also mentions touching the puncture with a lump of indigo as affording instant relief, as also touching the parts with naphthaline moth balls.

THE EDUCATIONAL FACTOR

GIVING the answer to the questions Why and How is the part the educator must play in the science of applied hygiene. If once the people of a town or village

FIG. 32. The entire school turns out when the Field Agent comes to give a lesson in mosquito control.

catch the vision of better things, and are taught how to realize these things, the problem is largely solved, for there will surely be some who will put the matter to the test.

To help answer these questions at least one lecture, well illustrated by means of charts and other material, should be given at the beginning of each campaign. This we generally follow up with brief newspaper articles, for the press is one of the greatest educational

FIG. 33. School children taking lessons in practical hygiene. Searching for mosquito wigglers in pools near the schoolhouse.

factors in America. Show-window displays in which the properly labeled living insects are exhibited as they pass through their various stages of development are effective. The action of the oil can be thus also nicely illustrated. The interest that this sort of display arouses is immense and few merchants hesitate to

FIG. 34. School boys locating myriads of mosquito wrigglers in boats partly filled with water.

allow at least a part of their windows to be so used.

A laboratory may or may not be established in which the more scientific phases of the subject are illustrated by means of the microscope and

other apparatus. The writer has found such a laboratory very valuable, since it gives the inspector an

FIG. 35. School children searching for mosquito wrigglers in an old dredger pond.

added impetus and adds to his efficiency in the field. Here the more detailed habits of the individual insect can be observed.

One of the most important factors in our work is that accomplished with and through the school children. The school children are visited in the classroom and the story of the mosquito wriggler is told, — how the mosquito carries disease and how to prevent it. Demonstrations with the living wrigglers can easily be made. Interesting essays are then written by the children and the best may be published in the local paper, all of which stimulates interest and gives the

FIG. 36. Mosquito pin used as a reward of merit. School children were given a pin when some small service was rendered.

children a grasp on practical subjects. The lessons (Figs. 32, 33, 34, 35) learned at this time will be applied at once, and a generation of citizens is reared with some knowledge of practical hygiene.

The use of a mosquito pin or button (Fig. 36) has resulted in much good. On answering some simple question on mosquitoes correctly, or after putting oil on a pool of water, the child receives such a pin from the inspector as a reward of merit.

Essays by School Children. — An interesting feature

of the educational work has been the instruction given in the schools. The interest taken in this work is evidenced by a large number of essays on the subject that have been written by the pupils beginning with the third grade. All of the essays show an understanding not only of the work, but of the importance of exterminating the mosquito. Several of these are given below. The reader must bear in mind that the essays are written by children and are here given only to show the interest taken in the work.

HOW THE CHILDREN CAN HELP

(By a Fifth-grade Pupil)

You can help your city with the mosquitoes. To do this do not be careless by leaving anything that will hold water. To prevent mosquitoes from laying eggs do any one of the things I have written here.

1. By turning buckets over so the rain cannot fill them with water.
2. By putting oil or lard into the bucket.
3. By putting holes into the bucket so that the water will run out.
4. By covering it over so that the mosquito cannot get in and lay her eggs.

If you put lard or oil into the bucket it rises to the top and the wrigglers that are in it cannot breathe. From the egg to the "Wiggler" takes about twenty-four hours. It takes ten days for the wriggler to become a mosquito. A mosquito lives about thirty-five days, but sometimes they make a home in damp places and sleep all winter, and they come out in later winter or early spring. When they are wrigglers they have tubes to breathe through, but when they are "tumblers" they breathe through trum-

pets. All this time the mosquito is preparing to bite us, but it is inside of the "tumbler." When the tumbler bursts open the mosquito comes out, but as soon as he comes out he has to make use of his wings, and if he doesn't, the "tumbler's skin" begins to float on the water and knocks the mosquito over and it falls into the water and gets drowned and that's why he has to use his wings.

THE MOSQUITO AND THE LITTLE POND

(By a Fourth-grade Pupil)

In a pond there were some little eggs. In a few days there could be seen a little creature wiggling around. It was little Miss Wiggler. She lived down there in the pond very happy, going ever so often up to the surface to get fresh air, till one day she became a little tumbler. She tumbled and played, going every once in a while up to the surface to get some fresh air, till one day her skin split open and a perfect mosquito came flying through the air ready to bite whomever she got a chance. This mosquito lived about thirty-five days. She laid eggs four times in her life. She laid about one hundred eggs each time.

THE LIFE OF THE MOSQUITO

(By a Third-grade Pupil)

I am going to tell you about the life of a mosquito. It lays its eggs on the edge of the water. Some lay one at a time and others lay them in bunches. A bunch of eggs is called an egg boat. It lays several hundred in all. It takes about one day for the egg to hatch into the larva. The larva has but one breathing tube. Next comes the pupa. It has two breathing trumpets. It is large at the head and then it grows small. The pupa splits across the head and then it turns upside down and out comes the mosquito.

Do you know how little boys and girls can help to kill the

mosquitoes? They can turn up all the old cans and break them up and put up a little flag. If your mamma has a barrel with some rain water in it that she wants to keep, how are you going to keep the mosquitoes from hatching? I would cover it up, of course. That is a good way to keep from getting sick.

EXAMINATION FOR MALARIA

PHYSICIANS are coming to recognize more and more the importance of blood examinations to determine the presence of the malaria parasite. This is important because it gives the basis for proper treatment. Other diseases often have similar symptoms and do not respond, of course, to the treatment given when the disease has been improperly diagnosed.

To examine the blood for malaria parasites a drop is taken from the lobe of the ear or the finger tip, placed on a glass slide, and a smear preparation made. These "smears" are then properly stained, to differentiate the parasite from the red blood corpuscles. (See also page 10.) The California State Board of Health has established laboratories at Berkeley and branches at Fresno and elsewhere for the determination of disease in blood specimens, sputum, etc. It is highly desirable that the physicians of the state make use of the facilities thus afforded for the determination of malaria.

INTERNAL MEDICINES

OWING to the fact that there are relapses in malaria without the necessity of reinoculation by the mosquito, makes it imperative that a systematic treatment for malaria should parallel the preventive measures. In this way the disease can be stamped out in a much shorter time. The spring relapses can be prevented in large measure by the systematic and intelligent use of internal medicine during the winter months. This does not mean, of course, that the individual must take quinine incessantly—indeed that may frustrate the eventual cure.

THE COMMUNITY CRUSADE IN CALIFORNIA

THUS far there have been established five organized malaria crusades in the state, two in Placer County (Penryn and Roseville), one in Butte County (Oroville), one in Tehama County (Los Molinos), and one in Kern County (Bakersfield). These crusades, owing to their distribution, have given a good opportunity to study the characteristic local conditions in widely separated parts of the state and under greatly differing topographical conditions.

Leading up to the organization of a special crusade against the malaria mosquito, a number of lectures were delivered by the writer on the subject of "Insects as Disease Carriers (Medical Entomology)." These lectures were materially strengthened by an exhibit illustrative of this subject on board the Demonstration Train. Apparently considerable interest was manifested, but it was not until December, 1909, that any visible results were secured. From a letter written by Mr. Fred E. Morgan of Penryn, Placer County, California, dated December 22, 1909, the following is quoted: "We, here in the Placer foothill region, want to fight the malaria mosquito, but do not know just how to proceed. . . . Can we not expect some aid in this . . .?" This letter was answered

by the writer, the following being an extract from his reply :—

A campaign such as you wish to undertake should begin as an educational movement in the form of lectures and demonstrations. This can be done while the ground is being carefully covered and points of attack marked. I recommend that at first a vigorous campaign be made in some restricted, isolated area where *Anopheles* mosquitoes and malaria have been extremely bad, in order to demonstrate beyond question the practicability of the plan.

During January and early February, 1910, lectures on "Mosquitoes and Malaria" were delivered at Loomis, Penryn, Auburn, Newcastle, and Roseville, all in Placer County, and on February 12, 1910, a permanent "anti-malaria-mosquito organization" was effected in the office of the Penryn Fruit Company. At that time about a dozen representative men gathered, elected Mr. H. E. Butler of Penryn as the permanent Chairman of the organization with W. E. Eckles, Secretary, and J. R. Huffaker, Treasurer.

To assume the responsibility for such an undertaking is not a small matter in the face of adverse criticism and the task of securing financial support. Earlier in the history of this undertaking the work was loudly denounced by certain boosters and certain newspaper editors as being the wrong kind of advertising. Although nearly all knew that malaria was prevalent in a given district, these individuals cried out that there was nothing of the kind nor ever had

been. Not very long after the work had been in progress, the matter was seen in a different light, and it was agreed that the best kind of advertising was the fact that malaria was being combated with vigor. It is now wisely said that "An open policy of education, with evidence of active work toward the eradication of a disease, immediately engenders confidence. Investors say, 'Here is a community that has waked up and is going ahead. They've got the country and the resources. Its future looks good to me. I'll buy.'"

Thus was launched what will pretty surely be considered one of the pioneer civic movements against malaria specifically, and undoubtedly the first of its kind in the state.

In a recent publication Dr. L. O. Howard laments the fact that there are so few mosquito campaigns that are directed primarily against the *Anopheles* (malaria-bearing) mosquitoes. "In the United States, it is sad to relate, almost nothing has been done in the way of an active campaign against malaria alone, even in the restricted localities. It is true that extensive work has been done against mosquitoes, but in the most of these cases the incentive does not seem to have been to better the health of the people nor to stamp out the malaria." Unfortunately, Dr. Howard was for some reason not informed of California's leading rôle in this respect. In a conversation with the writer on his recent visit to this state, he (Dr. Howard)

said this oversight was a matter which he regretted extremely.

The following report indicates the plan of organization in the Penryn crusade :—

Report of H. E. Butler, Chairman of Executive Committee, Penryn Anti-malaria-mosquito Crusade. December, 1910.

Recognizing malaria as the chief drawback to the rapid development of our section, and to the happiness and prosperity of its residents, an investigation of its causes and control was undertaken, commencing in December, 1909.

Mr. Fred E. Morgan of Berkeley, a former property owner and former resident of Penryn, with the undersigned, met at Penryn to discuss the matter, and directed a communication to the Entomological Department of the University of California, setting forth at considerable length the facts in regard to the existence of malaria in the irrigated districts of Placer County. In due course, under date of January 3, 1910, we received a communication from Professor Herms, Assistant Professor in Entomology, commending the idea of taking up a fight against malaria and the malaria mosquito, also offering his assistance.

He recommended a vigorous campaign in some area where mosquitoes have been bad, in order to demonstrate the practicability of control of the disease by the extermination of mosquitoes. He also furnished

us with various bulletins and publications of the University and State Board of Health, bearing on the subject of parasitic diseases. In this same communication Professor Herms set the date of January 5th to meet us at Penryn to arrange details of the campaign. These were promptly made and Professor Herms addressed mass meetings at Loomis, Penryn, Newcastle, and Auburn during January and February, 1910, on malaria and its control.

At each of these meetings committees were appointed to meet at Penryn, as a joint executive committee, to make definite arrangements for the prosecution of a crusade to control malaria by the extermination of the malaria mosquito. On February 12, 1910, this joint committee met at Penryn and organized by election of the following officers: H. E. Butler, Chairman; W. E. Eckles, Secretary; James R. Huffaker, Treasurer.

Following is a list of those present at this initial meeting: Professor W. B. Herms of the University of California, Dr. G. H. Fay, Health Officer of Placer County, James H. Breslin, Health Officer of Auburn, H. E. Butler, J. Huffaker, H. A. Snelling, George H. Fisher of Penryn, Robert Jones, Louis Ames, and P. F. Lynn of Newcastle. The Loomis Committee was unavoidably absent.

At this meeting telegrams and letters were read from Professor E. J. Wickson, Dean of the College of Agriculture, University of California, Dr. W. F. Snow,

Secretary State Board of Health, and Wallace A. Briggs, M.D., of Sacramento, emphasizing the fact that malaria is a disease transmitted to the human race only by the bite of the mosquito. They also congratulated the district on its inauguration of the campaign.

It was decided at this meeting to make the campaign within a district extending from Newcastle on the east and Loomis on the west, including those districts and Penryn.

A room offered by the Penryn Fruit Company was accepted as permanent headquarters, and later this was fitted up with all necessary paraphernalia.

Arrangements for raising funds by popular subscription were made and an agreement entered into with Professor Herms whereby he was to direct the campaign and be furnished field assistants and material. The actual work of the campaign commenced March 1st. Prior to this time Newcastle district withdrew from the campaign, Loomis district continued until the 2d of May, then withdrew, but Penryn district maintained and carried on the campaign actively, with a competent field man and under the direction of Professor Herms until December 1, 1910.

In the campaign of the past season we have been aided very materially by the State Board of Health, by the Southern Pacific Company, who drained off and cleaned up its right of way through the district, by the Sacramento newspapers and the County Health

Officials. We also had a donation of Nicotine Sulphate from the Kentucky Tobacco Products Company.

The results of the campaign will be fully treated in reports of Professor Herms and Field Agents who carried on the actual work during the season.

Appended hereto is a report of the expenses of the campaign.

While the campaign was not enthusiastically supported in the district at first, before the season had progressed far, much interest was manifested and at the close of the year sentiment in the Penryn district seems to be very strongly in favor of continuing, and on broader lines, such as the formation of a sanitary district, and coöperation of adjoining sections and of the County Board of Supervisors.

H. E. BUTLER,
Chairman Executive Committee
Anti-malaria-mosquito Campaign.

PENRYN, December 10, 1910.

When it became known that a malaria mosquito campaign had been inaugurated at Penryn, interest in the movement soon became widespread, and many letters of inquiry were received. At the outset the following letter from Dr. W. A. Briggs of Sacramento was especially encouraging to the citizens of Penryn, as were the telegrams from Dean E. J. Wickson of the College of Agriculture at Berkeley and from State Horticultural Commissioner J. W. Jeffrey.

MY DEAR MR. BUTLER:

Permit me to assure you of my hearty indorsement of your crusade against malaria. Malarial fever is an absolutely preventable disease and is one serious objection to your beautiful country. No stagnant water, no mosquitoes; no mosquitoes, no malaria.

Wishing you and your friends success in this movement, I am

Yours sincerely,

(Signed) W. A. BRIGGS.

PROFESSOR W. B. HERMS, care H. E. BUTLER, Penryn, California.

We indorse most heartily your plan for eradication mosquitoes in Placer County. Will do anything in our power to assist.

(Signed) J. W. JEFFREY.

Each district offered its own specific problems: at Penryn, it was irrigation and mountain streams; at Oroville, dredger ponds, prospecting wells, water pipes, and the Feather River; at Roseville, it was hard pan and level country with poor natural drainage, also lack of sewer system.

The first thing in each case was to make a careful survey of the territory to be protected, in order to determine the nature of the problem; this was usually done with persons of influence concerned in the respective communities. Next a field agent or inspector was secured who was taken over the ground and put in charge. House-to-house work was done to secure intelligent coöperation, public lectures were given, the school children listened to talks and saw demonstrations, exhibits were placed in store windows, newspapers were provided with material on the subject, etc. At the same time proper corrections were made in irrigation, pools were oiled, etc.

THE PENRYN CRUSADE

THE following report by Field Agent Gray gives us a more detailed account of a specific crusade; namely, the Penryn Crusade.

Report of Field Agent Harold F. Gray

Penryn, Placer County, is located in the foothills of the Sierra Nevadas, on the main overland route of the Southern Pacific Railroad, at an elevation of about 650 feet. The country is rolling, the climate mild, the soil deep and fertile, water is cheap and abundant, and conditions are naturally such that fruit growing, the principal industry of the region, should be highly profitable, and should support many small orchards.

With the introduction of irrigation in the 70's, malaria appeared and soon became endemic. A region which had previously been perfectly healthy became thoroughly infected with this curse, and gradually the original owners moved away, and either leased or sold their land. When sold, the orchards gradually passed into the hands of large holders who did not work the land themselves, but leased. Finally, the last and worst stage was reached when the Caucasian lessees were replaced mainly by Orientals, who entered the region in 1895 and 1896.

In December, 1909, a few public-spirited citizens of Penryn, learning that malaria is a disease which can be eradicated or largely controlled by proper measures, got together, organized a campaign, and called in the assistance of the scientists of the University of California. William B. Herms, Assistant Professor of Entomology in the College of Agriculture at the University, took the campaign under his personal supervision, and its success is largely due to his ability and energy.

The work done at Penryn is especially worthy of note because of the fact that it is the first of its kind in the state, and is typical of the gradual awakening of the public to the facts of the recent marvelous increase in our knowledge of the control and prevention of disease. While many other communities in the central region of California either are indifferent to the presence of malaria, or deny its existence for fear of hurting business, Penryn has been the first to look the facts squarely in the face, and then intelligently set about remedying the conditions. Two other communities, Oroville and Bakersfield, followed suit in 1910, and from the inquiries sent to the State Board of Health during the past year it is probable that many more will start campaigns in 1911.

In the following pages will be found a brief description of the campaign, with methods, costs, and other data of interest.

On March 5, 1910, Mr. Herbert Leak, a resident of

Penryn, was employed by the campaign committee of Penryn and Loomis to act as Field Agent. He was to cover the vicinity of Penryn and Loomis, dividing his time equally between the two towns. This plan was adhered to until summer, when the people of Loomis lost interest in the campaign and failed to contribute their share of the funds necessary to carry on the work. The work of the Field Agent was thereafter confined to Penryn.

A survey of the region to be covered was first undertaken under the personal supervision of Professor Herms, and the places where *Anopheles* larvæ were found were marked with small red flags. The Field Agent, when these pools were oiled, replaced the red flags with white ones, and the pools thus marked were kept under observation. After Loomis dropped out of the campaign, the activities of the Field Agent were confined to an area of such size that marking the pools was unnecessary, and as the campaign progressed definite breeding places were recognized, kept constantly under observation, and oiled as often as necessary.

The construction of the Southern Pacific Railroad obstructed the natural drainage in several places, causing standing pools of water, notably those in the center of Penryn. The officials of the company were spoken to in the matter, and at once responded by sending the Roadmaster to Penryn to see Professor Herms. The places referred to were promptly filled

or provided with drainage, according to the conditions. The Southern Pacific officials have extended the same aid to the anti-malaria movement in Oroville, and it has been their policy to make permanent improvements, rather than have a continual expense for temporary measures of control. The work of draining the right of way of the railroad was done in April, and eliminated some of the worst Anopheline pools, in most cases permanently. One marshy place in Penryn which was corrected was not filled deep enough, and in September the overflow from a ditch formed a pool of some size, which promptly began to breed many *Culex* and a few *Anophelines*. It was kept oiled until it dried up in October, and served as a useful object lesson for the school children, to whom two talks on the relation of mosquitoes to malaria were given.

Early in May Loomis began to lose interest in the campaign. A personal canvass by Mr. Leak showed that the people in that town were either hostile or indifferent to the movement, and did not care to help defray their share of the expense. The Field Agent continued work in Loomis until late in July, hoping that when the people saw the good results they would support it.

Mr. Leak resigned as Field Agent on May 14th, and he was succeeded by Mr. Earl Cornell on May 23d. One of the first things undertaken by Mr. Cornell after getting the work well in hand was a house to house

inspection, which brought to light many pails and tubs, especially in Chinatown, breeding mosquitoes, chiefly *Culex*. A short explanation to the white residents will usually stop this condition, but the Orientals are continual offenders in this respect.

One of the most illuminating instances of the effectiveness of the control method used occurred during Mr. Cornell's work, and the following description of the circumstances is taken direct from his notes : "Aug. 5. Investigated the reported case of malaria at Mr. Magnison's place. Found that he had been sick with chills and fever for a week or more, also that there were many mosquitoes around in the evening. On inspecting the premises I found a place in the orchard where a leaky pipe left pools of water standing continually. They contained many *Culex* and *Anopheles* wrigglers and tumblers. Since the place is but one hundred yards from the house, I concluded that it was the source of the trouble. On further investigation I found no other bad places. Mr. Magnison was in the habit of working around this place in the evenings, and so got inoculated. In the afternoon I sprayed and shall have the pipe fixed." On September 16th Mr. Magnison reported that he had had no malaria since.

Mr. Cornell resigned on August 11th, and was succeeded on the same day by Mr. W. H. Davidson. Mr. Davidson continued the work of inspection and oiling, keeping the situation in hand until September 9th, when he resigned. It was unfortunate that he should

have resigned at this time, as it was impossible to get an experienced man for continuous work during the rest of the season, especially so because of the fact that it is usually during September and October that the greatest number of cases of malaria seem to develop, and therefore the greatest vigilance should be exercised at that time.

Mr. Davidson was succeeded by Mr. Harold F. Gray, who arranged to devote two days a week to the campaign, commencing on September 16th. Owing to the small amount of time available, the territory covered was reduced to the immediate vicinity of Penryn, and more time than heretofore was spent on publicity and educational work. Instructions concerning malaria-control methods were posted in prominent places, an endeavor was made where time permitted (and the opportunity) to talk personally to the people; a large number of the July Bulletin of the State Board of Health containing Professor Herms' article on malaria control ("How to control Mosquitoes, with Special Reference to Anopheles") was distributed; and a talk was given to the local school children on the relation of the mosquito to malaria, illustrated by photographs kindly supplied by Professor Herms, and by actual demonstrations of the larvæ in the field. The two varieties (*Culex* and *Anopheles*) were grown under glass jars in the classroom from larvæ to adults. A talk to the school children on the same subject was given by Mr. Leak on May 5th.

A rain on October 10th, 11th, and 12th washed out old pools and was followed by warm weather, which dried up the greater part of the pools. It was therefore unnecessary to do much oiling, and the greater part of the remaining time in October was devoted to getting together the material for this report, and working it up.

The Problem at Penryn.—Previous to the introduction of irrigation water it is certain that malaria was not endemic. The natural drainage is excellent, and the long, warm summers dry up in a very short time any pools left by the spring rains, thus giving the mosquitoes little chance to breed. Whether *Anopheles* were present before irrigation was introduced is not known, but the mosquito has certainly been present since, being imported probably from the valley region. It is easy to conceive of a person with malarial parasites in his blood coming into this region after the introduction of *Anopheles*, and from this person the *Anopheles* mosquitoes becoming infected, and in turn inoculating other persons, the disease then becoming endemic. This can only occur where conditions are favorable to mosquitoes, and implies the presence of standing water during a large portion of the year.

Owing to the good natural drainage and the dry summer weather, the presence of pools and marshes in summer is an unnatural condition, and can be explained only by improper use of irrigation water. Irrigation should always be accompanied by provision

for the removal of excess and seepage, and wherever such provision is not made, standing water will accumulate in the low spots, not only causing unhealthy conditions, but in some cases impairing the value of the land by flooding on the deposit of alkali, as may be seen in the San Joaquin Valley.

Permanent control of malaria in the vicinity of Penryn therefore depends on the control of waste irrigation water by means of efficient drainage, the provision of overflows and waterways from main ditches and laterals, and the prevention of leaks and seepage from the ditches. The Sacramento Valley Irrigation Company, known as the Kuhn or Pittsburg Project, at Willow, California, realizes this so thoroughly that they are spending nearly as much money on drainage works as on irrigation ditches.

There are few places in the vicinity of Penryn where the land is naturally swampy, and these places can be cheaply remedied by assisting the natural drainage, or in the case of the small pools, by filling.

The work of the Field Agents in the past year has been confined to temporary work almost exclusively, as the funds available were not sufficient to do extensive permanent work. Oiling methods have been employed and some experiments were made with nicotine sulphate, a quantity of which was kindly donated by the Kentucky Tobacco Products Company. While effective, the nicotine was found to be impracticable, on account of expense, and it does not kill the larvæ

as quickly as oil. It has the additional disadvantage of being poisonous. In the oiling methods a knapsack spray pump having a capacity of five gallons was used. The oil applied varied, the following being used: stove distillate, either straight or mixed with crude oil, and water white, straight or mixed with crude oil. The oiling kills all the wrigglers and tumblers within fifteen minutes. Nicotine sulphate does not kill all the wrigglers and tumblers in less than five hours.

To properly protect Penryn by oiling methods would require an annual expense of about \$900.¹ This would be a constant expense, and if for any reason the control were discontinued, conditions would soon relapse into a state as bad as previous to the beginning of control. The cost of permanent improvement work would be slight as compared with the benefits obtained (Professor Herms has estimated it at about \$200 per square mile for a tract of ten square miles), and the results would be maintained in effective condition with but a slight annual expense. It is more effective, better and cheaper in the end to install permanent work and provide for the slight annual expense of maintenance. Owing to the uncertainty of the popular subscription method, permanent work over a large area cannot be done in a businesslike manner, and therefore such work should be put on a basis of taxation of the people benefited. It is possible for the Board of Supervisors

¹ The reader's attention is called to later estimates given on another page of this book.

to levy a special sanitary tax of one half mill on the dollar, but this would put part of the burden on people not directly benefited. The State Sanitary Districts Act¹ makes it possible to control infectious diseases endemic in a definite locality by throwing the expense on the people directly benefited and by taxation assures that sufficient money will be raised.

The State Sanitary Districts Act provides for the formation of a sanitary district for the control of infectious diseases, and other measures of sanitation as follows. A petition signed by twenty-five residents and freeholders within the district to be formed is presented to the Board of Supervisors; the petition states the name and boundaries of the proposed district, and asks that an election be called to establish the district. The Board of Supervisors within thirty days from the presenting of the petition must order that an election be held, the date of the election to be within sixty days from the date of the order. At the election, besides voting for or against the district, a Sanitary Assessor and five members of the Sanitary Board are voted for. The members of the Sanitary

¹ Later investigations by Mr. Gray in regard to the "Sanitary Districts Act" have shown that bonds can be voted by the district only for sewer construction, and with the present tax limit of 15 cents on \$100, aside from the tax to meet payments of principal and interest on bonds, not enough money could be raised for the purpose. For instance, in the Penryn district the assessment is \$450,000, which at a tax limit of 15 cents on \$100 would yield only \$675 a year. It is desirable that a special enabling act be passed by the next legislature.

Board serve without pay. After the district is established, the Sanitary Assessor estimates the value of the assessable property within the district and the tax necessary to pay for the work required. The Sanitary Board directs the work, and engages the necessary assistance to carry it forward. It is important that some professional man especially prepared by education and experience should be placed in charge of the work.

Results Accomplished. — It is not possible to entirely eliminate malaria from a community in a single season, or even in several seasons. Even under the most favorable conditions of construction of all necessary improvements, oiling where temporarily necessary during such construction, rigid sanitary inspection and control, and medical treatment and protection of all cases of malaria, cases of long standing may suffer relapse. Malaria is a disease which may remain latent in the system for a long time after the subsidence of the original infection and attack of fever, and then appear on exposure or overexertion, and entirely without fresh inoculation by the bite of an infected Anopheline mosquito. This is especially true in the case of adults. Children, while subject to attacks of greater severity than adults, recover generally more quickly, due to their greater physiological elasticity, and are less subject to relapses. In addition a parent will usually call in medical attendance for a case of malaria in his child, and to save the expense will neglect proper

treatment of his own case. It is therefore plain that the best index of the efficiency of the methods used in any malaria-control campaign will be the relative number of cases of malaria among the school children during the period of control, and the number of cases during the same period in the previous year when there was no attempt at control. The appended report on the number of absences due to malaria among the school children at Penryn during 1909 and 1910, kindly furnished by Mr. Huffaker, Principal of the School and Treasurer of the Committee, shows conclusively that much good has been accomplished. Unfortunately, only four months of each year are available for accurate figures for comparison, based on school attendance. During the spring and summer months of 1910 the decrease in absence from school due to malaria is apparently greater than that shown by the figures given, but the school records were not kept in such a manner that the actual figures are available. The months of September and October were the least efficient of any during the control, as it was not possible to have a field agent constantly on the ground during these months. Under the circumstances, I consider that the results have been far greater than could have been expected, for while many residents have actively aided the campaign, a great many have been indifferent, and a few, through ignorance, have been hostile. The majority have not taken sufficient personal care to prevent being bitten by mosquitoes

and it has not been possible to keep persons affected with malaria screened during sleep, thus preventing the infection of such *Anopheles* as may have escaped the vigilance of the Field Agent, which may in turn, after a period of ten or twelve days, inoculate another person.

As to the general conditions with regard to both adults and children, Dr. O. L. Barton of Loomis, whose practice includes practically all cases in Penryn and its vicinity, personally told me, and authorized me to state in his name, that there has been very much less malaria this year (1910) than last year (1909) and that a large majority of the cases this year have been chronic forms, manifesting themselves principally as malarial neuralgia. He further stated that in his opinion, even if it were not a fact that malaria is transmitted only by *Anopheline* mosquitoes, the personal comfort of a summer free from mosquitoes and their attendant irritating bites is well worth the cost of the control, and that next year Loomis¹ would certainly have an efficient control campaign throughout the entire year. He expressed himself as being very much in favor of coöperation among the communities in Placer County affected with malaria, especially on the basis of the formation of a Sanitary District.

Conclusion. — It has been demonstrated that malaria can be and has been controlled in Penryn through the destruction of the *Anopheline* mosquito, which

¹ Loomis did not carry on a crusade in 1911.

is the only known means of transmission of the disease. In conclusion it would be well to show what is gained beyond the improvement in health of the community which is alone sufficient "excuse" for the expenditure of many times the cost of the present campaign.

Fruit growing is the most important industry of Penryn, and like all forms of agriculture is dependent on labor for the gathering and marketing of its products. Labor imported into a malarial district is quickly attacked by the disease. Such men as remain and work in spite of the disease are only capable of doing a fraction of a man's work, although receiving a full day's pay, resulting in a direct loss to the employer. The men who leave on account of the disease spread the report that the district is malarial, making it increasingly difficult to obtain labor, and therefore fruit may be spoiled or not even picked for lack of men to gather and pick it, another direct loss to the employer. Finally, the district having the name of being malarial, real estate values depreciate, a loss to the owner. A typical case of the latter is personally known to me. A certain property in Penryn was several years ago listed for sale in San Francisco, but the agents frankly told the owner that it would be impossible to sell it on account of the reputation of the region for malaria. It was admitted that the property was valuable, and well worth the price. Cases are known where ranches producing a yearly

income of at least \$2000 cannot be sold for more than about \$8000, and then only to persons who do not work them, but lease. Such a price is out of all proportion to the earning capacity of the property.

It is therefore demonstrated that malaria is a direct financial loss to a community in at least four ways : first, through the loss in doctor's bills, cost of medicine, and incapacity for work on the part of the actual resident ; secondly, through the inefficiency of labor affected by the disease ; third, through the lack of labor ; and, fourth, through the depreciation in the value of real estate.

If Penryn should continue the control work in the future, either separately or in coöperation with adjacent towns, it is highly desirable that accurate records be kept of the cost of the work, and that statistics be compiled of the malaria cases.

Above all financial considerations should be placed the fact that the endemic existence of malaria in a community is a reproach to the inhabitants therein, individually and collectively. Penryn is to be congratulated on being the first rural community in California to take intelligent steps to rid itself of the disease, and especially that it has public-spirited citizens, who, with a vision of better conditions, have been willing to make sacrifices to obtain them. Such sacrifices should not be permitted to continue, but all should work together for a common benefit. Malaria control will pay a far greater profit on the invest-

ment than any other improvement, either public or private.

Respectfully submitted,

HAROLD FARNSWORTH GRAY,
Field Agent and County Sanitary Inspector.

ANALYSIS OF COST OF PENRYN CAMPAIGN

1. Field and Laboratory Equipment	\$ 30.83
2. Materials (oil, etc.)	35.20
3. Freight	4.27
4. Salaries of Field Agents	458.70
5. Expenses of Expert (Professor Herms)	129.15
6. Expenses of Field Agents	39.70
7. Incidentals	<u>17.90</u>
Total	\$715.75

PERCENTAGES OF TOTAL COST

	PER CENT
1. Field and Laboratory Equipment	4.3
2. Materials	5.0
3. Freight	0.6
4. Salaries of Field Agents	64.1
5. Expenses of Expert (Professor Herms)	18.0
6. Expenses of Field Agents	5.5
7. Incidentals	<u>2.5</u>
Total	100.0

Number of days Field Agents worked in each month: March, 31; April, 20; May, 23; June, 30; July, 22; August, 31; September, 15; October, 6; November, 1.

Approximately 360 gallons of oil used.

From the above it will be seen that the Field Agents devoted about 180 working days to the crusade, at a total cost, materials and all, of about \$715. The area continuously covered during that time was approxi-

mately eight square miles. This means that the campaign cost Penryn about forty cents a day per square mile of protection. Where there are only ten families to a square mile the protection afforded would cost approximately four cents a day per family, and yet one man was required to bear more than half the total cost of the crusade.

Local Occurrence of Anopheles.—The first careful field inspection in the vicinity of Penryn and Loomis was made January 14 and 15, 1910. At that time no wrigglers of any kind were discovered. Occasionally adult mosquitoes were reported occurring in houses during January. On February 11 and 12, balmy spring days, Anopheles mosquitoes were flying about abundantly during the daytime, and few persons, if any, escaped being bitten. Six specimens were taken in the office of the Penryn Fruit Company in a very few minutes. The school-teacher at Newcastle reported swarms of mosquitoes emerging from beneath the schoolhouse.

All these mosquitoes, and none other than Anopheles could be found, were coming forth from their winter quarters, *i.e.* had been in hibernation, consequently were hungry and were actively in search of blood during the daytime. In a few days this day flying ceased.

A careful search was made on these dates for Anopheles wrigglers, but none was found, although Culicine larvæ were abundant. The first Anopheles wrigglers

were found March 11 and 12 in the swampy grass areas around Penryn and Loomis.

The following data show the distribution for Penryn from this time on :—

DATA ON PLACES WHERE ANOPHELES WRIGGLERS WERE FOUND

PLACE	DATE	REMARKS
Callison (lower end pasture)	March 14	Larvæ
Griffith	17	Larvæ
Snelling	17	Larvæ
Douglas (pasture) . . .	19	Larvæ
Callison	April 12	Larvæ
Griswold	27	Larvæ
Owens	27	Larvæ
Callison	28	Larvæ
Turner (and adjoining) .	May 4	Larvæ
Gibson	14	Larvæ
Snelling	31	Larvæ
Gibson (swamp to north) .	June 17	Larvæ
Producers (swamp near) .	23	Larvæ
Gibson (swamp near) . .	July 16	Larvæ
Secret Ravine	16	Larvæ
Gibson (pasture)	August 1	Larvæ
Magnison	5 (see report)	Larvæ
Antelope Creek	12	Larvæ
Snelling (Japanese house) .	14	Adults
Snelling (Japanese house) .	17	Adults
Hale	19	Larvæ
Gibson (peach orchard) . .	22	Larvæ
Snelling (pasture). . . .	22	Larvæ
Near R.R. tracks (leaky pipe)	23	Larvæ
Butler (pasture)	25	Larvæ
Camp No. 14	29 (much malaria)	Larvæ
Camp No. 12	September 2	Larvæ
Red Ravine	5	Larvæ
Struble	25	Larvæ
Graff (back of saloon) . .	24	Larvæ
Old China Slough	30	Larvæ
Producers (drain under warehouse)	30	Larvæ
Owens	October 1	Larvæ

There have been many other cases where *Anopheles* have been identified, which were not specifically stated in the reports of the Field Agents. Also many other places where the evidence indicated *Anopheles* so strongly that a specific identification was considered unnecessary and the place oiled at once. Camps No. 12 and No. 14 are Southern Pacific Construction camps beyond the protected district and throughout the year have been full of malaria.

Just as soon as the mosquitoes became conspicuous by their absence, people began asserting that it was an "off year" for the insects. It was quite generally remarked that one could sit out on the open porches and enjoy the beautiful evenings without being pestered by mosquitoes, but few credited this to the mosquito crusade. (This also holds good for the Oroville campaign.) However, any one who found it necessary to travel over the state or even just outside the protected areas discovered the difference very quickly. Not only were mosquitoes present elsewhere in normal abundance, but in some places they were unusually bad. No account had been taken in the protected districts of the innumerable wrigglers that had been killed by the "mosquito man" or had been prevented from ever beginning their existence. After a while the prejudice subsided and the credit was placed where it properly belonged.

The prevalence of malaria in the adjacent districts was especially striking when compared with the crusading district. The statements made by prominent physicians practicing in these districts are still further

evidence of these facts. From a letter received from Dr. C. L. Wellman, dated November 3, 1910, the following is quoted:—

“From the fifteenth of August to the first of September we had forty-eight (48) cases of Malaria who were admitted to the hospital. During the month of September sixty-nine (69) were admitted and seventy-two (72) in October. Of course this does not include the cases which were not treated in the hospital but were prescribed for in quarters. Of these we have no record. I think a safe estimate of the prevalence of Malaria among the workmen would be 25 per cent. It seems to be fairly evenly distributed between Rocklin and Clipper Gap.”

FIELD AGENT GRAY'S POSTER

MALARIA

MALARIA is caused by a microscopic organism in the blood, introduced into the human body by the bite of a certain species of mosquito (*Anopheles mosquito*) which breeds in still water, preferably in grassy marshes having a few inches of standing water.

The malaria-bearing mosquito is seldom found more than 100 yards from the place where it is bred.

Malaria Can be Prevented by the Following Measures

1. Drain all damp areas where possible, especially such as are grass covered. You will not only remove a possible source of infection but will increase the value of such land. The drainage ditches should be given as much and as even slope as possible, and should have clean, straight banks with a berm. Tile drains are the most effective, but are more expensive than open drains; they are, however, well worth the extra initial cost.

2. Standing pools of water which can be more easily filled than drained should be filled with earth to the surrounding surface level.

3. Stop at once any and all breaks in irrigation ditches and water pipes. Such breaks very often cause pools or marsh most favorable to the breeding of the malaria-bearing mosquito.

4. Large ponds and streams which exist throughout the year will *not* breed mosquitoes if stocked with minnows, sticklebacks, etc., which eat the larvæ, or young mosquitoes.

5. Clean up your premises. Clear away all brush within 100 yards of your house. Do not allow standing water to remain in tubs, buckets or old tin cans.

A THIMBLEFUL OF WATER WILL BREED MANY MOSQUITOES.

6. Keep your well thoroughly covered by a screen, especially at night; mosquitoes are seldom active during the day.

7. Screen the windows of your house, especially in the bedrooms. Be sure that the screens are effective. A fine-mesh copper screen is best.

8. Interest your neighbor, and see that he takes as much care of his place as you do of yours. *THIS IS IMPORTANT. COÖPERATION WILL ACCOMPLISH MORE THAN SINGLE EFFORTS.*

The Sanitary Inspector will be glad to advise you as to the best method of removing sources of malaria-bearing mosquitoes from your premises. This advice costs you nothing.

HAROLD F. GRAY,

Sanitary Inspector, Placer County, California;

Field Agent Malaria-mosquito-control Campaign.

PENRYN, September 30, 1910.

THE PRESS

THE writer has from the beginning of this work considered the Press as one of the most potent educational agents. The campaigns at Penryn, Oroville, and Bakersfield have at all times received intelligent newspaper support. At no time has the work been thrown in disrepute by ridiculous statements or overdrawn accounts. On several occasions these crusades have received whole-column editorial comment and encouragement. The *Sacramento Bee*, the *Sacramento Union*, the *Oroville Register*, *Oroville Mercury*, *Bakersfield Echo*, and *Bakersfield Daily Californian* deserve special credit for their intelligent agitation along the lines of malaria control. The following extracts from newspaper clippings will show how the people of a given community were reached and given an account of the progress of the work as well as suggestions for the future :—

“Professor W. B. Herms, who is in charge of the anti-mosquito campaign, was in the city yesterday. Professor Herms had the following to say with reference to the campaign here :

“With the disappearance of mosquitoes in Oroville and the immediate vicinity, which is surely taking place, the citizens should not rest on present accomplishments, but should continue vigorously to wage the campaign. The fullest results will be appreciated during the next two months, when other communi-

ties, not carrying on such a crusade, will be pestered with an abundance of mosquitoes. With the disappearance of the mosquitoes, malaria is also said to be on the wane, according to the statements of several close observers.

"All situations in which *Anopheles* breed have now been discovered and are under control. The situation most feared, namely, the pools left by the receding water of Feather River, has been found to be of comparatively easy control. The work now being done along the levee demonstrates beyond a question that malaria need not exist next the river in any town similarly situated. Countless thousands of malaria-transmitting mosquitoes were found to be breeding in these pools, kept under constant surveillance in expectance of what has actually happened. Mr. Bairos (Field Agent) has already succeeded in draining several of these left-over ponds, diverting the water into the river, and the use of only ten gallons of oil along the levee during the last two or three days has reduced the number of wrigglers to a minimum and the rest will be taken care of during the next day or two. Thus what was looked upon as the greatest menace has been reduced to a controllable situation.

"In all cases where malaria has existed at any time, there have also been found the breeding places for *Anopheles* in the immediate vicinity. The correlation between the two conditions has now been established absolutely, the last spots having been determined during the past day or two, as already mentioned."

"Though only a partial survey was made of Oroville on Monday by Professor Herms, yet the observation was complete enough to make it possible to state that the work of killing the malaria-breeding mosquito in Oroville will not be as difficult a task as was at first supposed. In the first place, it was learned immediately that the dredger ponds, with their load of muddy water, offer no menace, as the *Anopheles* mosquito does not breed there. In the second place, the stagnant reservoirs of water, while eminently unhealthy, do not in their turn breed the *Anopheles*. Nor does the river, with its burden of running water. Where the *Anopheles* was found in Oroville, was rather in pools of clear

fresh water, that had collected from leaks in pipes or from other sources, and in which grass was found to be growing.

“The fact that there is no extended marsh in and around Oroville, according to Professor Herms, will greatly lessen the problem of eradicating the mosquito here. But while attention will be particularly devoted to these places, yet other spots in which other mosquitoes breed will also be drained and treated with oil, in an effort to rid Oroville of the insect pest.”

“Professor Herms, who has supervision over the anti-mosquito campaign, was in Oroville yesterday, and spent the day in consultation with Field Agent Ben Bairos. Discussing the campaign, Professor Herms had the following to say:

“‘The card system of reporting the condition of premises, as used by the inspector, is not only an important factor in the local health campaign, but will prove a source of information for future use by the City Board of Health. Mr. Bairos, who is collecting this data, will always offer suggestions and recommendations for the abatement of nuisances when found and ordered corrected. It will be necessary that corrections be made at once. Many of the business men have taken an active interest in this, and have their yards and inclosures in good condition. Business houses, especially where food products in any form are handled, should willingly do their part. A clean establishment both in the show window, main floor, and back yard, is the best kind of recommendation.

“‘Very commendable work is in progress on the east side reservoir, and will be carried to completion. The leaky ditch in the El Medio Tract is badly in need of permanent repair; the conditions on either side produce an abundance of *Anopheles* mosquitoes. We are glad to state, however, that the necessary repairs and corrections will be made soon, according to the statement of those in authority.’”

“Assistant Professor Herms of the University of California, who has complete charge of the anti-mosquito campaign now being carried on here, arrived in Oroville last night, and to-day will go over the field with Mr. Ben Bairos.

"In an interview granted the *Register* last night, Professor Herms expressed himself as greatly pleased with the progress of the campaign here. He said:

"The personal interest on my part is growing as I see the sane development of this important movement. The work as carried on by Mr. Bairos, my Field Agent, is thoroughly satisfactory. The original plans are being carried out in every respect and results are already evident, not only in the growing knowledge of the subject, but in the actual control measures. Many, many thousands of mosquitoes have already been destroyed and countless thousands have been prevented from coming into existence.

"The demonstrations and lectures which are being given in the store windows, on the street, and in the schoolhouses are of inestimable value in disseminating the knowledge which will make this campaign a success, basing the work on rational principles. Even the children will know the significance of the campaign, and already they are organizing to carry on the fight and know much about the habits of these insects.

"The citizens of Oroville are to be congratulated upon their wide-awake interest in matters of public health. Outside interest is keen, and men of wide business reputation do not hesitate in expressing their praise with reference to this splendid movement. Oroville's example will be followed soon in many parts of the State.

"The proposed "clean-up" day is a movement in the right direction, not because Oroville needs to clean up more than other towns of its size, but because she wants to be the "Gem of the Foothills" indeed, and the citizens now know that many places which have been considered insignificant heretofore are indeed breeders of disease and can be easily remedied. Concerted action under proper direction will bring this about. Well-kept lawns, tidy back yards, clean stables and outhouses will add much to the sum total of public health. Rubbish heaps cleaned away, tin cans removed and buried, garbage heaps destroyed, — all this should be attended to. Enlisting the school

children systematically in this day's work is proper. These little hands love to help, and they can accomplish much and will learn thereby to keep up and advance the work now being inaugurated.

“The tag-day is commendable, and will stand out as an event unique in the history of anti-mosquito campaigns. The scientific apparatus, which will greatly facilitate the progress of demonstration and control, has arrived, and will be installed in a suitable laboratory as soon as possible. Charts and drawings illustrating the life history of mosquitoes and their relation to public health, will be placed upon the walls, and exhibits of the living insects will always be on hand. The public will be welcome to visit the laboratory during certain hours.’”

Other Publications Used. — Besides the local press, which published frequent articles on mosquito control, several publications were used and widely distributed, among them the California State Board of Health Monthly Bulletins, especially of the July, 1910, issue, containing a paper by the writer on “How to control Mosquitoes, with Special Reference to *Anopheles*.” The May Bulletin was also widely circulated on account of the article entitled “How to control the Common House Fly,” as was also the November Bulletin with a paper on “Anti-mosquito Organizations in California.”

A printed address entitled “Protecting California's Health Resources through the Control of Disease-bearing Insects,” delivered before the Commonwealth Club at San Francisco, was found useful, inasmuch as it touches upon the value of this work to the State.

THE OROVILLE CAMPAIGN

THE following extracts from the Field Agent's daily notes will serve to indicate the methods pursued in this community and vicinity.

DAILY NOTES FROM FIELD AGENT BAIROS' REPORT

April 1, 1910. Went over the situation near the Lava Bed Dredgers demonstrating the use of the spray pump and left one out there for future use. The Company took up the work. Later had the ponds along the river near the bridge oiled.

April 2, 1910. Inspected the ground above bridge and toward East Side schoolhouse. Found many old mining shafts in the field near the schoolhouse, flagged one in particular for the purpose of demonstrating the methods of destroying mosquito breeding places to the school children; oiled remainder.

April 4, 1910. Prepared bottle exhibits of wrigglers for the schoolroom demonstration. Gave chalk talk lecture to school children at East Side and had them visit pond outside of school yard. Took some photos. Continued the oiling of that field in the afternoon. Some school children were found in the field interested in the mosquito ponds.

April 5, 1910. Wrigglers in window exhibits hatched. Many spectators gathered about window to inspect the simple life of the mosquito. Gave simple explanation of what was occurring there to those interested. Inspected some of the southeast part of town where tub, horse's trough, and barrel were found containing many wrigglers. Demonstrated mosquito work to a number of citizens and children thereabout. Took photos of children. In afternoon went over the ground in Thermalito and Natomas Consolidated dredgers with J. J. Hamlin and flagged most important places so as to stir up interest in that vicinity.

April 6, 1910. Inspected along the levee and back of part of business section toward Chinatown. Found five barrels back of restaurant filled with water; many wrigglers were found in three of them, the other two had been swill barrels and had some grease in them which prevented wrigglers from breeding. A number of citizens became interested in these barrels. Prepared more exhibits for school children. Went over the ground as far as Indiana dredgers; found some dredger buckets back of Boston Machine Shop with wrigglers and flagged them.

April 7, 1910. Spent the whole day in demonstrating to the school children by chalk talk lecture and exhibits prepared. Visited ten rooms at the Bird Street schoolhouse. After school hours passed the Boston Machine Shop and found that buckets had all been turned over, also found some of the school chil-

dren about the rock piles looking for ponds. Took photos of a few of them.

April 8, 1910. Demonstrated by chalk talk and bottle of wrigglers to school children at Thermalito the work of the league. Found a ditch with *Anopheles* mosquito wrigglers near the schoolhouse. Inspected the ground about Oro Vista and El Medio. Found leak in the Palermo Land and Water Company's ditch above reservoir which caused a large field to be flooded and made great breeding places for *Anopheles* mosquitoes.

April 9, 1910. Professor Herms came up and visited some parts of field work, in particular the ground about the reservoir. Inspected the El Oro dredger ground and flagged many old mining shafts and ponds containing water and demonstrated the mosquito work to the superintendent there.

April 11, 1910. Put man to work oiling and repairing ditch in the field above the reservoir. Flagged another field on opposite side of the ditch into which some water from ditch was overflowing and where many *Anopheles* wrigglers were found. Found a few *Culex* eggs.

April 12, 1910. Prepared some more window exhibits for the business section and demonstrated the work of the league to the high school students and continued the flagging of the El Oro dredger ground. Showed the men belonging to the Company method of oiling.

Progress During Second Year.—The following data taken from H. F. Gray's report for 1911 indicate the progress made in the second year's work.

Oroville continued the anti-mosquito campaign in 1911, but on broader lines. The control of the house fly and matters of general sanitation were combined with the work against the mosquito. Special attention was paid to educational publicity, and an earnest attempt was made to bring the citizens to a realization of the importance of better health conditions. From the standpoint of increasing the public virtue and interest in such matters, the campaign was an unqualified success. Though no actual statistics were available, it is certain that malaria was reduced beyond the reduction of the previous year; in fact, at present malaria is practically stamped out within the city limits. As a mosquito eradication campaign alone, however, the campaign was not completely successful for several reasons. Owing to the expected early completion of the sewer system, cesspools were in extremely bad condition, and many were breeding *Culex* mosquitoes, but no *Anophelines*; the weather conditions (a large precipitation in the winter, a cool spring, followed by a sudden onset of the hot weather) were such that mosquitoes were naturally unusually numerous; the campaign being general, the efforts of the Field Agent were divided among several important matters, and while every endeavor was made to eradicate *Anophelines* whenever found in either larval or

adult stage, the presence of Culicines, except in large numbers, was not considered as a matter requiring unusual efforts to exterminate them.

The good results of the campaign were many and may be summarized as follows:—

1. A further reduction of malaria almost to the point of actual elimination.

2. The appointment of an able and efficient Board of Health, which has the confidence of the people, and does its duty.

3. The passage of ordinances against mosquitoes and house flies, which in the hands of the present Board of Health will bring results.

4. The improvement of garbage 'removal and disposal.

5. An increased knowledge of sanitation on the part of the citizens, and a strong sentiment on their part for the further extension of public health measures in their city, together with a general improvement of the sanitary condition of the city made by each citizen taking proper care of his own premises.

6. A demand for the continuance of the campaign in 1912.

The campaign cost about \$1500 for eight months, of which about \$600 was supplied by the city government and about \$300 by the Anti-mosquito League through subscription; the remainder was spent by different individuals and companies for corrections and improvements.

Results of the Oroville Campaign. — The following extract from the California State Board of Health Bulletin of February, 1912, under the heading "Oroville and Malaria part company" is ample comment on the results of two years' aggressive crusading against malaria in Oroville.

"It is not known how malaria came into California, but it is here. There is some evidence to suggest that it came with the influx of pioneers from the malaria-ridden lowlands of the Mississippi Valley, and finding *Anopheles* mosquitoes and other favorable conditions, stayed and prospered as did the other pioneers. Oroville was one of the early towns that developed in response to the demands of the miners, and having been established, grew because of its superb location and the richness of its contributing territory. But this location was also favorable for malaria. Innumerable stories have been told of the quinine cup on the mantel shelf and reservations for 'chill day' in making all appointments. Such stories had a grim foundation in fact, and are still uncomfortably near the truth for some sections of California. But Oroville has applied the new discoveries of science, and is waging incessant and successful warfare on the disease. Under recent date the following newspaper item has appeared :

"*Sacramento Bee*, February 22, 1912.

"Malaria has been Eradicated in Butte.

"Hospital Records Show Disease has been Placed Under Control.

“Oroville (Butte Co.), February 22. — That a decrease of 25 per cent in the number of patients cared for this year at the County Hospital is due to the increase in sanitary precautions taken by the general public, and to the mosquito campaign, is the statement of Superintendent M. L. Copeland, of that institution.

“Copeland states that in previous years there have been approximately 100 patients cared for at the hospital, and that the average for the past year has been seventy-five. Twenty-five per cent heretofore, he says, were malarial patients. During the past year but four malarial cases have been treated at the hospital.’

“No settler need fear for his health or his investment in a community that makes the policy being followed by Oroville a permanent part of its plan of progress. Unfortunately many such campaigns, like New Year resolutions, must be placed on probation a while before the stamp of final approval can be safely given, but Oroville has passed the stage of probation, and has proved that malaria can be made to ‘move on’ into the undrained lowland haunts of the *Anopheles* mosquito, and to those communities possessing less of the get-together spirit evinced by the residents of the county seat of Butte County.

“At the present time only one county in California has above fifty deaths from malaria annually per thousand deaths from all causes. Five counties have from twenty-five to fifty; nine counties from ten to twenty-

five; eighteen counties less than ten; and twenty-five counties have no deaths from malaria.

“The excellent work of Oroville and neighboring towns is rapidly transferring Butte County from the top towards the bottom of this list. Other northern and central California towns and counties are carrying on this work with equal assurance of ultimate success. It is to be hoped that the next legislature will again take up this important question with a view to making a state wide attack on the last strongholds of malaria.”

THE PRELIMINARY SURVEY

THE success of a campaign depends on a proper preliminary survey of the situation with wise recommendations for procedure. Hardly two localities offer the same difficulties, and no one could wisely specify a workable program without first having visited the field and studied the situation. The following is the preliminary report on the Los Molinos project. This report indicates the necessity for a specific study of each proposed crusade.

Preliminary Report on Malaria Prevalence and Control on the Irrigated Land Project of the Los Molinos Land Company of Los Molinos, Tehama County, California, made at the request of Thomas F. Means, Manager, by Harold Farnsworth Gray, under the direction of William B. Herms, Assistant Professor of Applied Parasitology, University of California, Berkeley, California, September 30, 1911.

Introduction. — On the afternoon of Monday, September 25, 1911, Thomas F. Means, Manager of the Los Molinos Land Company of Los Molinos, Tehama County, California, called on Professor William B. Herms of the Subdivision of Parasitology, University of California, Berkeley, California, stating that on the irrigated project of the said company malaria had become prevalent and that it was feared that the prev-

alence of malaria might make their lands less desirable to the prospective buyers. Knowing that malaria is a disease which can be eliminated by the destruction of the Anopheline species of mosquito, he requested that Professor Herms assist the said company by advising them as to the methods of mosquito extermination, and if possible to visit the project and advise in detail as to the best method to pursue.

Professor Herms, being unable to make the visit requested, owing to press of other work, directed the undersigned to proceed to Los Molinos, examine the situation thoroughly in detail, and to report thereon. The following report is the result of investigations made on September 27, 28, and 29, 1911.

Description of Project. — The Los Molinos Land Company's project consists of approximately twelve thousand acres of level, fertile land, lying along the east side of the Sacramento River, extending from about one mile south of the town of Los Molinos to within about six miles of Red Bluff on the north. Part of the project is at present under irrigation, and the remainder will be put under irrigation during the season of 1912. The soil is deep and porous, and the general height of the land above the Sacramento River and the various creeks and drain ways assures a good natural drainage. The general slope of the land is westerly towards the river. On the east the foothills approach the limits of the project closely. In general it may be stated that with the exception of the land

immediately contiguous to the river, the region is not naturally suited to a prevalence of malaria, and that the presence of malaria is due almost entirely to artificially produced conditions.

Prevalence of Malaria. — I was unable to obtain any information in the field as to the exact type or types of the malaria parasite present in this region, as the making of blood smears was not possible, owing to the fact that every person known to me having malaria had been taking quinine recently, which would make a determination by blood examination unreliable. From what I can find out, the infection is of a very mild form, incapacitating a person for a few days on arrival, and not subject to frequent relapse. I will endeavor to find out as much as possible from the physicians in Red Bluff who attend cases in the vicinity of Los Molinos, and report the information in an appendix to this report at a later date. There is no doubt, however, that it is a true malaria, and can be controlled by the usual prophylaxis.

Presence of Mosquitoes. — The month of September, especially the latter part of it, is well along toward the latter part of the mosquito-breeding season, and it was not expected that they would be particularly noticeable. They were sufficiently in evidence in the evening during my visit to show that they were fairly numerous. Both types, Anopheline and Culicine, were seen in larval as well as adult form. The Anopheline mosquitoes were apparently mostly *Anopheles maculipennis*, this being the only one identified, but others

may be present. No determination of the *Culex* varieties was made, but there are at least two. The breeding belt of the greatest numbers of mosquitoes was found to be close to the river in low, wet areas. The most important breeding places, from the standpoint of malaria control, were found in all cases in connection with the irrigation water, either in the shape of seepage or overflow from the ditches, or else the result of excessive or careless use of the water. In a few cases, mosquito larvæ were found in sluggish and weed-overgrown ditches, and only very slightly in the natural drains. Some of the creeks running through the region breed mosquitoes in pools along their edges, but not to any great extent, with the possible exception of the mill ditch below the Runyon place. A copy of my field notes is appended, giving my findings in detail.

Conclusions. — I have given in the appendix to this report the various recommendations and directions that I consider are necessary to control malaria on this project. I consider that it is both possible and comparatively easy to eradicate malaria from this project with a reasonable expenditure of money, and within a reasonable length of time. In regard to the matter of expenditure of money I will state that the greater part of the work required should be properly charged to the maintenance account, as the necessary work is largely a matter of good irrigation, in keeping ditches in good order, and preventing loss of water

through seepage and waste. In regard to the matter of time, I am convinced that malaria may be very greatly reduced by the end of the year 1912, and by the end of the year 1913 it should be a matter of history only.

This result cannot be accomplished by the efforts of the Los Molinos Land Company alone. To get the most perfect and thorough results the company must obtain and maintain a cordial understanding and coöperation of the persons to whom the land is sold, and at the same time must make such regulations with regard to the use of water that will enable them to control the few obstinate or irresponsible owners that they may have.

Respectfully submitted,

(Signed) HAROLD F. GRAY.

Approved.

(Signed) W. B. HERMS,

Assistant Professor of Applied Parasitology,
University of California, Berkeley, California.

APPENDIX I

Recommendations and Suggestions. — 1. As a temporary measure to partly control the development of mosquitoes during the remainder of the breeding season, I recommend the application of oil to the stagnant water known to be breeding mosquitoes, provided that the stagnant water is within 300 yards of a dwelling house. The oil should be a mixture of approximately 100 gallons of “stove distillate” and 5 gallons of crude oil, applied in spray form from a special sprayer, once every 15 days¹ up to the middle of November.

2. With the reconstruction of the ditch system during the coming winter and spring, every ditch should be put in good condition, with solid banks sufficiently high to prevent overflow. Sufficient grade to give good current should be provided. Where the ditch runs through soil that permits any considerable seepage, the ditch should be water-proofed, or the water carried in a pipe. The ditches should be kept with clean banks and free from weeds. The gates should be so constructed as to obviate leakage when shut, and should be kept padlocked and operated only by the regular ditch tender.

¹ During midsummer every twelve days.

3. In the construction of ditches, the company should carefully avoid borrowing dirt for banks from the ground immediately contiguous to the ditch bank, as this forms low spots which will usually fill with seepage water.

4. Where the drainage for any piece of land is not sufficient to remove the seepage from a proper amount of irrigation, the company should cut a drain to the nearest natural drain, and maintain it in good condition.

5. The company should make regulations with regard to the use of irrigation water, and enforce them. Appendix II contains a suggestion for such rules.

6. The company should provide for a lecture by an authority on malaria and mosquito control at the beginning of the mosquito season in 1912, say about the first of March, the Company to make arrangements and give thorough publicity to the same to assure a large attendance from the people that will be affected.

7. The Company should have printed and distribute to the persons who already own land on the project, and who will buy land in the future, circulars containing the necessary concise directions to prevent the breeding of mosquitoes on their own premises, and to prevent malarial infection. (See Appendix III.)

8. Talks should be given to the school children in the district on mosquitoes and malaria, as they have been found to be a great assistance in this matter in other communities doing the same work.

9. The company should urge upon the Board of Supervisors of Tehama County the passage of an anti-

mosquito act, and also that the County Health Officer be given funds to put the legislation into effect.

10. Automatic oiling of ditches and creeks is of doubtful value under the conditions here, but the automatic application of copper sulphate solution to the ditches to prevent or kill the growth of algæ, on which the mosquito larvæ feed, may be found useful. It should not be used in excess of one part per million of water.

APPENDIX II

Regulations Concerning the Use of Irrigation Water. —

1. Irrigation water will be supplied to water users at stated times, to be determined at the beginning of the irrigating season. If the water user does not call at the office of the company at the beginning of the irrigating season to arrange a schedule of supply, the company will make such a schedule as it deems proper. All schedules shall be subject to change, provided that the rights of other water users are not interfered with.

2. All head gates and other ditch appliances will be kept locked, and shall be operated only by the proper ditch tender. All persons are forbidden to tamper with such fixtures without proper authority.

3. No irrigation water shall be so used that there will be any overflow onto adjoining property, or so that water in a stagnant condition collects and remains in any part of the water user's property for more than 24 hours after the time that the irrigation has been stopped, nor more than six days from the commencement of irrigating.

4. No stagnant water on any portion of the premises of a water user will be permitted for any purpose whatever. No stock pond shall be permitted. Water

troughs for stock must be emptied once a week and cleaned. Wells and water storage receptacles must be kept thoroughly screened or covered at all times.

5. The water user must maintain any private ditch or ditches for distribution of irrigation water on his own premises in good condition, so that seepage from them shall be a minimum, and no water remains stagnant in them.

6. Horses, cattle, sheep, and swine shall not be allowed to pass over, upon or across, or wander at large upon any ditch or ditches owned and operated by the Los Molinos Land Company.

APPENDIX III

Rules for the Prevention of Malaria. — 1. *Allow no stagnant water* on your premises. Go over every part of your property carefully, fill in or drain every low spot where stagnant water can collect for any length of time. See that there are no barrels, tin cans, or other things holding water, unless they are carefully covered or screened.

2. The *only way* in which you can get malaria is by the bite of a certain kind of *mosquito*. You *cannot* get malaria from drinking water, bad or marshy air, overripe fruit, stale beer, or in any way except by the bite of a mosquito. The mosquito breeds in stagnant water. Only a very small amount of water is necessary to breed many mosquitoes, and it is usually the small, insignificant pools that breed the greatest numbers, not the big, open ponds of water.

3. Where you find it impossible to either fill in or drain away water that is stagnant for more than a week, a coating of coal oil once a week will keep the mosquitoes from breeding in that water, but try first to get rid of the water as far as possible.

4. Clear away all brush, tall grass, and weeds around your house, as these make places for the mosquito to hide in during the heat of the day. Keep things trim and neat.

5. Screen your windows and doors with a fine-mesh (No. 18) copper-wire screen, the screen frame to fit tight against wood strips at the back, to prevent mosquitoes getting in through the space between the edge of the screen and the casing of the door and window. If possible, sleep in the second story of the house. If by chance there should be mosquitoes in the room when you go to bed, kill them.

6. Obey carefully the regulations of the Los Molinos Land Company with regard to the use of irrigation water. These rules are made for your own benefit and protection. Excessive or careless use of irrigation water not only breeds mosquitoes which cause malaria, but is bad for your land and your crops. Too much water is as bad as not enough, and is unhealthy besides.

7. If you have to be out in the evening, and the mosquitoes should be present, be careful not to be bitten. If you have to go into a place where you know the mosquitoes are thick, wear a veil and leather gloves.

8. If you have to sleep in the open where mosquitoes are present, sleep under mosquito netting.

9. Quinine is of as much use to prevent malaria as it is to cure it. A good method is to take nine to fifteen grains of quinine daily for three days, then take no quinine for three days, and repeat as necessary. If you know that you have been bitten by a mosquito, take quinine, and prevent having malaria.

10. Failure to obey these simple rules may mean that not only will you have malaria yourself, making it impossible for you to do a good day's work, but your family may be made sick, and perhaps even your neighbor. The Los Molinos Land Company is doing much work to prevent the mosquitoes from breeding, but cannot do it all. *You Must Help.* Keep your own place right.

11. Remember this : NO STAGNANT WATER, NO MOSQUITOES : NO MOSQUITOES, NO MALARIA.

APPENDIX IV

Extracts from Field Notes

September 27. On South Center Street, outside of town limits, in orchard of Douglas, overirrigation, leakage, and overflow from ditches causes swampy area near house. Larvæ of *Anopheles maculipennis* of *Culex* (*Theobaldia incidens*), and pupæ found in water, and adults in foliage. Cases of malaria in adjoining house.

Adult mosquitoes found in dense brush and foliage on mill race near Runyon place, small pools along edges. Should be brushed out and burned, and edges of mill race oiled. At concrete culvert of Runyon ditch crossing railroad tracks, small ditch running to right on west side tracks, sluggish current, *Anopheles* larvæ. Oil. East side track here, seepage pools. *Anopheles* and *Culex* larvæ numerous. Oil. Seepage water at other places along this ditch; ditch foul with weeds. Further down on mill race many pools and other water, breeding both types of mosquitoes, but too far away from town to need attention at present.

September 28. Mitchell place on end South Josephine Street, large area of wet ground, caused by water wasted for stock. Mosquito larvæ very abundant. Shut off water and oil.

Directly back of house with masonry first story, at intersection of two ditches, and in between, much wet area due to seepage, slow current in ditches, with algæ, both types mosquito larvæ. Clean ditches, use CuSO_4 (copper sulphate) to kill algæ, and oil. Stop seepage from ditches, and run drain down low spot if outlet is available.

September 29. In road in front of Moore's place, puddles of water from excessive irrigation, many *Culex* larvæ, some *Anopheles*, also pupæ. Drain ditch near here in bad condition; should be cleaned out to give good flow.

North of Spencer's place, 8, 26, Sub. No. 8, below main lateral, cattle have cut down banks, which are too low, causing considerable area of swamp, breeding both types of mosquitoes. Hog wallow bad. Place in unsanitary condition. In evening at hotel *Culex* mosquitoes noticeable on porch, being probably blown in by afternoon wind from river region.

THE FIELD AGENT OR INSPECTOR

As may be seen from the foregoing reports, the *Field Agent* or *Inspector* must be a many-sided individual. Not only is a scientific equipment necessary, but he must also be an educator and a good "mixer." Sanitary inspection in this sense is not so much the exercise of police power, which is indeed of very minor importance, but it is the process whereby a citizen is made to see defects and is shown the way to correct the same. The Field Agent must be an individual of infinite patience and resource, — he is a personal worker.

It is an unwise worker who proceeds to roundly denounce the man who does not at once get the vision of better things. This process may require some little time.

EXPENSES INVOLVED : RAISING FUNDS

IN order that a campaign may be successful and that the work may continue unhampered, it is essential that sufficient funds are in sight to begin with. The raising of funds is a matter that must be settled by each community for the present until such legislation

FIG. 37. Tags used on Tag Day to increase funds needed in mosquito control.

has been brought about that will insure county or state aid. Thus far the task of raising funds has been given over to civic organizations which through committees have solved the problem in one way or another. Several communities have raised their funds by popular subscription, while one pro-

gressive town has had two tag days with gratifying results (Figs. 37, 38, 39).

No crusade can hope to be successful unless it is properly organized and directed. The detailed scientific work must be done by one who is properly trained, and who is responsible for the results. This individual is the Field Agent, and his salary is the biggest item in the cost. That this item is really small when the returns in health are recognized, not only with refer-

ence to malaria but typhoid and other infectious diseases, is manifest. Men who are being trained in the University of California as "mosquito fighters" are getting the broader training in "Rural Health Problems" as well.

The average minimum cost of protection, giving to each Field Agent an area of ten square miles to cover, which is possible with some assistance, is about \$.75 per day per square mile. At this rate the cost of an average crusade covering an area of ten square

miles is about \$1600 for one season, covering a period of eight months. Estimating the cost of quinine and doctors' bills at \$20 per family, with not more than one hundred families within the ten square mile area (a low average), plus 25 per cent reduction in earning

Register April 19.

WILL GIVE TAG DAY ONE WEEK FROM SATURDAY

FUNDS WILL BE USED TO ASSIST
IN FIGHT AGAINST
MOSQUITOES.

The Anti-mosquito League is arranging for a tag day to be held for the purpose of raising funds for the campaign against mosquitoes. It is probable that the date selected for the tag day will be Saturday, April 29th. A more complete announcement will be made at a later date.

FIG. 38. Tag Day, — a new and successful way to raise funds to fight mosquitoes and malaria.

capacity per family with an average income of \$800, gives a total loss of $\$20 \times 100 (= \$2000) + \$800 \times 100 \times 25 \text{ per cent } (= \$20,000) = \$22,000$. Ordinarily it is possible to reduce the total amount of malaria by at least 50 per cent in one season. At this rate there is

FIG. 39. School children selling tags. The proceeds were added to the anti-mosquito fund.

a saving of $\$22,000 \times 50 \text{ per cent} - \$1600 = \$9400$ (nine thousand four hundred dollars) in one season to this scattered rural community. (The reader is referred to p. 7 for data relative to larger towns.) Surely this is a good investment.

The following table is intended to give an idea what items are involved in the monthly expense account.

TABLE IV

Tabular account of monthly expenses (for Oroville) ¹ from March to July, inclusive, 1911.

	MARCH AND APRIL	MAY	JUNE	JULY
Oil	\$15.10	\$2.50	\$16.90	\$25.45
Rig hire	19.50	10.50	9.00	9.00
Printing and stationery . . .	11.50	—	—	—
Postage	1.60	.50	—	.50
Labor ²	—	—	2.00	—
Sulphur	—	—	.50	—
Field Agent salary . . }	March 10.00	125.00	125.00	125.00
	April 125.00			
	\$182.70	\$138.50	\$153.40	\$159.95

The above estimate of \$.75 a day per square mile of protection does not include much permanent corrective work, and would continue from year to year without lessening greatly, though the educational factor will play an important part after two or three years, when individuals in a community will do considerable work of their own accord.

The following estimate (Table V), based on a thirty square mile area and including all necessary permanent corrective work of ordinary nature, shows conclusively

¹ The greater part of this work was confined to an area of about four square miles, including the City of Oroville, and only about one fifth of the time was spent in inspecting the rural surroundings.

² Practically all labor, to the value of approximately \$120, paid by city street department and several private companies.

that a larger primary investment is the cheapest in the end and certainly far more satisfactory.

TABLE V

Estimated cost of malaria control covering a thirty square mile tract and including all ordinary permanent corrections. Based on a taxation plan.

ITEMS	1ST YEAR	2D YEAR	3D YEAR
Assessor	\$1000	\$ 500	\$200
Director	2500	2000	500
Field Agents	3200 (3)	2400 (2)	1500 (1)
Surveys	2500	—	—
Maps	750	—	—
Stenographer	900	200	—
Equipment (teams, etc.) .	2000	—	—
Labor	3000	200	100
Materials	1500	—	—
Feed	700	250	120
Supplies	100	50	—
Office (postage, etc.) . .	100	100	100
Oil	350	200	100
Incidentals	200	100	100
	<u>\$18800</u>	<u>\$6000</u>	<u>\$2620</u>
Ten percent Contingencies	1880	600	262
	<u>30)20680</u>	<u>30)6600</u>	<u>30)2882</u>
	<u>365)689</u>	<u>365)220</u>	<u>365)96</u>
Approximate cost per square mile per day . .	\$1.90	\$.60	\$.27

WHEN TO BEGIN THE WORK AND WHEN TO CLOSE

THE best results are secured in a new district by eliminating as far as possible the last brood of mosquitoes in the autumn, *i.e.* oil or drain off all mosquito breeding pools in October and go over the territory once again in November. In this way the number of mosquitoes which hibernate over winter is reduced to a minimum. The spring work should begin in March, depending on the weather, — if warm, the work must begin earlier in the month; if cool, then later. This can only be ascertained by inspecting likely pools in order to determine whether mosquito larvæ are present and what size they have attained. Usually the last larvæ are found in October and the campaign may usually close safely with the end of this month. This applies only to the *Anopheles* mosquito (the malaria bearers) and does not apply to the *Culicine* varieties, including salt marsh species.

LEGISLATION

IN any malaria crusade all the inhabitants of a given district are equally benefited; it is therefore unreasonable that the entire cost of a campaign should be borne by a few individuals, which has been the case in several localities where funds were contributed through popular subscription. Because of the equal benefits derived, some plan of assessment or state appropriation seems to be more reasonable, however the latter (state appropriation) may be objectionable unless all parts of the state are concerned. It should be borne in mind after all that bad advertising for one part of the state means injury to every other part, and the fact that malaria is present in any state is bad advertising. Be it also known that no community can hide the fact that malaria is present within its bounds, however strenuously it is denied. To carry on an anti-malaria campaign and then to widely advertise the fact is the best sort of advertising. Note the change of heart suffered by the better real estate dealers and boosters in several of the more progressive towns in malaria ridden districts.

In January, 1911, an act known as the Guill Bill was introduced in the California Legislature, and was

passed by both houses, but did not receive the Governor's signature. Had this bill become a law, it would have been the first enactment of its kind in the United States directed specifically towards the extermination of the *Anopheles* mosquito by local communities with the object of controlling malaria.

The bill provided that the Board of Supervisors in any county, on its own motion or upon receiving a petition from ten or more taxpayers residing in the proposed district, should pass a resolution declaring its intention to do all work necessary for the extermination of *Anopheles* mosquitoes, describing the boundaries of the district to be benefited and assessed for the benefits. The petition mentioned was required to give the boundaries of the proposed district, to show that a survey had been made of the district under the direction of the State Board of Health; and that such survey showed that there were one or more breeding places of *Anopheles* mosquitoes within the proposed district.

The resolution of intention to do the work was required to be published, and opportunity was given to any one who objected to the work to appear before the Board and state his reasons for objecting. If they were not valid, the Board was to proceed to order the work done, appointing three commissioners to assess benefits and damages and have general supervision of the work. These commissioners were to have made a thorough sanitary survey of the district, make and

map a careful description of the work required, and report the same to the Board of Supervisors. All objections to this report or any portion of it were then to be filed in writing with the county clerk, and at the next regular meeting of the Board these objections were to be heard and sustained or rejected or modified according to the judgment of the Board.

Certified copies of the report, assessment roll, and map were then to be filed with the tax collector, the taxes were then to be payable, and work to proceed as funds became available.

The State of New Jersey enacted effective legislation against the mosquito in 1906. The act reads in part viz.: "An Act to provide for locating and abolishing mosquito-breeding salt marsh areas within the State, assistance in dealing with certain inland breeding places, and appropriating money to carry its provisions into effect" and "For the purpose of carrying into effect the provisions of this act, the said Director of the State Agricultural Experiment Station shall have power to spend such amount of money annually, as may be appropriated by the legislature, provided that the aggregate sum appropriated for the purpose of this act shall not exceed three hundred and fifty thousand dollars."

The first sound county legislation in the State of California has been enacted by the County of Tehama and reads as follows: Ordinance No. 46.

An ordinance to exterminate the mosquito larva.

The Board of Supervisors of the County of Tehama, State of California, do ordain as follows :—

SECTION 1. No person or persons, firm or corporation shall discharge, pour, empty out, or otherwise place upon the surface of the ground in any lot, yard, street, road, alley or premises within the limits of the County of Tehama, State of California, any water from any source whatever which remains in a stagnant condition within two thousand (2000) feet of any occupied dwelling house, or maintain water in stagnant condition in any barrel, can, tub or open receptacle of any character whatsoever, within two thousand (2000) feet of any occupied dwelling house. The presence of the mosquito larva in said water shall be conclusive evidence that said water is stagnant, and upon the finding of said mosquito larva the occupant, or if the premises are unoccupied, the owner, shall be liable to arrest, fine and imprisonment as hereinafter provided, and if the said stagnant water, which is hereby deemed a nuisance, be not drained away or treated in a manner satisfactory to the Health Officer of Tehama County or his authorized representative, and within a reasonable period of time as determined by the Health Officer or his authorized representative, the said nuisance shall be abated by the Health Officer. The cost thereof shall be paid from the General Fund of the treasury of Tehama County upon sworn warrant of the Health Officer, and the cost of said abatement shall be a lien upon the property upon which the said nuisance

was created and abated, and shall be collected by law as taxes are collected.

SECTION 2. Wells, cisterns, cesspools and privy vaults shall be so screened or covered as to prevent access to the contents thereof by mosquitoes, and such screens or coverings shall be maintained in good condition and to the satisfaction of the Health Officer of Tehama County.

SECTION 3. All violations of this ordinance shall be a misdemeanor, punishable by a fine of not less than five (\$5.00) dollars nor more than fifty (\$50.00) dollars, or by imprisonment in the County Jail for not less than five (5) days or more than fifty (50) days, or by both such fine and imprisonment.

SECTION 4. This ordinance to take effect shall be published with the names of the several members of the Board of Supervisors voting for and against the same, for two successive weeks in the *Daily People's Cause*, a newspaper published in the County of Tehama, State of California, and shall take effect June 20th, 1912.

(Signed) W. H. SAMSON,

Chairman of the Board of Supervisors of the County of Tehama,
State of California.

HEALTH OF RURAL SCHOOL CHILDREN

THE general health of a given community is fairly well indicated by the average health of the older school children. While it is difficult to secure satisfactory statistics with reference to the health of the entire population of a rural town, it is possible to secure such data for the school children, though also involving error. Inasmuch as the younger school children are often kept at home due to weather conditions; the following data are based only on fifth, sixth, seventh and eighth grade pupils. The school used as an example, if it were not for the malaria, is situated in one of the most healthful localities in the state, — malaria is the chief cause for absences.

The manner of keeping the ordinary school register does not furnish accurate statistics for our purpose, because the child is not considered a member of the school when it has been absent five days in succession. However, in a small school where the teacher is personally acquainted with each pupil as well as parents he has a means of knowing just how long the child has been absent and for what reasons. This is especially true of the school data used in this connection, because the principal is a man who takes an intelligent

interest in the children and is unusually well equipped to give the data used in the following tables.

Table VI is based on absences due to all causes as recorded in the ordinary school register, while Table VII is based on actual count of absences due to malaria alone, including cases over five days. Two years are used for comparison, namely 1909, during which no malaria campaign was in progress, and 1910, during which year a crusade was carried on. It should be borne in mind that the control measures did not begin until March 1st, 1910, and the *Anopheles* mosquitoes were abundant during the latter part of February and early March, *i.e.* these were insects that had been in hibernation from the previous summer. This accounts for the fact that malaria was as prevalent during March and April, 1910, as in the same months of the previous year.

TABLE VI

Showing percentage of absences due to all causes as recorded in the ordinary register, during two successive years, 1909 without protection and 1910 under malaria-control conditions.

	DAYS ABSENCE	NO. OF CHILDREN	DAYS ABSENCE PER CHILD
1909 January . . .	39	23	1.70
February . . .	33	24	1.37
March	16	23	.70
April	23	22	1.04
September . .	20	23	.87
October . . .	37	30	1.23
November . .	37	30	1.23
December . . .	24	30	.80
1910 January . . .	36	30	1.20
February . . .	30	28	1.07
March ¹	33	28	1.18
April ¹	22	28	.79
September . .	15	25	.60
October . . .	23	26	.88
November . . .	10	26	.39
December . . .	12	27	.44

¹ The prevalence of malaria during these months is always greatest, and furthermore the spring statistics would be faulty for comparison, inasmuch as the crusade did not begin until March 1, 1910, as already explained.

TABLE VII

Comparison based on actual count of absences due to malaria, including cases over five days from September to December inclusive, during 1909, when no anti-malaria work was in progress, and 1910, when such a crusade was carried on. The average reduction of absences in per cent is also shown.

MONTH	CHILD DAYS ATTENDANCE		DAYS ABSENT		AVERAGE % ABSENT		AVERAGE REDUCTION OF ABSENCES IN %
	1909	1910	1909	1910	1909	1910	
September. .	326	458	25	22	7.7	4.8	38
October . .	562	511	38	24	6.8	4.7	31
November. .	570	520	37	10	6.5	1.9	71
December . .	450	405	24	12	5.3	2.9	45
Totals . .	1908	1894	124	68	6.5	3.6	45

By an examination of the above comparisons it will be seen that the absences in the school due to malaria were reduced by 45 per cent, nearly one half, — and that in only one season's work. This showing in the face of limited funds is very good. The efficiency of this campaign was probably not higher than 50 per cent, therefore under full efficiency a reduction of 75 per cent of the cases of malaria could have been expected, with increasing reduction in succeeding years with continuous work. That the reduction of absences is less in October (31 per cent) than in September (38 per cent) is due to the fact that there was a change of inspectors in late August and during the interim there was insufficient protection. The result, of course, does not appear, however, until October.

THE STATE BOARD OF HEALTH ON MALARIA IN CALIFORNIA

“THERE are no complete statistics on malaria in California. The disease seldom results directly in death. In 1909 there were only 112 deaths¹ from malaria in the state, of which 104 were in Northern and Central California, and eight in Southern California. The average age at death of cases reported is 44 years. The mortality in California is probably less than 2 per cent, which would indicate approximately 5000 or 6000 cases in the past year. The Sacramento and San Joaquin Valleys are crossed by many tributaries of their two great rivers. The districts adjacent to these tributaries and close to the foothills of the Sierra Nevada Range are involved primarily in the spread of this disease, though its victims have transferred their residence to every part of the State. The annual losses from malaria may be estimated for purposes of illustration as follows.² (See Table on page 6, giving total loss at \$2,820,400.)

¹ The United States census, 1909, mortality report gives malaria 4.8 deaths per 100,000 population for the entire registration area. Checking this by the 1910 census, just completed for California, which gives over 2,300,000, the result is a striking verification of the forecast ($23.5 \times 4.8 = 112.8$ deaths).

² Professor L. O. Howard, entomologist for the United States Depart-

"The National Conservation Commission reported to President Roosevelt that 80 per cent of malaria could be prevented. Applying this same percentage to this total loss, there results a net preventable loss of \$2,256,000 annually. The significance of this loss can best be brought out by some comparative statistics. The United States mortality reports show that in 1909 California had one eleventh of all the deaths from malaria in the registration area,¹ which includes eighteen states, and ranked second in number of deaths for a single state. Indiana was first with 125 deaths, New York third (95 deaths), Ohio fourth (75 deaths), Pennsylvania fifth (50 deaths). In proportion to population California outranks all other states in this area. Within the State 66 per cent of the deaths occurred in ten counties extending in an almost unbroken chain along the base of the Sierra Nevada Mountains. The total population for these counties (1910 census) is 326,896. Malaria, therefore, causes five times as many deaths per 100,000 of population as the average for the United States registration area. In these ten counties² the 1909 death rate was one

ment of Agriculture, estimates the annual cost to the United States for malaria to be \$100,000,000. In proportion to population California should represent one thirty-eighth of this, or \$2,630,000 per year loss.

¹ Registration area is area making full reports of all deaths to Census Bureau. It includes California, Colorado, Connecticut, Indiana, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, Washington, and Wisconsin.

² Beginning at the northern end of Sacramento Valley these counties

death to 4400 people. A second group of ten counties ¹ contiguous to those of the first group shows one death to each 15,820 of population. A third group of ten counties ² forming a chain along the coast shows one death to each 57,614 of population. Twenty-eight ³ or almost 50 per cent of the counties show no malarial deaths. Excluding the counties of San Francisco and Los Angeles, ⁴ there remains the fact that two thirds of the population live in counties which contributed all the deaths from malaria, while one third of the population of the State lives in counties which had no malarial deaths in 1909. A further study of the distribution of malaria in California shows Butte County 15 per cent, Sacramento County 10 per cent. San Joaquin 9.8 per cent, Fresno 6.2 per cent, Shasta 5.4 per cent of the deaths in 1909. These counties, with only one sixteenth of the total population of the

are: Shasta, Tehama, Butte, Yuba, Placer, Sacramento, Amador, San Joaquin, Fresno, Kern. These ten counties alone sustain \$1,488,960 of the total annual estimated loss from malaria. The total value of all property in these counties is scarcely 160 times this annual loss.

¹ Similarly arranged, these counties are: Trinity, Sutter, Yolo, Napa, Contra Costa, Calaveras, Stanislaus, Merced, Tulare, and Kings.

² The third group forms a continuous chain of coast counties from San Francisco to the Tehachapi Mountains: San Francisco, San Mateo, Alameda, Santa Clara, Santa Cruz, San Benito, Monterey, San Luis Obispo, Santa Barbara, and Los Angeles.

³ One county, Sonoma, was inadvertently omitted from the coast county group, but the one death which occurred does not materially change the estimate.

⁴ These two counties have a population of 921,043 (1910 census). In 1909 there were twelve deaths from malaria, or one in 76,753 population.

state, have more than one third of all the deaths from malaria.

“If the counties bordering the Sacramento and San Joaquin Valleys and sending tributary streams to these two great rivers be divided by a line from the Suisun Bay to Mokelumne Peak, it will be found that eleven counties to the north of this line show 50 per cent of the deaths from malaria in 1909, and thirteen counties to the south of the line show 30 per cent of the deaths from this cause. In other words, the Sacramento and San Joaquin Valleys contributed 80 per cent of all the deaths from malaria within these valleys. The following figures are significant: Nine of the twenty-four counties had 75 per cent of the deaths, or 60.6 per cent of the deaths for the entire state. These nine counties fall into three groups: (1) Placer, Sacramento, San Joaquin, with 25 per cent of the deaths and a population of 136,774; (2) Butte, Tehama, Shasta, with 24 per cent of deaths and a population of 57,622; (3) Fresno, Tulare, Kern, with 11.6 per cent deaths and 148,812 population.

“Reducing these figures to terms of 100,000 population and comparing with the United States census average of 4.8 for the entire registration area, the Butte-Tehama-Shasta area shows 46.8 deaths per 100,000 population; the Placer-Sacramento-San Joaquin area shows 20.4 deaths per 100,000; and the Fresno-Tulare-Kern area shows 8.9 deaths per 100,000 population. These figures are not given to

indicate that these counties are hopelessly undesirable sections of the State to live in, but to prove beyond question that there is great need for centering a well-organized, persistent fight against malaria in these three areas. The object of the writer is to show the financial loss now being sustained and to illustrate clearly the importance of supporting the excellent work done during the past year.

“During 1910 three anti-mosquito organizations began work, with headquarters in Oroville (Butte County), Penryn (Placer County), and Bakersfield (Kern County). These organizations are described elsewhere in this book, but their significance to California’s future deserves emphasis. In mere money values their success means the saving of upwards of \$500,000 annually to each of the first two areas, \$225,000 annually to the third one, and ultimately over \$2,250,000 a year to the entire State.

“These organizations need money and the personal coöperation of every landowner in these districts. Their first work is educational. There are many residents of California who do not know that the prevalence of a special kind of mosquito in these districts is responsible for the losses and suffering caused by malaria. They must be taught that the malaria-bearing mosquito offers a vulnerable point of attack upon this disease, because this mosquito alone serves as the carrier of the malaria parasite from the blood of the person who has the disease to the blood of other persons who do not have it until bitten.”

SUMMARY

1. THE rural and small city population of the state is awakening to the possibilities of malaria control.

2. The losses due to malaria do not only consist in direct loss through drug and physicians' bills, but most especially in indirect losses through personal inefficiency and reduction in real estate valuation.

3. Malaria is a mosquito-borne disease in which the Anophe-line species are concerned, and the control of this disease is therefore dependent on the control of the mosquito as the cheapest and most efficient method.

4. The Anopheline mosquitoes as well as other species of mosquitoes must have water in which to breed. A thimbleful of water is enough to breed these insects. Partially overflowed pasture land is ideal. This condition is often produced by leaky irrigation ditches or water pipes.

5. Proper drainage is absolutely necessary; where this cannot be attained, the application of oil sprays, either crude and kerosene mixed approximately equal parts or stove distillates of about 30° Beaumé.

6. Oil must also be applied when drainage does not result in dry conditions before the larvæ or pupæ are ready to emerge as adults.

7. If oil is used, it must be applied repeatedly every twelve days during midsummer, less often in early spring and late autumn.

8. While malaria usually makes its appearance with irrigation, the latter is only indirectly the cause and is absolutely dependent on the slipshod methods in vogue in northern and central California. In the southern part of the state there is as much, if not more, irrigation, and malaria is virtually unknown.

9. Houses should be well screened in order to keep out mosquitoes at night. It pays to spend some time in searching for

the last mosquito that has chanced to enter — it takes only one bite from an infected mosquito to cause a case of malaria.

10. Communities that have carried on systematic mosquito campaigns have succeeded in reducing malaria to a very marked degree in one season, — 50 per cent has been accomplished in the first season.

11. A successful campaign can be conducted at the rate of seventy-five cents a day per square mile of protection, — each Inspector being responsible for ten square miles.

12. The crusade must be under the direct supervision of an expert Field Agent who has had proper training in malaria control and is familiar with rural health problems.

13. When a new campaign is undertaken, it is desirable that some work be done in October and November in order to eliminate the last brood of mosquitoes, which is the overwintering brood. The spring work should begin early in March, usually March 1st.

14. There is great need of a legislative act making it possible to provide funds to carry on anti-malaria work, since everybody in a given area is benefited, and a few should not be compelled to carry the financial burden. This can be accomplished by the organization of sanitary (mosquito) districts, in which the cost is covered by taxation, or secondly by a direct appropriation for such purposes. The increased influx of desirable colonists would more than offset the expense.

15. Malaria is the principal cause for absences in the rural public schools in the greater part of the malaria infested districts; otherwise climatic conditions favor good health. Absences due to malaria in a rural school were reduced by 45 per cent in one season, through a systematic anti-mosquito crusade.

16. Statistics show plainly that about three fourths of the malaria in the state of California is found in nine out of the twenty-four malarial counties. These nine counties are otherwise just as healthful as any of the others, malaria being virtually the only blight; — hence we find here the situation where systematic and energetic effort must be expended.

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