# Morphology and Biology of Simulium Vittatum and Its Distribution in Kansas

by Walter Titus Emery

*1913*

Submitted to the Department of Entomology of the University of Kansas in partial fulfillment of the requirements for the Degree of Master of Arts

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A THESIS

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WALTER TITUS EMERY, A.B. 1911, UNIVERSITY OF KANSAS.
Morphology and Biology

DECEMBER - 1913.

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# P R E F A C E

The following paper was written from the data and material collected as a result of a request from Governor Stubbs of Kansas, 1911, through the State Board of Health and Dr. S.J.Crumbine, Dean of the school of Medicine, and Prof. S.J.Hunter, Professor of Entomology at Kansas University to locate Sand-flies (Simulium) in their geographical location to pellagra cases in the State.

Here I wish to thank Prof. S.J.Hunter for his kind assistance in conducting the investigations, and for his many helpful suggestions in working out the problems, both in the field and in the laboratory. We are indebted to Dr. O.A.Johannsen for determining the species, Simulium vittatum. Mr. H.B.Hungerford was kind in helping me secure literature on Simulium. I also appreciate the assistance of Messrs. F.X.Williams, A.E.Mallory, E.C.O'Roke, and H.R. Jennings of the Kansas Biological Survey of 1911 for collecting specimens of Simulium and observing their habits and breeding places. I thank Dr. Grace M. Charles of Kansas University Botany department for determining the algae in the alimentary canal of Simulium larvae. Mr. L.M.Peace made the photographs of the Simulium figures used in the text.

# MORPHOLOGY AND BIOLOGY

# OF SIMULIUM VITTATUM AND ITS DISTRIBUTION IN KANSAS.

On casual observation Simulium flies are about the size of the common vinegar gnats (Drosophilidae) that we often see on a piece of apple peeling or on decaying fruit. However, upon closer examination they are found to be distinctly different both in form and color. These little gnats are gray to black in color and are from two to four millimeters in length, depending on the species and sex. They have a conspicuously prominent thorax, hump-backed in appearance, and their heads are drawn down in front of them. This latter characteristic adds to the prominence of their thorax, so much so, that they have received the popular name of Buffalo gnats. In the south they are called Turkey gnats, in the north, Black flies, and in Europe, Sand flies.

Perhaps the most conspicuous characteristics of Simulium flies are their comparatively heavy cone-shaped antennae that protrude from between the eyes at the base, diverging like a pair of horns. They are about the length of the head, ten jointed with the joints closely articulated except the two basal ones which are differentiated. Other noticeable characteristics are their relatively broad and slightly veined wings, their prominent

thorax, and the structure of their mouth parts.

The latter to be seen well must be dissected and placed under a compound microscope. These I shall describe further on in the paper. At the time of emergence their eyes have a reddish tinge. They have no ocelli. Compared with other flies of their size the legs are thick and heavy set.

Life History-- Habitat.

Nearly everyone has observed mosquito wigglers in rain barrels and pools of standing water, but unlike this habit of mosquitoes, Simulium flies breed only in running water, such as ripples and water falls. It seems that its aquatic larval nature demands well aerated water if it is going to live and complete its life cycle. For instance, if a Simulium larva is placed in a vessel of standing water, it soon dies, apparently for the want of sufficient oxygen. When S. vittatum is washed from the rocks in shallow ripples into deep water it will drown, unless it floats with the current to another ripple or water fall where it can attach to a stone or vegetation.

As a rule in regions where S. vittatum occurs the larvae are found in the ripples and falls of creeks and small streams, not rivers, that flow the year round. The most essential condition for the well being of these aquatic creatures is rapid motion of the water in which

they live.. Not only did the writer find this to be the condition but in the Kansas Biological Survey notes for 1912, Mr. E.C.O'roke writes at Hays City,-- "While scouting about for a camping place we observed larvae and pupae of Sand flies on a concrete dam and on the rocks below it in Big Creek." In another part of the notes Mr. A.E.Mallory at Rush Center, says,- "We found many Simulium larvae andpupae in the ripples." In the same field notes Mr. F.X.Williams at Ness City, writes,- "In a small branch of Walnut Creek where the ripples are weak and the bottom is pebbly, but with no stones, I found Simulium larvae, pupae, and eggs plentiful on the sedges lying flat in the ripple." This last note shows that while there were no stones to break the flow of the water, yet the sedges, on which the Simulium lived, were washed by the current.

As to the character of the water in their breeding places it is generally clear and well aerated, though sometimes it contains considerable organic matter. Two of the breeding places observed in Kansas where the flies were very numerous were streams that carried sewage. One was at Rosedale, Kansas, a suburb of Kansas City, and the other was at Oswego, Kansas. Dr. Forbes of Illinois University states in his report on Simulium of that state, that, the larvae were found in the sewage drains far up

into the city of Chicago.

Since their habitat is in ripples or in places where the water is accelerated by an obstruction it is interesting to observe what takes place in standing water. Our observations in the laboratory showed that they died in about an hour, at least they would not respond to stimulation after that time in a vessel of water. Consequently in a stream when the larvae are swept into quietly running water they drown unless they can maintain themselves in the current long enough to float to another ripple. In a little stream near Oswego in which there were two ripples about fifty yards apart, the second ripple or the one below was narrowed so I could observe approximately the number of larvae on the stones. After disturbing about fifty or more larvae in the up-stream ripple causing them to let go their holds on the rocks and drift into the quiet slow running water I was unable to detect any increase in the number of larvae in the small narrow ripple below. However, after a rain which caused a swifter current between the ripples I could sometimes find more larvae than usual in the lower ripple. Ordinarily the current was sluggish between the ripples.

From our observations there are three principal broods of S. vittatum each year. One occurs in early spring, the fore part of April, one in mid-summer, from the middle to the latter part of July, and one in mid-

autumn, the latter part of October, the time for these broods varying with the earliness or lateness of the seasons. The general time for the spring and fall broods seems to be at the heavy frost-line period. This period varies with different species and in different states.

Mr. Otto Lugger as State Entomologist of Minnesota, in his report of 1896, pages 201 and 203, says in part on Simulium flies,- "The first species seen and felt occurs early in the spring soon after the snow disappears. This species (name not given) flies from May 15 to June 1. A little later in the season, but chiefly during June and July, a somewhat larger species, S. decorum Walker (synonymous with vittatum Zetterstedt according to Coquillett) becomes numerous." Mr. C.V.Riley in the report of the United States Entomologist for 1886, pages 342 and 343, refers to Mrs. Sara J. McBride of Mumford, New York, as stating in one of her articles that,- "The perfect flies issued about April first." In the American Journal of Science, Vol. I, 1818, under the heading, "A Destructive Insect," mention is made that "Contrary to the custom of other insects, it (S. pecuarum) always appears when cold weather commences in December, and as invariably disappears on the approach of warm weather, which is about April first, (Choctaw county, Mississippi) and continued to return at the same season from year to year."

In the report of the Commissioners of Agriculture for 1886, Entomologist C.V.Riley says in speaking of the Southern Buffalo gnat (S. pecuarum) as to its time of appearance,- "The first swarms were observed last year in Louisiana on March 11, in Mississippi and Tennessee May 1, and in Indiana and Illinois May 12. Small local swarms may appear somewhat earlier or later in the neighborhood of their breeding places. The Turkey gnat (S. meriodionale Riley) appears usually later, although in 1886 it appeared near Memphis, Tennessee, as early ~~in~~ as April fifth. The swarms were quite local, however, and strictly confined to the vicinity of the creeks that produced them. The greater majority of the species of this genus are northern insects, and appear there in the winged form all through the summer. The larvae require cold water for development. As we go farther south the cold water can only be found in the more elevated regions or in winter or in the earlier months of of spring. Earliness of season or high altitude are the substitutes for the lower temperature of the more northern latitude." All this goes to show that the time of the appearance of Simulium broods varies with different species and in different states.

That S. vittatum emerges throughout the summer is shown from my field notes on that species in our experments to determine whether or not it is capable of trans-

mitting the disease pellagra. We collected pupae as theyformed on the rocks and placed them under a trap which was over the ripples so as to secure as many flies as possible (Plate II). The following dates show uneven emergence of the flies and how they increase in numbers as cooler weather approaches, until the creek freezes:-

Oswego, Kansas, 1911.

| Date | No. flies | Temp. Mx. | F. Mn. |
|---|---|---|---|
| Sept. 7 | 2 | 84 | 65 |
| 8 | 5 | 83 | 68 |
| 9 | 3 | 83 | 67 |
| 10 | 5 | 89 | 68 |
| 11 | 6 | 91 | 70 |
| 13 | 24 | 94 | 73 |
| 14 | 4 | 92 | 73 |
| 19 | 6 | 73 | 57 |
| 20 | 17 | 71 | 58 |
| 21 | 11 | 74 | 52 |
| 22 | 9 | 82 | 53 |
| 24 | 6 | 89 | 67 |
| 25 | 4 | 90 | 68 |
| 27 | 10 | 90 | 68 |
| 28 | 9 | 91 | 70 |
| 29 | 16 | 81 | 70 |
| 30 | 6 | 83 | 61 |
| Oct. 2 | 70 | 90 | 65 |
| 3 | 70 | 88 | 71 |
| 4 | 100 | 78 | 58 |
| 5 | 150 | 84 | 60 |
| 6 | 120 | 83 | 62 |
| 7 | 54 | 63 | 51 |
| 8 | 150 | 65 | 48 |
| 9 | 105 | 61 | 50 |
| 10 | 60 | 69 | 43 |
| 11 | 40 | 81 | 54 |
| 14 | 108 | 85 | 57 |
| 16 | 40 | 77 | 46 |
| 17 | 56 | 71 | 43 |
| 18 | 22 | 73 | 45 |
| 20 | 4 | 55 | 40 |
| 23 | 25 | 68 | 30 |

| Date | No. Flies | Temp. Mx. | F. Mn. |
|---|---|---|---|
| Oct. 24 | 5 | 69 | 37 |
| 25 | 12 | 67 | 45 |
| 26 | 12 | 73 | 36 |
| 30 | 2 | 53 | 34 |

February 15, 1912, Rosedale, Kansas. Full grown Simulium vittatum larvae covered the under sides of the rocks in the ripples in Turkey Creek where it enters the city. June 7, 1912, Rosedale, Kansas. Simulium larvae were less numerous and smaller than those observed February 15. This is a good evidence that a brood must have come off early in the spring, leaving these stragglers to emerge later. Some of these later larvae I placed in a ripple in the laboratory at Kansas University getting them to pupate and emerge later. From a few pupae that I brought to the laboratory at that time eight flies emerged on June 8. From the larvae that pupated in the laboratory twenty-four flies emerged June 19.

Of the mid-summer S. vittatum brood that emerged from a small stream on the University campus the following dates and number of fies taken were accounted for:-

| | | |
|---|---|---|
| July | 13 | 40 flies |
| | 16 | 15 " |
| | 21 | 2 |
| | 22 | 1 |
| | 25 | 3 |
| | 27 | 3 |
| | 28 | 5 |
| | 29 | 4 |
| Aug. | 4 | 2 |
| | 5 | 2 |
| | 7 | 2 |

Observations on Simulium could not be carried through the summer at Rosedale nor at Oswego because the streams at those places dried up during the drouth, and as a consequence the Simulium there ceased to propagate themselves.

The following number of Simulium flies were trapped in the Little Arkansas River at Wichita, Kansas:-

| | | |
|---|---|---|
| Nov. | 10 | 12 flies |
| | 11 | 5 " |
| | 12 | 33 " |
| | 13 | 20 " |

Simulium flies may emerge during a warm spell in the winter as our experiments in December, 1912, show. My field notes read as follows:- Dec. 11, Wichita, Kansas. Took 50 to 60 S. pupae from partly frozen river and placed them in a ripple in a laboratory, using city water. Dec. 12. 14 S. flies emerged. Dec. 13. 10 S. flies emerged.

A moderate or cool temperature seems to affect not only the length of an individual S. vittatum fly's life but also its biting habits of blood thirsty nature. "If cold weather follows their appearance, the gnats become semi-dormant; they are not killed by it nor by rain, but revive and become aggressive again with the first rays of the sun. Hot weather, however, soon kills them.*

During the months of September and October, 1911, we used over 1200 flies in our experiments with pellagra. Not until the cooler weather the latter part of October, did we succeed in getting the flies to bite. At this time the temperature was about 20 degrees cooler than when they had refused to bite. According to thelocal U.S. Govt. weather station, the temperature frequently ran above 90° in September with an average maximum of 86.1° and minimum of 65.7°, while in October, at the time of biting, the maximum was 67° and the minimum was 45° F. Again in the middle of November the following year, 1912, I caught S. vittatum at Wichita, carried them over 150 miles to Topeka and succeeded in getting them to bite. One month later I took Simulium pupae from the Little Arkansas River, which was partly frozen over, placed them in a laboratory with water running over them at a temperature of 60° F. and secured 24 flies. They were then taken about 200 miles to Parsons, Ks., where we succeeded in getting 4 of them to

*Dept. Agri. 1886

bite a supposed case of pellagra. (Only 16 flies, ½ of which were males, made the trip.)

Before this time I had supposed that perhaps the flies had to oviposit before they would bite, but from the above experiments it appears to be a matter of stirring them to that activity by the proper temperature during their life cycle. At no time have I been able to find eggs deposited on the rocks underneath the traps where the flies emerged that did the biting. Literature on the subject of their habits of biting refers to them as being the worst to bite in early spring and late fall, in the early morning and on cold rainy days. The argument in the U.S. Dept. Agri. Yr. Bk., 1886, quoted in Bul. 5, 1896, is that Simulium flies oviposit before going out in swarms seeking warm blooded animals, else the species would not propagate themselves. We have found out that S. vittatum does not necessarily oviposit before biting.

Our experiments brought out the fact that Simulium will bite in captivity, and in houses, also that they can be shipped long distances and kept alive for two and three days without feeding. As for keeping Simulium alive in captivity the males died soonest, living one to two days, while the females would live two to four days. When filled with blood, (human) we kept one female alive ~~six~~ seven and one-half days, from ~~Saturday~~ Friday P.M. of one week until Friday A.M. of the following week, at which time the fly was destroyed in our experiments. Just how long

they can be kept alive by refeeding, I do not know. They are said to feed on maggots and caterpillars. (British Diptera, p. 165)

It is interesting to watch the flies oviposit on the stones in ripples. The female selects a stone in the ripple where a film of water seeps upoon the lower down stream side in very small vibratory waves. In these tiny waves she places the tip of her abdomen and wings and deposits from 200 to 300 eggs strung back and forth as she moves along, in rows close together so as to form a mass, usually from 1/4 to 3/8 of an inch long and from 1/16 to 1/8 of an inch wide. Here the waves constantly wash the tip of the abdomen and afterwards keep the egg mass moist. From five to ten minutes is spent in the process. In midstream where the current made the small waves best, several egg masses were piled upon one another and alongside adjoining, sometimes covering the whole down stream side of the rocks. Frequently a fly would cease ovipositing and go away to finish on another rock or perhaps to return to finish on the same rock.

Some of the eggs were laid on old leaves in the ripple. N.Y. St. Mus. Bul. 47, p. 408, gives the following on oviposition;- "The place selected is always at the edge of a little waterfall, on a surface that is intermittently washed by the swaying current, and so kept wet.

Here the females flock and pile up great white masses of eggs which with a little age turn yellowish. Waves dash over them while ovipositing, and often sweep them away, but they at once return to their task."

The description of an egg mass is given in my field notes for October, 1911, as follows;- Simulium eggs when first deposited are whitish or creamy in color. In two or three days they begin to turn yellowish, becoming later a rusty yellow, then brownish to a dark brown, almost black at time for hatching. All this time they retain a shiny appearance. The empty shells after the larvae have hatched look dull, tattered, torn, and sunken in, soon breaking to pieces in the rippling water. When first hatched a larva is so small and light in color that one can hardly see it on a rock with the unaided eye. On account of the reflections of a wet rock it is even difficult to see with a 12x lens if the larva is not moving.

A variation in the length of the incubation period is shown in my field notes. October 26, 1911,- Discovered very small larvae, 1mm. long on rock with egg mass that I found October 19. Yesterday the eggs were full; to-day many of them were sunken in. October 28, Found more small larvae on rock with eggs discovered October 19. October 30, Part of the eggs laid on the rock that I placed in the ripple for that purpose October 23 are rusty yellow and very

shiny. November 2, Creek partly frozen over. Eggs of October 23 apparently still unhatched but covered with a dirty slime like empty shells. Part of them were hatched though I could find no young larvae with them.

The dates from October 19 to 26 show a period of eight days, while that from October 23 to November 2 shows a period of eleven days for incubation. That variation is due, no doubt, to the decrease in seasonal temperature to freezing.

Now the length of the larval stage may also vary. Taking the periods between the broods previously mentioned, that is, from the fore part of April to the middle of July, and from mid-July to the latter part of October we find the length of life cycle during the warmer months to be approximately three months and one week. Allowing five to six days for the length of the pupal stage, as we observed it in September, 1911, and eight days for the incubation of the eggs we get the length of the larval stage in the warmer months to be about two months and three weeks. For the life cycle of the spring brood, that leaves a period from the latter part of October to the first part of April, or about five and one-half months. Since it is in the larval stage that they winter over it would indicate that the winter temperature prolongs the length of the larval stage for the spring brood.

Newly hatched larvae are a pale creamy color, and

about one millimeter in length. They possess indications of the same general characteristics of form and structure that the full grown larvae have. The color soon darkens to a slaty green.

A full grown S. vittatum larva measures from 5/16 to 3/8 of an inch in length. The body is somewhat attenuated in the second abdominal segment and gradually increases in size in the third, fourth, fifth, and sixth segments until the seventh segment where there is a much increased or abrupt expansion so as to give it a widened and flattened appearance. (Plate. V .Figs 10, 11.) Segments seven, eight, nine, and ten are the largest of the much expanded part, while segments eleven and twelve taper to the caudal aperature.

The meta- and meso-thoracic segments and the first six abdominal segments are cylindrical. The prothoracic is thickened dorso-ventrally by the attanhment of the single prothoracic leg. (Pl V -Fig. 11.P) The head is semi-flattened with a slightly constricted neck and is about the length of the thorax.

On the head are some very unusual prehensile organs, used to collect food from the rippling water. They are fan like in shape with forty filaments or rays in S. vittatum (Pl XV Fig 31 -). When disturbed or when thelarva is taking food from the rays with its mandibles and maxillae into the mouth the fan is closed so that the tips of the rays come just to the oral opening. These rays are scythe shaped, ciliate on the inner side, with longer setae at regular in-

tervals. [redacted] The rest of the mouth parts, labrum, mandibles, maxillae, hypopharynx, and labium together with the antennae are shown individually and compositally arranged on plates XV-XVI Figs. 31-35. Between the fans are the slender, five-jointed antennae; the fifth joint is a pointed process at the end of the fourth. Back of the fans on each side of the head are two narrowly separated black spots. These may be eyes, or light organs. Besides the leg or foot on the sides of the thorax there appears on the full grown larva black spots which are the pupal gills, folded and drawn up beneath the skin.

At the caudal end is a sucker like aperture used to hold the larvae to the stones and debris in the ripples. It is made up of a series of rows of tiny hooks. On the dorsal side the sucker-like organ is produced into a V-shaped (Pl. XVI Fig. 35A) Cephalod of this are the breathing gills. In vittatum these are three branched as membranous sacks, finger like, when the larva is undisturbed in the water.

In preserved specimens the gills cannot be seen unless forced to distend by pressure from a dissecting needle placed cephalod of them.

The larvae, intermediate in size, appear to seek the swifter ripples while those about ready to pupate and the smaller ones seek the less violently agitated parts of the ripples. When moving about on the stones they have

a looping motion similar to that of a geometrid larva. They more frequently make their looping motion laterally instead of dorsally. In doing this they first attach their thoracic leg then draw their caudal sucker forward and attach it. Frequently one can see the silken thread they spin as they move about. It looks as though they always kept the thread attached because at any time they are washed from the stones or debris they will float away from one to ten inches holding fast to the thread which they spin as they go.

The larvae possesses two silk glands, laterally placed, extending about three-fourths the length of the body, then recurved, U shaped, extending back to the thoracic segments. The outlets are the two ducts which lead into the hypopharynx*. Besides being used as a means of security the thread is used to float out in the ripple while feeding, and for building the pupae case. Ordinarily while feeding, the larvae attach their caudal sucker to the object in the ripple and let the rest of their body and head float at an angle of sixty to ninety degrees. I have watched them in the water draw their fans in and scrape them with their mandibles as though collecting food.

With the kind assistance of Dr. Grace M. Charles of Kansas University, we found several species of diatoms

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* N.Y. St. Mus. Bul. 68.

and the following kinds of algae in the digestive tract which I take to be the food of S. vittatum,-- Conferva, Scenedesmus, Chlamydomonas, Euglena, and Charcium. Besides these I found several kinds of bacteria in a smear made from the alimentary tract of a simulium larva.

(N..Y. St. Mus. Bul. 68) "According to the unpublished observations of Miss R. Phillips (of the class of 1890, Cornell University) the larva feeds on algae, as Nothix, Chaetophora, Vaucheria, on diatoms, and parts of phanerogamous plants. Sand also has been found in the digestive canal." (U.S.Dept. Agri. Yr. Bk.,1886, quoted in Bul. 5N.S.)-- "A searching investigation of the water in their breeding places revealed the fact that it was swarming with animal life and was filled with the larval forms of small crustaceans belonging to various families, but chiefly to those of Copepods and Isopods. Larvae of the Southern buffalo gnat (pecuarum) kept in glasses were observed to swallow these minute crustaceans, and none of this food was seen to be expelled again. A number of square diatoms, jointed together in a chain, have also been observed by the aid of the microscope." The above would indicate that Simulium larvae are both herbivorous and carnivorous.

A very interesting part of Simulium larvae and pupae's habits was learned when we discovered their ability to keep alive in a wet pack of cloth or snow for several

hours. Our first experiment with that was on February 15, 1912, when I packed some Simulium larvae, on the rocks, in wet snow wrapped in cheese-cloth. The time of packing was 5:00 P.M., theplace Rosedale, Kansas. From there I transported the mass in an old suit case to Lawrence and placed them in a ripple in the laboratory at 8:00 P.M. The snow pack was frozen when I unpacked the larvae, but they were active and continued to live afterward in the laboratory.

The next time we tried that experiment was June 7, 1912, when I packed the larvae and pupae on rocks in wet cheese cloth at Rosedale at 5:00 P.M., brought them to Lawrence and placed them in the laboratory ripple alive at 11:00 P.M. Some of the larvae left in the wet cloth were still alive at 10:00 A.M. the next day, June 8. This made a total of seventeen hours that the larvae kept alive in the wet pack. The pupae continued to live so that imagoes emerged June 14.

The larvae soon transformed to pupae and 24 flies emerged June 19.

Again on August 3, 1912, I brought to Lawrence from Rosedale several pupae torn from the rocks and several larvae off the rocks in a wet pack in a tin box. Those larvae lived through that ordeal all right and two flies emerged from the pupae August 4. However, at this time the Lawrence city water was so impure that they were

using strong chemicals to purify it. This seemed to kill the larvae so that they were all gone from the ripple Aug. 5. No more flies emerged from the pupae. Larvae newly hatched from the eggs in the laboratory ripple soon died. On July 2, I placed Simulium eggs in the laboratory ripple and on the 5th and 7th, I found newly hatched larvae, but the city water seemed to kill them after hatching; at least they disappeared.

Our experiments had been so badly interfered with in the laboratory by drugged water, and the several streams in the state where we ~~are~~ were conducting experiments went dry during the drouth of the summer, so that our experiments looked dubious. Fortunately I located a good brood of larvae in the Little Arkansas River at Wichita. Knowing that Simulium breed in sewer ditches and desiring to establish a permanent brood near our laboratory I decided to take a number of the larvae from the stream at Wichita and place them in the sewer exit, in good ripples and a fall, at Lawrence where it empties into the Kaw River. On October 8, I collected several hundred nearly grown larvae, from 4:00 to 5:30 P.M., transported them in a wet pack off the rocks to Lawrence where I placed them alive in the sewer at 7:15 A.M. October 9. October 10, a lot of the larvae had disappeared. October 11, most of the larvae had disappeared. A piece of cloth that I had left in the sewer with larvae on it smelled strongly of

kerosene and had a white sediment on it. The rest of the larva soon disappeared. Since that time I have succeeded in keeping a simulium larvae alive in a tin box with a wet cloth for more than 72 hours.

Simulium pupae , when first formed are a yellowish brown color, later becoming darker as the dirt in the water discolors them and as the imago develops within the case. With the filamentary breathing gills a pupa measures about 1/8 of an inch long. (Pl. IV Figs. 7 8 9) Their gills or respiratory filaments arise from a common base on each side. In S. vittatum the base of one gill divides into two, and from each of these arise four branches, these again each dividing into two, making sixteen tracheal filaments for each gill.

According to observations made by Miss Phillips and recorded in her thesis, 1890, the spinning of the cocoon of S. pictipes is described as follows:- "In spinning, the thread issues from the mouth and is placed in the different positions by the thoracic/pro leg. The head is bent down, and with the proleg the thread is drawn around the body, except the head. The skin of the head is then cast off, and the insect then pulls itself out of the skin of the body leaving it whole. The cast skin may often be found in the cocoon, with the pupae. The cocoons are commenced at the upper margin and spun continuously down to the caudal end, where several threads are drawn from the cocoon and attached to the last one or two of the

body segments of the pupae. The threads hold the pupa very firmly and are always found when the pupa is pulled out of its case."*

I found it very difficult to watch vittatum spin their cocoons because the adult larvae almost invariably go to the under side of the rocks and debris, or seek a protected place in the ripples for pupating. Vittatum pupae are, when first formed, drawn back into their cases so that only the pupal gills show from a dorsal view. Inside of a day or two they begin to push out a little showing the head bent down and the origin of the gills. On the fifth day after pupating I observed some pupae that had swung free from their cases and faced in the opposite direction along side of them.

They were still attached by two threads that ran into the pupae cases. A description of the same habit of slipping from their cases is given in the U.S. Agri. Yr. Bk. 1886, p. 508. In the laboratory in a vessel of water we noticed a pupa turn over in its case, lying first on one side, then turning over, ventral side downward, to the other side. It was seen to do this several times.

When the pupa is drawn from its case, upon close examination one can see two small black blunt hooks on the dorso-caudal end of the pupa, and eight similar hooks on the dorsal front marginal side of the abdominal segments,

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* N.Y.St.Mus.Bul.68.

four in a row on each side, parallel to the margin of the segments; they are a part of a membranous covering as shown in plate IV fig 9. By means of them it attaches itself to the silky threads of the pupa case.

A general external view of the individual pupa on a rock is shown on plate I, fig 2. One can see the origin of thepupal gills, and thehead tucked beneath, also the prominence of the thorax within the case. ~~Plate -- shows a pupa with the imago within more developed and its habit of withdrawing from the case as it matures.~~ Plate IV, fig 8, shows a newly formed pupae removed from its case. This shows the wing pads in their early development. Plate IV, figs. 7 & 9, show lateral and dorsal views with the wing pads more developed.

Emergence of the adult:-

It is very interesting to watch the fly emerge from its pupal skin. The skin is split longitudinally on the fore part of the hump of the pupa. First the fly gets its head and fore legs out, then by pulling itself forward it gets the middle legs and part of the wings out, continues to crawl forward, freeing its wings, hind legs, and abdomen. The whole process took about five seconds on a stone that I held in my hand out of the water. It left the old pupal skin fast in the case with the respiratory filaments intact.

Empty skins soon wash out of their cases which are left as little tough empty pockets to fill with dirt and eventually be washed away.

Mr. E. C. O'roke in his field notes of the Entomological survey, 1912, notes the following about newly emerged Simulium:- "They would dry their wings about five seconds, then fly." He watched them emerge from a board which he held out of the water. On the same survey Mr. F. X. Williams notes:- "Almost immediately on reaching the surface (of the water) the fly (S. vittatum) would make efforts to rise on its still flexible wings. Sometimes being unable to do so immediately would skim along the water for a ways." His notes continued to say that unless they arose after skimming and floating around a short time they were devoured by some smalll fishes a few feet below the place of emergence. Mr. H. R. Jennings on the same survey notes:- "The adult fly would first show up on the surface of the water, having emerged from a pupa case among the spirogyra and then passed to a place free enough from spirogira to allow it to come to the surface. Once at the surface thefly would float on down the stream until it caught on the spirogira and was there able to wait until its wings were thoroughly ready before attempting flight, or, if carried by the current into a place free of spirogyra or other surface obstructions, the fly would, when permitted to float upon the surface of the water, wait until ~~it~~ ready for flight." This shows that the flies do not take flight immediately upon emerging from thepupae, either when in the open air or when emerging beneath the water,

instead wait a short time for their wings to dry and harden#.

Predaceous Enemies of Simulium.#

Like most insects Simulium flies have their predaceous enemies and may have some parasitic ones, though little is known of the latter. U.S.Dept.Agri.Bul5N.S.,1896, gives an account of some of the natural enemies of Buffalo gnats, as follows:-

"But few birds have been observed to feed upon them, though for the Southern forms, the mocking bird, winter wren, and especially barnyard fowls, after the flies become gorged with blood, feed upon them. Dragon flies (Libellulidae) and robber flies (Asilidae) have been observed to catch them. The larvae are devoured in large numbers by the smaller fishes, minnows, etc., and probably the carnivorous beetles, bugs, and other aquatic insects prey upon them."

Perhaps the best observations of predaceous enemies of Simulium flies and their larvae in our department were made by Messrs. E.C.O'roke and H.R.Jennings on their Entomological survey of 1912. Mr. O'roke in writing about Simulium larvae says in part:- "I observed some small Carabid beetles, the kind you see along mud on stream banks all over this section of the country, (Ellis County), feeding on the Sand fly larvae. Two would take hold of a small larvae and pull it much like two chickens pull an earthworm. This was after I had removed the

larvae from the water on a stone."

Mr. Jennings in writing of the chances a Sand fly has of getting away from the water upon emerging from their pupae where fish exist, says in part:- "Any fly unfortunate to remain on the surface until the water was deep enough for fish and also free from algae was very certain of having an immediate and fishy grave. Repeatedly I saw flies disappear from the surface in this manner, and to make sure that it was not by flight, I crippled some of them and took care that they floated with reach of the fish when their disappearance was both immediate and certain. In fact very few flies which got into the current were allowed to leave the surface of the water in flight, and these few probably owed their existence to the fact that a strong wind was blowing directly up stream and hence against the current. This would frequently delay the down stream journey of the fly, and occasionally long enough for safety."

Mr. Williams said he saw a Hydrobatid suck the life blood out of a fly. Here we have fish and beetles preying upon the adults and larvae.

## METHODS OF CATCHING AND HANDLING SIMULIUM FLIES.

Trapping Simulium flies is an interesting proposition from the nature of their habits and habitat. Ordinarily we can catch a great many kinds of insects with a net. In the case of Simulium flies, unless they are in swarms or are very numerous over the water, it is difficult to get many of them that way.

In order to carry on our experiments it was necessary to have them alive and in large numbers. Swarms of them were not to be found, and only a very few individuals were hovering over the ripples at any time. We at once decided to trap them in the ripples as the emerged from their pupae, and thereby secure flies free from any contagion that might interfere with our experiments.

On account of the habits of the pupae requiring simply moisture to keep their gills wet I had good success getting the flies to emerge by placing stones with pupae on them in straight running water and then setting a trap over them. The trap consisted of a small wooden box about one foot deep, one andone-half feet wide, and two feet long without a top. This was turned bottom side up and a hole eight inches in diameter cut in it. In this hole I tacked a cone made out of window screening covered with cheesecloth. Then by cutting notches in the ends of the box to let the water run through without leaving a hole for the flies to crawl out, the trap was com-

plete. The box being dark inside, the flies upon emerging came up into the light in the cone and rested on the inside of it. Plate II Figs 3&4. shows the structure of such a trap.

At first I tried the screening alone without covering it with cloth, but the flies crawled through the meshes and escaped. Another thing I tried was a small screen cone inside a larger cone like one sees in traps used nowadays to catch house flies, but this inner cone was useless because the simulium flies dropped back through the opening in the top of it when I tried to take them from the outer cone.

Now Simulium flies are stubborn creatures to handle, for the reason that frequently they seem unaffected by light stimuli, at least will remain in a darkened chamber instead of coming into the lighter one. It frequently took an hour to get a few flies to go from a cone in a trap, darkened by covering it with a double thickness of black cloth, into a lighter chamber. The flies were more active and much more easily handled in the early morning while it was cool than later in the day after the temperature had risen. The heat of the day seemed to make them sluggish and inactive, so much so, that it was extremely difficult to induce them to go from one cage to another at midday. Again in the evening when the heat of the day had subsided, they became more active. Literature

refers to them as being a cool weather fly, as most offensive with their biting in the early morning and on cool days. Other places they are spoken of as not biting in warm weather during the summer.

When Simulium flies move they generally go very quickly and fly with a great deal of force. At first we removed them from a trap into a glass bottle, but they flew against the transparent sides of the bottle with such force that it seemed to stun them. Their antennae are comparatively large and protrude forward, so that, in flying against the glass, their antennae, which are probably their sense organs of touch and perhaps of sound and smell, received a shock that seemed to make the flies more stupid. We then tried taking them into a gauntlet shaped wire cage covered with cheese cloth. In this they had more room and softer walls to butt their antennae against. Here they were more quiet and more easily handled.

Plate II-Fig. 3 shows the method of taking them out of a trap into a bottle, except that we placed a black cloth around the cone to darken it at that time. We substituted the gauntlet cage for the bottle. In this manner, when thepupae were numerous, we were enabled to secure plenty of flies for our experiments.

## ECONOMIC IMPORTANCE OF SIMULIUM

Considerable literature has been written on the depradations of "Black-flies," "Buffalo-gnats," "Turkey-gnats," and "Sand Flies"(Simulium) since the latter part of the eighteenth century in Europe, and since the pioneer days of settlement in the Mississippi river valley of America. Theobold (British Flies, Vol. I, p. 165) says.- "In England, we do not suffer much from these flies but in other parts of Eurppe they are very obnoxious; Schonbauer * gives an account of one, S. columbaschensis, which is one of the greatest scourges to man and beast in the Bannat of Temeswar, in Hungary. Fries ** also described the molestations of these "sand flies" in Lapland."

In America accounts have been written from time to time on the ravages of the different species of Simulium. The Black Fly of the North (S. molestum Harris) has been described by Dr. A. S. Packard (Amer. Nat. Vol. II,pp.589-590) as even more formidable a pest than the mosquito, that in the northern subartic regions it opposes a barrier against travel. "The Labrador fisherman spends his sum-

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* Gesch. der Shadl. Kolumbatezermucken, Wien, 1895; and Kollar's"Treatise on Injurious Insects," p. 68.

**Observ. Entom.(Simulium), Stockh., 1824, Fries.

mer on the seashore, scarcely daring to penetrate the interior on account of the swarms of these flies." *

The Southern Buffalo gnat (S. pecuarum Riley) and the Turkey gnat (S. meridionale Riley) in the lower Mississippi valley and tributary regions, and the Western Buffalo Gnat (S. occidentale Townsend) along the valley of the Rio Grande have been the cause of a great deal of suffering to humans by their bites, and the loss of hundreds of head of livestock, including poultry. Accounts of these conditions are given by Dr. C. V. Riley in the Year Book for 1886, U.S.Dept.Agri.,Div.Ent.,pp.492-517, and in Bul.No.5, 1896,pp.31-58, and in later publications by O.A.Johannsen, 1903, N.Y.St.Mus.Bul.68, Ent.18, Aquatic Insects in N.Y.State, and by Dr. S.A.Forbes, State Entomologist of Illinois, 1912, "On Black - Flies and Buffalo Gnats (Simulium) as possible carriers of Pellagra in Illinois."

Simulium flies, S. reptans in particular, has been accused of transmitting the human disease, pellagra, by Dr. L. W. Sambon. Dr. Sambon ~~ix~~ formulated the tsetse fly theory of sleeping-sickness, which has proved true. In 1910, he was detailed for three months in Italy,

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* Insects Affecting Domestic Animals, U.S.Dept.Agri. Div., of Ent. Bul. No. 5-N.S., p.40.

where he studied pellagra. He says, in a brief report on the investigations of pellagra,- "The many analogies existing between the epidemiology of pellagra and that of the best known insect-borne diseases, the constant association of the disease with Simulium-infested streams; the absence of any other arthropod with similar distribution that might account for it; the striking correlation between the fly and the disease in wide geographical distribution, peculiar typographical exigencies, are all facts which strongly point to Simulium as the necessary carriers of pellagra."*

Further elucidation of this theory is reviewed by Professor S.J.Hunter, in a paper, The Sand-Fly and Pellagra, presented before the Entomological Branch of the American Association for Advancement of Science, Washington, D.C., Dec. 27, 1911, and published in The Journal of the American Medical Association, Feb.24, 1912, Vol.8, pp.547-548. A part of this review is as follows:-

"A. The same endemic centers of pellagra in Italy have remained the same since the disease was first de-

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*L.W.Sambon, (Journ. Trop. Med. and Hyg., London,13, 1910, Nos. 18,pp. 271-282; 19, pp. 287-300; 20,pp.305-315; 21, pp. 319-321). Progress report of the investigation of pellagra, as given in U.S.Dept. Agri. Experiment Station Record, Vol. 26. Abstract No. 8.

scribed.

B. The season of the recurrence of pellagra coincides with the season of the appearance of the full-fledged sand-fly, even to the extent that if the spring is early or late, the sand fly is early or late in appearing, and pellagra cases are correspondingly early or late in their appearance.

C. In centers of pellagra infection whole families are attacked at times simultaneously.

D. In non-pellagrous districts the disease never spreads to others with the advent of a pellagrin from a pellagrous district.

E. In the case of a family which has removed from a pellagrous to a non-pellagrous district, the children born in the former district are pellagrins, while the children born subsequent to removal to a non-pellagrous district do not develop the disease.

F. The disease is not hereditary, although infants a few months old may become infected, especially if taken to the fields in pellagrous districts, where their mothers work during the season when sand flies are in evidence.

G. Pellagra is not contagious, but is transmitted to each individual by an infected sand-fly."

Dr. Sambon found three species of Simulium in Italy, S. reptans, S. ornatum, and S. pubescens, chiefly the last. In the United States S. reptans has not been

discovered, but the Kansas State Board of Health, through the State University and its department of Entomology, has carried on investigations as to the presence of Simulium flies in localities where pellagrins live, and with the most common species, S. vittatum, has made experiments to transmit pellagra to a monkey, by first letting the flies bite a pellagrin and then bite a monkey. The full significance of the relation of Simulium to the transmission of pellagra has not yet been determined.

# MOUTH PARTS OF SIMULIUM VITTATUM

The question of detemmining the mouth parts of S. vittatum I have attempted to answer, both by their location or place of attachment and by their function as given for the mouth parts of insects in general and especially those of diptera by Dimmock, Kraepelin, Packard, Meinert, and J.H.Smith.

## Mandibles

Packard says, "Mandibles are wanting in the imago male Diptera and the females of all flies except Culicidae and Tabanidae."*

In "The Skeleton of the Head of Insects," by Comstock and Chujiro Kochi, it says, "To this part," the clypeus, "one condyle (the ventral) of the mandible articulates." Now there is such an attachment as this in Simulium mouth parts as is shown in plate XII, fig.21, plate XIII, fig.28, female, and plate XIV, Fig.29 for the male. This forms an exception to Packard's statement quoted above. In Simulium the mandible has a basal piece similar to the stipes of the maxilla, plate XI, Fig.22C. The serrate edge of the mandible has about 32 saw-like teeth on its end and sides.

## Labrum and Hypopharynx.

The next part in question is the presence of a labrum. Kraepelin says, "The labrum (oberlippe) appears as the direct continuation forwards of the upper anterior margin of the basi-proboscis. It has a groove

*Packard,A.S.,A Text Book of Entomology,p.62.

on its under surface, and is in fact an inverted semi-cylinder with double walls." * Packard quotes Meinert as follows:- "The hypopharynx, most generally free, more or less produced, acute anteriorly, forms with the labrum the tube of the pump. (antliae)"**

A careful dissection of S. vittatum mouth parts shows that the part Smith called rods of the mandibles, Pl. XI Fig. 23L, and plate XIII fig 28 is the labrum and that it is connected at its base with the hypopharynx. Plate XI, Fig. 23AB shows its attachment and Plate XIII, Fig. 27, its place of attachment after the labrum has been removed. In making this dissection for Pl. XIII Fig. 28, I was unable to tear the hypopharynx away from the labrum without destroying the composite arrangement of the other parts. To keep the parts in tact I turned the hypopharynx under and backward. The end of it shows in the upper part of the figure. The muscular attachments of the labrum are shown in dotted outline in plate XII, composite view. Since the appendage which I have called the labrum, does unite with the hypopharynx to form the opening of the pharynx, and since Kraepelin states that "the so-called epipharynx has no existence***"and that the labrum has a lower wall which was once deemed a distinct piece, the epipharynx, I am

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* Kraepelin's Proboscis of Musca.
** Packard, A.S., A Text Book of Entomology, p.78.
*** Same as *.

persuaded that this appendage is the labrum. Those two chitenized points that Smith has called mandibles are closely connected to the end of the labrum, but not muscularly attached, Pl. VIII Fig. 16. Their origin is conjectural.

Theparts of the labrum A & B, Pl. XI, Fig. 24, are attached at their bases to the base of the hypopharynx at A' & B', Pl. XI Fig. 24. That part of the labrum C Pl. XI Fig. 24, seems to be of a muscular nature, or tenddonous. It is firmly attached to the clypeus, so firmly in fact, that I have been unable to tear it loose without tearing to pieces the clypeus. See Plate VII. Furthermore, it seems to be free and unattached except at its ends.

Maxillae of the "First Maxillae."

According to Packard the first maxillae are inserted in the sides of the head just behind the mandibles and mouth. The three basal pieces supporting the maxillae, the cardo, stipes, and palpifer, in the order given, may be distinguished as shown in Pl. IX Fig. LZSPF. "The three distal divisions of the maxillae are called, respectively, beginning with the innermost, the lacina, galea, and palpifer, the latter being a lobe or segment bearing the palpus."*

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* Packard, A.S. A Text Book of Ent. pp.62,63.

From our dissections these parts are found to be present in the order given, and bearing a like description of typical segments of the same, except the galea which is wanting. The lacina is attached inside the palpifer to the stipes. The palpifer bears a palpus and is also connected to the stipes. Pl. IX-Fig. 12 P.F. PA

A further description by Packard is as follows:- "The lacina is more or less jaw-like and armed on the inner edge with either flexible or stiff bristles, spines or teeth," Pl. VIII Fig. 15. In S. vittatum, the lacina is produced into a piercing organ with an arrow-like end with about 26 barb-like formations turned backward on its upper side, and it appears to have a like set on the lower side, ~~Pl.---Fig.---~~. These two piercing organs (the lacinae and mandibles) together with the nub-like chitenized points on the end of the labrum are evidently used to scrape and tear away the skin in biting. The reason Sand flies or Buffalo gnats are so tenacious about holding when they are sucking blood may be due to the barbed ends of the lacina caught in the wound. The palpi are four jointed, the first joint being irregular in shape but about the same length as the second and third joints. The fourth joint is more slender than the second or third and is about two andone-half times the length of one of them. From Pl. XIII Fig. 28, they can be seen to be sparsely covered with setae.

"Second Maxillae" or Labium.

Plate XIV Fig. 30 shows the so-called second maxillae, labium, or under lip removed. It will be noticed the palpi are wanting. It shows the other typical divisions of a labium, the mentum, glossa, and paraglossa. The labium in S. vittatum serves as a sheath for the other mouthparts. This is shown in plate XII fig 26, and plate VII composite. It is situated in front of the gula or gular region and is bounded on each side by the gena. See Packard, A Text Book of Entomology, p. 68.

Clypeus.

Plate VII C shows the clypeus of the female Simulium. According to Packard the clypeus "is that part of the head situated in front of the epicranium, and anterior to the eyes, forming the roof of the posterior part of the mouth." This describes the position and location of that part of the head of Simulium I have called the clypeus. Pl. XIV Fig. 29 shows a part of the clypeus of a male Simulium vittatum. It is smaller and less developed, as are all the mouth parts of the males in comparison to those of the females. Plates X fig 20C, XI fig 21, XIII fig 28, show the torn clypeus of the female.

After arriving at the above conclusions in naming the mouth parts of S. vittatum my attention was called to a paper by W. Wesche * which describes and

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*Wesche, W., The Mouth parts of the Nemocera and their

and figures the mouth parts of S. reptans L. The parts he has figured in plate IV of his paper are the maxilla with its palpus and palpifer, the mandible, the labrum with its two minute teeth, the hypopharynx, and the labium. He classes Simulidae in a group of Diptera in which all mouth parts are distinguishable except the labial palpi, which are aborted. I felt very much gratified at finding his paper to corroborate my conclusions.

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Relation to the other Families in Diptera; Journal of the Royal Microscopical Society, pp. 28-47, 1904, published in London.

The following descriptions of the female and male of Simulium vittatum, the list of North American species of Simuliidae, genus Simulium, and the key to the species of Simulium larvae, pupae, and imagines are all taken from O.A.Johannsea's work as given in the New York State Museum bulletin 68, Aquatic Insects in New York State.

S. vittatum Zetterstedt

Ins. Lapponica. 1844. p.803

(- S. tribulatum Lugger)

(According to Coquillett, decorum Walk. 1848 and argus Will. 1893 are synonyms)

Female Graynearly bare;dorsum of thorax with five black stripes, the median one entire, the intermediate pairs interrupted, the exterior pair spotlike. Each segment of the abdomen with a black dorsal stripe and basally on each side with a black spot, the penultimate segment black Wings whitish hyaline; halteres white; legs fuscous black, the front side of anterior tibiae, the base of the middle and hind tibiae, and the base of the middle and hind metatarsi white. Length 3mm. Zetterstedt.

Female. The abdomen gray, bases of segments 3 to 7 or 8 marked with a velvet black fascia produced backward in the middle and at the ends. Length 2 to 4mm. New York, Minnesota, Nebraska, Kansas, California.

Male. Hind tarsi bicolorous, mesonotum gray on sides and hind margin, center largely velvet-black; without gray streak extending inward from humerus; sides of abdominal segments 4 to 7 with silvery white hairs. Coquillett.

The markings of the female of this species seem somewhat variable. The thoracic markings are usually quite distinct. The median stripe is nearly of uniform width excepting at the posterior end, where it becomes narrower; the intermediate stripes are ∫ shaped, the extremities

larger, the intermediate portion usually a hair line, some times obsolete; the exterior pair usually elongated spots. The abdominal markings are as described by Coquillett, though occasionallythere are additional disconnected, velvet-black lateral spots, one on each side on segments 3,4 and 7, and a pair on 5 and 6. Sometimes also, owing either to the contracted condition of the abdomen or to the fasciae being narrow, only the black projections of the fasciae are visible on the more posterior segments, giving the appearance of three spots on each. The legs are often gray; the femora and tibiae paler at the base the tibiae black at tip, the tarsi deep black except basal portion of middle and hind metatarsi. Fore tibiae with one spur, middle and hind with a pair. Tarsal claws of female simple.

Some specimens from Brookings S,D,. received from Professor Aldrich, and which are the males of vittatum, possess the following characters:

Male. Velvety black, antennae and palpi dark brown; dorsum of thorax velvety black with the anteriorand lateral margins narrowly, and posterior margins in front of scutellum, widely silvery gray; also two narrow longitudinal gray stripes on dorsum. Or the dorsum might have been described as silvery gray with three very wide velvety black longitudinal stripes, abbreviated behind. Pleura black, bare; scutellum velvety black; metanotum silvery gray; abdomen velvet-black, the sides of first

two or three segments of the ventral surface with a silvery reflection in some lights; legs black, the tips of the fore femora, the basal half of fore and hind tibiae (sometimes the middle one also) the basal two thirds of hind metatarsi, and the extreme base of the second hind tarsal joint, yellow. Fore tibiae with a single spur, middle and hind tibiae with each two; tarsal claws tridentate. Halteres bright orange-yellow. Wings hyaline, the vein yellow. Length, 3mm.

In an article by Tugger, it is stated that in S. tribulatum the male is much smaller than the female, having very large brilliant, red eyes that meet on top of the head; the body is velvety black with bright golden yellow and blue spots; the female is gray with black markings. This species is said to be most abundant in Minnesota, where it is called "the black fly." No further description is given; the figures of the male and female sent by Mr Washburn of the Minnesota Experiment Station, Labeled S. tribulatum proved to be S. vittatum. I have specimens of larvae and pupae which belong to S. vittatum, which were sent to me by Professor Needham, he having obtained them from Mr J.C.Bradley of Philadelphia.

Larva (of S. vittatum). Somewhat mottled gray, the sides of each segment blackish. The larvae and pupae were collected by Mr J.C.Bradley, Philadelphia, 1901. The head is of the usual reddish brown color; the pale yellow antennae long and cylindric, the second joint about one third the length of the first, the third is a pointed

process at the tip of the second. The fans have about 40 rays, the cilia being relatively minute. The mandibles are provided with three large spical teeth besides the row of secondary ones; the apical pair of bristles is present. The maxillary palpus has a few spines, and a tuft ofa few spines on the basal joint. Hypopharynx and labrum apparently like those of other species. The labium has an elongate middle tooth, those at the end nearly as long, the intermediate ones short (pl.35, fig.2), and there are six bristles in each of the two longitudinal rows on the ventral surface. The three blood gills at candal end are unbranched.

Pupa. The thoracic respiratory filaments each consist of a single main trunk, from which arise eight branches, each of which divides into two, thus making 16 twigs inall (pl.35,, fig.1). Near the basal margin of the last few abdominal segments, are a few caudad projecting dorsal hooks, and on the tip of the last segment is a pair of blunt spines. The pupal case is of the wall pocket type, from which the respiratory filaments of the pupa project. Judging from the number of respiratory filaments of the pupa, the species described by Osten Sacken in American Entomologist, volume 2, seems to belong here.

List of the North American Species of Simuliidae,

Genus Simulium.

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Latreille, Hist. Nat. Crust. et Ins. 1804. 14:294.

argus Williston, N. Am. Fauna, no. 7. May 1893. p.253. Cal
(Syn. of S. vittatum Zett. according to Coquillett, Harriman Exp. 1900. p.393).

argyropeza. See reptans.

bracteatum Coquillett, U. S. Dep't Agric. Div. Ent. Bul. 10, n.s. 1898. p.69. Mass., Cal., N.Y., Kan., Mich.

calceatum Harris. A catalogue name according to Riley. Am. Ent. 1870. p.467.

cincta. See reptans.

cinereum Bellardi, Saggio di ditterologia Messicana. 1:13 Cal. (Townsend, Baja. etc. 1893). Mex. (Bellardi).

columbatchensis Fabricius nec Schönnauer. See reptans.

decorum Walker, List of Dipterous Insects, etc. pt1. 1848. p.112. Hudson Bay Ter. (Sun. of S. vittatum Zetterstedt, according to Coquillett, n.s.Bul.10, 1898. p.68).

elegans. See reptans.

eruthrocephala. See reptans.

fulvum Coquillett, U.S. Nat. Museum Proc. 1902. 25:96: 1898 ochraceum Coq. not Walk. Mont.; Id.; Col.; N.M.: Alaska

glaucum Coquillett, U.S.Nat. Museum Proc. 1902. 25:97. Missouri.

griseum Coquillett, U.S.Dep't Agric. Div. Ent. Bul. 10, n.s. 1909. p.69. Col.

hirtipes Fries, Obs. Entomol. Pars, Monogr. Simuliar. 1924. p.17,5. Tfl. 1,f.1. N.Y., Id., Cal.

The following synonymy is according to Schiner:

1830 rufipes Meigen, Syst. Beschr. 6:311-17.

1830 hirtipes Fries, Meigen, Syst. Bescher. 6:312-18

1850 hirtipes Fries, Zetterstedt, Dipt. Scand. 9:3426-28

innoxiom Comstock. See S. pictipes Hagen.

invenustum Walker, List of Dipterous Insects, stc. 1848. p.112. Hudson Bay Ter.

(pecuarum Riley is a synonym of this, according to Coquillett, 1898).

irritatum Lugger. Figured but not described in Univ. Minn. Sgric. Exp. Sta. Bul. 1896.p203.

meridionale Riley. Dep't Agric. An. Rep't for 1886. 1887. p.512. 1891 occidentale Townsend, Psyche, July 1891. p.107. Mass., Miss., Neb., Tex. (synonymy and localities according to Coquillett, Bul. 10, n.s. 1898), N.J.(Johnson), Kans, and Id.

Metalicum Bellardi, Saggio di ditterologis Messicana. 1859. 1:14. Mex.

Mexicanum Bellardi, Saggio di ditterologis Messicana, Appendix 6. 1862. Mex.

minutum Lugger, Minn. Agric. Exp. Sta. Bul. 1896. p.202. Minn. (Figured but not described). See

vittatum.

molestum Harris. See venustum.

novicum Harris, Ins. Inj. to Veg. p.601. This is a Ceratopogon.

occidentale Townsend. See meridionale.

ochraceum Walker, Ent. Soc. London. Trans. n.s. 3:332. Mex.

pecuarum Riley (Synonym of invenustum according to Coquillett). 1887 pecuarum Riley, U.S.Dep't Agric. Rep't for 1886. p.512.N.H., N.Y., Mass., Ctl, D.C., Mich., Miss., La. (synonymy and localities according to Coquillett, U.S.Ket't Agric. Bul. 10,n.s. 1898), N.J.(Johnson).

pictipes Hagen, Bost. Soc. Nat. Hist. Proc. 1880. 20: 305. N.Y., Tex., Cal. (Coquillett, 1898)Id. 1895 innoxium Comstock. Name given in Manual for the Study of Insects.

piscicidium Riley. See venustum.

pesticata Meigen. See reptans.

pulchrum Philippi, Chillian Diptera. 1865. p.633. S.Am. and St Vencent, W.I.

1896 tarsale Williston, Diptera of St Vincent, W.I. p.268. Synonymy according to Hunter, Catalogue of S. Am. Diptera. 1900.

quadrivittatum loew, Berl. Ent. Zeit. 1862. Centur. 2,p.2. Cuba.

reptans Linnaeus, Fauna Suec. 1893. Europe, Greenland

(Lundbeck, 1898). 1761.

Synonymy according to Schiner:

1767 sericea Linnaeus, Syst. Nat. 12:978,58

1776 erythrocephala DeGeer, Ins. 6:161, 37 (Tipula)

1781 reptans L. Schrank, Enum. Ins. Austr, p.985 (Culex)

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1804 argyropeza Meigen, Classif. 1:96

1818 reptans Meigen, Syst. Beschr. 1:291-92

1818 sericea Meigen, Syst. Beschr. 1:296-98

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rufipes Meigen. See hirtipes.

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Key to Species of Simulium.

Larvae.

1. Mature larva 6 of 7mm long, with the dorsal surface of the head nearly white; the rays of the fan number about 30. Larva from Santa Cruz mountains, Cal. (p. 387). Head usually brown; rays of the fan usually 40 or more----------(2)

2 The top of the head with six black blotches or spots. Larvae from New Mexico (p.286).

Head without six dark spots----------(3)

3 The caudal blood gills are three simple papillae-------(4)

The three main branches are again subdivided----------(6)

4 The middly tooth of the labium is simple and pointed, labium with six pairs of setae on its ventral surface (pl.35, fig.2). vittatum.

The middle tooth at least is trifid----------(5)

5 All marginal teeth of the labium except the outer pair are trifid----------hirtipes

The middle tooth only is trifid; ventral surface with three pairs of setae (pl.33, fig.8)---pecuarum (-invenustum)

6 Full grown larvae 10-12mm in length, black in color, its labium with an elongate middle tooth (pl.36,fig.3) ----------pictipes

Paler larvae less than 10mm in length----------(7)

7 No setae on the last joint of the maxillary palpus,

middle tooth of the labium longer than the two lateral ones, four pairs of setae on its ventral surface. The pair of apical setae of the mandible not differentiated from the hairs which overhang the apex--
----------meridionale.

Mandible with a pair of apical bristles, palpus of the maxilla with setae----------(8)

8 Middle tooth of the labium enlarged, ventral surface of labium with five pairs of setae (pl.37,fig.6)--
----------venustum.

Middle tooth not enlarged (varieties of venustum)----(9)

9 Labium with four pairs of ventral setae (pl.37, fig.14)
----------var. a.

With seven pairs of setae (fig.5)--------var. piscieidium.

PUPAE

(Arranged according to the number of filaments in each respiratory tuft)

1 With six filaments

a Legs in their cases appear bicolored--venustum

b Legs unicolored----------meridionale

2 With eight filaments

a Pupa 4.5mm long; Arizona species. Pupa described in Am. Ent. Soc. Trans. p.45. 1893.

b Less than 4,, long; eastern species----------
venustum, var. piscicidium

3 With nine filaments. Pupal case like that on pl.35,fig.5
---------pictipes

4 Wit 10 filaments ----------var. a of venustum

5 With 12 filaments. Pupal case (pl.35,fig.5). From Santa Cruz mountains, Cal. (p.387)

6 With 16 filaments----------vittatum

7 With 24 to 48 filaments (pl,33, fig. 10)---pecuarum

8 With 60 or more filaments----------hirtipes

IMAGINES

1 Ground color of the thorax and abdomen deep yellow--(2)

Gray or black; its hairs may be pale----------(3)

2 "Femors with black tip, length of fly 3mm." Mexico--ochraceum

"Femora without black tips. Length 3 to 4.5mm. Rocky mountains"----------fulvum

3 Hind tarsi with its basal joint partly yellow; legs bicolored----------(9)

Hind tarsi unicolored----------(4)

4 Halteres dusky; thorax not striped----------(5)

Halteres white or yellow; the female with striped thorax and bifid tarsal claws----------(6)

5 Body black; the female with dense yellow pile, her tarsal claws simple; the male with dense hair on the legs, his tarsal coaws trifid. The wing with its redius three branched. Length 3 to 4.5mm------hirtipes

"Body gray;; legs reddish gray, feet black; length 3mm." This is said by Mr. Coquilett to be the same as pecuarum Riley----------invenustum.

6 Males, eyes contiguous----------(7)

Females, eyes separated by a distinct line----------(8)

7 Thorax velvety black; legs reddish with black tarsi. Length 1.5 to 2mm. Compare here also bracteatum (male), "with legs wholly brown."----meridionale

Thorax brownish black; legs usually pale; tip of tarsi not black. Length from 2 to 4mm------pecuarum

8 Thorax with silvery white pubescence; legs brownish black, covered with whitish hairs. A small variety (less than 2mm long), from New Mexico has been named occidentale Town. (q.v.)----------meridionale

Thorax with yellow hairs; legs reddish brown, covered with yellow hair; tip of tarsi blackish---pecuarum

9 Males, eyes contiguous----------(10)

Females, eyes separated----------(20)

10 "Mesonotum wholly velvet black; gray spot on sides of the second, fifth, sixth, and seventh segments of abdomen. Length 1.5mm."----------bracteatum

Metanotum striped, or with grayish or metallic reflections----------(11)

11 Dorsum of thorax with one or more longitudinal stripes(12)

Dorsum unstriped----------(14)

12 Thorax with four longitudinal stripes; posterior margin white; abdomen black. Sex not given. Cuban species ---quadrivittatum.

Thorax not so marked----------(13)

13 Front and middle femora and tibiae wholly yellow; center of mesonotum with a black vitta, elsewhere gray.

Length 1.5mm. Colorado species---------griseum

Femora and tibiae wholly or partly brown----------(13a)

13a "Femora and front tibiae yellow, their apices brown; middle tibiae brown, a yellow ring beyond the base, hind tibiae brown, the extreme base yellowish. Mesonontum marked with a narrow median and laterally with a very broad velvet black fascia." Length 3mm. New Mexico----------virgatum

Front femora brown, tibiae brown on apical part----(13b)

13b Mesonotum with two narrow gray stripes (sometimes quite indistinct) on a velvet black ground, in which there are scattered golden hairs----------vittatum

"Mesonotum marked with a narrow median and slightly wider lateral black vittae." Length 2.5mm. Mo.-glaucum

14 Anterior femora yellow. Mexican species----------(15)

Anterior femora black----------(17)

15 Abdomen with the base of the second segment, and the sides of the third, fourth, and fifth yellowish white; tibiae fuscous black with yellow bases. Length 4mm ---------mexicanum

Abdomen black----------(16)

16 Metallic bluish black species; middle portion of fore tibiae, base of middle and hind tibiae, base of first and second joints of middle and hind tarsi, whitish. Length 2mm----------metallicum

Thorax fuscous and cinereous pollinose; the humeri pallid fore coxae pale, middle and hind ones dark; femora pale at the base, black at the tip; tibiae black.

Length 2mm----------cinereum

17 An oblique metallic streak extending inward from each humerus; posterior part of the thorax metallic. Length 2 to 2.5mm----------venustum

Humeral spots not metallic----------(18)

18 Anterior coxar yellow; long hair on femora and hind tibiae; thorax velvet black with white pruinose margin (Greenland)----------reptans

Anterior coxae black----------(19)

19 Thorax velvet black, with oblique cinereous humeral spots, and usually two tiny metallic spots between them. Length 3 to 4mm----------pictipes

Thorax velvety black with two very narrow gray stripes and posterior margin; hind tibiae usually yellow at the base, hair on ligs sparse----------vittatum

20 Thorax striped----------(21)

Thorax without stripes----------(25)

21 Dorsum of thorax with four longitudinal lines, posterior margin, white pollinose; abdomen opaque black. Cuban species----------quadrivittatum

Not with four stripes----------(22)

22 Dorsum of the thorax with five stripes, the outer ones spotlike, the intermediate ones clubbed at the ends; abdomen with black fascia on each segment, produsedposteriorly at the middle and the ends. Sometimes the last few segments have only three of five spots ----------vittatum

Thorax with one or three stripes----------(23)

23 With three stripes----------(24)

"With an indication of a darker median vitta" (see31)

----------griseum

24 Small species, length about 1.5mm. "Abdomen silvery, third and fourth segments wholly brownish, sometimes with a median spot on each; legs yellowish, tarsi blackish or brownish." Species from Texas--tamaulipense

Larger species 3mm. or more in length----------(24a)

24a Middle tibiae brown with a yellow ring beyond the base; vittae of mesonotum brownish, the median vitta dilated posteriorly, wider than either of the lateral ones. New Mexico----------virgatum

Femora and tibiae grayish, sometimes quite pale, tips of tibiae black. Laterodorsal thoracic stripes clubbed at the anterior end. Third, fourth, fifth, and part of sixth and seventh abdominal segments with velvet black fasciae; center of 6,7, and 8, grayish or dull brown----------pictipes

25 Abdomen without distinct black spots----------(26)

Abdomen spotted----------(31)

26 Abdomen black, covered with long yellow pile; legs yellow, the tips of the femora and tibiae, and all the tarsi except basal two thirds of the hind metatarsi brown----------bracteatum

Abdomen nearly bare----------(27)

27 Body gray or cinereous----------(28)

Body brown or black----------(29)

28 "Body gray with a white milky luster, specially the pleura and pectus. Legs tawny, femora and tibiae with irregular piceous bands, tarsi piceous. Length 2.5mm Hudson Bay Ter." This is a synonym of vittatum Zett. according to Mr Coquillett (1898)-------decorum

Thorax fuscous or cinereous pollinose, humeri pallid, pleura pale cinereous, scutellum pale at the tip; abdomen blackish; fore coxae pale, middle and hind ones cinereous; femora pale at the base, black at tip; tibiae black . Length 3mm. Mexican species--cinereum

29 Abdomen somewhat shining, yellowish gray or whitish at the sides, and yellow at the base; legs brown, tibiae and fore coxae white, tip of tibiae and all tarsi black European species, also occurring in Greenland--reptans

Basal segments of abdomen opaque, distal four segments somewhat shining black or brown, Two long hairs at the tip of the first and third fore tarsal joints-(30)

30 Legs reddish yellow, tarsi black, except proximal half of middle and hind metatarsi which are light yellow. Length 2mm. (St Vincent island) This is a synonym of pulchrum Phil. according to Hunter------tarsale

Legs black, base of tibiae, first joint of middle and hind tarsi and sometimes base of femora yellow; extensor surface of all the tibiae more or less whitish. A widely distributed and variable species--venustum

31 Length 1.5mm. Front and middle femora and tibiae wholly yellow; hind ones, except apices, also yellow. (Col.)

----------griseum

Length 2.5mm. Legs brownish black, distal part of femora, base of tibia, and greater part of metatarsi light yellow. California)----------argus

Some of the characters used in this table have been taken from the key given in United States Department of Agriculture, division of entomology, bulletin 10, new series, 1898, page 68, by Mr Coquillett. In the table given above, I have included all the North American species. For the southwestern and Mexican species it should however be used with caution as I did not have specimens of some of these.

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PLATE 1.

Fig. 1. Typical breeding place of Simulium vittatum, Turkey creek, Oswego, Kansas.

Fig. 2. Pupae on the under side of a stone from ripples in the stream shown in Fig. 1. (Slightly reduced).

PLATE 1.

Fig. 1.

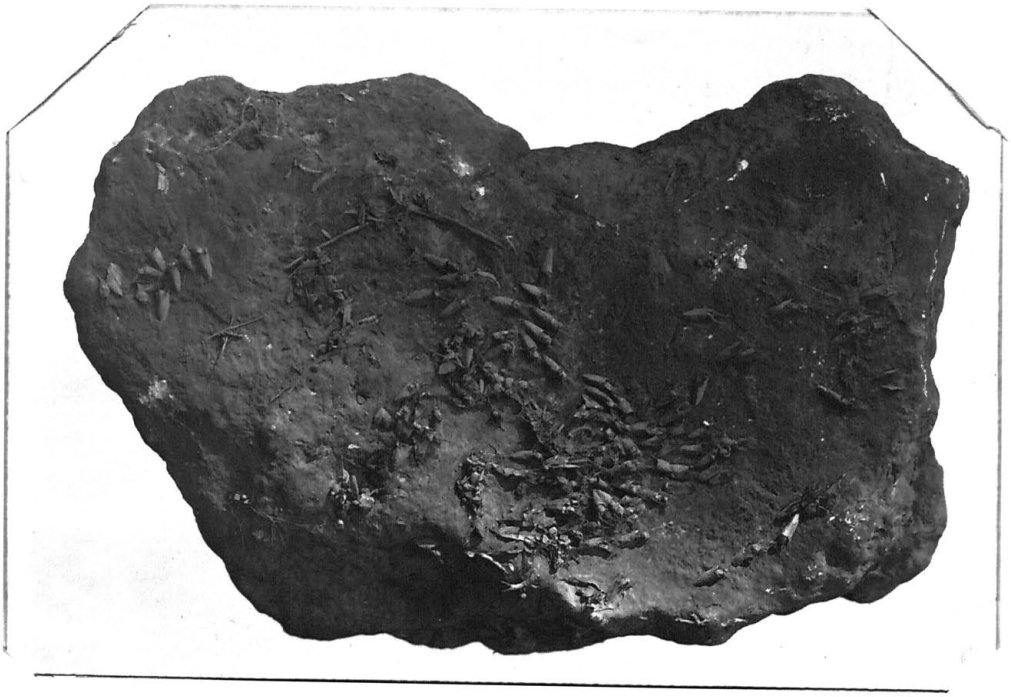

Fig. 2.

## PLATE II.

Fig. 3. A Simuliumfly trap in a ripple showing the method of catching the flies as they emerge. When removing the flies from the trap a black cloth is put around the white cone over which Prof. S.J. Hunter is holding a glass bottle for the flies to emerge into.

Fig. 4. A Simulium fly trap in a narrow ripple.

PLATE II.

Fig. 3.

Fig. 4.

PLATE III.

Fig. 5. Female S. vittatum. (Greatly enlarged).

Fig. 6. Male S. vittatum. (Greatly enlarged).

PLATE III.

Fig. 5.

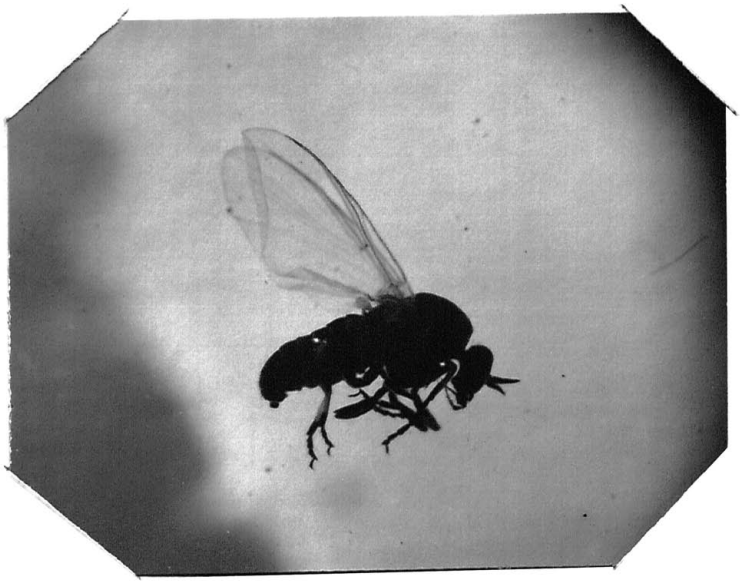

Fig. 6.

PLATE IV.

Fig. 7. Dorsal view of Simulium pupa removed from pupa case showing pupal breathing gills and development of wing pads.

Fig. 8. Simulium pupa immediately after trans forming from the larval state showing the immature development of wing pads.

Fig. 9. Lateral view of pupa showing the membrane which holds it in the pupa case.

PLATE IV.

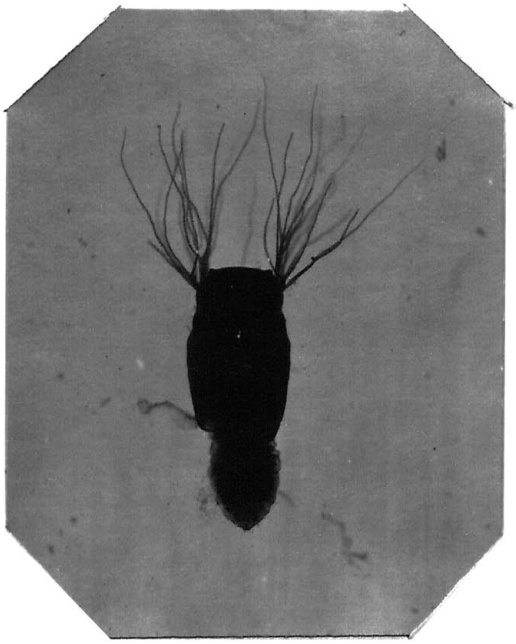

Fig. 7.

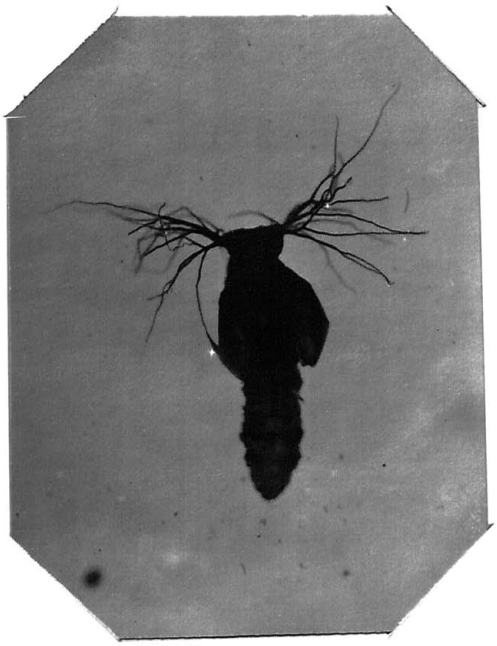

Fig. 8.

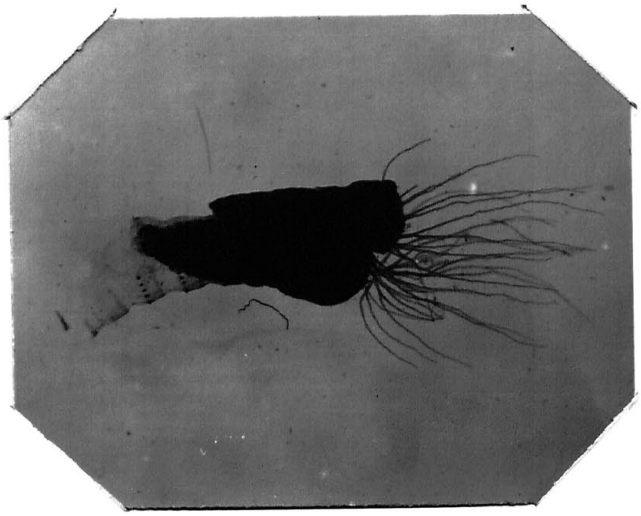

Fig. 9.

PLATE V.

Fig. 10. Adult Simulium larva.

Fig. 11. Adult Simulium larvae showing the pro-leg at P and the caudal aperature at A. See plate XVI, Fig. 34, A.

PLATE V.

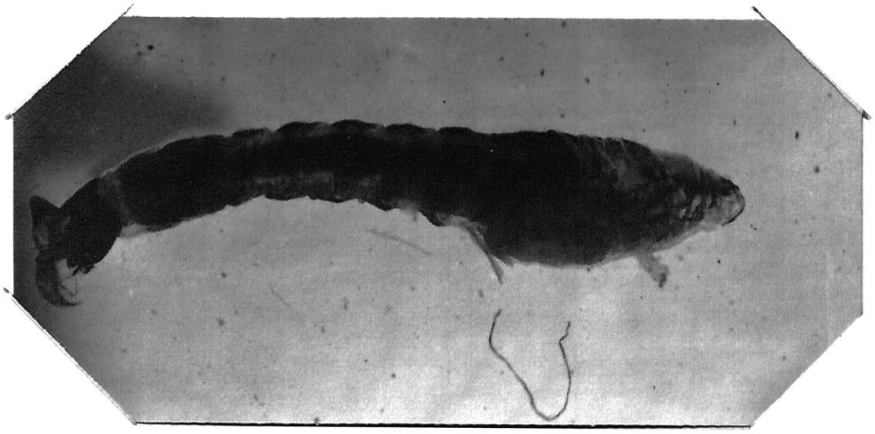

Fig. 10.


Fig. 11.

PLATE VI.

Fig. 12. Simulium egg highly magnified.

Fig. 13. Mass of Simulium eggs magnified.

PLATE VI.

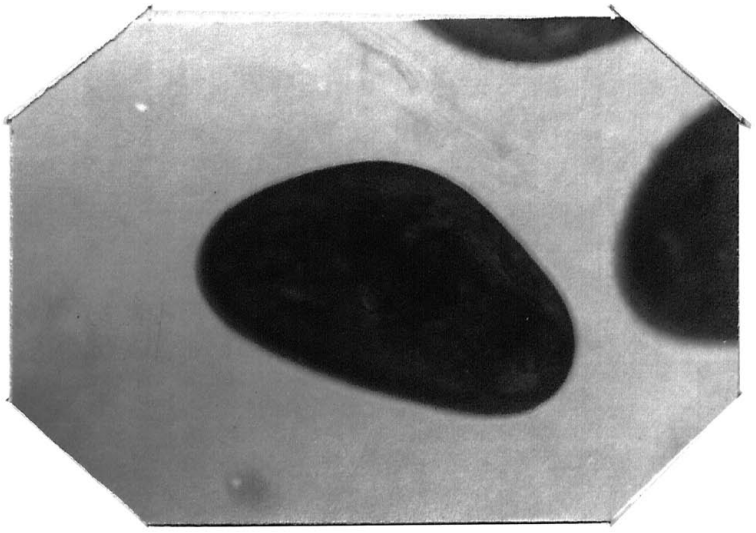

Fig. 12.

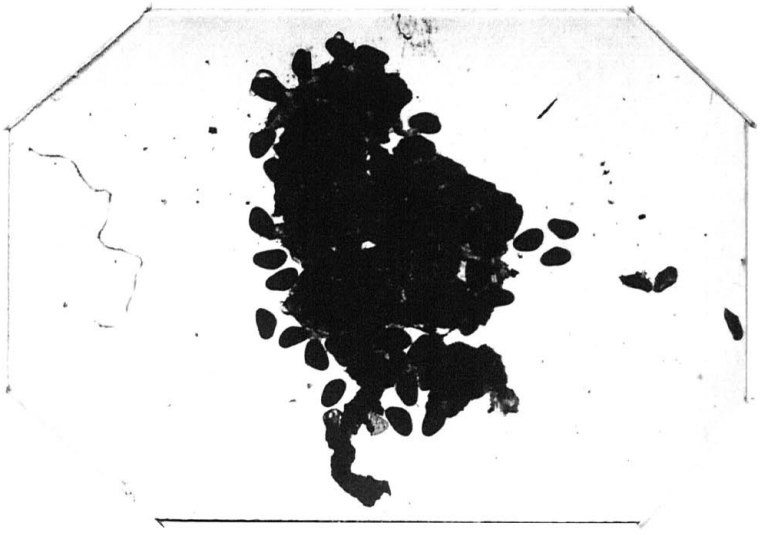

Fig. 13.

PLATE VII.

Fig. 14. Composite view of head and mouth parts of Simulium vittatum.

E--- Eyes.

C--- Clypeus.

MD--- Mandible.

MX--- Maxillae.

LA--- Labrum.

ooo--- Muscular attachments of labrum and clypeus.

LM--- Labium.

HPY--- Hypopharynx.

oo--- Attachments of hypopharynx and labrum.

PLATE VII.

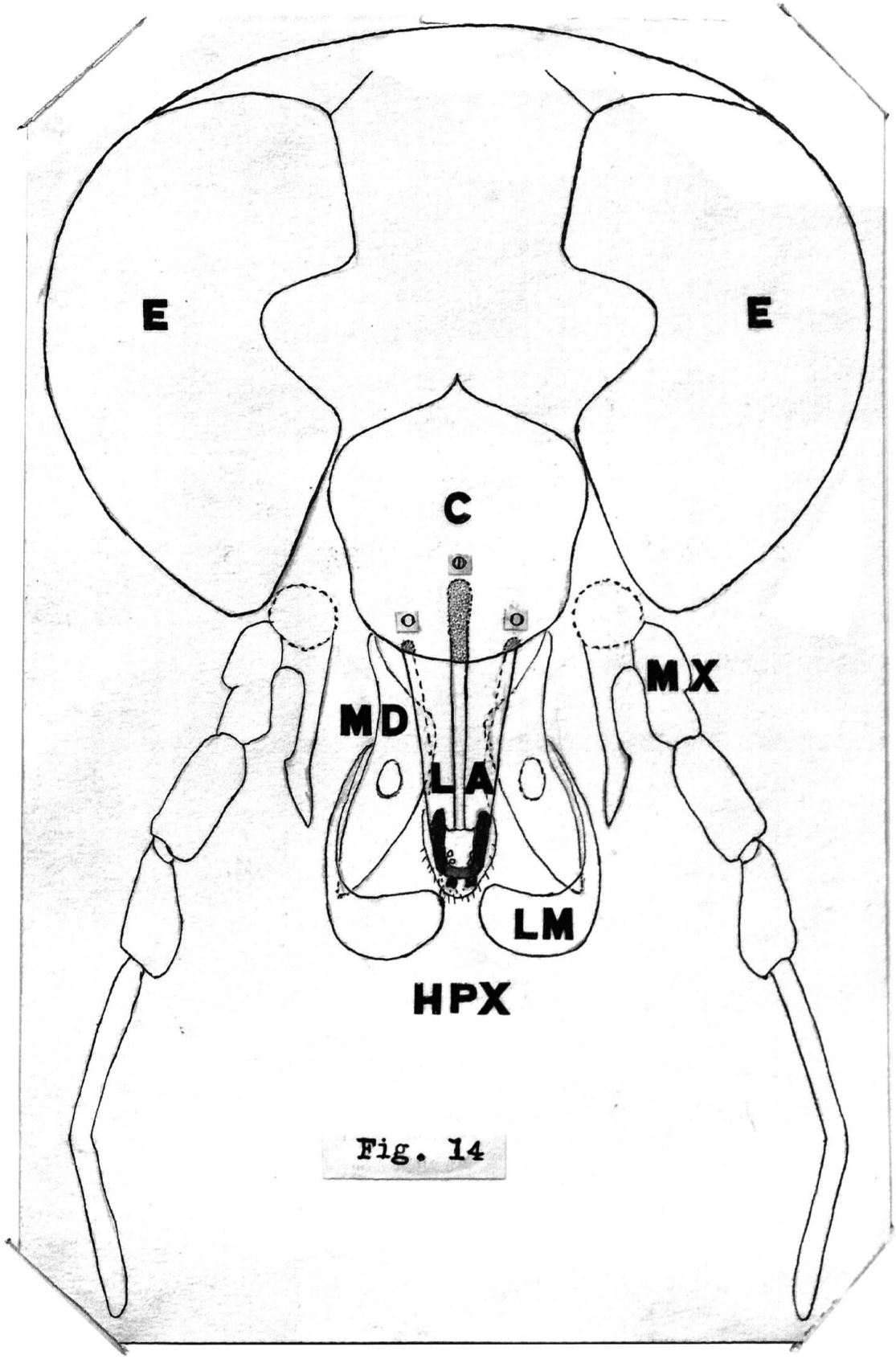


Fig. 14

Fig. 14.

## PLATE VIII.

Fig.15. Lacina of maxilla greatly enlarged showing the barb-like teeth turned backward on it.

Fig. 16. End of Labrum showing the chitinized parts and the two teeth.

PLATE VIII.

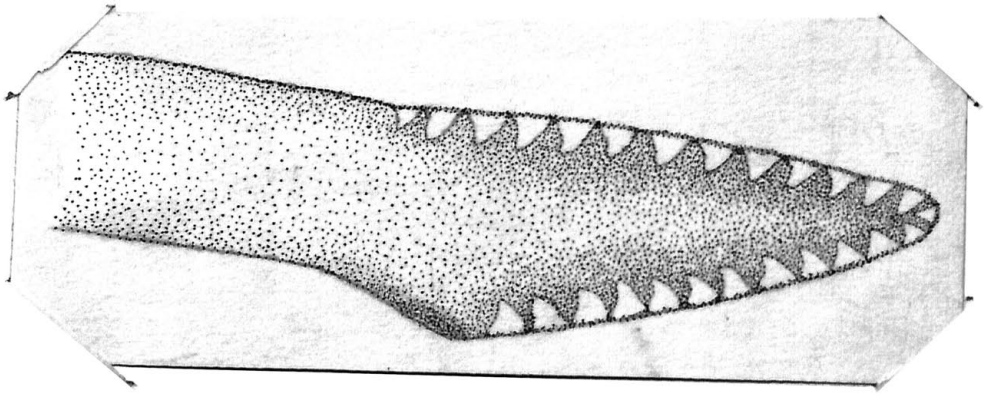

Fig. 15.

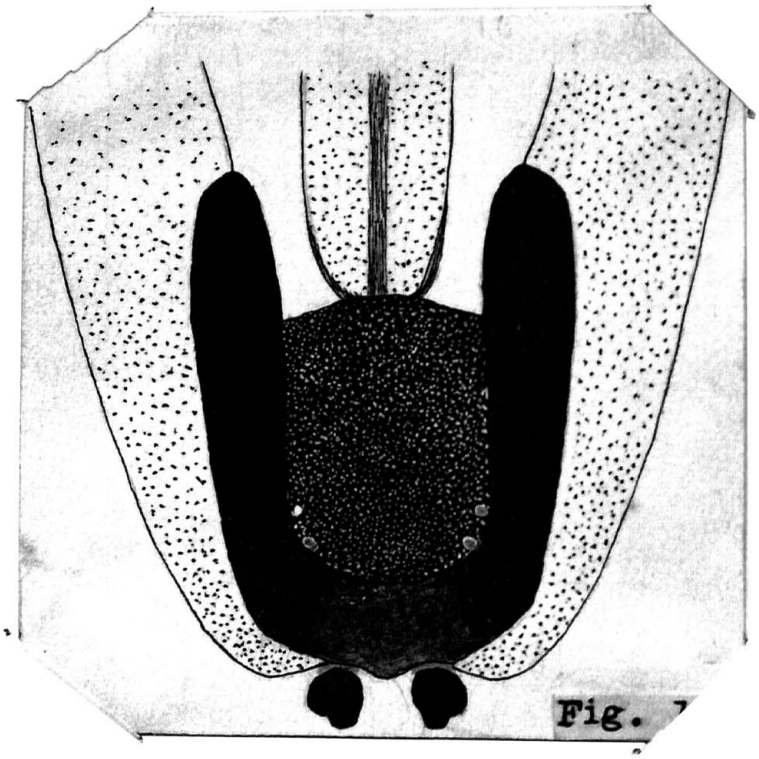

Fig. 16.

PLATE IX.

Fig. 17. Maxilla of S. vittatum.

C--- Cardo.

S--- Stipes.

PF--- Palpifer.

L--- Lacina.

PA--- Palpus.

PLATE IX.

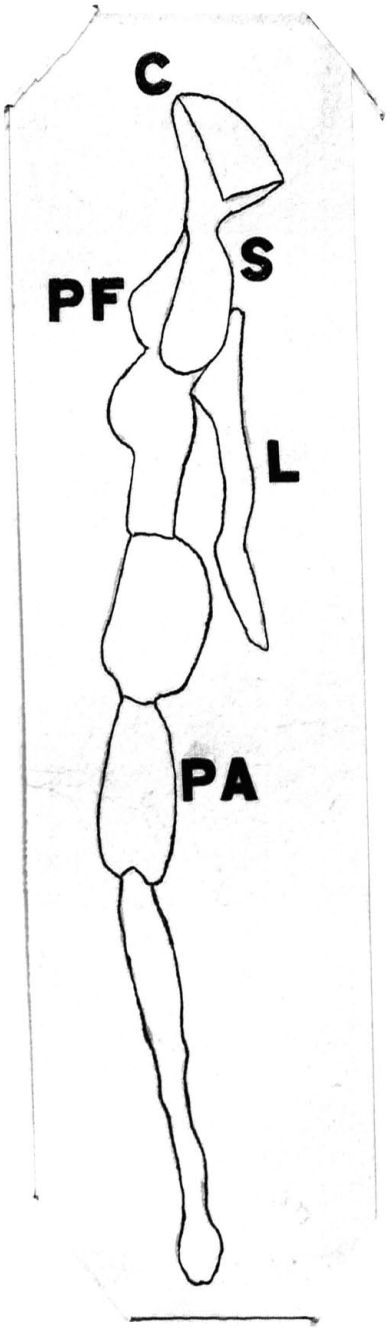


Fig. 17.

PLATE X.

Fig. 18. End of mandible greatly enlarged to show the saw-like teeth on its end.

Fig. 19. Antennae of S. vittatum.

Fig. 20. C--- Clypeus. M--- Mandibles.

PLATE X.

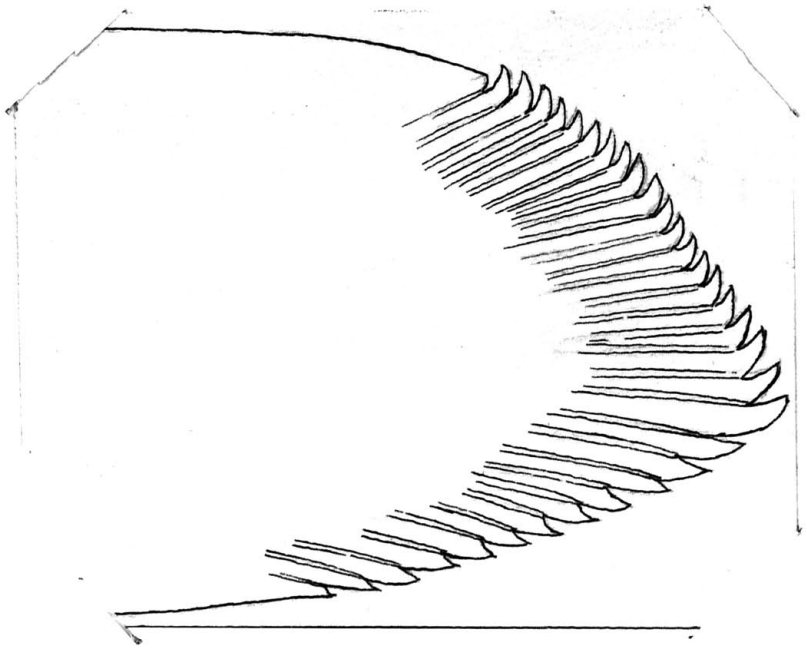

Fig. 18.

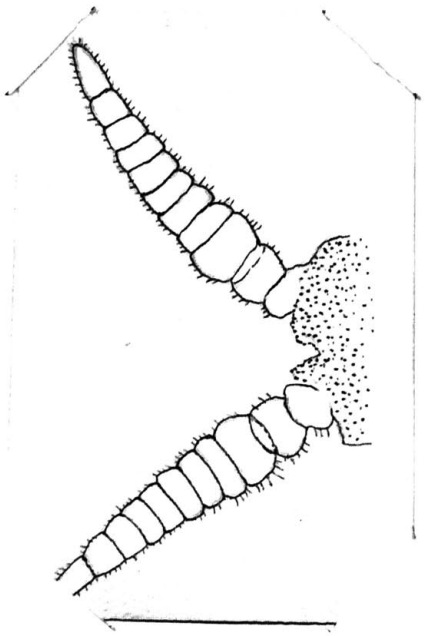

Fig. 19.

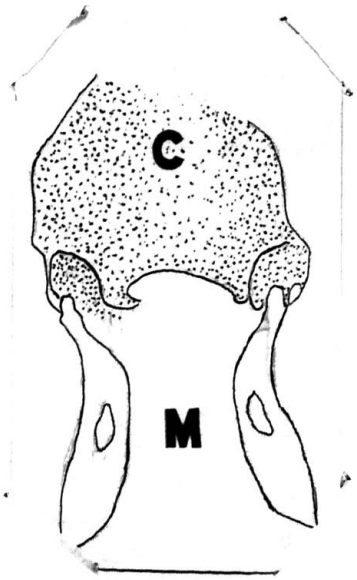


Fig. 20.

## PLATE XI.

Fig. 21. Mandibles and part of clypeus.

Fig. 22. Mandible. C--- Condyle(?)of mandible.

Fig. 23. Labrum and hypopharynx united.

A & B --- Points of attachment.

H--- Hypopharynx.

L--- Labrum.

Fig. 24. A' B' --- Points of hypopharynx where A & B of the labrum attach.

PLATE XI.

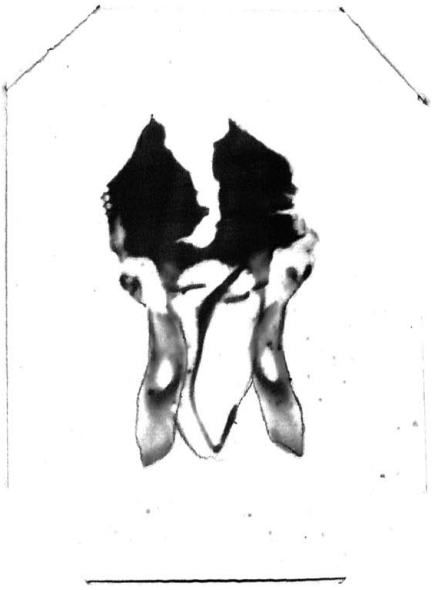

Fig. 21.

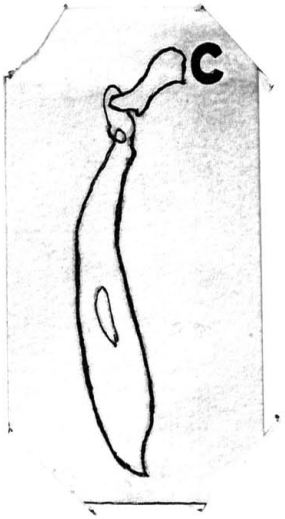


Fig. 22.


Fig. 23.

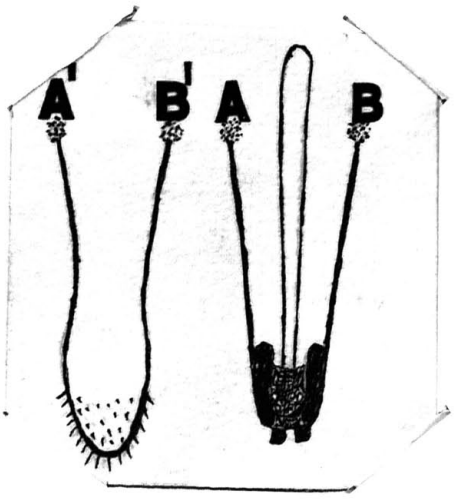


Fig. 24.

PLATE XII.

Fig. 25. Wing of S. vittatum.

Fig. 26. Composite view of head of a female S. vittatum. (All photographs of the fly except the one of the pupae on the stone are greatly enlarged views of the specimens).

PLATE XII.

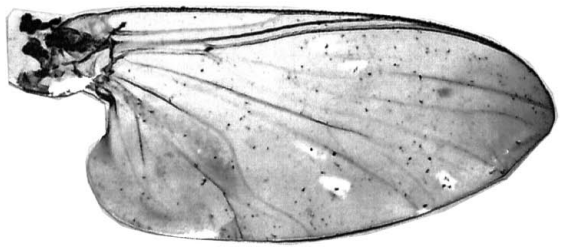

Fig. 25.

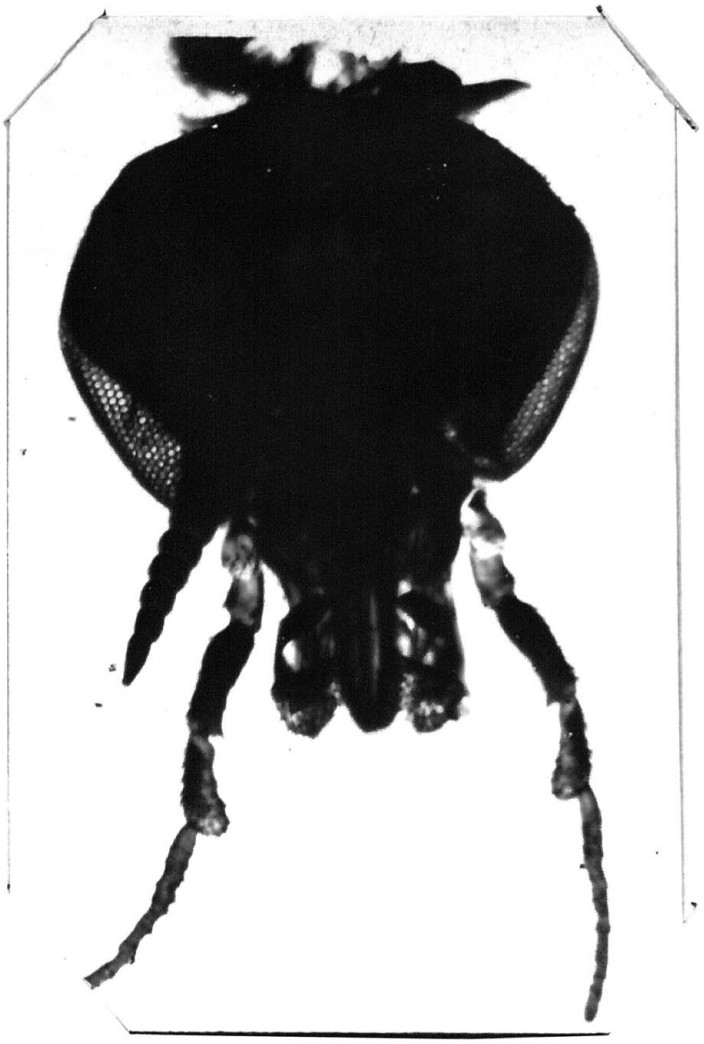

Fig. 26.

PLATE XIII.

Fig. 27 Hypopharynx and maxilla of S. vittatu m.

Fig. 28. Composite view of mouth parts showing all the parts intact except the labium which is entirely removed. The hypopharynx is turned under and upward in the photograph.

PLATE XIII.

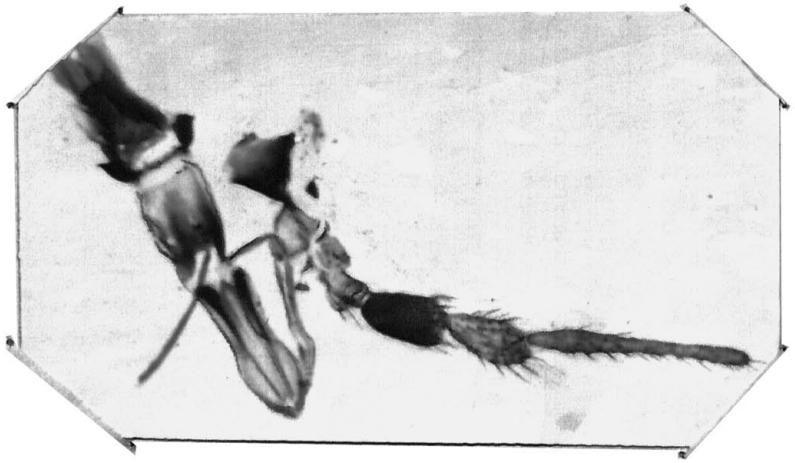

Fig. 27.

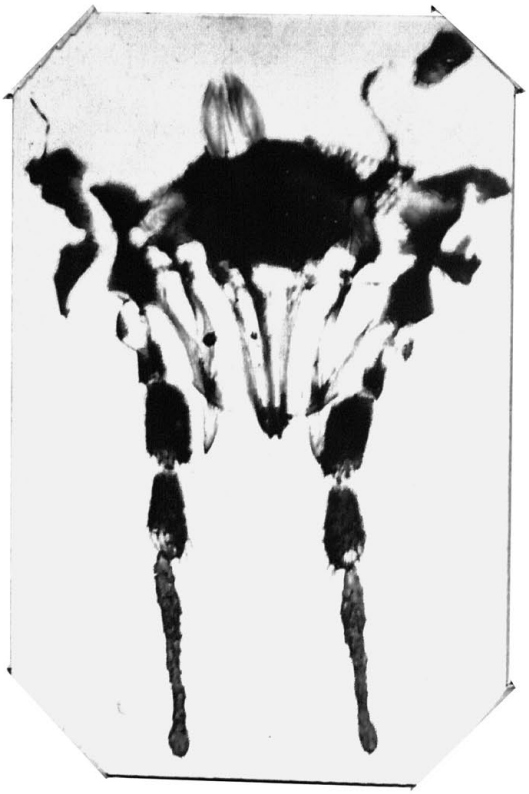

Fig. 28.

## PLATE XIV.

Fig. 29. Male S. vittatum mouth parts. Note the tip of the labrum has the two teeth coalesce d. Note the difference in the size of the facets of the eye.

Fig. 30. Labium of female. All mouth parts figured are of the female except Fig. 28.

G--- Glossa.

PG--- Paraglossa.

M--- Mentum.

PLATE XIV.

Fig. 29.


Fig. 30.

PLATE XV.

Fig. 31. Ventral view of head of Simulium larva showing the fan-like organs spread out.

Fig. 32. MD--- Mandible of Simulium larva.

AT--- Antennae of Simulium larva.

(According to Johannsen).

PLATE XV.

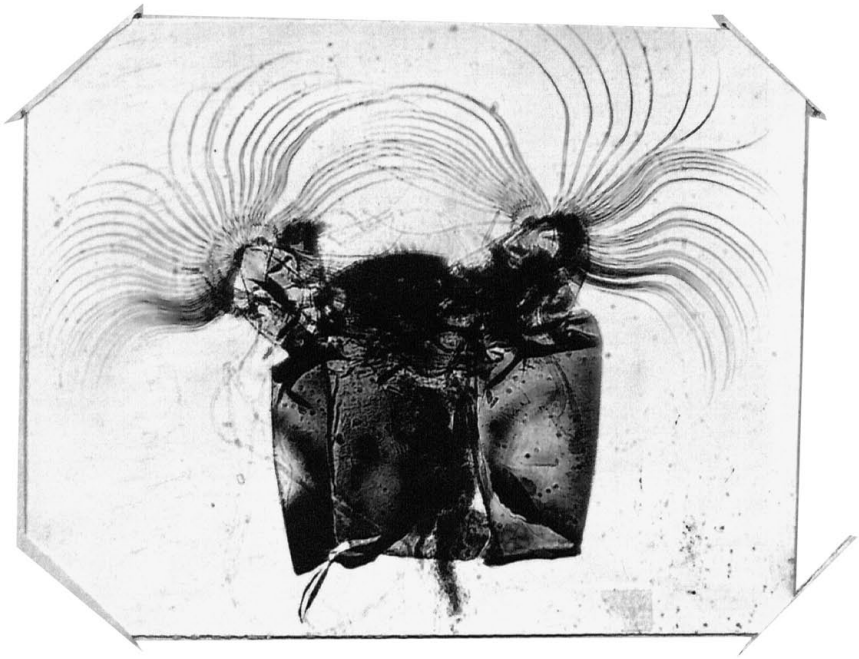

Fig. 31.


Fig. 32.

PLATE XVI.

Fig. 33. Maxilla of Simulium larva showing the palpus at P.

Fig. 34. Labium of Simulium larva.

Fig. 35. LA--- Labrum of S. larva.

HY--- Hypopharynx of S. larva.

A--- Anal aperature of Simulium larva. The U shaped part lies dorso-cephalid to the rest of it in the larva. Note the rasp-like formation of this organ. The larva uses it to hold onto the stones in the ripples.

PLATE XVI.

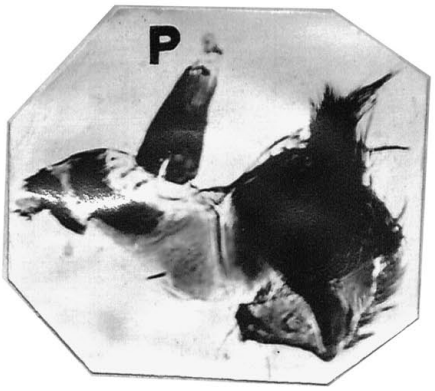


Fig. 33.

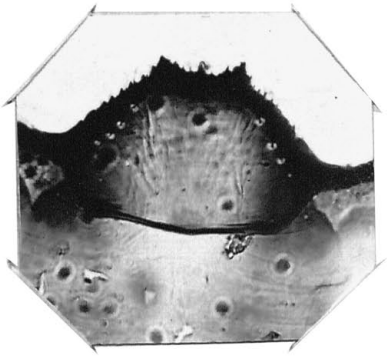

Fig. 34.

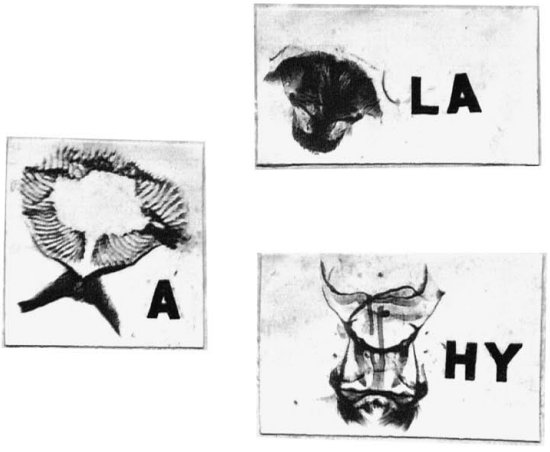


Fig. 35.

PLATE XVII.

Map of Kansas showing the location and distribution of Simulium flies in Kansas. A complete survey of Kansas for Simulium has not been made, but the survey that has been made to date as shown by the map would indicate that Simulium flies are generally distributed over the State where there are year-round flowing streams of water.

S--- Location of Simulium.

PLATE XVII.