BULLETIN No. 25—NEW SERIES.

U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF ENTOMOLOGY.

NOTES

ON

THE MOSQUITOES OF THE UNITED STATES:

GIVING SOME ACCOUNT OF THEIR STRUCTURE AND BIOLOGY,
WITH REMARKS ON REMEDIES.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., July 24, 1900.

SIR: I have the honor to transmit herewith manuscript of a bulletin on the mosquitoes of the United States, which gives some account of their structure and biology and indicates the differences in all stages of existence between the kinds of mosquitoes which have been shown to transmit malaria and those which do not. It also treats of the subject of remedies in considerable detail. It has been written mainly from the popular standpoint, although scientific details of structure and classification have been inserted for the use of physicians engaged in studying malaria. I recommend that it be published as Bulletin No. 25, New Series.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

INTRODUCTION.

A number of articles and notes concerning mosquitoes have been published in different bulletins of this Division. The most extensive was the leading article in Bulletin No. 4, New Series ("The Principal Household Insects of the United States"), and constituted the larger part of chapter 1, on "Mosquitoes and Fleas." In this treatment of mosquitoes the complete life history of *Culex pungens* was given, based upon original observations made in the summer of 1895, and some general remarks on the subject of other species were brought together. Four pages were devoted to the subject of remedies, and the mosquitoes of the country at large were tabulated, with such notes on geographical distribution as could be brought together. The earlier notes published by the Division, including those extracts from correspondence and general notes which had been published in the seven volumes of Insect Life, and the writer's two articles on the use of kerosene against mosquito larvæ, were all digested in this bulletin, which was published in the summer of 1896. Subsequent brief notes on remedies have been published by the writer in miscellaneous bulletins of the Division and in the Scientific American, and the life history of *Anopheles quadrimaculatus* was described, in comparison with that of *Culex pungens*, in a short illustrated article in the Scientific American for July 7, 1900.

The writer first became interested in mosquitoes thirty years or more ago, when as a boy he fished and collected insects in the marshes at the head of Cayuga Lake, New York, and as early as 1867 had experimented with the kerosene remedy against mosquito larvæ in a horse trough at Ithaca. In 1881 he discussed with Dr. A. F. A. King and the late C. V. Riley the bearings of the theory, which Dr. King was the first to bring forward in the United States, of the probable relation between mosquitoes and malaria, both Dr. Riley and the writer contending, it must be confessed, that the arguments brought forward by Dr. King in conversation were based upon coincidental observations, and afforded no good proof of cause and effect.

The writer's practical demonstration in 1894 of the value of the kerosene treatment as a practical large-scale remedy attracted considerable attention to the subject of remedies for mosquitoes, and many large-scale experiments were made, some of them being successful to a marked degree, as will be pointed out later in the section on remedies. The services of the members of this office force were called into requisition on a number of occasions to determine actual breeding points in mosquito-infested regions, and interest in the subject gradually increased until, during the past two or three years, the researches of those medical men, whose names have since become so well known in this connection, showed by exact methods that Dr. King's theory must no longer be considered a theory but a demonstrated fact. It has resulted that the attention of the entire civilized world has been drawn with vivid interest toward the whole mosquito question. Every fact concerning mosquitoes becomes now of great potential importance. The correspondence of this office on mosquitoes, owing largely to its publications, has become greatly increased. The writer has been invited to address scientific bodies and citizens' improvement associations on the subject of mosquito extermination, and in the spring of the present year lectured before the annual meeting of the Royal Society of Canada and before the section on theory and practice of medicine of the American Medical Association on the subject of the biology of the mosquitoes of the genus Anopheles as contrasted with that of the mosquitoes of the genus Culex. The demand for the publications of this Division on mosquito subjects has been so great that it has been deemed desirable to bring together the published and unpublished articles and notes in convenient reference form from the standpoint of the United States only, and this has been done in the present bulletin.

The writer is indebted to his assistants, Mr. D. W. Coquillett, for determinations of the different mosquitoes discussed; Mr. F. C. Pratt, for untiring efforts in the collection of material; Mr. August Busck, Mr. R. S. Clifton, and Mr. J. Kotinsky, for assistance in laboratory experiments, and Miss L. Sullivan, for the preparation of the illustrations. Information and specimens derived from many correspondents are acknowledged in the pages of the bulletin.

L. O. H.

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NOTES ON THE MOSQUITOES OF THE UNITED STATES.

ON MOSQUITOES IN GENERAL.

Abundance of mosquitoes.—The literature of popular entomology is full of instances of the enormous numbers in which mosquitoes occasionally occur. Persons interested in this line of curious reading should consult Kirby and Spence's An Introduction to Entomology, Volume 1, pages 112–120, and Frank Cowan's Curious Facts in the History of Insects, pages 278–286. Referring to their occurrence in the far northern regions, Kirby and Spence, for example, say: "In Lapland their numbers are so prodigious as to be compared to a flight of snow when the flakes fall thickest or to the dust of the earth. The natives can not take a mouthful of food or lie down to sleep in their cabins unless they be fumigated almost to suffocation. In the air you can not draw your breath without having your mouth and nostrils filled with them, and unguents of tar, fish grease, or cream, or nets steeped in fetid birch oil are scarcely sufficient to protect even the case-hardened cuticle of the Laplander from their bite." Elsewhere the same authorities say: "In the neighborhood of the Crimea the Russian soldiers are obliged to sleep in sacks to defend themselves from the mosquitoes, and even this is not a sufficient security, for several of them die in consequence of mortification produced by the bites of these furious bloodsuckers." Elsewhere: "And Captain Stedman, in America, as a proof of the dreadful state to which he and his soldiers were reduced by them, mentions that they were forced to sleep with their heads thrust into holes made in the earth with their bayonets and their necks wrapped round with their hammocks." Humboldt says: "Between the little harbor of Higuerote and the mouth of the Rio Unare the wretched inhabitants are accustomed to stretch themselves on the ground and pass the nights buried in the sand 3 or 4 inches deep, leaving out the head only, which they cover with a handkerchief." Theodoretus says that Sapor, King of Persia, was compelled to raise the siege of Nisibis by a plague of gnats, which attacked his elephants and beasts of burden and so caused the rout of his army.

In modern times nearly every hunter and fisherman in this country has had experience with mosquitoes which renders easy of belief all of the old-time stories. The instance mentioned in Bulletin No. 4, of the observations by Mr. Schwarz, of this office, at Corpus Christi, Tex., could be practically duplicated by many persons. He showed that when the wind blows from any other direction than south "hundreds of thousands of millions" of mosquitoes blow in upon the town. Great herds of hundreds of horses run before the mosquitoes in order to get to the water. With a change of wind, however, the mosquitoes blow away. Many regions, especially along the seacoast, have been actually rendered uninhabitable by the abundance of mosquitoes, and they have been a serious drawback to the settlement of many otherwise advantageous and fertile localities.

Dr. Otto Lugger reports, on pages 216, 217 of his annual report for 1896 as entomologist to the Minnesota State Agricultural Experiment Station, an interesting series of observations to determine the number of mosquitoes which may be bred in an ordinary rain barrel. The observations were made at St. Anthony Park, Minnesota. On July 6, 1896, the water in one barrel was filtered and was found to contain 17,259 eggs, larvæ, and pupæ. On July 22, 1896, by a similar process, 19,110 mosquitoes were counted. When we consider that at least twelve generations may breed in a summer it is obvious, from Dr. Lugger's account, that a neighborhood may be well supplied from one neglected rain-water barrel.

Alaskan and other far northern mosquitoes.—Since the opening up of the gold fields in Alaska and the great influx of miners and traders, knowledge of the abundance and ferocity of the Alaskan mosquitoes has become widespread, and surveying parties from the United States Coast and Geodetic Survey and the United States Geological Survey in starting for Alaska for their summer's work are in the habit of consulting this office for the best remedies for mosquito bites. Those who were in Alaska the preceding year always state that they never experienced or even imagined anything in the mosquito line quite equal to those found in our northern territory. Mr. W. C. Henderson, of Philadelphia, who spent some time in Alaska recently, writes: "They existed in countless millions, driving us to the verge of suicide or insanity." Nothing has as yet been published regarding the exact species found in Alaska, but Mr. Coquillett has determined *Culex consobrinus* and *Culex impiger* from specimens collected by Prof. Trevor Kincaid on the Harriman expedition of 1899. *C. consobrinus* was collected at Sitka June 16, and Yakutat June 21; and *C. impiger* was taken at Sitka June 16, Yakutat June 21, Virgins Bay June 26, and Popoff Island July 8–16.

That the knowledge of the existence of mosquitoes in boreal regions is not new is shown by the quotation just made from Kirby and Spence, and in Bulletin No. 4 the writer mentioned some of the instances of record by arctic explorers, citing, for example, the narrative of C. F. Hall's second arctic expedition, in which the statement is made that mosquitoes appeared on the 7th of July, 1869, in extraordinary abundance, and of Dr. E. Sterling, of Cleveland, Ohio, who sent us an account of the appearance of mosquitoes by thousands in March, 1844, when he was on a snowshoe trip from Mackinaw to Sault Ste. Marie. Their extraordinary appearance at that season of the year was remarkable as indicating a most plentiful hibernation. Mr. H. Stewart, of North Carolina, was also quoted as noticing, on the north shore of Lake Superior, in 1866, in the warm days of March, when the snow was several feet deep and the ice on the lake 5 feet in thickness, that mosquitoes appeared in swarms, "literally blackening the banks of snow in the sheltered places." Dr. Otto Lugger was also quoted as stating that *Culex consobrinus* made its appearance in April, 1896, at St. Anthony Park, Minnesota, in a genuine swarm with a heavy snowstorm, at a time when all the lakes were covered with ice.

Dr. Lugger has also called the writer's attention to the fact that Dr. Emile Bessels, of the Polaris expedition, was obliged to interrupt his work in Davis Straits (latitude 72° N.) on account of the multitude of these insects.

Length of life of the adult mosquito.—A curious and as yet unexplained point in regard to a phase of mosquito existence is their extraordinary abundance at certain times upon dry prairies miles from water, which has led to the very generally accepted idea among far Westerners that all mosquitoes do not need pools of stagnant water in which to breed, but that certain of them must have some other breeding habit. This supposition still appears incredible to the writer, who is much more inclined to attribute this abundance in dry regions to a greater longevity on the part of the adult mosquitoes of certain species than has been proven, thus enabling these great swarms to live from one rainy spell to another, no matter how widely separated. The gravid females of most insects seem to be able to live until they have opportunity for appropriate oviposition. The writer is frequently asked as to the duration of the adult stage of mosquitoes, but beyond the statement that although adults hibernate, living in this condition from November until April or May in the latitude of Washington, he is obliged to state that they die rather quickly in confinement in the summer. He has had living specimens of *Anopheles quadrimaculatus* confined in breeding jars for eight days, all dying, however, at the expiration of that time. Dr. Woldert has kept adults for fifteen days in a wide-mouthed bottle in which was placed a small slice of banana, the gauze with which the bottle was covered being sprinkled every day. Other specimens were kept from fifty to sixty days, but this was in the late fall, and many of them would probably have hibernated. Dr. Manson states that they may be kept for weeks in a glass vessel containing a piece of ripe banana, the banana being renewed every three or four days.

Life history of mosquitoes in general.—In general terms the biology of the Culicidæ—the family to which the true mosquitoes belong—may briefly be summed up. All general statements heretofore have been based upon the life history of one or two species of the genus Culex, yet it is certain that such remarks will not only not hold for the whole family, but that, except in a general way, they will not hold for all the species of Culex. So far as is definitely known, the larvæ of all mosquitoes are aquatic, although they are true air breathers; that is to say, they must come to the surface of the water to breathe. They are rapid breeders and pass the pupal condition also in water, but floating normally at the surface. They pass through several generations in the course of a year and hibernate as adults. Hibernating mosquitoes may frequently be found during the winter months in barns and in the cellars and cold garrets of houses. Dr. W. S. Thayer, of Baltimore, informs the writer that he found *Anopheles crucians* and *A. quadrimaculatus* hibernating in enormous numbers in barns near New Orleans, clustering under the roofs and on the walls. In the extreme Southern States many mosquitoes are active all through the winter, and mosquito bars are almost as necessary at Christmas time as during the summer.

Food of adult mosquitoes.—It is a well-known fact that the adult male mosquito does not necessarily take nourishment and that the adult female does not necessarily rely on the blood of warm-blooded animals. The mouth parts of the male are so different from those of the female that it is probable that if it feeds at all it obtains its food in a quite different manner from the female. They are often observed sipping at drops of water, and in one instance a fondness for molasses has been recorded.

The writer has already placed on record the instance in which his colleague, Mr. E. A. Schwarz, observed a male mosquito sipping beer, but the most interesting instance of alcoholism of the male mosquito which has come to his notice was described in a letter received last spring from Dr. St. George Gray, of Castries, St. Lucia, British West Indies. Dr. Gray wrote:

"The males, especially *C. pipiens*, are very fond of wine, and almost every day I can catch one or two—always males—on the neck of the decanter or in a wineglass that has just been used. I put a few mosquitoes under a bell jar one day in order to watch them. I put a single drop of port wine under the jar, as I had heard that mosquitoes could be kept alive for a long time on wine. When I went to look at them a few hours later I found them all apparently dead, so I put them in a dry bottle, intending to pin them later. When I went to pin them shortly afterwards they were all staggering about in the most ridiculous manner—they were drunk!"

The female mosquitoes are normally without much doubt plant feeders. Why they should draw blood at all is a question which has not been solved. It has been surmised that a supply of highly nutritive fluid is necessary for the formation of the eggs, but this supposition is at once emphatically negatived by the fact that mosquitoes abound in regions into which warm-blooded animals never penetrate. The statement which the writer has elsewhere made, that not one in a million ever gets the opportunity to taste the blood of a warm-blooded animal, is unquestionably an underestimate. There are in this country enormous tracts of marshy land into which warm-blooded animals never find their way and in which mosquitoes are breeding in countless numbers, and when we get within the Arctic Circle and other uninhabited regions the point is emphasized. Scattered through the seven volumes of Insect Life are records of the observation of the vegetarian habit, one writer stating that he has seen mosquitoes with their beaks inserted in boiled potatoes and another that he has seen watermelon rinds with many mosquitoes settled upon them busily engaged in sucking the juice. That they may and occasionally do feed upon other than warm-blooded animals, however, is evidenced by an observation by the late Dr. H. A. Hagen, who mentions taking a species of mosquito in the Northwest which was engaged in feeding upon the chrysalis of a butterfly, while there are several instances on record where they have been observed puncturing the heads of young fish and killing them.

How far will mosquitoes fly?—The question is often asked: "How far will mosquitoes fly from their breeding places, or how far can they be driven by the wind?" In some instances this becomes a matter of practical importance, since, if mosquitoes fly great distances, exterminative work on the breeding places near a house or community will be of comparatively slight avail. There exists on this point a difference of opinion. In a discussion at the meeting of the Association of Economic Entomologists at Boston, in August, 1898, Dr. John B. Smith stated, in referring to the possibility of mosquitoes being carried by strong winds to considerable distances, that he had noticed that they would not rise or take flight when a brisk breeze was blowing, and that even a comparatively slight breeze will keep them from upper stories in houses. He, therefore, doubted the wide distribution of mosquitoes by high winds. Dr. H. T. Fernald stated that at Cold Spring Harbor, Long Island, with a north breeze there are no mosquitoes. With a south breeze, on the other hand, they are often very troublesome, especially after a prolonged gentle wind of five or more hours' duration. There are no pools in the center of the island, and the mosquitoes are supposed to have been carried from the south shore, a distance of some 15 miles. This question became a very practical one to the members of the Richmond County Country Club on Staten Island, in their operations against the breeding places of mosquitoes on the island, since, if a new supply could be carried over by the winds from the New Jersey coast near by, a large portion of their labor would be wasted. Mr. W. C. Kerr, the originator of the mosquito work at that place, and an excellent observer, is decidedly of the opinion that mosquitoes are not brought over from New Jersey.

Almost everyone must have noticed the habit of mosquitoes of clinging to branches of trees and grasses during a high wind, swarming out in flight as the wind subsides, but there must be instances when they are greatly aided in spreading by such gentle winds as those mentioned above by Dr. Fernald.

In this connection an observation made by Mr. R. M. Reese in Baltimore is significant. He found that by treating the privy vault in his backyard with kerosene, the supply of mosquitoes to the house was greatly reduced, although there were many other breeding places only a little farther removed.

Another significant instance was mentioned by Prof. Herbert Osborn at the Boston meeting of the Association of Economic Entomologists. He said that in dry seasons the small pools within a quarter to a half a mile from the college buildings at Ames, Iowa, dry up and the mosquitoes disappear, in spite of the fact that within about a mile there are large pools which never become dry.

On this point Mrs. C. B. Aaron writes very sensibly as follows (Dragon Flies *vs.* Mosquitoes—The Lamborn Essays, Appleton & Co., 1890, pp. 35–36):

> The migration of mosquitoes has been the source of much misapprehension on the part of the public. The idea prevalent at our seaside resorts that a land breeze brings the swarms of mosquitoes from far inland is based on the supposition that it is capable of long-sustained flight and a certain amount of battling against the wind. This is an error. Mosquitoes are frail of wing; a light puff of breath will illustrate this by hurling the helpless creature away, and it will not venture on the wing again for some time after finding a safe harbor. The prevalence of mosquitoes during a land breeze is easily explained. It is usually only during the lulls in the wind at such times that Culex can fly. Generally on our coast a sea breeze means a stiff breeze, and during these even the Odonata, and often the robust and ventursome Tabanidæ, will be found hovering on the leeward side of the houses, sand dunes, and thick foliage. In the meadows south of Atlantic City, N. J., large swarms of Culex are sheltered in the dense grass or wind-battered tree tops on the off side of the sand dunes. Here, in common with all localities so exposed to searching wind, the trees and large bushes are much stunted in growth and battered down to a flat top and common level by the wind. In these matted branches, dense with the close-clustered foliage, the mosquitoes may be discovered in such numbers as to bring despair to the heart of the student who is plotting their final extermination. While the strong breezes last Culex will stick close to these friendly shelters, though a cluster of houses may be but a few rods off, filled with unsuspecting mortals who imagine their tormentors are far inland over the salt meadows. But if the wind dies down, as it usually does when veering, out come swarms upon swarms of the females intent upon satisfying their depraved taste for blood. This explains why they appear on the field of action almost immediately after the cessation in the strong breeze; on the supposition that they were blown far inland, this sudden reappearance would be unaccountable.

Carriage of mosquitoes by railway trains.—The State of New Jersey has an unfortunate reputation in connection with mosquitoes. While it is undoubtedly true that mosquitoes are very abundant in most parts of the State, that fact does not mean to the writer that in the greater part of the State there are any more breeding spaces or that mosquitoes are any more prolific within the State borders than elsewhere. It does, however, seem to him that there is constant carriage inland from the marshy seacoast of very many mosquitoes, but by this he does not intend to convey the idea that they are carried by wind or that they fly to any great distance inland. There are other means of conveyance, and of these railway trains seem to be very important. All through the summer evenings many trains are started inland from Weehawken, Hoboken, Jersey City, South Amboy, Long Branch, Atlantic City, Ocean City, and Cape May, N. J. Many of the cars, as the writer knows from experience, contain mosquitoes by the hundreds. In this way unlimited quantities of mosquitoes are carried unlimited distances, and, emerging from the cars, will start to breed even in localities where mosquitoes are ordinarily rare, or would be rare under ordinary conditions. In this way even mountain resorts will get their supply of lowland mosquitoes, and with the improvement of railway service and the increase in number of through cars the danger is constantly increasing. The writer knows of one instance in the Catskill Mountains in New York where the infestation of a previously uninfested place could have been brought about in no other way. Through parlor and through baggage cars now run from Jersey City and Weehawken into the heart of the Catskills and through trains from Boston into the White Mountains.

In the same way through cars run from Baltimore into the Blue Ridge, and thus a constant source of supply may be, and undoubtedly is, kept up.

How long can the larvæ live out of water?—At the meeting of the Association of Economic Entomologists above referred to, Dr. Smith asked if it were possible for mosquitoes to breed in mud, and suggested that there was no reason to believe that the actual presence of water was necessary for all mosquito species. The writer has seen a statement from some Californian, which he is unable to place at the present time, to the effect that there is a prevalent belief in some parts of the United States that when a surface pool dries up half-grown larvæ may exist in the drying mud for some time, reviving with a fresh rain. Mr. C. A. Sperry, of Chicago, wrote us early in 1899 and advanced the same theory. He said that experiments made in small vessels had always been very unsatisfactory to him, and that he abandoned that method and sought the natural breeding places for investigation and experiment. Early in July he found a wet-weather pond with mosquito larvæ in it, the pond being nearly dry. In a few days the water was all gone. He examined closely and discovered no dead larvæ. In about a week it rained, and as soon as the rain stopped he went to the place and found the mosquito larvæ all through the water as lively as ever, and they began to issue as adults about a week from that time. Again he discovered a place where the water had nearly dried up, and hundreds of mosquito larvæ were seen by him on the wet ground. Three days later it rained, and he found the larvæ in the water as lively as ever. In the same way Mr. Benjamin S. Paschall, of Newfield, N. J., has communicated to us observations of his own which indicate to him a possibility that mosquitoes may breed in grass or moist earth.

Experiments made at this office on a small scale in glass vessels have shown that the larvæ of Culex will exist for some little time in wet mud, and some of them will successfully transform after water has been added. 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. An interesting pool has been under observation during the present month. The pool contained a surface area of abcut 24 square feet, and was fed entirely by rain water and surface drainage, reaching a depth when full of about 1 foot. All through the summer this pool is well stocked with mosquito larvæ. After a somewhat long drought the water was observed on July 18 to have evaporated almost entirely, a small puddle in the center of the cavity, containing only 3 or 4 cubic inches of water, remaining. It was dark in color, owing to the drainage from a manure pile near by, and to the casual observer showed no signs of life. The water in this little puddle was very shallow. On dipping in a coffee strainer, however, it was found to be literally massed with nearly full-grown mosquito larvæ, many hundreds of which had been brought together into this restricted place. The drying continued until there was almost no water left. On the night of the 20th came a heavy rain, followed with a still heavier one on the morning of the 22d. On the 23d the pool was found to be entirely full of water and to contain its usual stock of mosquito larvæ.

This may be safely said to indicate the usual habit of mosquito larvæ in evaporating pools. As the water gradually recedes toward the deepest portion of the excavation, the larvæ recede with it, concentrating themselves at the deepest point, i. e., at the point where the moisture remains longest. Knowing as we do, then, that even in the absence of any free water the larvæ will remain alive in moist mud for from twenty-four to forty-eight hours, it is evident that such a pool as the one described gradually drying would give the appearance of having been practically dried up for some days before the last cubic inch of free water has entirely disappeared. The concentration of many larvæ at this point in the manner which has been described could not fail to give rise to the belief that mosquito larvæ will exist in the absence of free water for a much longer period than is really the case. In the opinion of the writer, where the mud dries up entirely the mosquito larvæ are necessarily killed, but that they may exist in very wet mud for a longer or shorter time is true.

An interesting observation bearing upon this point has been made by Dr. St. George Gray, of Castries, St. Lucia, British West Indies, and reported in the Journal of Tropical Medicine, London, May 15, 1900. He says that on February 7, 1900, he examined a spot where he had obtained larvæ of Anopheles a few months before. The pool had been dry for three weeks, hardly any rain having fallen during that time. The surface of the mud at the bottom was cracked and dry, although soft enough under the crust. He put the mud into a clean pickle bottle and put about 3 inches of filtered water over it, but there was no result. He also took some grass from the sides of the pool and put that grass into another pickle bottle, adding 3 inches of filtered water. On the following morning he found a few minute larvæ wriggling about in this bottle. These rapidly grew in size, and he soon had a half dozen healthy looking larvæ in his bottle. On the 21st, a fortnight after he had taken the grass from the sides of the pool, he reared the imago of *Culex tæniatus.* From this observation he argues that some species of Culex, at any rate, do not always lay their eggs on the surface of the water, but where they will be washed into the pool by the first heavy rain. Other similar experiments were failures. This record is a very interesting one, but, like all isolated observations, needs verification.[1] It may here be mentioned that Drs. J. W. W. Stephens and S. R. Christophers, in their article on "The distribution of Anopheles in Sierra Leone," published in the reports of the malarial committee to the Royal Society (London, July 6, 1900), stated that they were unable to hatch the eggs of Anopheles after desiccation on blotting paper for more than forty-eight hours, although they hatched after twenty-four and forty-eight hours' drying, respectively.

The number of species of mosquitoes.—As regards the different kinds of mosquitoes, about 250 species are known, of which only about 30 have been found in the United States. These are divided into 5 different genera, each of which will receive consideration in the following pages. Of the malarial genus Anopheles, Mr. F. V. Theobald writes us there are 27 species in the British Museum collection.

MOSQUITOES AND MALARIA.

This is not the place to discuss at length the history of the discoveries which have brought about the very perfect proof that mosquitoes may and do transfer the malaria germ from a malaria patient and

[1] Dr. Walter Reed, U. S. A., tells me that Dr. Lazear has just made a similar observation in Cuba.

deposit it in the blood of a healthy person. Those interested are referred to the admirable paper entitled "On the rôle of insects, Arachnids and Myriapods, as carriers in the spread of bacterial and parasitic diseases of man and animals; a critical and historical study," by George H. Nuttall, M. D., Ph. D., published in Volume VIII of the Johns Hopkins Hospital Reports, and to later American summaries, among which may be mentioned that by Dr. W. N. Berkeley in the New York Medical Record for December 23, 1899, by Dr. Albert Woldert in the Journal of the American Medical Association for February 10, 1900,[1] and by Dr. William Britt Burns in the Memphis Medical Monthly for March, 1900. One of the most thorough of the recent reviews will be found in Nature for March 29, 1900, pages 522–527, entitled "Malaria and mosquitoes," a lecture delivered at the Royal Institution of Great Britain on March 2, by Maj. Ronald Ross, D. P. H., M. R. C. S., lecturer in tropical medicine, University College, Liverpool, himself one of the workers whose results contributed most materially to the establishment of definite proof. Another recent account will be found in the Popular Science Monthly for July, 1900, by Dr. Patrick Manson, entitled "Malaria and the malarial parasite." It should be stated here, however, that only the mosquitoes of the genus Anopheles have been found to contain the human blood parasites, although it does not appear from the published accounts which have met the writer's eye that any other genera than Anopheles and Culex have been studied in this connection.

The Italian observers have found that all three species of the human Hæmamoebidæ are cultivable in *Anopheles claviger* and not only in this but in other Italian species of Anopheles, while they, together with Ross and other observers, have failed to cultivate the parasites in Culex. The same fact is upheld by the extended observations made in West Africa and in this country so far as observations have been made as yet. The writer, however, wishes to emphasize the point which he made before the American Medical Association on June 6, 1900, that American physicians, especially those in the Southern States, should not delay the investigation of the very large mosquitoes of the genus Psorophora and Megarhinus from the malarial standpoint. Both of these genera have been figured and described in succeeding pages.

SYNOPTIC TABLES OF THE NORTH AMERICAN MOSQUITOES.

In order to enable the ready determination of our different mosquitoes the writer published in Circular 40, second series, of this office, in February of the present year, a series of tables, drawn up at his request by Mr. D. W. Coquillett, of the office force, comprising (1) a

[1] Dr. Woldert's article contains a good account of the internal anatomy of mosquitoes and describes his methods of dissection.

synopsis of the five genera under which the long-beaked, blood-sucking species known to occur in North America were divided; (2) a synoptic consideration of the species of the genus Culex, divided into (*a*) table of the recognized species, specimens of which occur in the National Museum collection, and (*b*) an account of the unrecognized species, which are known only from the literature; (3) a synoptic consideration of the species of the genus Anopheles, divided into (*a*) recognized forms, and (*b*) unrecognized forms; (4) a brief description of the only valid known species of the genus Psorophora; (5) a synoptic table of the three known species of the genus Megarhinus; and (6) a synoptic consideration of the two known species of the genus Aedes.

Mr. Coquillett's tables are here reprinted with slight changes:

I.—Generic Synopsis.

The following table contains all the genera of the long-beaked mosquitoes known to occur in North America. The males are readily recognized by the antennæ being densely covered with long hairs; in the females the hairs of the antennæ are short and very sparse:

1. Palpi in the male at least nearly as long as the proboscis; in the female less than one-half as long .... 2.
   Palpi in both sexes at least almost as long as the proboscis .... *Anopheles.*
   Palpi in both sexes less than one half as long as the proboscis .... *Aedes.*
2. Proboscis straight or nearly so, colors of body brown and yellowish .... 3.
   Proboscis strongly curving downward toward the tip, colors bluish or greenish. *Megarhinus.*
3. Legs bearing many nearly erect scales .... *Psorophora.*
   Legs destitute of such scales .... *Culex.*

II.—Genus Culex.

(*a*) recognized species.

Males.

1. Front tarsal claws bearing a distinct tooth near the middle of the underside of each .... 3.
   Front tarsal claws bearing two teeth on the underside of one claw, and one on underside of the other, proboscis destitute of a whitish band near the middle .... 2.
   Front tarsal claws with one tooth on underside of one of the claws, none on the other, bases of tarsal joints white, proboscis destitute of a whitish band near the middle .... *fasciatus* Fabr.
2. Tarsi distinctly white at bases of the joints .... *excitans* Walk.
   Tarsi not white at bases of the joints .... *consobrinus* Desv.
3. Proboscis destitute of a whitish ring near the middle .... 4.
   Proboscis with such a ring, ends of tarsal joints white .... *tarsalis* Coq.
4. Bases of tarsal joints not white .... 5.
   Bases of tarsal joints white .... *stimulans* Walk.
5. Petiole of submarginal cell less than one-third of the length of that cell. *pungens* Wied.
   Petiole of submarginal cell at least one-half of the length of that cell. *impiger* Walk.

Females.

1. Front tarsal claws bearing a distinct tooth near middle of underside of each .. 2.
   Front tarsal claws destitute of teeth .... 7.

2. Proboscis destitute of a white ring near the middle .... 3.
Proboscis marked with such a ring, bases of tarsal joints white.
tæniorhynchus Wied.
3. Bases of tarsal joints distinctly white .... 4.
Bases of tarsal joints never white .... 5.
4. Mesonotum marked with four stripes of silvery scales .... *fasciatus* Fabr.
Mesonotum destitute of such stripes:
Fifth joint of hind tarsi white .... *tæniatus* Wied.
Fifth joint, except its extreme base, dark brown .... *stimulans* Walk.
5. Last two joints of hind tarsi never white .... 6.
Last two joints of hind tarsi snow white .... *posticatus* Wied.
6. Abdomen marked with a cross band of whitish scales at base of each segment.
impiger Walk.
Abdomen never marked in this manner, but with a cluster of whitish scales at front angles of some of the segments .... *triseriatus* Say.
7. Proboscis marked with a distinct whitish ring near the middle, tarsi white at sutures of the joints .... 8.
Proboscis destitute of a whitish ring near the middle .... 9.
8. Tarsal joints white at bases only .... *perturbans* Walk.[1]
Tarsal joints white at both ends .... *tarsalis* Coq.
9. Tarsi white at bases of joints .... 10.
Tarsi never white at bases of the joints .... 12.
10. Mesonotum never marked with stripes of silvery scales .... 11.
Mesonotum marked with four stripes of silvery scales, first tarsal joint never marked with a whitish ring near the middle .... *signifer* Coq.
11. First tarsal joint marked with a whitish ring near middle of each.
excrucians Walk.
First tarsal joint destitute of such a ring .... *excitans* Walk.
12. Petiole of submarginal cell less than one-third of the length of that cell.
pungens Wied.
Petiole of submarginal cell at least almost one-half of the length of that cell.
consobrinus Desv.

(*b*) UNRECOGNIZED SPECIES.

annulatus Schrank. This European species was credited to our fauna by Osten Sacken. The description agrees fairly well with specimens which I have identified as *excitans*, Walker, except that in the latter there is no white ring on the femora toward their apices.

boscii Desv. Probably a rubbed specimen of *pungens*.

nigripes Zett. Black, the legs of the male dark yellow, hairs of pleura of female gray, a band of white scales at base of each segment of her abdomen.

rubidus Desv. The description was apparently founded on a rubbed specimen of *Psorophora ciliata*.

testaceus v. d. Wulp. Is probably a somewhat injured example of *consobrinus*.

incidens Thomson. Is evidently a synonym of *impiger* Walker.

bigoti Bellardi. According to the figure and description, the bands of black scales are at the *bases* of the abdominal segments; in the recognized species these bands are always at the apices of the segments. In other respects this species must greatly resemble *pungens*.

cubensis Bigot. Apparently founded on a badly rubbed specimen of *pungens*.

frater Desv. This name was proposed for the *Culex fasciatus* of Wiedemann, under the impression that this is not the same species as the one described by Fabricius under the same name. It seems quite certain, however, that the word "proboscis" in Fabricius' description was simply a lapsus for "palpi," and with this emendation the two descriptions agree very well.

mexicana Bellardi. Is evidently a synonym of *posticatus*.

provocans Walker. Is probably a synonym of *stimulans*. In some specimens of this species the light color at the bases of the tarsal joints is very indistinct.

territans Walker. Is apparently a synonym of *pungens*.

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[1] Mr. F. V. Theobald, after studying Walker's type of *perturbans*, writes us that it has toothed claws in the female.

Our recognized species of Culex and their synonyms may be listed as follows, the synonyms indented:

consobrinus Desv.
  ? *annulimanus* v. d. Wulp (Anopheles).
  impatiens Walker.
  inornatus Williston.
  pinguis Walker.
  punctor Kirby.
  ? *testaceus* v. d. Wulp.
excitans Walker.
  ? *annulatus* Osten Sacken (*nec* Meigen, etc.).
excrucians Walker.
fasciatus Fabr.
  frater Desv.
  mosquito Desv.
taeniatus Wied.
impiger Walker.
  implacabilis Walker.
  incidens Thomson.
  ? *quinquefasciatus* Say.
perturbans Walker.
posticatus Wied.
  ? *mexicanus* Bellardi.
  musicus Say.
pungens Wied.
  ? *boscii* Desv.
  ? *cubensis* Bigot.
  ? *territans* Walker.
signifer Coquillett.
stimulans Walker.
  ? *provocans* Walker.
taeniorhynchus Wied.
  damnosus Say.
  sollicitans Walker.
tarsalis Coquillett.
triseriatus Say.

III.—Genus Anopheles.

(*a*) recognized species.

1. With a yellowish white spot near three-fourths of the length of the front margin of the wing; scales of last vein white, those at each end black. *punctipennis* Say.
   Without such a spot .... 2.
2. Scales of last vein wholly black, palpi wholly black .... *quadrimaculatus* Say.
   Scales of last vein white, marked with three black spots, palpi marked with white at bases of last four joints .... *crucians* Wied.

(*b*) unrecognized species.

The following species which have been credited to our country have not been recognized with certainty; some of them probably do not belong to the present genus, while a few were evidently founded on badly rubbed specimens in which the distinctive characters were therefore wanting:

annulimanus v. d. Wulp. I strongly suspect that this does not belong to the present genus; the description applies fairly well to the male of *Culex consobrinus* Desv.

ferruginosus Wied. This author proposes this name for the species previously described by Say under the name of *Culex quinquefasciatus*, but the description which he gives differs so decidedly from the one published by Say as to give the impression that it is founded on a different species. I strongly suspect that the type of *ferruginosus* is a rubbed example of *Anopheles crucians*, which was described from the same locality. Say's description of his *Culex quinquefasciatus* agrees very well with the species which I have identified as *Culex impiger* Walker.

maculipennis Meigen. I strongly suspect that this European form is identical with our *Anopheles quadrimaculatus* Say, but this point can not be settled definitely at present, owing to the lack of any European specimens for comparison with ours.

nigripes Staeger. This European species should be readily recognized by its unspotted wings.

albimanus Wied. Differs from our other species by the snow-white apices of the tarsi.

Anopheles pictus Loew is evidently a synonym of *A. crucians* Wied.

Our recognized species of Anopheles and their synonyms may therefore be listed as follows, the synonyms indented:

crucians Wied.
  pictus Loew.
  ? *ferruginosus* Wied.
punctipennis Say.
  hiemalis Fitch.
quadrimaculatus Say.
  ? *maculipennis* Meigen.

IV.—Genus Psorophora.

Our single species is of a yellowish color, usually varied with brown, the bases of the tarsal joints white. It is considerably larger than any of our other species of yellowish or brown mosquitoes:

ciliatus Fabr.
  conterrens Walker.
  molestus Wied.
  ? *rubidus* Desv.

V.—Genus Megarhinus.

Our three species are among the largest in this family, and are not known to occur north of the District of Columbia. They may be separated as follows:

All tarsi marked with white .... *rutilus* Coq.
Hind tarsi alone marked with white .... *portoricensis* Roeder.
None of the tarsi marked with white .... *hæmorrhoidalis* Fabr.

VI.—Genus Aedes.

Our two species are among the smallest of our mosquitoes, and have a pale brownish ground color. They may be distinguished as follows:

Thorax marked with a median violet blue stripe .... *sapphirinus* O. S.
Thorax destitute of such a stripe .... *fuscus* O. S.

THE BIOLOGY OF CULEX, WITH REMARKS UPON SOME OF THE SPECIES.

It is tolerably certain that the life round of all of the species of the genus Culex is practically the same. They will differ more or less in the character of the water in which they preferably breed, and differing in this respect, they will differ also in some degree in their preferred food, which consists of all sorts of aquatic micro-organisms. Down to the time when the writer published his account of *Culex pungens*, in Bulletin No. 4, New Series, of this office, there was not in any published work a thoroughly satisfactory figure of a well-determined species of mosquito from the United States, or of its earlier stages. The statements quoted in the text-books and manuals dated back in general to the time of Réaumur—more than one hundred and fifty years ago. Réaumur's observations were made in the month of May upon a species (*Culex pipiens*) which does not occur in North America, and the observations were all made at Paris, so that statements as to the duration of the insect in any stage would be incorrect even for the same species in a warmer or colder locality. The following account of the life history of *Culex pungens* (fig. 1) is quoted from the writer's bulletin above cited:

Life history of Culex pungens.—The operation of egg laying was not observed, but it probably takes place in the very early morning hours. The eggs are laid in the usual boat-shaped mass, just as those of *Culex pipiens*, as described by Réaumur. We say boat-shaped mass, because that is the ordinary expression. As a matter of fact, however, the egg masses are of all sorts of shapes. The most common one is the pointed ellipse, convex below and concave above, all the eggs perpendicular, in 6 to 13 longitudinal rows, with from 3 or 4 to 40 eggs in a row. The number of eggs in each batch varies from 200 to 400. As seen from above the egg mass is gray brown; from below, silvery white, the latter appearance being due to the air film. It seems impossible to wet these egg masses. They may be pushed under water, but bob up apparently as dry as ever. The egg mass separates rather regularly, and the eggs are not stuck together very firmly. After they have hatched the mass will disintegrate in a few days, even in perfectly still water.

The individual eggs are 0.7 mm. in length and 0.16 mm. in diameter at the base. They are slender, broader and blunt at bottom, slenderer and somewhat pointed at tip. The tip is always dark grayish brown in

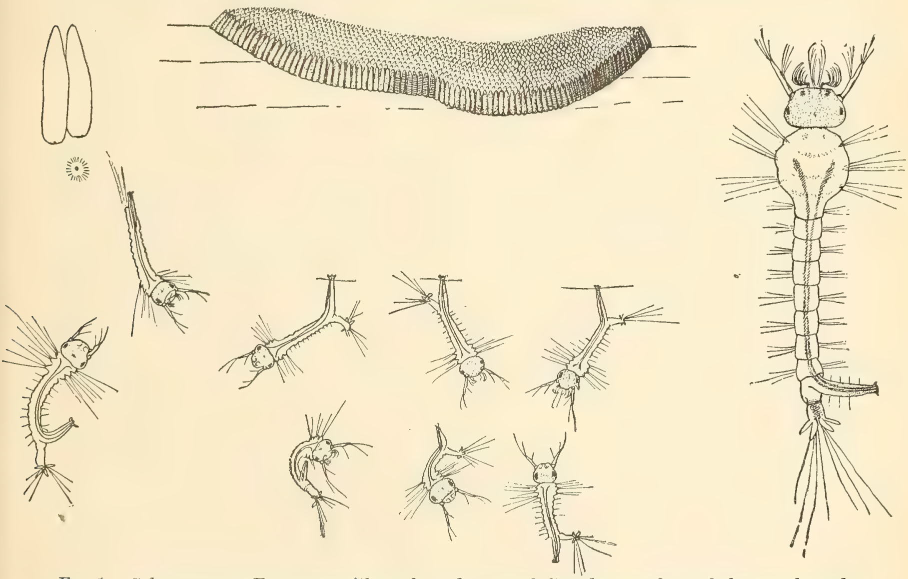

FIG. 1.—*Culex pungens:* Egg mass, with englarged eggs at left and young larvæ below—enlarged (original).

color, while the rest of the egg is dirty white. Repeated observations show that the eggs hatch, under advantageous conditions, certainly as soon as sixteen hours. Water buckets containing no egg masses, placed out at night, were found to contain egg masses at 8 o'clock in the morning, which, as above stated, were probably laid in the early morning, before daylight. These eggs, the third week in May, began to hatch quite regularly at 2 o'clock in the afternoon of the same day on warm days. In cooler weather they sometimes remained unhatched until the second day. If we apply the evidence of European observers to this species, the period of the egg state may be under twelve hours; but there is a possibility that they are laid earlier in the night, which accounts for the fact that sixteen hours is the shortest period which we can definitely mention.

The larvæ issue from the underside of the egg masses, and are extremely active at birth. When first observed it is easy to fall into an error regarding the length of time which they can remain under water, or rather without coming to the surface to breathe, since, in striving to come to the surface for air, many of them will strike the underside of the egg mass and remain there for many minntes. It is altogether likely, however, that they get air at this point through the eggs or through the air film by which the egg mass is surrounded, and that they are as readily drowned by continuous immersion as are the older ones, as will be shown later.

One of the first peculiarities which strikes one on observing these newly-hatched larvæ under the lens is that the tufts of filaments which are conspicuous at the mouth are in absolutely constant vibration. This peculiarity, and the wriggling of the larvæ through the water, and

FIG. 2.—*Culex pungens:* Head of larva from below at left; same from above at right—greatly enlarged (original).

their great activity, render them interesting objects of study. In general the larvæ, passing through apparently three different stages, reach maturity and transform to pupæ in a minimum of seven days. When nearly full grown, their movements were studied with more care, as they were easier to observe than when newly hatched. At this time the larva remains near the surface of the water, with its respiratory siphon at the exact surface and its mouth filaments in constant vibration, directing food into the mouth cavity. Occasionally the larva descends to the bottom, but, though repeatedly timed, a healthy individual was never seen to remain voluntarily below the surface more than a minute. In ascending it comes up with an effort, with a series of jerks and wrigglings with its tail. It descends without effort, but ascends with difficulty; in other words, its specific gravity seems to be greater than that of the water. As soon, however, as the respiratory siphon reaches the surface, fresh air flows into its tracheæ, and the physical properties of the so-called surface film of the water assist it in maintaining its position.

The respiratory tube takes its origin from the tip of the eighth abdominal segment, and the very large tracheæ can be seen extending to its extremity, where they have a double orifice. The ninth segment of the abdomen is armed at the tip with four flaps and six hairs, as shown in fig. 3. These flaps are gill-like in appearance, though they are probably simply locomotory in function. With so remarkably developed an apparatus for direct air breathing there is no necessity for gill structures. Raschke[1] and Hurst[2] consider that the larva breathes both by the anus and by these gill flaps, as well as by the large tracheæ which open at the tip of the respiratory tube. Raschke considers that these tracheæ are so unnecessarily large that they possess a hydrostatic function. The writer is inclined to believe that the gill flaps may be functional as branchial structures in the young larva, but that they largely lose this office in later life.

After seven or eight days, at a minimum, as just stated, the larva transforms to pupa. The pupa, as has been repeatedly pointed out with other species, differs most pronouncedly from the larva in the great swelling of the thoracic segments. In this stage the insect is lighter than water. It remains motionless at the surface, and when disturbed does not sink without effort, as does the larva, but is only able to descend by a violent muscular action. It wriggles and swims as actively as does the larva, and soon reaches the bottom of the jar or breeding place. As soon as it ceases to exert itself, however, it floats gradually up to the surface of the water again. The fact, however, that the larva, after it is once below the surface of the water, sinks rather than rises, accounts for the death of many individuals. If they become sick or weak, or for any reason are unable to exert sufficient muscular force to wriggle to the surface at frequent intervals, they will actually drown, and the writer has seen many of them die in this way. It seems almost like a contradiction in terms to speak of an aquatic insect drowning, but this is a frequent cause of mortality among wrigglers. This fact also explains the efficacy of the remedial treatment which causes the surface of the water to become covered with a film of oil of any kind. Aside from the actual insecticide effect of the oil, the larvæ drown from not being able to reach the air. The structure of the pupa differs in no material respect from that of corresponding stages of European species, as so admirably figured and described by the older writers, notably Réaumur and Swammerdam[3], and needs no description

[1] Raschke, Die Larve von *Culex nemorosus*, Berlin, 1887.

[2] Hurst, the Pupal Stage of Culex, Manchester, 1890.

[3] Even Bonanni, in 1691, gave very fair figures of the larva and pupa of a European species. Micrographia Curiosa, Rome, MDCXCI, Pars. II, Tab. I.

in view of the care with which the figures accompanying this article have been drawn. The air tubes no longer open at the anal end of the body, but through two trumpet-shaped sclerites on the thorax, from which it results that the pupa remains upright at the surface, instead of with the head downward. There is a very apparent object in this reversal of the position of the body, since the adult insect issues from the thorax and needs the floating skin to support itself while its wings are expanding.

In general, the adult insects issue from the pupæ that are two days

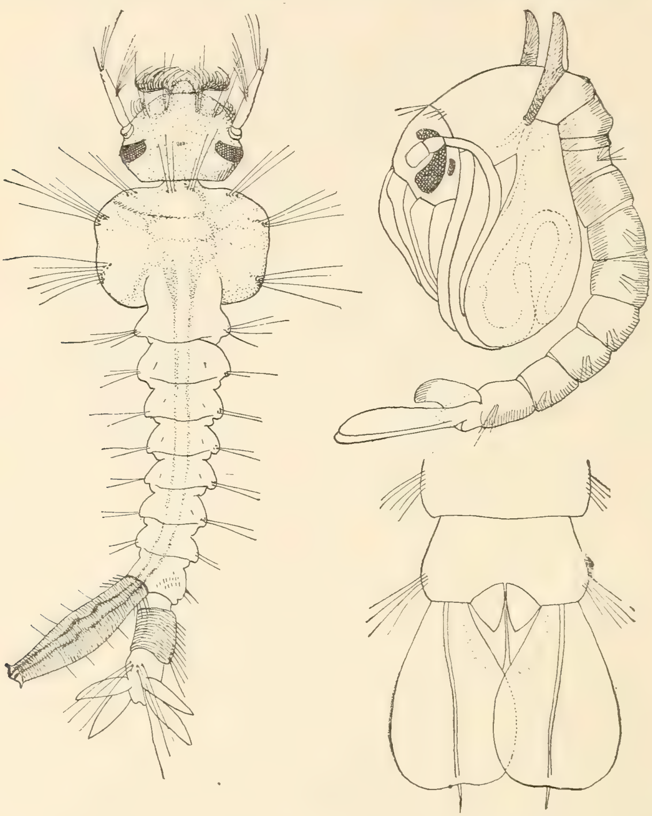

FIG. 3.—*Culex pungens:* Full-grown larva at left, pupa at right—enlarged (original).

old. This gives what is probably the minimum generation for this species as ten days, namely, sixteen to twenty-four hours for the egg, seven days for the larva, and two days for the pupa. The individuals emerging on the first day were invariably males. On the second day the great majority were males, but there were also a few females. The preponderance of males continued to hold for three days; later the females were in the majority. In confinement the males died quickly; several lived for four days, but none for more than that period. The females, however, lived for a much longer time. Some were kept alive without food, in a confined space of not more than 4 inches deep by 6 across, for three weeks. But one egg mass was deposited in confinement. This was deposited on the morning of June 30 by a female which issued from the pupa June 27. No further observations were made upon the time elapsing between the emergence of the female and the laying of the eggs, but in no case, probably, does it exceed a few days.

The length of time which elapses for a generation, which we have just mentioned, is almost indefinitely enlarged if the weather be cool. As a matter of fact, a long spell of cool weather followed the issuing

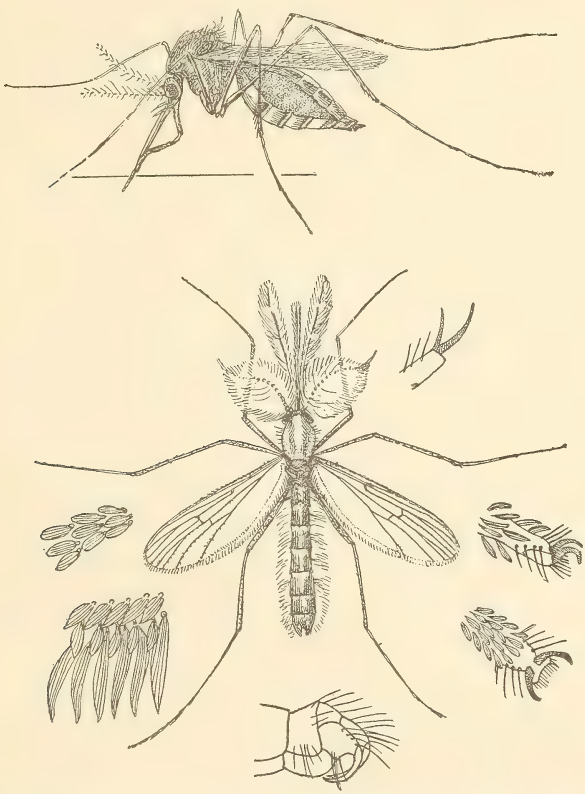

FIG. 4.—*Culex pungens;* Female above, male below—enlarged (original).

of the adults just mentioned. Larvæ were watched for twenty days, during which time they did not reach full growth.

The extreme shortness of this June generation is significant. It accounts for the fact that swarms of mosquitoes may develop upon occasion in surface pools of rain water, which may dry up entirely in the course of two weeks, or in a chance bucket of water left undisturbed for that length of time. Further, the shortness of this generation was, while not unexpected, not at all in accordance with any published statements as to the length of life of any immature mosquito of any species. But these published statements, as previously shown, were nearly all based upon observations made in a colder climate and in the month of May.

Remarks on other species of Culex.—The writer is inclined to believe that *Culex tæniorhynchus* (fig. 5) is more or less specifically the seacoast mosquito of the Atlantic seaboard; that is to say, it is the mosquito in this part of the country which is able to breed and prefers to breed in the brackish swamps which are occasionally overflowed at high tide. It has been found by Mr. C. W. Johnson at Avalon, Anglesea, and Atlantic City, N. J.; by the writer at Far Rockaway, Amergansett, and on the beach at Staten Island, New York; by Mr.

Fig. 5.—*Culex tæniorhynchus:* Female, showing the short palpi which distinguish *Culex* from *Anopheles;* toothed front tarsal claw at right—enlarged (original).

Barber at Chesapeake Beach, Md., and again by Mr. Johnson at St. Augustine and Charlotte Harbor, Fla. Other species, like *Culex pungens*, are seen at seaside resorts, but it is probable that these breed back of the coast in fresh water. This difference in breeding habit is very marked on the east coast of Staten Island. The people there distinguish between the brown-legged mosquitoes and the ring-legged mosquitoes, the former being *C. pungens*, which breeds in the hilly ponds and swamps back of the bluffs, and the latter being *C. tæniorhyncus*, which breeds in the brackish marshes below the bluffs. Dr. A. D. Hopkins states (Bulletin 17, new series, Div. Entom., Dept. Agric.) that what is probably this species apparently breeds in West

Virginia in pools and small streams fed from coal-mine drainage, the water of which contains a large percentage of sulphate of iron.

Culex impiger has been found by Mr. Pratt, of this office, breeding in privy vaults in Alexandria, Va., and this species is likely to be the one found usually in such places where the water is fouled with decomposing or excreted animal matter.

Culex taeniatus is said by Dr. Veazie, of New Orleans, to be the so-called "day mosquito" of New Orleans; that is, the form which flies and bites in the daytime. This statement is corroborated to a certain extent by Dr. St. George Gray, of St. Lucia, British West Indies, who writes, under date of August 12 last:

> I have made some observations on the hours at which the different species are most industrious, and find that most mosquitoes have regular feeding times. For instance, *C. tæniatus* is very vigorous and troublesome in the early afternoon (between noon and 3 p. m). Then she usually takes a rest, and renews her attacks at 9 or 10 p. m. During the morning it can be found resting on walls and clothing, particularly dark-colored clothing, and is easily caught.

The distribution of the species of Culex in the United States.—In preparing Bulletin No. 4 the writer was at pains to borrow all of the mosquitoes from the collections of such entomologists as he supposed had saved specimens in this family and placed them in the hands of Mr. Coquillett for study. The material received was not large, since mosquitoes are difficult to preserve satisfactorily in a collection, and it is an inexplicable fact that as a rule collectors do not save such extremely common things as mosquitoes. Yet he was able from Mr. Coquillett's work on the specimens received and on those already contained in the national collection at Washington to show several interesting points. As is the case with many other species of Diptera, most of the different forms were found to be very widespread. The whole group has little or no faunistic value; that is to say, different climatic conditions and other environmental factors do not limit the range of the species as they do with those of other groups. It was thus found that some of the commoner forms, like *C. consobrinus*, *C. excitans*, *C. perturbans*, and *C. posticatus*, and *C. pungens*, were found almost all over the country, from New England to Texas and even to southern California, so that in almost any given locality in the United States one would be able to find all of these common species of Culex, with two or three species of other genera and possibly two or three other species of Culex. Since the publication of the bulletin (No. 4), other localities of distribution have been ascertained, and the following list indicates such actual localities as have come to our notice. Persons interested will observe several points worth noticing in the list which follows. Certain species seem to be rare, while others are very common, in addition to being widespread. It seems from the list that *Culex consobrinus* is a more northern form; that is, it comes nearer being restricted to a boreal habitat than any of the other species. It is one of the two species which we have from Alaska. The other Alaskan form which has been determined, namely, *C. impiger*, extends south to New Mexico, Georgia, and the island of Jamaica.

Culex tæniatus, according to Mr. Theobald, has a wide tropical and subtropical distribution, occurring in West Africa, India, South Europe, and East and West Indies, but never in the north or south cold temperate zones.

CULEX CONSOBRINUS Desv.

Habitat: White Mountains, N. H.; Beverly, Mass., September 28 (Nat. Mus.); Catskill Mountains, Greene County, N. Y., 2,500 feet (Howard); Illinois, March 21, April 29, May 6, October 16 (Nason); St. Anthony Park, Minn., April, May, on snow (Lugger); Saskatchewan River, British America; South Dakota (Nat. Mus.); Lincoln, Nebr., May, September (Bruner); Colorado (Nat. Mus.); Los Angeles, Cal., February (Coquillett); Argus Mountains, Cal., April (Nat. Mus.); Santa Fé, N. Mex., July (Cockerell); New Orleans, La., November (Thayer); Ottawa, Canada, May (Howard); Summit, N. J. (Holmes); Trenton, Ontario, May 24 (Fletcher).

CULEX EXCITANS Walk.

Habitat: New Bedford, Mass. (Johnson); Lincoln, Nebr., May (Bruner); Santa Fé, N. Mex., July (Cockerell); Laggan, British Columbia (Wickham).

CULEX EXCRUCIANS Walk.

Habitat: Ithaca, N. Y., July 14 (Comstock).

CULEX FASCIATUS Fabr.

Habitat: Georgia, August (Coquillett); Natchitoches, La., October 6 (Johnson); Isle of Pines, West Indies (Scudder); Kingston, Jamaica, July 13 (Johnson); New Orleans, La., November (Thayer); eastern Texas (Woldert); Cuba (Lazear).

CULEX IMPIGER Walk.

Habitat: White Mountains, N. H.; Beverly, Mass., May 24, June 2 (Nat. Mus.); Ithaca, N. Y., July 9 and 17, August 28; Wilmuth, N. Y., June 10 (Comstock); Saskatchewan River, British America (Nat. Mus.); Minnesota (Lugger); Loudoun County, Va., August 26 (Pratt): Tyrone, Ky., July 14 (Garman); Georgia (Nat. Mus.); Mesilla, N. Mex. (Cockerell); Isle of Pines, West Indies (Scudder); Portland, Jamaica (Johnson); District of Columbia, September 12 (Barber); Alexandria, Va. (Pratt); Ogdensburg, N. Y., June 3 (Howard); Middletown, Conn., June (Davis); Ottawa, Canada, May 31 (Howard); Chats Rapids, Quebec, May 24 (Fletcher); Buckeye, Wash. (Nat. Mus.); Stikine River, British Columbia (Wickham).

CULEX PERTURBANS Walk.

Habitat: Lakeland, Md., August 8 (Pratt); Virginia, August 17 (Pergande); Tick Island, Fla., May 12 (Johnson); Texas (Nat. Mus.); Bayamon, Porto Rico January (Busck); District of Columbia, September 1–5 (Barber); St. Elmo, Va., June, July (Pratt); Cuba (Lazear).

CULEX POSTICATUS Wied.

Habitat: Montgomery County, Pa., July 17 (Johnson); Texas (Nat. Mus.); Loudoun County, Va., August (Pratt); Roanoke, Va., October (Thayer); District of Columbia, June 10 (Barber).

CULEX PUNGENS Wied.

Habitat: White Mountains, N. H.; Beverly, Mass., Sep em er 5; Cambridge, Mass., September 16 to November 5; Boston, Mass.; Baltimore, Md., November 5 (Nat. Mus.), November 26 (Lugger); Charlton Heights, Md., December 1 (Pratt); District of Columbia, January 30, March 5, May 6 and 15, June 28, July 11, August, October 10, 15, 25, and 31, November 4, 8, 13, 16, and 23, December 23 (Pergande); Ithaca, N. Y., May 29, July 17, August 28 (Comstock); Illinois (Nason); Minnesota (Lugger); Lincoln, Nebr., September 20 (Bruner); Lexington, Ky., November 10 (Garman); New Orleans, La., December 17 (Howard); San Antonio, Tex., May 5 (Marlatt); Georgia, August (Coquillett); Portland, Jamaica, (Johnson); Mexico City (Barrett); District of Columbia, August 22, 28, September 1 (Barber); Jackson, Va., October (Thayer); Woodstock, Va., June (Pratt); Newport News, Va., October (Thayer); Stillwater, Okla., June (Bogue); Philadelphia, Pa., (Woldert); New Orleans, La., June (Veazie); eastern Texas (Woldert); Summit, N. J., May (La Rue Holmes); Middletown, Conn., June (Davis); Cuba (Lazear).

Culex signifer Coq.

Habitat: District of Columbia, June (Coquillett), May, August (Barber); St. Elmo, Va., June 4 (Pratt).

Culex stimulans Walk.

Habitat: White Mountains, N. H.; Beverly, Mass., June 2, July 9; Cambridge, Mass., May; Jamaica Plain, Mass., August 25 (Nat. Mus.); Baltimore, Md. (Lugger); Illinois, August 1, September 15, October 5 (Nason); Agricultural College, Mich. (Gillette); Saskatchewan River, British America (Nat. Mus.); Lincoln, Nebr. (Bruner); Colorado (Nat. Mus.); Ithaca, N. Y., June 13, 18, 29, July 14, August 28; Wilmuth, N. Y., June 10 (Comstock); Georgia (Nat. Mus.); Bladensburg, Md., May 27 (Barber); St. Elmo, Va., June 5 (Pratt); District of Columbia, September (Barber), June 10 (Miss L. Sullivan); Ottawa, Canada, June 1 (Howard); Ogdensburg, N. Y., June 3 (Howard); Rochester, N. Y. June (Ewers); Summit, N. J., May (La Rue Holmes); Middletown, Conn., June (Davis); Mesilla, N. Mex., October 26 (Cockerell); Tacna, Ariz., April 13 (Hubbard); Juarez, Mexico, May 12 (Cockerell); Summit, N. J. (Holmes).

Culex tæniatus Wied.

Habitat: New Orleans, July (Veazie); Cuba (Lazear).

Culex tæniorhynchus Wied.

(Not the *Culex tæniorhynchus* Wied. of Arribalzaga.)

Habitat: Maine, August; Beverly, Mass., June, September 15 (Nat. Mus.); Avalon, Anglesea, and Atlantic City, N. J., July 10 to 29 (Johnson); Far Rockaway, Long Island, N. Y., August 30 (Howard); District of Columbia (Pergande); Georgia (Nat. Mus.); St. Augustine and Charlotte Harbor, Fla., July; Portland, Jamaica (Johnson); Chesapeake Beach, Md. (Barber); Baltimore, Md. (Thayer); Plymouth, N. C. (Thayer); Galapagos Islands, February 1–4 (Snodgrass).

Culex tarsalis Coq.

Habitat: Argus Mountains, Cal., April; Folsom, Cal., July 3 (Nat. Mus.).

Culex triseriatus Say.

Habitat: White Mountains, N. H. (Nat. Mus.); Delaware County, Pa., June 12 (Johnson); Washington, D. C., May 5 and June 10; Loudoun County, Va. (Pratt); Near Baltimore, Md. (Thayer); Roanoke, Va., October (Thayer); Middletown, Conn., June (Davis); New Jersey (Woldert).

THE BIOLOGY OF ANOPHELES, WITH GENERAL REMARKS.

So far as the writer can ascertain, no detailed illustrated account of the early stages of any species of Anopheles had been published before his paper in the Scientific American, above referred to.[1] He conceived it to be nearly as important that the malarial-bearing mosquitoes should be readily recognized in their early stages as in their adult condition. He was very fortunate in April of the present year in being

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[1] See appendix.

able to secure a large number of gravid females of *Anopheles quadrimaculatus* Say through the abundance of this species near the home of one of his assistants, Mr. Pratt, in Virginia, a few miles from Washington. Mr. Pratt was enthusiastic and assiduous in collecting living adults, and these were kept in confinement and their offspring reared in large water jars during April and May, 1900. It may be mentioned here that this species is without doubt identical with the European *Anopheles maculipennis* Meigen, a fact which Mr. Coquillett has always strongly suspected, although he had no European material with which to compare our American specimens. Dr. W. S. Thayer saw *A. maculipennis* in Grassi's laboratory in Italy, and on his return to this country told the writer that he thought the two forms identical. The question has now been definitely settled by Mr. F. V. Theobald, of England, who is monographing the mosquitoes of the world for the British Museum, and who writes us under date of May 28, 1900, that he has studied a large series of *A. quadrimaculatus* received from Canada and that "they exactly tally with *A. maculipennis.*"

Fig. 6.—*Anopheles quadrimaculatus:* Adult; male at left, female at right—enlarged (original).

LIFE HISTORY OF ANOPHELES QUADRIMACULATUS.

The adult.—The accompanying illustrations (figs. 6, 7, 8) will show very well the general appearance of the adult insect. It is a rather large mosquito and is very blood-thirsty. It is attracted to the house in numbers. The differences between the males and females are well brought out in the illustrations, and the striking feathery antennæ and palpi of the male render it very conspicuous. The wing markings and the color of the palpi differentiate this species from our other species of Anopheles, and the long palpi of the female at once distinguish it from all species of Culex.

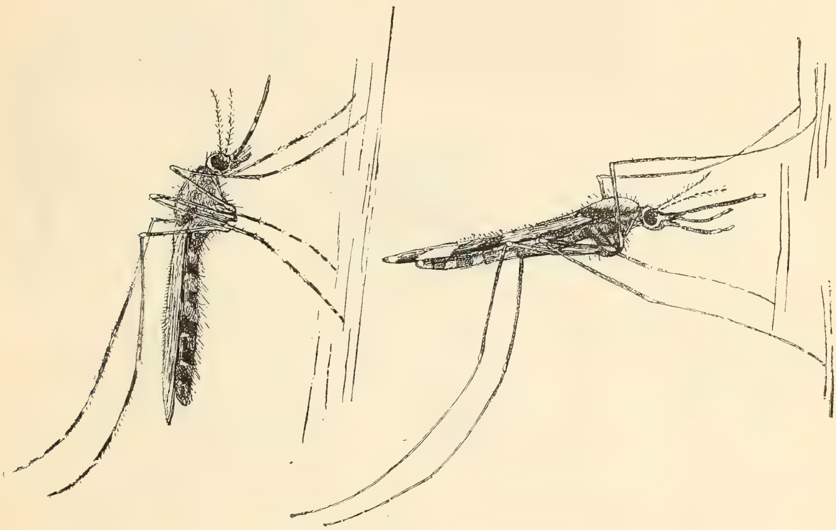

FIG. 7.—Resting positions of Culex (at left) and Anopheles (at right), enlarged (redrawn from a rough sketch published in the British Medical Journal).

Resting position.—Owing to the publication of a field sketch made at Sierra Leone by a member of the Ross expedition, and which is here reproduced, the writer has been much interested in watching the resting positions of the adult insects. He finds that when resting upon a horizontal surface—such as the ceiling of a room or the covering of the breeding jars—the insect clings with its four anterior legs in a nearly perpendicular position, its beak thrust forward toward the surface to which it clings. The hind legs are frequently in motion, but as a rule hang downward with more or less of a bend at the knee joint (femero-tibial articulation). When resting upon a perpendicular surface, however—such as the side wall of a room or the side of a breeding jar—the body is held only at a comparatively slight angle from the surface. Sometimes it is nearly parallel with the surface. At other times it assumes an angle of 10° to 20° (occasionally even as great an angle as 30° to 40°), the proboscis being held nearly in a line with the body. Here again the insect supports itself by the four anterior legs, the hind legs dangling down with more or less of a bend at the knee. This position is common to both males and females, and is illustrated at fig. 8. When the body is held parallel it will generally be found that one of the middle or hind legs has been broken off. They are very delicate and readily break.

FIG. 8.—Actual resting positions of *A. quadrimaculatus* on a horizontal ceiling and on a side wall; drawn from life—enlarged (original).

The writer has taken the liberty of having fig. 9 engraved from a drawing sent him by Mr. C. O. Waterhouse of the British Museum. Mr. Waterhouse made the drawing himself and wrote: "Whatever

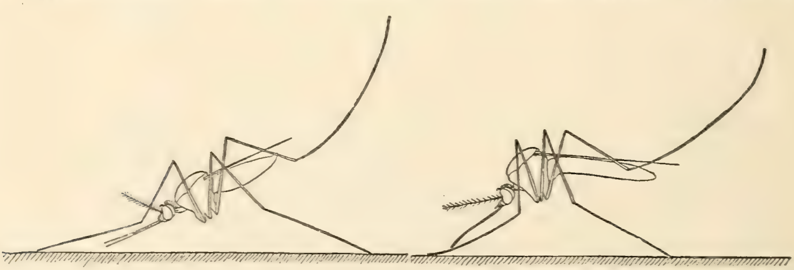

FIG. 9.—Anopheles at left, Culex at right—enlarged (drawn by C. O. Waterhouse).

may be the attitude of Anopheles, it is all in one line. Culex is angular, humpbacked."

Note of female.—The peculiar hum of the mosquito is well-known. There is a distinct difference between the hum of *Anopheles quadrima-*

culatus and that of the common species of Culex in that the former is noticeably lower in tone. The note of Culex as it approaches the ear

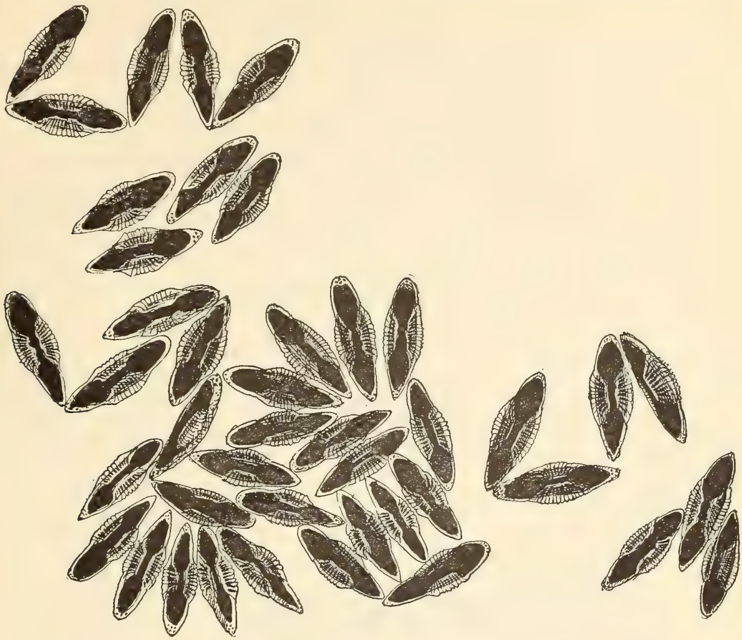

FIG. 10.—*Anopheles quadrimaculatus:* Group of 44 eggs deposited by a single female as they appear resting naturally on the surface of the water—enlarged (original).

is high in pitch; that of Anopheles is certainly several tones lower and of not so clear a character. In quality it is something between the buzzing of a house fly and the note of Culex. Mr. Pratt states that he can at once distinguish the two genera in this way as he is sitting reading in the house, and the writer feels quite sure after listening to them in breeding jars that the statement is correct.

These observations have been made with an abundance of material, nearly 100 adults having been under observation.

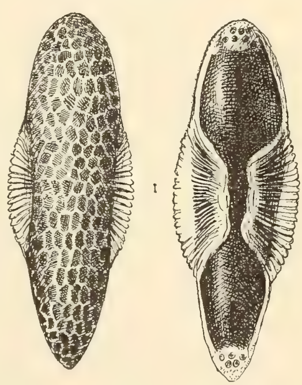

FIG. 11.—*Anopheles quadrimaculatus:* Egg from below at left, from above at right—greatly enlarged (original).

THE EGGS.—The well-known and often-mentioned boat-shaped masses of eggs of Culex are not even remotely resembled by the Anopheles ovipositions, and the individual eggs are equally dissimilar. In the accompanying illustration (fig. 10) the egg mass of Anopheles is illustrated for comparison with fig. 1. In Culex from 200 to 400 eggs are laid in a mass ordinarily shaped like a pointed ellipse, convex below and concave above, all the eggs perpendicular, and stuck closely together at the sides by some gummy secretion, and arranged in rows. The mass with Anopheles, however, is laid loosely upon the surface of the water, each egg lying upon its side instead of being placed upon its end as in the egg mass of Culex. They are not attached together except that they naturally float close to each other and there are from 40 to 100 eggs in each lot. In *Culex pungens* the individual egg is 0.7 mm. long and 0.16 mm. in diameter at the base. It is slender, broader, and blunt at the bottom, slenderer and more pointed at the tip. The tip is always dark grayish brown in color, while the rest is dirty white. The egg of Anopheles when seen from above is of a rather regular elliptical outline, the two ends having practically the same shape; seen from the side, it is strongly convex below and nearly plane above; seen from below, it is dark in color and when examined with a high power is seen to be covered with a reticulate hexagonal sculpturing. At the sides, in the middle, there appears a clasping membrane with many strong transverse wrinkles. Seen from above, the egg is black except for a clasping membrane which nearly

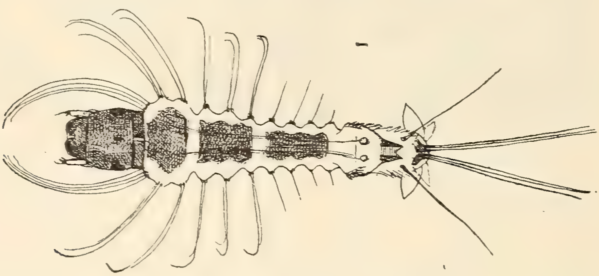

FIG. 12.—*Anopheles quadrimaculatus:* Newly hatched larva—greatly enlarged (original).

meets on the middle line in the middle third of the body, but retires to the extreme sides for the anterior and posterior thirds. At each end the color is lighter, with a group of from 5 to 7 minute dark circular spots. It is 0.57 mm. long. Eggs laid April 26 hatched April 30. Others laid May 13 and 14 hatched May 16 and 17.

THE LARVA.—The larva is quite as unlike that of *Culex pungens* as is the egg. It differs in structure, in its food habits, and in its customary position so markedly that it can at once be distinguished with the utmost ease. The larva of Culex, it will be remembered, comes to the surface of the water to breathe, thrusting its breathing tube through the surface layer and holding its body at an angle of about 45 degrees with the surface of the water. While in this position its mouth parts are in motion and it is taking into its alimentary canal such minute particles as may be in the water at that depth, but these are naturally few in number and the larva descends at frequent intervals toward the bottom to feed. The want of oxygen, however, causes it to wriggle up again to the surface at very frequent intervals. Its specific gravity seems greater than that of water, so that it reaches the surface only by an effort, and the writer has already pointed out in the case of *C. pungens* that when the larva becomes enfeebled and is not strong enough to wriggle up to the surface it drowns. Feeding as it does at the bottom upon the heavier particles which sink, its specific gravity is explained. The larva of *Anopheles quadrimaculatus*, however, habitually remains at the surface of the water. Its breathing tube is very much shorter than that of Culex and its body is held not at an angle at the surface, but practically parallel with the surface and immediately below the surface film, so that portions of its head, as well as its breathing tube, are practically out of the water. Its head rotates upon its neck in a most extraordinary way, so that the larva

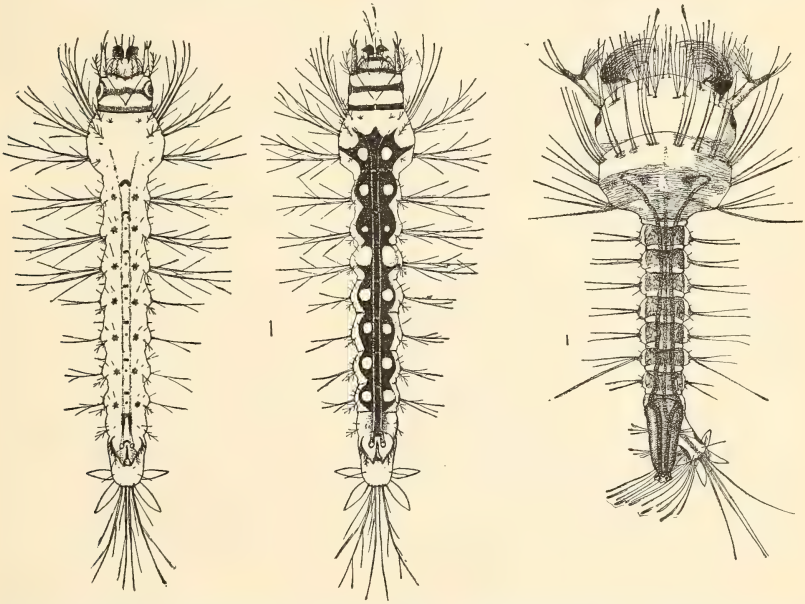

FIG. 13.—*Anopheles quadrimaculatus* and *Culex pungens:* Half-grown larva at left and in center, in comparison with half-grown larva of Culex pungens at right (figure at left has been cleared)—greatly enlarged (original).

can turn it completely around with the utmost ease and feeds habitually with the under side of the head toward the surface of the water, whereas the upper side of the body is toward the surface. In this customary resting position the mouth parts are working violently, the long fringes of the mouth parts causing a constant current toward the mouth of particles floating on the surface of the water in the neighborhood, which thus gradually converge to this miniature maelstrom and enter the alimentary canal. The spores of algæ, bits of dust, minute sticks, bits of cast larval skins, everything in fact which floats, follow this course, and, watching the larva under the microscope, they can plainly be seen to pass through the head into the thorax until they are obscured by the dark color of the insect's back. Occasionally too large a fragment to be swallowed with ease clogs the mouth. Sometimes it enters the mouth and sticks. In such cases the head of the larva revolves with lightning-like rapidity and the fragment is nearly always disgorged, although sometimes it is swallowed with an evident effort. Since the Anopheles larva feeds only upon these light floating particles, its specific gravity is nearly that of the water itself and it supports this horizontal position just beneath the surface film with comparative ease, and in fact without effort, the tension of the surface film itself being hardly needed to hold it. It requires an effort in fact for the Anopheles larva to descend (which it apparently never does up to the period of the final larval stage, except when alarmed), while it requires an effort for the Culex larva to ascend.

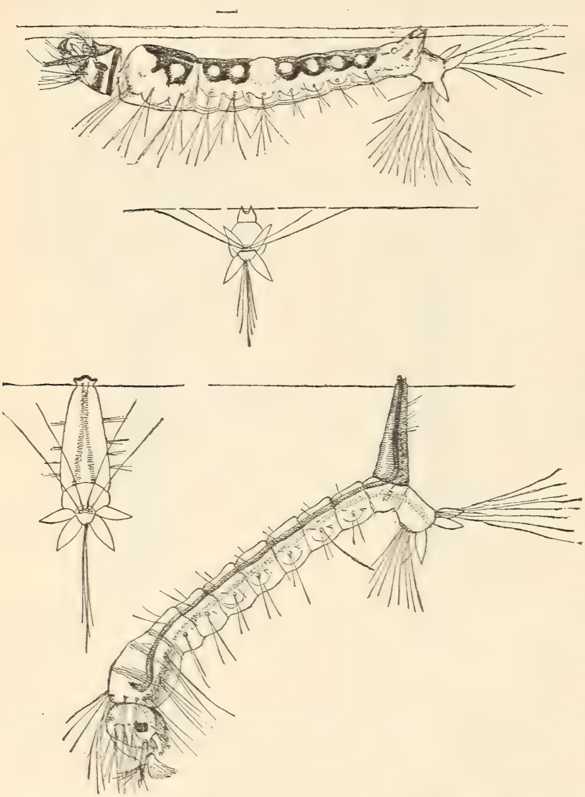

FIG. 14.—Figure at top, half grown larva of Anopheles in feeding position, just beneath surface film. Figure at bottom, half grown larva of Culex in breathing position—greatly enlarged (original).

Structurally the differences between the half-grown larvæ of Culex and Anopheles are well shown at figs. 13, 14, and 15. The great size of the head of Culex, as contrasted with the small head of Anopheles is a most striking difference. The very long respiratory siphon (as Miall calls it) of Culex contrasts markedly with the short one of Anopheles. The arrangement of the hairs is entirely different, the branching of the hairs of Anopheles, as contrasted with the simple hairs of Culex and the little paired star-shaped (apparently branchial) tufts on the dorsum of Anopheles are entirely absent with Culex. The flaps at the tail end of the body are similar in number, but are held in a somewhat different position.

The larvæ first studied—those which hatched from the eggs on April 30—grew very slowly for a number of days. This was partly owing to cool weather in the early part of May, and partly, I believe, to the absence of proper food. They were reared in glass jars of water, with sand at the bottom and a willow twig rooting in the sand. As above noted, they swallowed every small particle floating on the surface of the water, and the dark coloration shown in fig. 14 was largely due to the fact that most of these food particles were dark colored. About the 10th of May, the larvæ having passed through two molts, a small quantity of the green algæ growing on the lily ponds on the Department grounds was placed in the jar.[1] The larvæ commence to thrive much better, grew rapidly, and the general color of the body changed to green. The description of the habits given above held well until after the last molt preceding the change to pupæ. In this final larval stage, as shown in fig. 15, the diameter of the thorax became much greater in comparison with the rest of the body. The larva was less marked, more inconspicuous, and altered its feeding habits to some extent. After

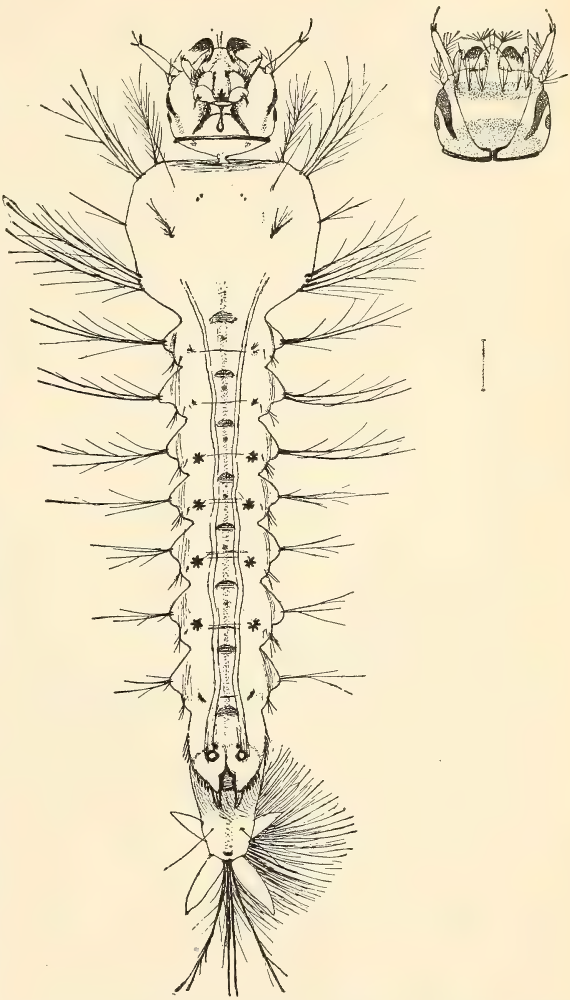

FIG. 15.—*Anopheles quadrimaculatus:* Full grown larva in feeding position, seen from above (head reversed, in feeding position); dorsal side of head above at right—greatly enlarged (original).

[1]These algæ were studied by Mr. A. F. Woods, of the Division of Vegetable Physiology and Pathology, who informed me that the larger part belong to a species of the genus Œdogonium, but that there was also quite a large amount of a species of Cladophora, with some Spirogyra. There was also some of the blue green Oscilaria.

remaining at the surface of the water, feeding, as before, upon floating particles for some time, it would wriggle violently and descend to the bottom, where it would remain frequently as long as two minutes before reascending to the top. Its appetite was evidently so great that it was not satisfied with the floating particles, and when it descended to the bottom it mouthed the particles of sand, evidently swallowing the slime on the little stones and frequently even picking up quite a a large sand pebble and then dropping it again. In this stage the individual which grew most rapidly remained only four days, and transformed to pupa on the morning of the 17th, after a larval existence of sixteen days. The accompanying figures of the larvæ have been drawn with such care that detailed description will be unnecessary. They were drawn from life under the compound microscope. Some of the structures are puzzling, notably the organs occuring on the dorsum of the abdominal segments, shown most plainly in fig. 15, and which look as though they might be spiracles until they are examined under a high power in the cast skin. The writer does not care to risk an expression of opinion as to their function, although possibly it is known, and they possibly occur in other aquatic dipterous larvæ. In the early stages of the larvæ they resemble minute branchial tufts, but no tracheal connection has been found.

THE PUPA.—The accompanying figure (fig. 16) well represents the

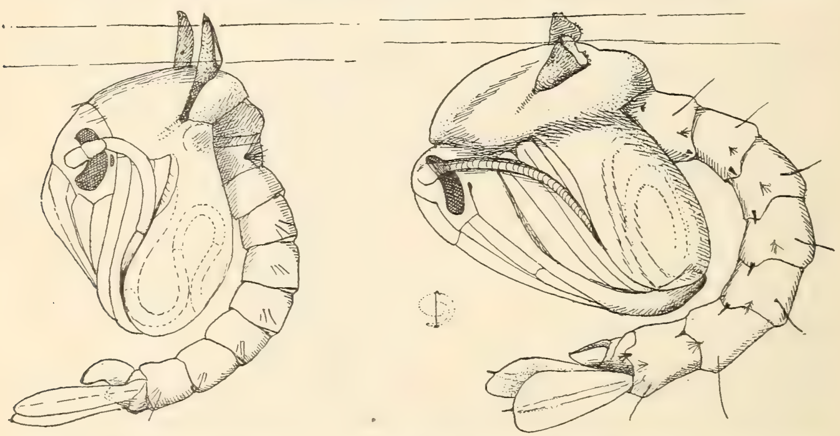

FIG. 16.—Pupa of *Culex pungens* at left; pupa of *Anopheles quadrimaculatus* at right—greatly enlarged (original).

differences between the pupa of Culex and that of Anopheles. In this stage the insects of the two genera are not so markedly different as in the larval stage. Structural differences need not be described, as they are sufficiently shown in the illustration. The eye will at once be caught by the difference in position, the pupa of Culex resting in a more perpendicular attitude than that of Anopheles, and the marked difference in shape between the respiratory siphons, which issue from the thorax instead of from the anal end of the abdomen, will at once be noticed. The pupa of Anopheles is quite as active, when disturbed, as is that of Culex. If one touches the near-by surface of the water with the finger the pupa at once wriggles violently away, returning shortly to the surface for air.

The duration of the pupal stage in Anopheles varies according to the weather. Five days was the minimum observed during June, although several specimens remained in this stage for ten days. The adults issue as do those of Culex.

The entire life round, therefore, of *Anopheles quadrimaculatus* in the generation studied by the writer is as follows: Egg stage, three days; larval stage, sixteen days; pupal stage, five days; making a total period in the early stages of twenty-four days. It should be stated, however, that during the early larval existence toward the end of May there occurred nearly a week of cool weather, so that it is certain that in the hot season in July and August the growth and transformations will be more rapid. It will be remembered that the writer traced *Culex pungens* through an entire generation in the latter part of June, 1895, in ten days.

NATURAL BREEDING PLACES OF ANOPHELES.

Having accomplished the preliminary work of studying different stages of growth of Anopheles by breeding from captured females, we were enabled to become familiar with the larvæ and pupæ so as to recognize them readily and it was then not difficult to find the natural breeding places. The first breeding place discovered was in Maryland, and the larvæ found there were those of what is probably *A. punctipennis.* They closely resemble the corresponding stage of *A. quadrimaculatus* except in the maculation of the head. A figure of the head of this form is shown here (fig. 17) in order that it may be compared with the corresponding figure of *A. quadrimaculatus* shown in fig. 15. This first breeding place of Anopheles was a small permanent stream running through the woods which had here and there broadened out into little shallows, and in these shallows the Anopheles larvæ were found resting at the surface of the water, and occasionally darting from one spot to another. All of these little pools were abundantly supplied with algæ, and from specimens brought in Mr. A. F. Woods has found that they belong to the genus Mougeotia. There were also many Diatoms present. The next natural breeding place found was in pools about a disused spring in Virginia. At the sides of the spring were several more or less permanent pools of considerable depth (8 to 10 inches). Here the larvæ of *A. quadrimaculatus* were found. Algæ also occurred here and Mr. Woods has determined them as belonging to the same genus Mougeotia. The

FIG. 17.—*Anopheles punctipennis:* Head of full-grown larva from above—enlarged (original).

temperature of this water was 18° C. The third locality was an old canal bed so nearly dried out after a season of drought that the water lay in rather small puddles. In this case the water was very foul and algæ of the genus Lyngbya were present. The temperature of this water was 25° C., and the conditions were those of extreme stagnation. The first locality was discovered by the writer in company with Mr. Pratt and the second and third were found by Mr. Pratt. Later, the writer in company with Mr. Busck and Hospital Steward Smith, found empty pupa skins of *A. quadrimaculatus* in a dried up surface pool at the Washington Barracks, at a time when malaria was very prevalent among the troops. I am informed by Dr. Thayer, of Baltimore, that Dr. Lazear found *A. punctipennis* breeding in a stone quarry near Baltimore, in the summer of 1899. Ross found in India that while the species of Culex generally bred in vessels of water around the houses, the species of the genus Anopheles bred in small pools of water on the ground. This point was made the subject of a special investigation by the expedition of the Liverpool School of Tropical Medicine to Sierra Leone. While Culex larvæ were to be seen in almost every vessel of water or empty gourd or flowerpot in which a little rain water had collected, in only one case were Anopheles larvæ found in such receptacles. On the other hand, they occurred in about 100 small puddles scattered throughout the city of Freetown—puddles mostly of a fairly permanent description, kept filled by the rain, and not liable to washing out during heavy showers. It was noticed also that the larvæ seemed chiefly to feed on green water weed.

In the interesting and important paper by Dr. J. W. W. Stephens and Mr. S. R. Christophers entitled "The distribution of Anopheles in Sierra Leone," published in the report of the malarial committee of the Royal Society, July 6, 1900, it is stated that at Freetown not only do the larvæ of Anopheles exist in the small pools in the rocks, but also in the pools by the sides of streams and in certain small drains, and that in the dry season, in the absence of the rock pools, Anopheles breeds freely in streams and drains; also, in the dry season, the adults exist in most parts of the town in dwellings, especially in overcrowded native huts and native quarters, ready to lay their eggs when pools appear. It is interesting to note, from this latter observation, that the authors of the paper recommend the destruction of dirty huts and the prevention of excessive overcrowding. Outside of the city, in the "bush," Anopheles larvæ were present throughout the whole district. In the mountain streams, wherever there were suitable pools, multitudes of larvæ existed. In tracing the mountain streams, occasionally for a half mile or so, they found no larvæ, but then a rock pool occurred, and there they were again found in numbers. At Songo and Mabang they were able to detect Anopheles larvæ in the swamps. They were not present in the main swamp water on account of the innumerable small fish, but were occasionally observed in small, isolated pools on the mud, and were still more common in small pools at the edges of swamps. It is a noteworthy fact that they did not occur in swamp pools in such numbers as in the streams and rock pools among the hills of Sierra Leone. "These rock pools would appear to be the most suitable conditions for the breeding of Anopheles."

The avidity with which Anopheles larvæ under observation in Washington fed upon algæ spores of the genera previously mentioned, and the character of the breeding pools found here, indicate that without doubt similar conditions will prevail generally in this country, and Anopheles will always be found to breed most abundantly in fairly permanent stagnant pools of water uninhabited by fish, but more or less covered with green scum.

OTHER SPECIES OF ANOPHELES.

As appears from the synoptic table on previous pages, we have in the United States, so far as ascertained, three recognized species of

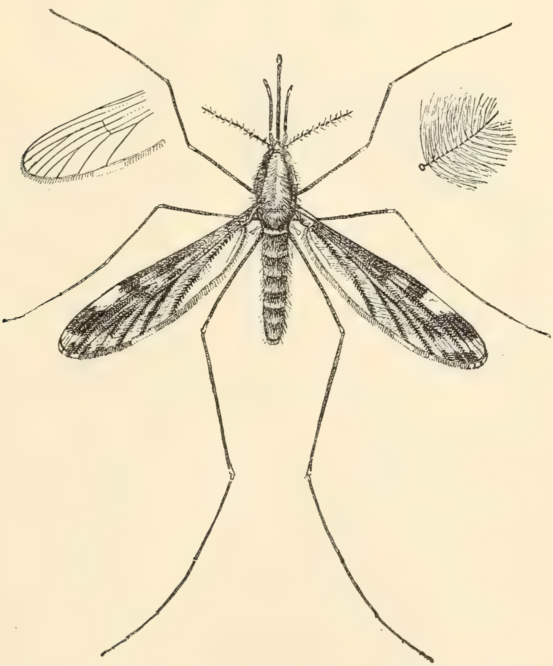

FIG. 18.—*Anopheles punctipennis:* Female, with male antenna at right, and wing tip showing venation at left—enlarged (original).

this genus. *A. quadrimaculatus* has just been figured in all its stages, and the accompanying illustration (fig. 18) shows very well the beautiful species known as *A. punctipennis* Say. *A. crucians* (fig. 19) seems to be rarer than the other two and has been taken only in a few instances.

FIG. 19.—*Anopheles crucians:* Female—enlarged (original).

DISTRIBUTION OF THE SPECIES OF ANOPHELES IN THE UNITED STATES.

ANOPHELES CRUCIANS Wied.

Habitat: District of Columbia, April 27 (Pergande); Georgia (Nat. Mus.); New Orleans, La., June 28 (Veazie), November (Thayer); Richmond, Va. (Slosson).

ANOPHELES PUNCTIPENNIS Say.

(Considered by Wiedemann to be the same species as his *Anopheles crucians*, but the two are certainly distinct.)

Habitat: Castleton, Vt., February 1 (temperature 6° F.); Beverly, Mass., September 19, October 2; Cambridge, Mass., June 16, September 30, October 20 (Nat. Mus.); Charlton Heights, Md., March 31, November 17 (Pratt); District of Columbia, June 6 and 7, October 15, 25, and 31 (Pergande); Philadelphia, Pa., October 12 (Johnson); Ithaca, N. Y., April 17, August 28 (Comstock); Illinois, October 16 (Nason); Texas (Nat. Mus.); Mesilla, N. Mex. (Cockerell); Portland, Jamaica (Johnson); Middletown, Conn. (Davis); Summit, N. J., April 26 (Howard); Roanoke, Va., October (Thayer); St. Elmo, Va., May, June (Pratt); Brazos River, Tex. (Woldert); Baltimore (Thayer and Lazear); Walbrook, Md. (Thayer and Lazear); Onaga, Kans. (Crevecoeur).

ANOPHELES QUADRIMACULATUS Say.

Habitat: Berlin Falls, N. H., August (Nat. Mus.); Ithaca, N. Y., January, July 31, November 28 (Comstock); Lakeland, Md., August 8; Charlton Heights, Md., Novembe 24 (Pratt); District of Columbia, July, October 15, November 2 and 14 (Pergande); Illinois, September 10, October 10 (Nason); St. Anthony Park, Minn., December 11 (Lugger); Tick Island, Fla., May 12 (Johnson); Texas (Nat. Mus.); Oneco, Fla., May 26 (Gossard); Roanoke, Va., October (Thayer); Newport News, Va., October (Thayer); St. Elmo, Va., April, May, June, July (Pratt); New Orleans (Thayer); Sparrows Point, Md., and vicinity (Thayer and Lazear); Middletown, Conn. (Davis).

THE GENUS PSOROPHORA.

But one species, *P. ciliata*, of the genus Psorophora is known in the United States. This is well illustrated in the accompanying figure (fig. 20). Although this insect, as indicated in the synoptic

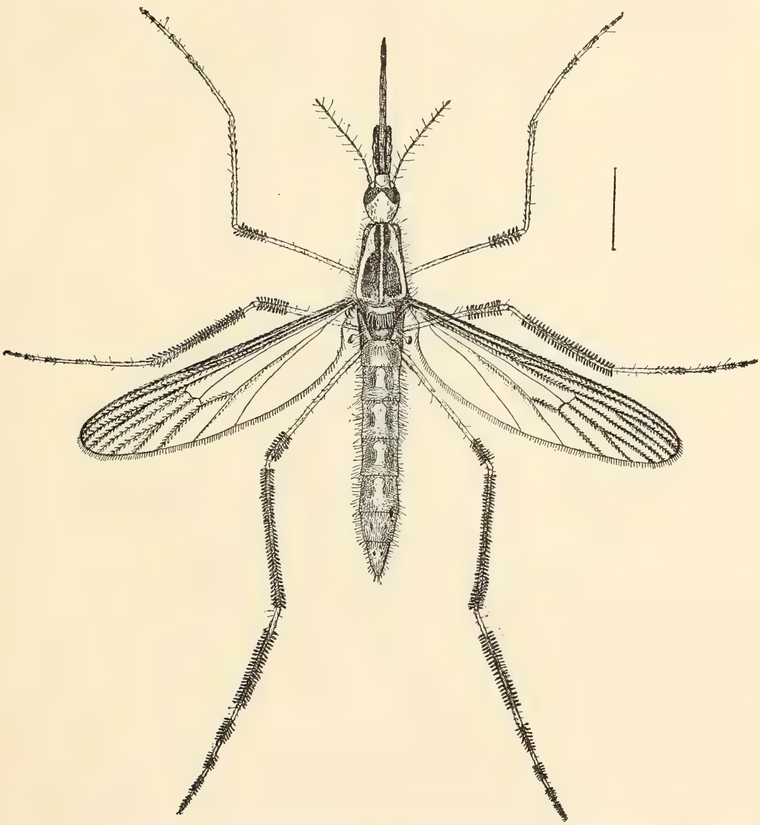

FIG. 20.—*Psorophora ciliata:* Female—enlarged (original).

tables, is really yellowish in color, yet the general effect when one glances at it, or sees it flying, is that it is very dark, almost black. The wings are not really spotted or infuscated, but the very numerous dark scales on the main veins make the wings appear dark. They are also when seen in certain lights prismatic in color effect. The palpi of the female are nearly half as long as the beak, and the beak itself is very stout. The most striking feature of this insect, however, is the curious series of erect close-set hairs or scales on the legs, which distinguishes it at once from other mosquitoes. This mosquito is widespread in the United States, and we have specimens from Dorchester, Mass. (Nat. Mus.); Washington, D. C. (Chittenden); Westfield, N. J., July 2 (Johnson); Illinois (Nason); Brooklyn Bridge, Ky., June 23 (Garman); Lincoln, Nebr., July and August (Bruner); Los Angeles, Cal. (Coquillett); San Diego, Tex., May 15 (Schwarz); Florida, July (Nat. Mus.); Hastings, Fla., July (Dept. Agric.); New Orleans, August, (Veazie). A rather large series was captured in June of the

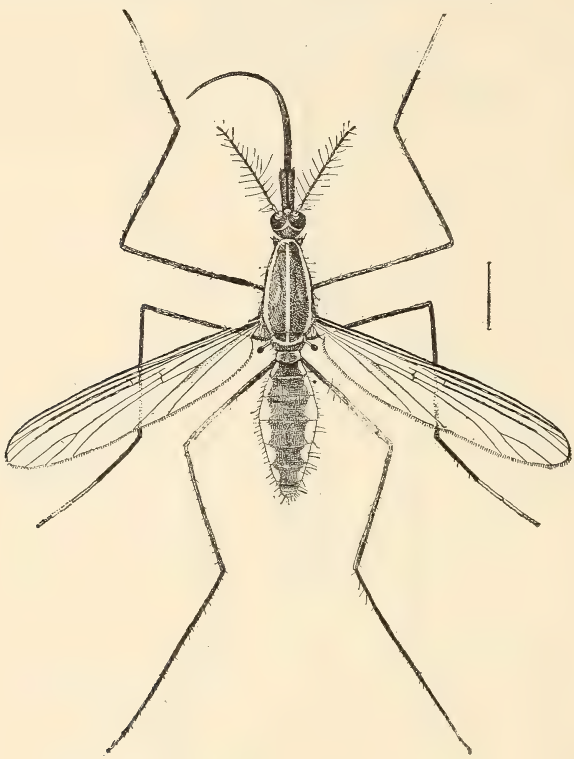

FIG. 21.—*Megarhinus rutilus:* Female—enlarged (original),

present year at St. Elmo, Va., by Mr. Pratt. The writer felt certain that he would be able to follow out the life history of this species from the living material captured by Mr. Pratt. Females were placed alive in breeding jars under conditions which had repeatedly been successful with Culex and Anopheles, but no eggs were obtained. The breeding habits, therefore, may be different from those of the other two genera, and the biology of this form is an interesting and important point for future investigation. As elsewhere stated, the possible relations between Psorophora and the Hæmatamœbæ deserve early investigation.

THE GENUS MEGARHINUS.

This is the other genus (fig. 21), the species of which are more or less abundant in the South, which should be investigated by Southern observers in regard to its possible connection with malaria. As indicated in the synoptic table, the mosquitoes of this genus are readily distinguished by the curved beak, which is also well shown in the drawing. They are especially distinguished also by their metallic greenish or bluish coloration. Nothing is known of the life history of the mosquitoes of this genus, and the species known to occur in this country are distributed as follows, so far as our records go:

MEGARHINUS FEROX Wied.
Habitat: District of Colombia, August 22 (Pergande); (Georgia according to Walker's list).

MEGARHINUS HÆMORRHOIDALIS Fabr.
Habitat: (Cayenne and Cuba according to Osten Sacken's catalogue).

MEGARHINUS PORTORICENSIS Roeder.
Habitat: Benoit, Miss., July 18 (Hine).

MEGARHINUS RUTILUS Coq.
Habitat: North Carolina; Georgiana, Fla. (Nat. Mus.).

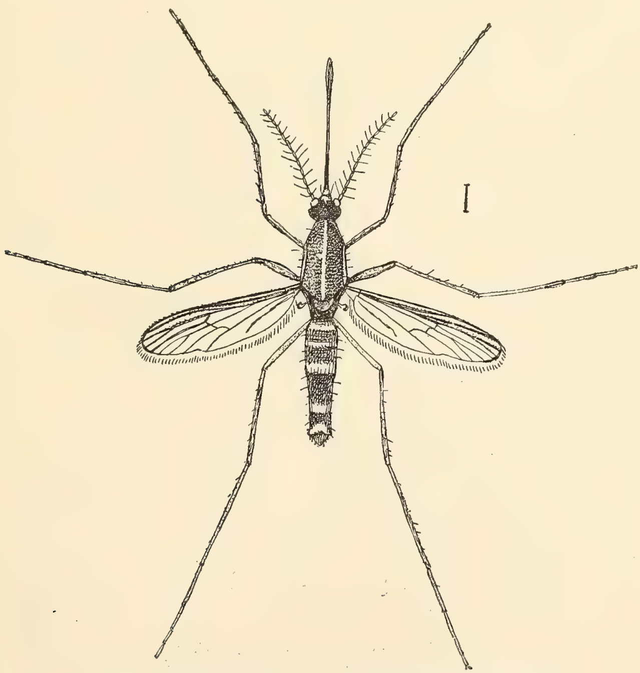

FIG. 22.—*Aëdes sapphirinus:* Female—enlarged (original).

THE GENUS AËDES.

The mosquitoes of this genus (fig. 22) are minute forms, insignificant in color, and the only one of which we possess specimens, viz., *A. sapphirinus*, is shown in the accompanying figure. We have received it only from Ithaca, N. Y., through the kindness of Prof. J. H. Comstock. Another species, *A. fuscus*, is said by Osten Sacken to occur at Cambridge, Mass.

THE NATURAL ENEMIES OF MOSQUITOES.

The late Dr. Robert H. Lamborn, of New York and Philadelphia, while engaged a number of years ago in building the Lake Superior and Mississippi Railroad, fell in with a great many mosquitoes. He often, "with a sentiment of gratitude," as he expressed it, looked through his mosquito veil at the dragon flies which collected in the open spaces among the pine trees. "They darted from side to side, like swallows in a meadow, but with amazing rapidity, and at every turn a mosquito 'ceased from troubling.'" This gave Dr. Lamborn the idea that perhaps dragon flies might be domesticated and utilized to destroy mosquitoes along the New Jersey coast and elsewhere; and so he offered prizes for the three best essays regarding methods of destroying the mosquito and the house fly, especially designating the dragon fly for careful investigation. The successful essays—by Mrs. C. B. Aaron, Mr. A. C. Weeks, and Mr. William Beutenmüller—were published by Dr. Lamborn in a volume entitled "Dragon-Flies *vs.* Mosquitoes. The Lamborn prize essays." The essays were all excellent. Here, however, they are mentioned, by the way, in connection with the group of the best-known natural enemies of mosquitoes, namely, the dragon flies. It is needless to say that none of the essays were able to solve the problem of a practical breeding, on a large scale, of dragon flies for mosquito extermination, and, in fact, the whole subject of the natural enemies of the mosquito is of little practical importance. It is simply a matter of general interest. Dragon flies, as adults, feed upon adult mosquitoes, just as they will upon all other insects which they are able to capture and devour. Dragon flies, as larvæ, feed upon the larvæ and pupæ of mosquitoes, although other and larger and less active aquatic insects and small fish form the bulk of their food.

The extreme activity of both larvæ and pupæ of mosquitoes is a necessary factor in their struggle for existence, since stagnant pools of water fairly swarm with predatory animal life. The larva of one of the water beetles of the family Hydrophilidæ eats hundreds of other insects in the course of its existence, and the larvæ of mosquitoes do not escape entirely, although by their extreme activity they stand a better chance than do other more sluggish species. A small pool of water on the Department grounds at Washington is situated near a manure pile, and the water is colored dark brown by the drainage from the manure. The pool is kept by Mr. Saunders, the superintendent of the grounds, for the purpose of securing manure water for some of his plants. It is, at all times through the summer, swarming with the larvæ of *Culex pungens*, *C. stimulans*, and *C. perturbans;* also with the larva of an Ephydrid—*Brachydeutera argentata* Walk.—and with the larva of an Ephemerid of the genus Cænis, and other aquatic species. A number of specimens of Hydrophilid larvæ were found by the writer in this pool. They fed upon the other aquatic insects with avidity, and three of them were placed in a large battery jar with about a half gallon of this water, teeming with insect life and containing apparently some hundreds of the mosquito larvæ and many of the others just mentioned. These three Hydrophilid larvæ, in the course of a week, practically devoured all of the other animal life in the jar. Only two male mosquitoes and one female succeeded in reaching the adult stage.

No one can realize the intensity of the struggle for existence which is going on in a stagnant pool until he forces himself to the seemingly rather unpleasant occupation of lying down by its side and watching with a large hand lens the various forms of life with which the water is swarming. Aside from the larvæ of the dragon flies and the predatory larvæ of the three great families of aquatic beetles, namely, the Dytiscidæ, the Hydrophilidæ, and the Gyrinidæ, there are aquatic neuropteroid insects which are predatory and which feed upon mosquito larvæ as well as others, like those of the genus Hydropsyche; and there are aquatic Heteroptera which are also predatory.

Aside from insects, there are many other natural enemies of mosquitoes. Many fish eat their larvæ and pupæ, and such night-flying birds as nighthawks and whip-poor-wills, and bats as well, destroy the adults. Harvey (American Naturalist, 1880, p. 896), quoted by Mrs. Aaron, found 600 mosquitoes in the crop of a nighthawk.

REMEDIES AGAINST MOSQUITOES.

Remedies in houses and the prevention of bites.—Of the remedies in use in houses the burning of pyrethrum powder and the catching of mosquitoes on the walls in kerosene cups are probably the best, next to a thorough screening and mosquito bars about the bed. In burning pyrethrum powder it is well to moisten the powder sufficiently with water so that it can be molded roughly into little cones about the size of a chocolate drop. These cones are placed on a pan and dried in the oven. If ignited at the apex the cones smolder slowly, giving off an odor not unlike that of the prepared punk which boys in this country use to light firecrackers. Two or three of these cones burned in a room in the evening will give relief by stupefying the mosquitoes. This smoke appears to be perfectly innocuous to human beings. The writer has breathed it evening after evening without the slightest perceptible ill effect. The method of catching mosquitoes on the walls with kerosene in cups is now in frequent use in different parts of the country. No one seems to know who invented it, but the writer first saw it in operation some years ago in New Jersey, and was struck with its simplicity and efficacy. The top of a tin baking-powder box is inverted and nailed to the end of a stick of sufficient length to reach to the ceiling. A small quantity of kerosene is put into this improvised cup and the apparatus is pushed up under resting mosquitoes, which fall into the kerosene and are destroyed. It is the custom in certain houses to systematically hunt for mosquitoes in the bedrooms with such an apparatus every night before retiring.

Camphor rubbed on the face and hands or a few drops upon the pillow at night will keep mosquitoes away for a time, and this is also a well-known property of oil of pennyroyal. The use of oil of peppermint, lemon juice, and vinegar have all been recommended as protectors against mosquitoes, while oil of tar as used against the black fly in Canada is also used in bad mosquito localities. Strongly camphorated vaseline, although recommended, has been found by Dr. Nuttall to be of scarcely any use in Canada.

One of the London papers, the Daily Telegraph, invited its readers to send in mosquito remedies of this kind during the summer of 1899, and some of the substances recommended were as follows:

Eucalyptol on the skin, with a handkerchief saturated with it placed on the pillow at night—the result of South African experience. (Arthur E. Edwards.)

Carbolated vaseline. (Dr. George Mackern.)

One drop of oil of lavender on pillow, and one on the head at night. (A. E. S.)

Tincture of *Ledum palustræ*. (M. Fisher.)

Piece of cotton wool soaked in oil of cloves on each side of the bed curtains. (W. B.)

Anoint skin with 3 parts refined paraffin and 1 part crushed camphor. (W. T. Catleugh.)

To heal the bites, a drop of liquid ammonia. (P. G. L.)

Eucalyptus oil. (X.)

Same substance. (Dr. George Cohen.)

Oil of eucalyptus and creosote, each 5 drops, to be thoroughly mixed with 1 ounce of glycerin. (R. R. P. S. Bowker.)

Place a fine, juicy, uncooked beefsteak near the bed on retiring. (M. M. M.)

A substance with which the writer is not familiar, but which is spoken of very highly in the interesting paper by the Italians Celli and Casagrandi in a paper to which we shall have occasion to refer later in speaking of remedies against the larva, is a yellow aniline color, referred to in the work of the Italians as Larycith III. They state that a little of this substance burned will kill the adult mosquitoes and that this method constitutes the most efficacious means of destroying them. The Chinese use pine or juniper sawdust, mixed with a small quantity of brimstone and 1 ounce of arsenic, run into slender bags in a dry state. Each bag is coiled like a snake, and tied with thread. The outer end is lighted. Two coils are said to be sufficient for an ordinary room, and 100 coils sell for 6 cents.

Remedies for bites.—Dr. E. O. Peck, of Morristown, N. J., wrote to this office last summer stating that he had found glycerin a sovereign cure for the bites. Touch the bite with glycerin, and in a few minutes the pain is gone. According to Dr. Peck it also took the pain from bee stings. Dr. Charles A. Nash, of New York City, has recently informed the writer, by correspondence, that whenever a mosquito bites him he rubs the spot and marks it with a lump of indigo. This, he says, "instantaneously renders the bite absolutely of no account," whether the application is made immediately, the next day, or the day after. He has used it since 1878, and lives in a New Jersey town where, he writes, "mosquitoes are a pest every year." He finds the same application to give relief from the stings of the yellow jacket. Household ammonia has been found by many persons to give relief.

DESTRUCTION OF LARVÆ AND ABOLITION OF BREEDING PLACES.

The following paragraphs are quoted from the writer's article in Bulletin No. 4:

"Altogether the most satisfactory ways of fighting mosquitoes are those which result in the destruction of the larvæ or the abolition of their breeding places. In not every locality are these measures feasible, but in many places there is absolutely no necessity for the mosquito annoyance. The three main preventive measures are the draining of breeding places, the introduction of small fish into fishless breeding places, and the treatment of such pools with kerosene. These are three alternatives, any one of which will be efficacious, and any one of which may be used where there are reasons against the trial of the others.

"*Kerosene on breeding pools.*—In 1892 the writer published the first account of extensive out-of-doors experiments to determine the actual effect upon the mosquitoes of a thin layer of kerosene upon the surface of water in breeding pools and the relative amount to be used. He showed the quantity of kerosene necessary for a given water surface, and demonstrated further that not only are the larvæ and pupæ thereby destroyed almost immediately, but that the female mosquitoes are not deterred from attempting to oviposit upon the surface of the water, and that they are thus destroyed in large numbers *before their eggs are laid*. He also showed approximately the length of time for which one such treatment would remain operative. No originality was claimed for the suggestion, but only for the more or less exact experimentation. The writer, himself, as early as 1867, had found that kerosene would kill mosquito larvæ, and the same knowledge was probably put in practice, although without publicity, in other parts of the country. In fact, Mr. H. E. Weed states (Insect Life, Vol. VII,

p. 212) that in the French quarter of New Orleans it has been a common practice for many years to place kerosene in the water tanks to lessen the numbers of mosquitoes in a given locality, although he knew nothing that had been written to show that such was the case, and he says: 'In this age of advancement we can no longer go by hearsay evidence.' Suggestions as to the use of kerosene, and even experiments on a water surface 10 inches square, showing that the larvæ could be killed by kerosene, were recorded by Mrs. C. B. Aaron in her Lamborn prize essay and published in the work entitled 'Dragon Flies *versus* Mosquitoes' (D. Appleton & Co., 1890). Mr. W. Beutenmüller, also in the same work, made the same suggestion.

"The quantity of kerosene to be practically used, as shown by the writer's experiments, is approximately 1 ounce to 15 square feet of water surface, and ordinarily the application need not be renewed for one month. Since 1892 several demonstrations, on both a large and a small scale, have been made. Two localities were rid of the mosquito plague under the supervision of the writer by the use of kerosene alone. Mr. Weed, in the article above mentioned, states that he rid the college campus of the Mississippi Agricultural College of mosquitoes by the treatment with kerosene of eleven large water tanks. Dr. John B. Smith has recorded, though without details, success with this remedy in two cases on Long Island (Insect Life, Vol. VI, p. 91). Prof. J. H. Comstock tells the writer that a similar series of experiments, with perfectly satisfactory results, was carried out by Mr. Vernon L. Kellogg on the campus of Stanford University, at Palo Alto, Cal. In this case post holes filled with surface water were treated, with the result that the mosquito plague was almost immediately alleviated.

"Additional experiments on a somewhat larger scale have been made by Rev. John D. Long at Oak Island Beach, Long Island Sound, and by Mr. W. R. Hopson, near Bridgeport, Conn., also on the shores of Long Island Sound, the experiments in both cases indicating the efficacy of the remedy when applied intelligently. I have not been able to learn the details of Mr. Hopson's operations, but am told that they included extensive draining as well as the use of kerosene.

"It is not, however, the great sea marshes along the coast, where mosquitoes breed in countless numbers, which we can expect to treat by this method, but the inland places, where the mosquito supply is derived from comparatively small swamps and circumscribed pools. In most localities people endure the torment or direct their remedies against the adult insect only, without the slightest attempt to investigate the source of the supply, when the very first step should be the undertaking of such an investigation. In 'Gleanings in Bee Culture' (October 1, 1895) we notice the statement in the California column that in some California towns the pit or vault behind water-closets is subject to flushing with water during the irrigation of the land near by. A period of several weeks elapses before more water is turned in, and in the meantime the water becomes stagnant and the breeding place of millions of mosquitoes. Then, as the correspondent says, 'people go around wondering where all the mosquitoes come from, put up screens, burn buhach, and make a great fuss.' Nothing could be easier than to pour an ounce of kerosene into each of these pits, and all danger from mosquitoes will have passed.

"In many houses in Baltimore, Md., the sewage drains first into wells or sinks in the back yard, and thence in some cases into sewers, and in other cases is pumped out periodically. These wells invariably have open privies built over them, and the mosquitoes, which breed in the stagnant contents of the sinks, have free egress into the open air back of the houses. Hence parts of Baltimore much farther removed from either running or stagnant water than certain parts of Washington, where no mosquitoes are found, are terribly mosquito ridden, and sleep without mosquito bars is, from May to December, almost impossible. Specimens of *Culex pungens* captured November 5 in such a privy as described have been brought to the writer from Baltimore by one of his assistants, Mr. R. M. Reese.

"Kerosene has been tried by Mr. Reese in one case in Baltimore, and two treatments of a privy made about May 1 and June 1, respectively, seemed to diminish the numbers of the pest in that particular house; but without concerted action of all the householders in a given block (all the houses, be it remembered, being exactly alike in the method of sewage disposal) no great amount of good could be accomplished. With such concerted action, however, there seems to be no reason why the mosquito plague could not be greatly diminished in many, if not most, parts of Baltimore at a very small expense. Usually one well serves two houses, the privies being built in pairs, so that one treatment would suffice for two dwellings.

On ponds of any size the quickest and most perfect method of forming a film of kerosene will be to spray the oil over the surface of the water.

"*Drainage.*—The remedy which depends upon draining breeding places needs no extended discussion. Naturally the draining off of the water of pools will prevent mosquitoes from breeding there, and the possibility of such draining and the means by which it may be done will vary with each individual case. The writer is informed that an elaborate bit of work which has been done at Virginia Beach bears on this method. Behind the hotels at this place, the hotels themselves fronting upon the beach, was a large fresh-water lake, which, with its adjoining swamps, was a source of mosquito supply, and it was further feared that it made the neighborhood malarious. Two canals were cut from the lake to the ocean, and by means of machinery the water of the lake was changed from a body of fresh to a body of salt water. Water that is somewhat brackish will support mosquitoes, but water which is purely salt will destroy them.

"*Practical use of fish.*—The introduction of fish into fishless breeding places is another matter. It may be undesirable to treat certain breeding places with kerosene, as, for instance, water which is intended for drinking, although this has been done without harm in tanks where, as is customary, the drinking supply is drawn from the bottom of the tank. An interesting case noted in Insect Life (Vol. IV, p. 223), in which a pair of carp was placed in each of several tanks, in the Riviera, is a case in point. The value of most small fishes for the purpose of destroying mosquito larvæ was well indicated by an experience described to us by Mr. C. H. Russell, of Bridgeport, Conn. In this case a very high tide broke away a dike and flooded the salt meadows of Stratford, a small town a few miles from Bridgeport. The receding tide left two small lakes, nearly side by side and of the same size. In one lake the tide left a dozen or more small fishes, while the other was fishless. An examination by Mr. Russell in the summer of 1891 showed that while the fishless lake contained tens of thousands of mosquito larvæ, that containing the fish had no larvæ.

"The use of carp for this purpose has been mentioned in the preceding paragraph, but most small fish will answer as well. The writer knows of none that will be better than either of the common little sticklebacks (*Gasterosteus aculeatus* or *Pygosteus pungitius*). They are small, but very active and very voracious. Mr. F. W. Urich, of Trinidad, has written us that there is a little cyprinoid common in that island which answers admirably for this purpose. This fish has not been specifically determined, but we hope to make an effort to introduce it into our Southern States, if it proves to be new to our fauna. At Beeville, Tex., a little fish is used for this purpose, which is there called a perch, although we have not been able to find out just what the species is. They soon eat up the mosquito larvæ, however, and in order to keep them alive the people adopt an ingenious flytrap, which they keep in their houses and in which about a quart of flies a day is caught. These flies are then fed to the fish. This makes a little circle which strikes us as particularly ingenious and pleasant. The flytraps catch the flies and rid the house of that pest. The flies are fed to the fish in the water tanks and keep them alive in order that they may feed on the mosquito larvæ, thus keeping the houses free of mosquitoes.

"*Artificial agitation of the water.*—Where kerosene is considered objectionable, and where fish can not be readily obtained, there is another course left open. It is the constant artificial agitation of the water, since mosquitoes will oviposit only in still water. At San Diego, Tex., in the summer there are no streams for many miles, but plenty of mosquitoes breed in the water tanks. Some enterprising individuals kept their tanks free by putting in a little wheel, which is turned by the windmill, and keeps the water almost constantly agitated."

Later use of kerosene.—Since the publication of the recommendations just quoted, a great deal of experimental work has been carried on in different parts of the country, both on a small scale and on large scales. An unfortunate editorial note published in the American Naturalist in 1895 states that the writer discovered the kerosene treatment against mosquito larvæ, whereas in his first article on the subject (Insect Life, Vol. V, pp. 12 to 14) he began with the words: "One of the most reasonable of the recommendations which have been made from time to time * * * is the application of kerosene to restricted and fishless breeding ponds." The note in the Naturalist was the text, however, for a sarcastic note in the Revue Scientifique, 1895, Volume IV, page 729, by a writer named Delbœuf, aimed not only against the writer, but against Americans in general. He stated that he had used kerosene as a remedy for fully fifty years, and that its use is referred to in the Journal Pittoresque for 1847, page 80, where it is spoken of as something already well known. Since the writer made no claims to any originality, but simply announced exact experimentation upon a somewhat large scale, the matter may rest very comfortably where it is. But it is interesting to note here that as long ago as 1812, in a work published in London under the title "Omniana or Horæ Otiosiores," a collection of odds and ends of all kinds, the following suggestion is made:

> The mosquito, which is of all the race of flies the most noxious, breeds in the water. Might it not be possible at the seasons when they emerge and when they deposit their eggs upon the surface to diminish their numbers by pouring oil upon great standing water and large rivers in those places which are most infested by them?

The writer is indebted to Mr. D. C. Clark, of Baltimore, for this interesting reference.

During the past few years kerosene has been rather extensively used at many places in an effort to limit the mosquito supply. As already pointed out, there are many places where the source of mosquito supply is definitely limited and easy of treatment, and in such cases on account of the cheapness of kerosene it will be the best means of eradication. In other places where communities are surrounded with swamp land or in the case of extensive sea marshes kerosene can be practically used in connection with other and more elaborate measures, comprehending, as a rule, dyking and draining. At a relatively slight expense, however, a country club on Staten Island has during one season practically stopped the breeding of *Culex pungens* in ponds and marshes in the vicinity by the use of kerosene alone. This substance has also been used with good effect by the Town Improvement Society at Summit, N. J., in woodland pools and swamp land, and its use on a large scale is being attempted the present year in the vicinity of a arge town on Long Island. Dr. A. D. Hopkins, of Morgantown, W. Va., tells the writer that about ten years ago an extensive pumping station was located near the river bank where the oil pipe line crosses a mile above Morgantown and that the oil frequently escapes out over the river. Since that time the city has been almost exempt from mosquitoes.

In 1897, Mr. M. J. Wightman, while interested in developing a new resort known as Midland Beach, had 4 barrels of crude petroleum scattered over the marshes surrounding the beach. For three weeks previously the mosquitoes had been unbearable. The employees at the beach went about with their heads covered with netting, and of course this had a very discouraging influence upon visitors. The oiled district covered a radius of half a mile, and Mr. Wightman, writing in 1899, stated that within three days after the oil was distributed mosquitoes were rare along the beach. This condition lasted throughout the season. Recently, owing to a change of management, the writer is informed that nothing has been done and that mosquitoes have become plentiful again.

Dr. St. George Gray, of St. Lucia, British West Indies, writes, after reading Bulletin 4 of this office, that he has tried kerosene in his well and in the water jars in his yard with the result that one species has disappeared from his house and that the other mosquitoes give him very little trouble.

The remedial experiments against mosquito larvæ tried by Doctors Stephens and Christopher at Sierra Leone are given in the reports to the malaria committee of the Royal Society, London, July 6, 1900. They selected as the most practical larvicides kerosene (paraffin oil) and salt. The salt, requiring a very strong solution, was not experimented with extensively. A few handfuls thrown into pools containing not more than 3 or 4 pints of water produced no effect in three days. With kerosene the rock pools and small runnells of water were treated: "The larvicidal effect in the pools was very striking, most of the larvæ being killed in fifteen minutes or less. In many cases again, besides the larvicidal effect, adult females were found next day killed by the paraffin on the surface of the pool where they had come to lay their eggs." Thus the writer's 1893 observation on the non-deterrent effect of the kerosene film on adult mosquitoes and their resultant destruction before the eggs are laid is confirmed. This has always seemed to be a point of great practical value in the use of kerosene. The final result by the English observers, however, was found to be the immediate return of the insects on the cessation of the application of petroleum. An interesting test experiment was made by them upon a surface drain arising from a spring and running for 300 yards when it entered a brook. The spring was free from larvæ, but the drain teemed with them throughout its entire length. Over this drain kerosene oil was sprinkled by means of a watering pot. About 4 gallons sufficed to cover the drain thickly with oil. "The larvicidal effect was immediate, and on the following day no living larvæ were seen. Four days later traces of oil were still present in places. Eight days later small larvæ were present along the whole drain. * * * A weekly application of paraffin then would effectually prevent the formation of the perfect insect in these situations."

The rapid disappearance of the kerosene covering in this last experiment is quite contrary to the results of our applications made to still pools of water. This may have been due in part to the fact that there was more or less of a current in the drain, and may also have been due to the use of an especially volatile kerosene. The writer is now advising the use of the grade known as lubricating oil as the result of the extensive experiments made on Staten Island. It is much more persistent than the ordinary illuminating oils.

An interesting plan, suggested to the writer by Mr. W. C. Kerr, of New York, in conversation, to disseminate oil over salt marshes, was that of putting barrels of oil in the marshes in winter when the ground is frozen and piercing the barrels with small holes so that the oil will escape slowly through the following breeding season. The best method of distributing oil on the surface of water is a practical question which each experimenter is apt to settle for himself. The writer has adopted the plan of simply pouring the requisite quantity of oil upon the water and allowing it to spread by itself, which it does in the course of time. The Staten Island and Summit, N. J., people use a spray pump, but in some ways this seems to the writer not perfectly satisfactory. A great deal of kerosene is apt to be wasted and the continuous layer of oil which is desirable is frequently not brought about. The Liverpool School of Tropical Diseases advises as the result of the Sierra Leone work that the oil can be best applied by smearing the pool with a rag fixed to the end of a stick and dipped in a pot of oil. "In this manner a number of pools can be dealt with in five minutes at the expense of very little oil."

OTHER LARVICIDES.

Permanganate of potash.—Other substances have been experimented with. Two years ago many newspapers contained an item concerning the use of permanganate of potash. As this item was credited to the Public Health Journal it gained a great deal of credence, and was afterwards mentioned in an interesting article by Mr. A. C. Weeks, in the Scientific American. The published note read as follows:

Two and one-half hours are required for a mosquito to develop from its first stage, a speck resembling cholera bacteria, to its active and venomous maturity. The insect in all its phases may be instantly killed by contact with minute quantities of permanganate of potash. It is claimed that 1 part of this substance in 1,500 of solution distributed in mosquito marshes will render the development of larvæ impossible; that a handful of permanganate will oxidize a 10-acre swamp, kill its embryo insects, and keep it free from organic matter for thirty days, at a cost of 25 cents; that with care a whole State may be kept free of insect pests at a small cost. An efficacious method is to scatter a few crystals widely apart. A single pinch of permanganate has killed all the germs in a 1,000-gallon tank.

The item is so obviously ridiculous upon its face that it would hardly seem worth while to make any attempt to refute its statements. Nevertheless, it has been so widely read that definite experimentation seems necessary to set the matter at rest. The unknown author's ignorance of the life history of mosquitoes in the opening sentence need not necessarily imply that he would not know a good remedy if he found one. Careful experiments were undertaken by the writer in July, 1898, with various strengths of permanganate of potash in water containing mosquito larvæ from one to six days old. It was found that small amounts of the chemical had no effect whatever upon the larvæ, which were, however, killed by using amounts so large that, instead of using a "handful to a 10-acre swamp," at least a wagon load would have to be used to accomplish any result. Moreover, after the use of this large amount and after the larvæ were killed, the same water twenty-four hours later, sustained freshly-hatched mosquito larvæ perfectly, so that even were a person to go to the prohibitive expense of killing mosquito larvæ in the swamp with permanganate of potash, the same task would have to be done over again two days later.

The same conclusion was subsequently reached, after careful experiment, by Dr. Lederle, of the New York health office, and by the Italians Celli and Casagrandi.

Proprietary mixtures.—A number of proprietary and secret mixtures recommended for mosquito-breeding pools and which have been put on the market since the wide-spread interest in the mosquito question has sprung up have been tested by the writer, but none have been found more satisfactory than the cheapest petroleum oil.

Experiments of Celli and Casagrandi.—The most extensive series of experiments with culicidal mixtures which has been made was conducted by the Italians Celli and Casagrandi, above referred to. They have tabulated in the "Annali d' Igiene Sperimentale, Rome (Vol. IX, Fasc. III, 1899, pp. 317–353), the results of experiments with many substances. Referring to petroleum, they say that apart from the question of the expense, which outside of America is worthy of note, the action of petroleum in destroying mosquito larvæ is not always to be put in the front rank. Their conclusions are practically as follows:

(1) Of the whole period of the cycle of development of mosquitoes the stages in which they are most easily destroyed are those of larvæ and of the aerial mosquito, and larvæ are most easily killed the younger they are.

(2) To kill the larvæ, among numerous substances experimented with, there will have, in decreasing order, culicidal action: (a) Mineral: sulphurous oxide, permanganate of potash with hydrochloric acid, common salt, potash, ammonia, carburet of lime, corrosive sublimate, chloride of lime, the bisulphites, sulphate of iron or copper, lime, bichromate of potash, and sodium sulphite. (b) Organic: powders of the unexpanded flowers of chrysanthemum, tobacco, petroleum and oils, formalin, cresol, certain aniline colors (gallot, green malachite), coal tar. Taking into account, however, the dose necessary to kill the larvæ, the practicability and the price, all of the mineral and some of the organic substances are excluded, and there remain as available the vegetable powders, petroleum, and the aniline colors.

(3) To kill aerial mosquitoes, we have odors, fumes, or gases. Among the odors are turpentine, iodoform, menthol, nutmeg, camphor, garlic. Among the fumes are tobacco, chrysanthemum powder, fresh leaves of eucalyptus, quassia wood, pyrethrum powder. Among the gases, sulphuric oxide. It is, however, to be noted that for these odors, fumes, or gases to exercise their culicidal action they must fill or saturate the whole ambient; otherwise they produce only apparent death, or at most only a culicifugal action, which sometimes in houses may be useful in protecting man from being bitten by mosquitoes, and preventing the latter infecting him when they have sucked the blood of malarious persons.

(4) The problem of the destruction of mosquitoes is experimentally soluble, but practically it will only be so when economic interests desire it. In this latter sense it is remarkable that the old larvicidal use of petroleum has not become much diffused in those places where it is very cheap. The chrysanthemum plants might be grown on a large scale, this making the malarial place itself produce that substance which frees it of the mosquitoes that infest it.

(5) The opportune season for killing the larvæ is in the winter, when they are in least numbers in the waters and new generations are not born; this also is the season for their destruction in houses, for they come here for a warmer abode. Their habits and places of nesting should be studied to this end. This may not be accomplished on a large scale as easily as some boast; nevertheless, after the treasures spent by nations and individuals for preserving vines and vegetation from the oidium, the peronospora, and the phylloxera, we may hope that something may be done for protecting the life of man from the mosquitoes of malaria.

It will be noticed that they really exclude from further consideration all substances except vegetable powders, petroleum, and the aniline colors. By vegetable powders they refer to the powders from the flowers of plants of the genus Pyrethrum, and their experiments upon the aniline colors practically center upon the recommendation of the substance already referred to as the yellow aniline dye which they call "Larycith III." This color has the property of other aniline colors in that it is soluble and diffusible in water. The practice recommended is to make a concentrated solution, which is poured into the pool or pond to be treated. It is said by the authors that it will destroy all insect life and fishes, but is harmless to warm-blooded animals; thus domestic animals may, without danger, drink from pools being treated.

Just what "Larycith III" will prove to be and whether it will be available for use in this country unfortunately can not be ascertained at the present moment. Correspondence has been entered into with large dye firms in New York who have sent abroad for information.

Dr. Ross, in his article in Nature of March 29, previously referred to, says: "On the whole, the most promising method which suggests itself is the employment of some cheap solid material or powder which dissolves slowly, which kills the larvæ without injuring higher animals, and which renders small pools uninhabitable for the larvæ for some months. If, for instance, a cartload of such material would suffice to extirpate the larvæ over a square mile of a malarious town, the result would be a large gain to its healthfulness. Dr. Fielding-Ould has lately reported favorably on tar."

Tar and its compounds.—Again, in the report of the Liverpool School of Tropical Diseases the following words occur: "Perhaps more permanent oil than kerosene would be more permanently effective. Fresh tar dropped in a puddle makes a film like that of oil and has been favorably reported on. Quicklime has been suggested, and all these should certainly be tried."

The writer is rather at a loss to know exactly what is meant by the expressions "fresh tar" and "tar" in the above paragraphs. He has conducted an experiment, however, with a substance known to the trade as "coal tar," a thick viscid liquid. A few large drops of this substance were dropped into a glass vessel containing approximately 2 quarts of water in which were more than 100 full-grown larvæ of Culex. All the drops but one sank at once to the bottom, the last one floating upon the surface for some time. No surface film seemed to form from the tar, but after the expiration of forty-eight hours the water was found to be more or less impregnated by the tar, having turned somewhat darker in color, while the odor of the tar was perceptible. At the expiration of five days nearly all the Culex larvæ were dead; 1 had succeeded in transforming to pupa, and 5 or 6 remained at the surface enfeebled and dying. Thus more than 95 per cent had been killed. In the meantime, however, twenty-four hours after the experiment began, 3 egg masses were laid on the surface of the water by outside females of Culex. These had hatched in forty-eight hours more, and on the fifth day, although the original full-grown larvæ were practically exterminated, many young larvæ were swarming actively about in the tar water. They continued to grow and to remain apparently perfectly active and healthy, although the odor of the tar was distinctly perceptible and the color of the water was dark, and even a thin oily film remained over a portion of the surface.

From this experiment it was plain that the killing effect of the tar in the preparation used is comparatively fugitive, and it was next decided to test some of the coal-tar products. The object of this line of experimentation was not only to test the suggestions of the English observers, but also on account of the fact that as almost every community manufactures its own illuminating gas it was considered an easy and probably econominal way of securing a mosquito larvicide, if it should prove to be effective. Coal tar is distilled into various grades of oil, and two of the heavier of these grades were used in the succeeding experiments. One of these was called "creosote oil," and was a rather light oil of a specific gravity of 1.035 at 60° F., and the other, bearing no name, was somewhat heavier. The experiments were necessarily on a somewhat small scale. Eighty nearly full-grown larvæ of *Culex stimulans* and *C. perturbans* were placed in 3 quarts of water and one-fourth ounce of creosote oil was poured in at 4.15 p. m. At 5.45 17 pupæ and 3 larvæ were left alive. The next morning at 9 o'clock it was found that 8 adults had issued over night, but all had been killed by the creosote. At 3 p. m. of the same day, twenty-three hours after the introduction of the insecticide, all larvæ and pupæ were dead. With the slightly heavier oil, 150 larvæ of the same species, all full grown or nearly so, were placed in 2 quarts of water and three-sixteenths ounce of the oil was added at 4.15 p. m. At 5.45 all were dead except 28 pupæ and about 30 larvæ. The next morning at 9 o'clock it was discovered that 10 adults had issued over night, but had been killed before flight by the oil. At 4.30 p. m. of the same day all the larvæ were dead, but 10 pupæ were still active. On the following morning, at 9 o'clock, forty-two hours after the application, all larvæ were dead and the adults had issued from the remaining pupæ, but had been caught by the oily film in the act of issuing and had died upon the surface of the water.

Still another experiment was tried with pupae only. Two hundred and fifty pupæ of the same Culices were placed in 3 quarts of water and one-fourth ounce of creosote oil was added. Twenty hours later many of the pupæ were still living, but thirty-six hours from the time of application all were dead, no adults having issued. A check experiment with kerosene was carried on parallel with this last experiment with creosote, and it was noticed that the action of the kerosene upon the pupae was much quicker, all dying within forty-five minutes. A few young larvæ, however, in the same jar lived for several hours.

An interesting effect of the application of the creosote in the first two of these experiments was that it seemed without doubt to hasten the transformation of the insect. When at 4.15 the creosote was poured in jars 1 and 2, no pupæ were observed, but all larvæ were full grown or nearly so. After fifteen minutes 10 pupæ were observed in jar 2 and 5 in jar 1. Ten minutes later 15 were counted in jar 2 and 13 in jar 1. Twenty minutes later there were 19 in jar 2 and 22 in jar 1. Fifteen minutes later still there were 19 in jar 2 and 22 in jar 1. Thirty minutes later there were 17 in jar 2 (2 having died in the interval) and 28 in jar 1. As above stated, over night a number of adults issued, 10 in jar 1 and 8 in jar 2, and twenty-four hours later 10 more adults issued in jar 1. It must be remarked that the full-grown larvæ struggled violently on perceiving the uncomfortable presence of the creosote, and as they were just ready to transform this violent struggling evidently assisted in the breaking of the larval skin, leaving the pupa bare. This transformation from larva to pupa is hardly as interesting as the rapid development of adults, 18 of which issued within fifteen hours after transformation to pupa, whereas previously the shortest duration of the pupal state which we had observed was forty-eight hours. It looks like an effort of nature to perpetuate the species in the presence of a unique emergency.

On the whole, the result of the experiments with tar and tar oils was rather unsatisfactory as compared with the heavier grades of kerosene. The effect of the tar was not permanent, and the effect of the creosote oils was not as rapid as that of kerosene, and the writer is inclined to the opinion that the heavier grades of kerosene oils are, on the whole, preferable, although the effect of the creosote oils is very good, and they can be used to advantage. He is inclined to think that they may prove to be more permanent, although not quite so rapid in their effect, than the lighter illuminating oils.

EUCALYPTUS TREES.

In addition to the use of eucalyptus oil on the skin to keep mosquitoes from biting, the growth of eucalyptus trees is said by certain persons to drive mosquitoes away, and trees of the genus Eucalyptus have been especially recommended for planting in malarial regions. Mr. Alvah A. Eaton, of California, wrote us in 1893 that in portions of California where the blue gum occurs no other remedy need be sought for. Further than that, he stated that no matter how plentiful the mosquitoes, a few twigs or leaves laid on the pillow at night would secure perfect immunity. The same year Mr. W. A. Sanders, of California, sent the following interesting account of the value of eucalyptus trees in answer to our published request in Insect Life:

I have the largest and oldest grove of trees of *Eucalyptus globulus* in this part of California, and have had fifteen years of opportunity to study these trees as insect repellants, and deem it my duty to respond to your request on page 268 of Insect Life.

Thirty-three years ago I spent a portion of one summer with a Dr. McConnell, who had just returned from some years of residence among the Eucalyptus forests of Australia. We were in the Sequoia (*Sequoia sempervirens*) forest of the coast region of our State. The mosquitoes were so bad that it was nearly impossible to work during days when there was no wind. The doctor assured me that our common mosquito was never found in the Australian Eucalyptus forests and swamps, but added, There's a "spotted mosquito" nearly as bad there in some places. He, not being an entomologist, was unable to tell me whether the "spotted mosquito" was a species of the genus Culex, or of some allied genus.

The doctor being a reliable, close observer, I determined to test the antimosquito qualities of the Eucalyptus; so when I began to improve my house here nineteen years ago, one of the first things I did was to get a lot of eucalyptus seed from Australia and plant out a grove of the trees. The tallest of them are now over 140 feet tall, and can be seen for 20 miles around. My house stands in the midst of these trees. My irrigating ditch, a dozen feet wide, of sluggish current, runs through the grove beside the house. There has never a single mosquito larva been seen in the ditch from where it enters the first shade of these trees to where it emerges from them 200 yards away, while above and below mosquito larvæ are plentiful—not immediately below, but some hundreds of yards away, where the water stands in pools and becomes stagnant among a growth of black walnuts and cottonwoods.

My live stock pasture in this timber, going into the walnuts and back again under the eucalyptus shade at pleasure. Frequently when the cows come up at night they bring a swarm of mosquitoes; occasionally some of them get into the house, but cause us so little annoyance that we scarcely notice them. Before this ditch reaches the Eucalypti it runs through a jungle of "fence bamboo" (*Arundo macrophylla*), where the mosquitoes are so bad that we avoid working there except on the windiest days. And, though the ditch has more current there, the larvæ of mosquitoes are plentiful in the water till it reaches the Eucalyptus trees, below which point none are found till it has become stagnant away below them.

People who have camped along the willows of Kings River, only a few miles away, have come here with faces so blotched and swollen from mosquito bites as to be hardly recognizable, and have camped in the shade of "Sanders's gum trees," as my grove is popularly called, for weeks, and declare that they never even heard a mosquito sing during that time.

To the non-botanical reader I may say that this species of Eucalyptus is very tender to frost. The coldest weather ever known here, 19° F. above zero, killed thousands of them.

Dr. Nuttall points out that the planting of eucalyptus trees is not a sovereign remedy, from the fact that malaria still prevails at Tre Fontane, outside of Rome, in spite of Eucalyptus plantings. The mere planting of trees, however, is undoubtedly of use in malarial districts, since it will modify the condition of drainage of the soil. In view of Mr. Sanders's strong evidence it really appears that planting of eucalyptus trees will be worth while in certain locations, not entirely (on account of the conflicting and not thoroughly satisfactory evidence) for mosquito protection, but incidentally for this use as well as other purposes.

DRAINAGE AND COMMUNITY WORK.

After all, the best of the means which may be adopted against mosquitoes will always consist in the abolition of their breeding places. Small pools with stagnant water can be treated, but it is a great deal better to drain them or to fill them up. Swamp areas must sooner or later be drained. It is perfectly obvious that the sooner this is done the better from every point of view, not only from that of human health but from the increased value of real estate in the neighborhood and from the practical value of the reclaimed land itself. The time is coming, and rapidly, when this drainage of large swamps will not remain a matter which concerns the individual owner of the land, but one for town or county action, and even for States. The report of T. J. Gardner on the policy of the State respecting drainage of large swamps, published in the Report of the Board of Health for New York, Albany, 1885, although antedating the recent important mosquito discoveries, is well worth reading by all public-minded persons, and the annual reports of the State geologist of New Jersey for 1897 and 1898, in which the reclamation of the great Hackensack Meadows, near Jersey City, Newark, and Elizabeth, N. J., makes interesting reading along this line. Work on these marshes has actually been begun. The solution of this case is taking the form of separate action by cities and their municipalities, each improving the territory within its corporate limits. The city of Newark has a tract of 4,600 acres of marsh within its limits; Jersey City has within its limits 2,086 acres of tide marsh, and Elizabeth has 2,658 acres. The three cities, therefore, have about 8,700 acres of the 27,000 acres lying between Elizabeth and Hackensack. The sanitary importance of reclaiming these lands is of the greatest, but the capabilities of the improvement plans are attracting attention on the part of capitalists and business men, who see in these tide lands valuable sites for manufacturing, industrial, and commercial activity.

Even to individual land owners of a community, the drainage of swamps and the consequent abolition of mosquitoes will in many cases become well worth while. The writer knows of a town in New Jersey, with a good elevation, within easy distance of New York, and admirably adapted for summer residences of New Yorkers, where the mosquitoes are so abundant as to prevent the rise in the price of real estate. An examination of the surrounding country has convinced him that if the large real estate owners were to club together they might, by the expenditure of a few thousand dollars, largely do away with the mosquito plague. Another case which is well worth specific mention, and the truth of which the writer will vouch for, may best be told in the words of a correspondent, printed in one of the Flushing papers late in March:

> In the town of Stratford, Conn., where I have resided for the past forty-five years, we have been greatly plagued by swarms of mosquitoes, so great, in fact, that the "Stratford mosquito" became a well-known characteristic of Stratford. We have in the southern part of our town, bordering on the sound, several acres of marsh land or meadow, which would become periodically overflowed with water in the summer and a tremendous breeding ground for mosquitoes, and this plague to the town continued until about 1890–91, when a party from Bridgeport, Conn., purchased a large section of the meadows and began to protect them by a dike, both on the north and south ends, which shut out the water. In addition to this, numerous drain ditches were made, which helped to carry the water away. The result of this work made the land perfectly dry and spongy, so that after a rain no pools collected on the surface of the meadow and prevented the creation of the mosquitoes. The transformation was so remarkable that people outside the town would hardly believe that it had been effected, and a year or two later the town voted a special appropriation of $2,000 to the party who undertook to build the dike and render the meadows mosquito proof. It had also the effect of placing on the market a large tract of land elevated from the sound for residences, and as many as 25 summer residences have

been built upon this land bordering the sound, and are increasing each year. They are free from mosquitoes, so that the operation shows the economy and the benefit that will result by using some means for eliminating the mosquito-breeding pools.

As to community work, we must not fail to mention the interesting fact that the city of Winchester, Va., is reported to have passed an ordinance requiring property holders to treat drains and stagnant pools of water with kerosene during the summer season. Winchester is a town of high elevation and has for a long time enjoyed a reputation among Virginians as a cool place to spend the summer. Mosquitoes, we are told, however, made their appearance there a few years ago, with the effect that summer visitors became fewer and fewer. The passing of the city ordinance was deemed a matter of public policy and met with general approval. Police measures of this kind may not be inadvisable under certain circumstances. Surely in such instances as the Baltimore case, mentioned in previous pages, it seems entirely appropriate that the board of health should be called upon to enforce kerosene treatment.

APPENDIX.

AN EARLIER ACCOUNT OF THE LARVA OF ANOPHELES.

Just as this manuscript was about to be sent to the printer the writer's attention was called to a paper by F. Meinert, entitled "Die encephale Myggelarver" (Sur les larves encéphales des Diptères; leurs mœurs et leurs métamorphoses), K. Danske Videnskabernes Selskabs Skrifter (Copenhagen), iii, pp. 373–493, Pls. I–IV (1886), in which, among other observations, he gives a brief statement concerning Anopheles which is sufficiently interesting to translate:

"*Anopheles.*—In the 'Observations d'Histoire Naturelle' of Joblot one finds a description of this larva, "Description of a new fish," which is rather insignificant, and a drawing which is not badly done. The larva drawn by Brauer as Anopheles is a larva of Dixa, and those reported by Fischer d'Waldheim as *C. claviger* are larvæ and nymphs of the genus Corethra, while his nymph is a Tanypus, and his fly an Anopheles. Aside from this, Gerke has briefly mentioned this larva in his paper entitled 'On the metamorphoses of the dipterous genus Dixa,' page 166.

"The larva of Anopheles lives in still waters or in a weak current with a rich vegetation, in wooded or unwooded regions. It does not like the shade of great trees, but seeks the sun and the light, as is indicated by its fresh green color. It does not hibernate, but in mild seasons it is found in a half-grown condition by the end of March. In July or a little later in the course of a summer the second generation of the full-grown larvæ are found, and in 1882, a year when the spring was very forward, the writer found at the end of October small larvæ which certainly belonged to the third generation; but it was not to be supposed that these larvæ would become full grown, since as they live at the surface of the water the first film of ice would kill them.

"The larvæ hold themselves at the surface of the water, where they float with the extremity of the abdomen turned toward the bank or toward the plants which cover the surface. The larva is stretched out in the water with the respiratory tube at the surface. The larger part of the abdomen and posterior part of the thorax are submerged, only a little portion of the prothorax emerging. The head is under water. The long hairs with which the body of the female is provided on the sides, on the metathorax, and the first three segments of the abdomen are of great assistance to it in maintaining a fixed position. It rests often for a long time immovable and only occasionally changes its location. Its movements denote a certain apathy or indolence, but at the same time much prudence and apprehension. When it moves it moves rapidly and dives to the bottom of the water. Recovering from its fright, it rises obliquely to the surface.

"Just as with the larvæ of Culex, the larvæ of Anopheles live upon organic microscopic particles which float upon the water, and which are brought into the mouth by the movements of the rotatory organs. These organs are much more developed than with the larvæ of Culex, and while they serve, like the former, as a brush or sieve to strain their food the larvæ of Anopheles, like those of Simulium, holding the head stretched forward, use them to agitate the water. The larvæ of Anopheles present this peculiarity, that in producing these currents, which they do the greater part of the day, they lie upon the belly with the under part of the head turned upward. This rotation of the head is executed with the greatest rapidity; and scarcely, for example, have the larvæ come to the surface to float, when, by a rotation of the head upon its longitudinal axis, it is turned bottom side upward and commences to agitate the surface of the water. This agitation is undoubtedly for the purpose of drawing floating objects surely and completely into the orifice of the mouth. This, however, is not necessary, for often one sees the larva with its head working in normal position, mouth organs below, but in general they do not remain in this position for a long time, and it is only after having turned the head upward that they seem to work *con amore.*

"As a rule the larvæ seek their nourishment while they are floating at the surface, but at other times they descend two or three inches under the water. They can rest several minutes in this position with the head below, after which they come to the surface again."

This account shows that Meinert knew the larvæ very well, and one can only regret that he did not describe the eggs and the pupæ.

THE MALARIAL EXPEDITION OF THE LIVERPOOL SCHOOL OF TROPICAL MEDICINE.

This interesting and most valuable report was known to the writer only by brief newspaper notes until the present bulletin had reached page proof—too late to insert in proper place several important observations made by Ross, Annett, Austen, and Fielding-Ould. To-day (August 13) it has reached him in Volume II of the Thompson Yates Laboratory Reports (University Press of Liverpool, 1900), and he is glad of the opportunity to add the following paragraphs quoted from its pages:

8. METHODS FOR ASCERTAINING DEFINITIVE HOSTS.

The long researches of one of us in India, followed by those of Koch, Daniels, and the Italian investigators, have given us a very exact knowledge of the life history of the Hæmamœbidæ in gnats, and have shown us how to detect them in the insects with ease and certainty. It has been noted that in inhospitable species of gnats the ingested parasites perish within the stomach cavity, whereas in hospitable species the zygotes escape from that cavity and develop in the tissues, ultimately giving rise to blasts which are found in the juices and salivary glands of the insect. * * *

15. BIONOMICS OF ANOPHELES LARVÆ.

We made the following observations:

(1) *Eggs.*—These are *boat-shaped*, like those of *Anopheles* observed in India. They appear to be laid singly on water, but cohere by their ends, forming typical triangular patterns, and also adhere to floating objects, the sides of the vessel, etc. We observed no facts indicating that they are ever laid on solid surfaces. *In vitro* they take about twenty-four hours to hatch, but the period is probably much shorter in puddles.

(2) *Duration of larval stage.*—This depends on temperature and amount of food. Under natural conditions it may probably be only three or four days, but under unfavorable conditions (cold, overcrowding, absence of food) it may certainly extend to weeks.[1] There are reasons for thinking that development is much hastened by bright weather, in order to enable the imago to hatch out before desiccation of the containing puddle.

(3) *Food.*—The larvæ were frequently watched floating on the surface and feeding on filaments of waterweed, amongst which they often entangle themselves. On dissection the intestine was found crammed with these filaments. It was observed that *in vitro* the larvæ scarcely grow in size unless they are given large quantities of waterweed, which they dispose of very rapidly. On the other hand, larvæ were often caught in puddles in which no green vegetation could be seen. They may eat other food, but it would seem as if waterweeds constitute their favorite diet. It was also noted that they obtain shelter among these weeds from the current running through the pools during or after rain.

(4) *Enemies.*—No observations could be made under this head, but we often found many frogs and tadpoles in the breeding pools, apparently living at peace with the larvæ.

(5) *Effects of desiccation.*—During most of our stay in Freetown heavy showers fell several times a day, so that the larvæ could live secure from desiccation in all but the most evanescent puddles. In September, however, there was a complete break in the rains, lasting three days. A large number of the pools, even many of those containing waterweed, and those fed by springs during rain, dried up completely. The question whether the larvæ had the power of living in the mud at the bottom of the pools could now be tested by direct observation. The break in the rains was followed by heavy showers, which immediately refilled all the puddles. Had the larvæ continued to exist in the mud, they would now have emerged again. As regards the puddles in which the mud had completely dried, this was not the case. No larvæ at all were found in them for at least two days after the rain had refilled them. After that interval larvæ again appeared, but they were very small ones, evidently just hatched from the egg. On the other hand, it was frequently observed that if the mud did not become completely dry, the larvæ would emerge into active existence after another shower. These observations were supported by some experiments *in vitro*, and we therefore conclude that the larvæ can withstand partial, though not complete, desiccation.[2]

(6) *The same puddles constantly occupied.*—We have suggested (paragraph 13) that the position of the breeding pools may change according to the seasons, but while we were in Freetown there was no change of season, and we generally found *Anopheles* larvæ in the same puddle, namely, in those which were suitable for them. Thus, of two puddles lying close together, one would never contain larvæ and the other would always contain them. The explanation of this probably is that the larvæ

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[1] One of us kept *Culex* larvæ alive for two months in a bottle in the cold weather in India.

[2] One of us reared adults from full-grown larvæ kept on damp blotting paper (in India), but found that the young larvæ died when kept under these conditions.

perish in the unsuitable pools, or that the adults generally return to the same pools in order to lay their eggs. It seems likely that the adults generally lay their eggs in the pools in which they themselves were bred, and that the insects thus learn by experience the places most suitable for them.

(7) *Detection.*—It is easy to overlook *Anopheles* larvæ unless they are searched for in a bright light.

(8) *Pupæ.*—The pupæ of *Anopheles* seem to be smaller than those of the commoner species of *Culex.* They require about forty-eight hours to reach maturity *in vitro;* perhaps less in natural conditions.

16. BIONOMICS OF ADULT ANOPHELES.

(1) *Hatching.*—The adults generally hatch out in the evening; but their exit seems often to depend on the meteorological conditions of the moment, and appears to be delayed by rainy and windy weather.

(2) *Food.*—They can easily be kept alive in glass cages, test tubes, bottles, etc. We kept some in this manner for a fortnight, and could doubtless have kept them longer if we had wished to do so. We are able to confirm Bancroft's statement (18) that gnats feed on bananas; but they seem to prefer the fresh fruit. During the day the insects remained at rest on the walls of the cage, but in the evening began to fly about and to walk over the fruit, plunging their proboscis into it in many places, so that the banana was sometimes covered with gnats, both male and female. They also drink water frequently, and each can often be seen to be distended with the fluid. Raw meat was offered to them, but they could not be observed to touch it. Earth placed at the bottom of the cage seems to be suitable for them.

According to the accounts of the soldiers at Wilberforce, they bite almost entirely in the evening and night, but have been known to feed on men during the day. They can certainly be fed on men artificially during the daytime, simply by placing them in test tubes and then applying the mouth of the tube to the skin. The stomach can be observed to become distended in from one to two minutes or more; after which the insect continues to suck, but commences to evacuate by the anus serum containing a small percentage of red corpuscles. *Culex* voids only a clear fluid under the same circumstances. The insects sometimes continue sucking like leeches for five or ten minutes, voiding blood all the while; but at other times soon withdraw the proboscis and then try another spot. It was noted, however, that *Anopheles* fed in this manner, even after they had remained sucking for five or ten minutes, never showed any great distension of the abdomen; while the contents of the stomach still remained for some time transparent and red as seen through the scales of the living insect. Moreover, in these cases the meal was generally digested or voided within about twenty-four hours.

On the other hand, *Anopheles* which had fed themselves under natural conditions generally presented a very different appearance. They were enormously distended; while the contents of the stomach were thick, opaque, and black, and sometimes did not disappear for three days. The only inference is that, under natural conditions, the insects which can manage to do so gorge themselves over and over again during the night—probably from the same subject.

(3) *Propagation.*—We also observed that while naturally fed gnats invariably laid eggs after two or three days, those which had been bred from the larvæ in captivity, and had then been isolated and fed in test tubes, never did so, although before being isolated they had long been in company with males. The inference is that fertilization takes place only after the female has been fed.

We noted also that in a cage where many male and female gnats, *Culex* and *Anopheles*, were kept together for weeks eggs were never laid, although the insects were fed as described on bananas, and the cage contained water for them to lay their eggs in. It seems, then, that a meal of blood is necessary before fertilization.

Lastly, we observed that previously fed and fertilized insects would lay a second batch of eggs after a second meal of blood without a second fertilization, but never laid a second batch of eggs without a second meal of blood. That is, one fertilization suffices for several batches of eggs, but one meal of blood for only one batch of eggs.

These observations are wholly in accord with the results of the prolonged study of many kinds of gnats made in India by one of us; and it therefore seems likely that the following law is likely to hold good for the *Culicidæ* which feed on men, at least for the commoner species.

Although these gnats can live indefinitely on fruit and perhaps juices of plants, the female requires a meal of blood, both for fertilization and for the development of her ova. In other words, the insects need blood for the propagation of their species.

Blood was never found in male *Culicidæ* in Freetown, according with the general law.

(4) *Haunts.*—The large majority of *Anopheles* caught by us in dwellings were females which were generally much gorged, and, if fed at all, were invariably fertilized; in other words, the males and unfed, or only slightly fed, females do not generally remain in the houses during the daytime, or if they did remain, kept in the roofs or other dark places where they were little observed. On the whole, we think that only those females which are so gorged that they can not fly far remain in the houses during the day. We observed that if a cage full of *Anopheles* was disturbed in the daytime, the insects always struggled toward the light as if to fly out from the windows, and several which escaped from the cages actually did so. On one occasion a large number escaped from their cage during the night in the rooms occupied by one of us; none of them could be seen next morning.

Yet we may be quite sure that both the males and the unfed females haunt the houses during the night. The invariably fertilized conditions of the gorged females caught in the houses show that the males must be present in the houses when the females feed, since the latter are often so much distended after feeding that they are obviously unwilling to fly even a few feet from the bed of their victim; in other words, fertilization must take place within the houses. The unfed females must, of course, resort to human habitations during the night in order to obtain their food at all.

These facts would seem to indicate that in Freetown in the rainy season the *Anopheles* resort to the houses during the night, but that all except the gorged females live elsewhere during the daytime—possibly sleep in the trees and shrubs. The point is of interest as tending to show that large numbers of *Anopheles* may be present in a dwelling during the night, without it being easy to find them during the day.

It should, however, be added that in India males and unfed females were often found in the houses in large numbers by one of us. Possibly different species have different habits in this respect.

Several old residents of the country informed us that gnats are usually very prevalent in the presence of much vegetation—especially long grass and undergrowth. Though it is difficult to see how such can favor the larvæ, we can understand that much vegetation can shelter the adults of certain species, which may even feed on particular kinds of plants when they can not obtain blood, and may consequently find it easier to live where these plants afford them both food and shelter than elsewhere. It must also be remembered that gnats can certainly bite birds and other mammalia besides man; and that such are apt to congregate where there is much vegetation. On the whole, then, there is nothing improbable in the idea that the Freetown *Anopheles* should live outside the houses in the daytime.

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