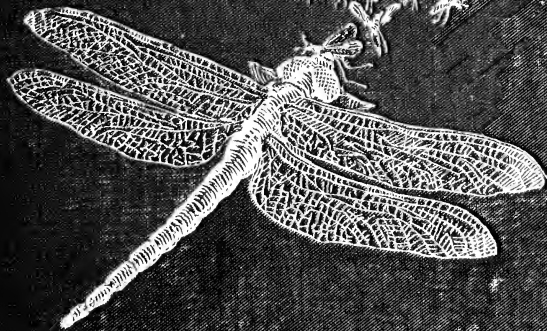


DRAGON-FLIES
vs.
MOSQUITOES



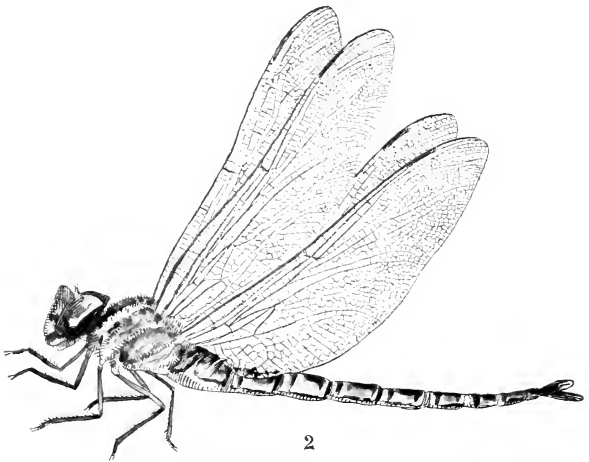
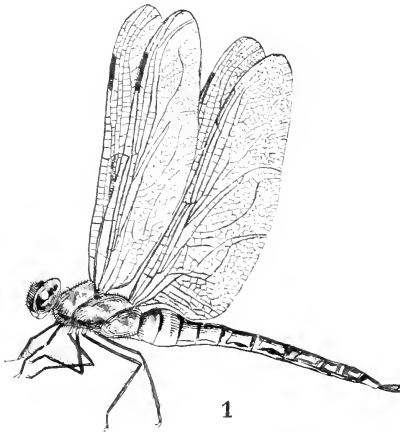
THE LAMBORN
PRIZE ESSAYS







J. W. Lentz
419 Broad St.
Newark, N.J.



MOSQUITO HAWKS, OR DRAGON FLIES.

1. *ANAX JUNIUS*. 2. *ÆSCHNA HEROS*.

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DRAGON FLIES vs. MOSQUITOES.

CAN THE MOSQUITO PEST BE MITIGATED?

STUDIES IN THE LIFE HISTORY OF IRRITATING INSECTS,
THEIR NATURAL ENEMIES, AND ARTIFICIAL CHECKS,

BY WORKING ENTOMOLOGISTS.

WITH AN INTRODUCTION BY

ROBERT H. LAMBORN, PH. D.



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PREFACE.

IN the early summer of 1889 a circular letter was issued to "The Working Entomologists of the Country," offering prizes for essays containing original investigations regarding methods of destroying the mosquito and the house fly.

The object of this effort was to bring about an intelligent discussion of the question, what natural enemies of these irritating insects may be easily and efficiently arrayed against them.

The voracious and harmless dragon fly, of which our country supplies so many beautiful varieties, was especially designated as possessing qualities that made it a promising subject for careful investigation.

The plan of destruction thus sought for is that so commonly observed in operation upon a grand scale in Nature, where individual species and whole families are swept out of existence through its operation.

The questions formulated in the circular letter were widely discussed. Newspapers and other periodicals treated them from a hundred standpoints—the grave—the gay—the lively—the serene—a volume could be filled with articles relating to the subject published in this country and in Europe.

The most valuable results were, as expected, those submitted by the scientific experts especially appealed to. The essays that they presented are the outgrowth of long years

spent in rearing insects, studying their transformations and habits, and of extensive special reading.

These essays were found so full of valuable scientific and popular information that the recommendation of the distinguished judges acting under the terms of the circular letter, to place them in a printed form before the public, has here been complied with. An article contributed by Dr. McCook to the "North American Review" is reproduced with especial view to his observations on mosquito-catching spiders. Captain Macauley of the United States Army furnishes an interesting chapter of his experience among the dragon flies and mosquitoes of the Upper Missouri.

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I.

INTRODUCTION.

BY ROBERT H. LAMBORN, PH. D.

INTRODUCTION.

A NUMBER of years ago, while engaged in building the Lake Superior and Mississippi Railroad, I made frequent excursions, in the capacity of director and treasurer of the company, through the swampy forests around the head of the great lake. Sitting in camp at supper time, I often, with a sentiment of gratitude, looked through my mosquito veil at the dragon flies that 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, the natives assured me, a mosquito "ceased from troubling." Afterwards I happened to observe an entomologist feeding a dragon fly that had eaten thirty house flies in rapid succession without lessening its voracity. What thought could be more natural than the one that came to me, that an artificial multiplication of dragon flies might accomplish a mitigation of the mosquito pest. The proposition was so evident that I sought among entomological works for some account of experiments tending to throw light on a subject of such enormous practical importance, but without result. Then followed consultation with men eminent among specialists whose lives are spent in the study of insects, and to my surprise the fact was developed that science had left almost untouched those investigations into

the life history of the dragon flies that would enable a competent opinion to be formed as to the possibility of making my suggestion practically useful.

From Dr. Uhler, of Baltimore, the highest American authority in the great class to which the "mosquito hawk" belongs, the Neuroptera, I received the following:—

“BALTIMORE, July 16th, 1889.

“Permit me to say that you have taken hold of one of the hobbies of my young manhood, in which I have never ceased to take an interest, and that is the development of the Odonata in our rivers and marsh ditches to such an extent as to greatly reduce the number of mosquito larvæ, as well as those of other pestiferous Diptera which develop in such places.

“How extensively this can be done I do not know; but as I have raised all the common forms of our Atlantic coastal plain region, I know that the dragon fly larvæ can be reared in vast numbers.

“Of course, you know that each locality supports its own species, and the forms which develop in the brackish drains and pools near tide, where they are covered twice each day by salt water, cannot flourish in fresh water. Accordingly, for the littoral belt from Long Island to Beaufort, N. C., I would select *Diplax berenice*, *Libellula auripennis*, and *Mezothemis longipennis*. For the region next inland from this, multitudes of common species could be had, such as *Anax junius*, *Æschna heros*, *Libellula pulchella*, *L. luctuosa*, *L. semifasciata*, *Plathemis trimaculata*, and most of the species of *Diplax*. In the clear streams which rush down from the hills, *Cordulia*,

Epitheca, and Gomphus prevail. In order to raise any of the species, Cyprinodonts and all other carnivorous fishes will have to be excluded.

“I agree with you that the mosquito nuisance might be greatly lessened by filling the mosquito breeding waters with the larvæ of dragon flies.

“I believe this might be done by securing vast numbers of the eggs of dragon flies, protecting them until hatched, and then turning them loose in the waters where the mosquitoes breed most abundantly.

“Along the seacoast, however, most of the eggs and hibernating female mosquitoes might be exterminated by burning the grass, in early cold weather of autumn, all over the marshes.

“Permit me to say that I hope you will offer the prize, as stated in your letter, and agitate the subject quite extensively.

Yours sincerely,

“P. R. UHLER.”

The Rev. Dr. McCook, the first arachnologist of the country, took time from his great treatise on “American Spiders and their Spinningwork” to send me this appreciative note :—

“I have received your communication of July 2d with very great interest. * * * As to the matter of dragon flies—you have certainly hit upon something that has in it immeasurable possibilities. If the dragon fly can be domesticated and utilized to destroy the mosquito along the New Jersey coast it will render available and valuable millions of property now comparatively useless, and it will add to the comfort of visitors to the ‘many

sounding sea' more than can possibly be expressed. I certainly agree with the learned gentlemen of Harvard and Yale with whom you have communicated, that the subject is at least worthy of careful investigation. I know of no experiments in the propagation of these insects. I am plunged over head and ears in my 'American Spiders and their Spinningwork.' It is the consummation of fifteen years of labor and observation, and now I am preparing hundreds of engravings and colored figures. I can be of little assistance to you, but be assured of my cordial sympathy. It is, of course, possible that the experimentation will result in nothing practicable; but some of the most helpful schemes for the relief of mankind have begun with less promise than this which you propose. Undoubtedly many failures must be the inevitable accompaniment of a few successes; and who knows which will be the success and which the failure?"

Prof. Cope, editor of the "American Naturalist," whose knowledge of almost every branch of natural history is so exact that his general statements have an unusual value, wrote on the 9th of July: "A prize for a carefully prepared practical essay on the means of multiplication of the larger predaceous Libellulidae would be apt to bring out something good."

Not a little encouragement toward an endeavor to turn additional scientific light upon the question at issue was received by finding in a publication of one of our highest entomological authorities this statement:—

"Little, almost nothing, is known regarding the habits of the dragon flies, and any one who can spend the necessary time and patience in rearing them so as to trace up

the different stages of the larvæ to the adult fly, and describe and figure them accurately, will do a good service to science."

From Dr. Packard, whose original investigations into the metamorphoses of the house fly are so highly appreciated by scientific students, and whose publications have done so much toward rendering the study of American insects systematic and popular, I received upon his return from Europe the following: "* * * I am glad you have offered the prize. I hope it will elicit a great deal of good observational work as to just what good dragon flies and others do in reducing the numbers of mosquitoes. As to house flies, I think that something practical can be done, as the evil is more easily reached, since they breed in stables, and by combined action their number can be diminished. I am sure that the offer of the prize will do a great deal of good."

After assuring myself, by consultation with the highest authorities, that the extensive and artificial propagation and liberation of dragon flies could result in no conceivable harm, the following circular was issued:—

"TO THE WORKING ENTOMOLOGISTS OF THE COUNTRY :

"Mosquitoes and house flies are, perhaps, the most numerous, widely distributed, and persistent of the creatures that attack the health and comfort of human beings. Of their attacks upon our comfort every one is aware. Scientific investigation favors the belief that tuberculosis and ophthalmia are carried from diseased persons to healthy ones by the house fly, and German experimenters have shown that serious blood maladies may be transmitted by the mosquito.

“Certainly, therefore, any suggestion, however remote, of a means of decreasing the numbers of or exterminating these pests should be followed with all possible skill and patience. I have observed dragon flies gathering in scores around my camp in Minnesota to feed on the mosquitoes. I recently saw a dragon fly that had devoured over thirty house flies still voracious for more. Entomologists have observed the larvæ of the dragon fly swallowing undeveloped mosquitoes in large numbers. Now, may we not have in the active, voracious, harmless ‘mosquito hawk’ an agency for greatly diminishing the numbers of the smaller insects?

“Prof. Baird’s success in producing millions of healthy fish in a few laboratory boxes and jars; the propagation of silk worms by scores of millions from eggs carried half around the world to Italy; the success of the plan for breeding foreign bumble bees in Australasia to fertilize the red clover—these and many other similar facts seem to show that scientific methods have reached a stage where it is reasonable to hope that a plan may be devised whereby whole tribes of noxious insects may be exterminated by the artificial multiplication of their innoxious enemies.

“Not being an entomologist, I have consulted with several distinguished students of that science as to the best means of reaching some practical result in the direction above indicated, and they agree with me that the following preliminary step may be usefully taken: For the purpose of drawing the attention of entomologists to the subject mentioned, I have placed in the hands of Morris K. Jesup, Esq., President of the American Museum of Natural History, New York City, \$200 to be paid by him in three prizes of \$150, \$30, and \$20 for the three

best essays based on original observations and experiments on the destruction of mosquitoes and flies by other insects.

“The following suggestions are made as to the direction in which the investigation should be carried and the essay formulated.

“1. Observations and experiments upon various insects that destroy mosquitoes and house flies, stating the method of and capacity of destruction.

“2. Observations and experiments to determine the best dragon flies to be artificially multiplied for the two above named objects—probably species of *Æschna*, *Libellula*, or *Diplax*.

“3. Give detailed statements of the habits and life history of the species chosen, based on original and careful experiments and observations.

“4. Suggest a plan for breeding the insects in large numbers; with a sketch of apparatus, and estimated cost of producing them per thousand.

“5. Formulate a plan for using the insects in the larva, pupa, or perfect state for the destruction of mosquitoes and flies (a) in houses, (b) in cities, (c) in neighborhoods.

“The prizes will be awarded after careful consideration by Dr. Henry C. McCook, Vice-President of the Academy of Natural Sciences of Philadelphia and Vice-President of the American Entomological Society, and Dr. J. S. Newberry, President of the New York Academy of Sciences, Professor of Geology of Columbia College, and late Chief of the Geological Survey of Ohio.

“In awarding the prizes, clearness of statement obtained by accompanying sketches, and new and purely scientific facts in the life history of the Libellulidae, of which so little is known, will be duly considered. All the essays

received may be published wholly or in part, at the discretion of the judges, and full credit will in all cases be given to each observer. The essays should be forwarded by December 1st, 1889, to Mr. J. H. Winser, at the American Museum of Natural History, Seventy-seventh Street and Eighth Avenue, New York, to whom all communications should be addressed.

“ROBERT H. LAMBORN,
“32 Nassau Street, N. Y.

“JULY 15th, 1889.”

The short period given to work out and answer the complicated questions set forth by the circular was evident to every one, and to no one more clearly than to its author. But that the time accorded was well used by those entering upon the investigation, every one reading the essays appended will be convinced, and in awarding the prizes the distinguished judges placed on record their appreciation of the value of the results secured and methods pursued. They say:—

“Under the circumstances, and after careful consideration, your committee have awarded the first prize to Mrs. Carrie B. Aaron, 1832 Pine Street, Philadelphia, and decided that the second and third prizes should be divided equally between Mr. Archibald C. Weeks, 120 Broadway, New York, and Mr. William Bentenmüller, 182 East Seventy-sixth Street, New York.

“The decision to divide the second and third prizes was determined by the fact that while Mr. Bentenmüller’s paper exhibited a vast amount of painstaking study and laborious research of the authorities bearing upon the subject, that of Mr. Weeks conformed more closely to the

terms of the circular note under which entomologists were asked to compete for the prizes. This fact, together with the merits of his composition, seem to be a fair offset to the greater labor bestowed upon the paper of Mr. Beutenmüller.

“We have pleasure in bearing testimony to the fact which has appeared from the reading of the papers submitted, that the various essayists have pursued their studies in a conscientious spirit and with painstaking methods worthy of high commendation, and which give promise that future investigations and studies, should they seem to be justified, will be conducted in a manner and with results in every way creditable to American entomologists.

“Very truly yours,

“HENRY C. MCCOOK,
“J. S. NEWBERRY.”

It is not too much to say that the work done by Mrs. Aaron, Mr. Weeks, and Mr. Beutenmüller is an honor to science, to American entomologists, and to themselves.

It is important that this good work should be recorded in an easily accessible and durable form and lodged upon the shelves of our libraries. The subject is one of great possibilities, and, whatever the final outcome may be, each step should be faithfully written out and the record carefully preserved.

It is not to be supposed that the investigations here begun will rest with this publication. And in order that any observer may continue the subject to greater completeness, reasonably clear that he is in possession of all that the world has done in this connection up to the year 1890,

a careful bibliography has been prepared which will refer him to all important records, in American and European publications, that bear upon the habits of the dragon fly, and several other questions herein handled.

The testimony given in Capt. Macauley's letter is similar to that of many residents in the treeless country west of Lake Superior, and a thorough study of the characteristics of the Libellulidæ of that great region will be awaited with interest.

While the present one is probably the first systematic attempt to array the Odonata against the Diptera, it is far from being the first time that the method adopted by Cortez in his much bepraised contest in Mexico, of arraying tribe against tribe, has been adopted with advantage by entomologists.

The brilliant success attending Dr. C. V. Riley's plan of pitting the Coccinellidæ against the Coccidæ by colonizing the Australian *Vedalia cardinalis* in California, there to attack and exterminate the destructive little insect, the Fluted scale (*Icerya purchasi*), that bid fair to ruin the orange industry of the Pacific coast, is the most recent example to the point, and grateful Californians will long honor the scientist and the wise Government that originates and disseminates knowledge of such inestimable value.

The automatic method is, I am convinced, the only one science in its present state designates as likely to finally succeed in the warfare of extermination that humanity has entered upon against the smaller noxious organisms, and to this end the life history of every animate thing becomes a matter of public importance. If Riley saved the orange orchards of a nation by thoroughly studying the

habits of an inconspicuous beetle, who shall say that any living thing is too minute or too humble to be unworthy of the gravest study of the wisest minds. "He prayeth best who loveth best all things, both great and small." A spot of mould, a streak on a boulder, a tiny insect, may, through the exhaustive research of a modern scientist, possess the potentiality of blessing a famishing province with the joy of permanent abundance.

JULY 4th, 1890.

II.

THE DIPTEROUS ENEMIES OF MAN:

THEIR LIFE HISTORIES AND STRUCTURE.

A TREATISE ON

THEIR EXTERMINATION.

By MRS. C. B. AARON.

THE DIPTEROUS ENEMIES OF MAN.

IN this, the century of invention and age of scientific discovery, few more permanent records will be left on the page of history than that which contains the accounts of man's successful efforts to master the insect world and turn the strength or weakness of the various important species to his use.

The stores of wealth accumulated by some all powerful syndicate, or wrenched from a helpless community by a seemingly resistless trust, sink into insignificance when compared with the vast amounts in value which are annually annihilated by the noxious insects of this continent. So great has been the recuperative energy of the American people, and so easy has it seemed in the past to prepare crops in sufficiency to allow for a large percentage of destruction, that the annual loss has not appealed to them, as a people, but has simply touched the pocket book of the individual loser and attracted the attention of the economic entomologist. The great volume of work which has been done and is now in progress in our various State experiment stations, and on a still larger scale at our National Department of Entomology at Washington, is far beyond the ken of the public, and is even too little appreciated by many entomologists, to some of whom the work of suggesting new genera and species is far more fascinating. The records of the agencies for relieving man of the dread effects of his insect

enemies, which are now estimated at fifteen thousand species, teem with the accounts of successful experiments. The thousands of abortive attempts, which of necessity were required to lead to final success, are not narrated, and the magnitude of the work which they entailed is thus lost sight of. In the United States, so free are we from a parental form of government, national aid is by no means a necessity, nor is it a prime factor in a large proportion of the results coming from these lines of inquiry.

The public spiritedness of private individuals has been productive of much which is now recorded of the life histories of noxious insects. It is to this class of incentives to economic research that this essay, and others with which it will compete, is to be attributed. Much has been written, far more has been said in scientific gatherings, of the mosquito and fly as destroyers of human comfort; but the question of their utility is still unsettled, and it is to the generosity of Dr. Robert H. Lamborn that the present discussion is due. If anything of value be added to our present knowledge of these pests, the honor and credit should be his. The circular note issued by him on the 15th of last July has brought about much beneficial discussion, which must lead to a clearer understanding of the problem. We propose to discuss this subject in the following order:—

1. Life Histories and Structure.
2. The Medical Problem.
3. Possibilities and Cost.
4. A Bibliography.

As much that follows may be made more comprehensible by figures of the creatures or articles under discus-

sion, such have been added, made from original studies of the natural object during the past four months. Where any of these illustrations are taken from the works of other authors, credit will be given on the leaf facing the plate.

Equally important to a clear understanding of this entire discussion is a knowledge of the literature on the subject. A bibliography of this sort will be found in the appendix, with the method of its selection fully explained. The system of reference numbers used is probably the most convenient attainable. A full reference in parenthesis each time an authority is quoted is cumbersome, and foot notes are more or less distracting to the attention; consequently the bibliographical list has been arranged alphabetically by authors or journals, and chronologically under each heading. These separate references have been numbered consecutively, and these numbers follow an authority when quoted.

I.

LIFE HISTORIES AND STRUCTURE OF CULEX.

THE Culicidæ for the most part prefer stagnant water for their breeding places; not, it is believed, for any advantages in the food producing effect of such water, but because the enemies most dreaded by them are only capable of prolonged life in fresher water. They have been observed living in considerable numbers, in all stages up to the imago, in a puddle of water, eight inches square and one inch deep, made by the rain in an iron pulley in a foundry yard. They are also to be observed teeming to overcrowding in the hoof holes in boggy cow pastures. But the shallows occasionally overflowed and replenished by rivulets in swamps, the stagnant pools formed by ditches without outlets, and the vastly more numerous murky pools made by the joining of tufts of grass in marshes, are the usual breeding places in the rural districts. In village and urban localities, rain tanks, undrained gutters, badly paved damp byways, and garden ditches are the most fruitful places for recruiting their numbers. These surroundings are selected by the female with a view to the fact that from three to four weeks will be required to perfect the changes from the egg to the imago; and they must be situated so as to receive sufficient water from rain or outside overflow to replenish the evaporation or soaking into the ground. In this selection

the female shows the usual instinct, which is so noticeable in insect economies. E. A. Butler, "Ent. of Pond,"¹¹ has described the oviposition of *Culex* so graphically that no excuse is necessary for inserting it here. "Finding some floating shred of straw, stick, grass, or other support, the expectant mother rests her two fore legs on this, allows the next pair gently to touch the water, and crosses the third pair behind, to form a sort of vise in which to hold the eggs as they are deposited. Then a long oval egg is lodged in the angle formed by the crossed legs, with its longer diameter vertical; another following it is glued on to the side of the first in a similar position, and so on till some two or three hundred are fastened into a sort of raft, or rather lifeboat, as the mass is curved upward at each end. Then the little vessel is abandoned to the mercy of winds and wavelets, and so floats about for a few days, benefiting by sun and air, till the growing embryos, finding their quarters too close, push open a kind of trapdoor in the floor of the egg, and take a dive at once into a watery home."

When hatched the larvæ hug the sides of pools and shallow margins; owing to the frequency with which they need to come to the surface for air, and the fact that they are not deepwater feeders, they are not usually found in the depths. Much of their time is spent at the surface with the orifice of the air tube just in contact with the air. (Plate II., Fig. 4.) Here they are easily frightened by any stir or motion from above, but pay little attention to any dangers which may menace them from the water. The approach of other insects or of small fish seems to afford them no uneasiness.

Very little is known of the feeding habits of Culicid larvæ; the statement that they are scavengers, feeding on

decaying substances in stagnant water, is frequently met in popular works, but there seems to be little that is conclusive in these statements, and we have been unable by observation to add anything of value. That they do feed on minute animals, such as Cyclops, Cypris, etc., we have observed, and that they have destroyed young trout is attested by Westwood¹⁷⁵ and others.

The external breathing apparatus of the larval Cnecid consists of a straight tube branching at an obtuse angle near the anal extremity (Plate II., Fig. 1); this communicates internally with the tracheal system. To use this breathing tube, the larva needs simply to float at the surface, head downward and the orifice in contact with the air. After three or four transformations the pupal stage is reached (Plate II., Fig. 2), and here a remarkable change in the appearance takes place. The head, thorax, legs, and wings all being folded in one mass, and the abdominal segments being left free for the purpose of navigation, the pupa has a very top heavy and clumsy appearance, although it is quite as active as the larva, but not capable of feeding.

Butler¹¹ describes an interesting feature of this period as follows: "The most astonishing change of all is that which takes place in the respiratory system; the entrance to this is now transferred to the opposite end of the body, and appears as two small twisted horns projecting from the gigantic head. * * * Therefore it turns a somersault in the water, and henceforth goes about head uppermost." (Plate II., Fig. 3.) This change takes place at the surface of the water within two hours.

Authorities vary in their statements of the time passed in the pupal state, but our observations on *C. damnosus*,

the commonest species in this locality, show that only two days are needed in favorable weather in August; perhaps, a longer period is required in the cooler weather of spring and fall.

As the insect approaches the imago stage it needs more air, and consequently remains altogether at the surface, unless disturbed from above; it drops quickly below and rises again almost immediately.

The newly formed pupa is usually much paler than that of a few hours' existence, and its bulk also appears to increase slightly. When the period of emergence arrives the abdominal segments are distended backwards on the surface, and the pupa cracks through the middle of the cephalothoracic region. Now the imago may be seen to rapidly extricate itself, using its long hind legs to push with, and balancing itself with the anterior and middle pairs. Though it can stand for ten or fifteen minutes on the surface free from the skin, the surface must be very smooth or covered with a scum; a high wind is sure destruction, and even small ripples make the task a hazardous one. After the puparium is abandoned the imago stands lightly on the water, holding up first one leg and then another, evidently drying the feet; suddenly it takes wing and disappears. This is the method in an open pond or a tank; where grass or other growth abounds along the margins, it is usual for the imago to emerge in such a position as to crawl directly up on some stalk and proceed more rapidly. We have seen *C. damnosus* fly away in four and a half minutes from the time of emergence, when there was no herbage to facilitate the proceeding. From this time forth the principal object in the remaining brief existence is the duty of reproduction.

To suppose that the tormenting of man occupies any considerable time in the mosquito economy is certainly a mistake. It is only the female (Plate II., Fig. 5) which can thus make our lives miserable. In repeated examinations of hundreds of individual specimens we have failed to find a single male with a distended abdomen containing human blood, and subsequent microscopical study has shown the male proboscis incapable of drawing blood. Dr. Bonavia,⁸ in a readable article entitled "Do Mosquitoes Live on Animal or Vegetable Juices?" relates the following: "On one occasion I put a plant in a pot in my room. At night I happened to pass by it with a lamp, and found its leaves covered with mosquitoes, who appeared to me to be sucking the juice of the plant. Here, I think, I had discovered a clue to the real nature of the mosquito. I think that naturally the perfect insect lives by sucking the juices of plants by night. * * * With the foregoing clues I think now the statements of travelers and sportsmen in the jungles of Burmah, and of trappers in the backwoods of America and Canada, become intelligible."

Dr. Dimmock²⁴ has, by keeping a male mosquito several days, had the satisfaction of seeing it drink freely from a moist cloth. We have observed a male to alight several times on a hand held perfectly motionless, and after searching for some unfound desideratum, fly off to a water pitcher and dip its proboscis in a drop on the rim. We have also noticed a female on a molasses jug imbibe freely. These habits, and others too numerous to here detail, as well as the fact that myriads of these pests are born in such localities as never to enable them to find human victims, seem to show that bloodsucking is an acquired taste to the female alone; and even to her it is a

secondary consideration, a means to an end—the pursuit of sustenance needed until the reproductive period is passed and her brief span is finished.

The irritating effect of the mosquito bite has long been a source of much conflicting testimony. Especially in the popular prints has the “sting of a gnat” figured as a formidable weapon, and at times has it assumed the proportions of a veritable hypodermic syringe, loaded with the most virulent poison. From Westwood’s Classification we extract the following: “It is supposed that at the same time it instills into the wound a venomous liquid, which, while it enables the blood to flow faster, is the chief cause of the trouble.” Packard,¹¹⁴ after quoting the above, says: “So far as we are aware, no poison glands have been demonstrated to exist in the head of flies or other six footed insects, and we are disposed to doubt whether any poison is poured into the wound, and to question whether the barbed mandibles are not sufficient to produce the irritation ordinarily accompanying the punctured wound.” Two biologists of our own country have contributed much of our present knowledge of the sucking apparatus in *Culex*. Dr. George Dimmock,²⁴ of Cambridge, and Prof. Macloskie, of Princeton,⁸³ have each given the entomological world the benefit of patient research and study in this department of Dipterology. To the latter belongs the credit of discovering the existence and probable nature of certain glands in the antero inferior region of the prothorax of *Culex*, which evidently empty through a duct which, in turn, empties into the reservoir at the base of the hypopharynx. Says Prof. Macloskie: “The secret was first discovered by an observation of fine droplets of a yellow, oily looking fluid

escaping from the apex of the hypopharynx." This seems to settle the opinion hazarded by Dr. Dimmock²⁴ when he says that he believes, "without as yet being able to give anatomical proof of it, that the hypopharynx of *Culex* contains a duct that pours out its poisonous saliva." We have copied such of the figures of these authors as illustrate the discoveries made; notes of explanation on the page facing the plate make further mention unnecessary.

It has been demonstrated in many instances that if the female be allowed to fill her abdomen and allowed to fly away unmolested, the effect of the poison is very much reduced; in some cases entirely so. It is the interrupted performance which produces the greatest itching. This seems to prove that, if allowed to finish her meal undisturbed, the mosquito will pump back the venemous salivary secretion, whereas a quick withdrawal of the tube results in the consequent abandonment of this irritating fluid to be a source of annoyance in the flesh.

Were our *Culicid* foes only occasional visitants we would not be greatly occupied with a means for their extermination; it is their overpowering number which constitutes the chief terror. Aside from their rapidly succeeding broods, their nonmigratory and hibernating tendencies are especially calculated to keep up the enormous numbers which Nature seems to regard as their full quota.

Commenting on the latter, Westwood¹⁷³ and Young¹⁸⁰ call attention to the fact that various species of the mosquito tribe hibernate in houses. Our own experiments in raising many thousands of these insects have resulted in the presence at this writing of a large number of three species of *Culex* in our cellar.

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 venturesome Tabanidæ, will be found hovering on the leeward side of houses, sand dunes, and thick foliage. In the meadows south of Atlantic City, New Jersey, 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—whether from land or sea—*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 swarm upon swarm 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.

So local are the ranges of the Culicidae, that every observer has noted that they may be seen year after year, flying in tall columns, and breeding swarms in exactly the same localities as the year previous. "E. L. A."² describes these swarms as "so vast that they looked like the ascending smoke of a campfire, and so numerous that the hum of their myriad tiny wings could be heard at least thirty yards." Magis⁸⁵ also writes of this habit.

Unfortunately for us, these flights occur at an hour when even the most untiring Odonat has betaken himself to his night's rest, and only the swallow or whippoorwill is likely to make any effective attack on these hordes. This must be remembered when we come to a final discussion of the dragon fly as a mosquito destroyer; their times and habits of flight have but little in common; not only their daily period of flight but the annual period as well must be noted in this connection. One or two broods of mosquitoes appear in the middle Atlantic seaboard region after the Odonats have become very rare or have entirely disappeared.

It now remains merely to allude to mosquitoes as pests in other ways than as biters, and our treatment of their life history is finished. As harborers of hæmatozoa their menacing character will be discussed in our chapter on the medical aspect of this subject.

That they have frequently interfered with the arts and

manufactures by their great numbers, J. W. Clarke¹⁶ and others have narrated. Perhaps the most surprising charge made against them is that of Murray,¹⁰¹ who states that he has observed the imago of *Culex* light upon baby trout which come to the surface of the water, and literally pump out their unsuspecting little brains before they could escape.

Since writing the above we have been able to observe the poison droplets alluded to by Macloskie,⁸³ see page 33, and have been successful in getting this minute amount of fluid on the point of a needle. An attempt to inoculate ourselves with the poison was, however, not successful, owing probably to the inferiority of the needle as an injector compared with the delicate hypopharynx.

II.

LIFE HISTORIES AND STRUCTURE OF MUSCA AND ALLIES.

It is not our purpose to devote as much space to the early stages and habits of *Musca* and its allies as has been given to *Culex*, for the following reasons:—

1. They are better understood and the descriptions in the various text books of the science are fuller and more accurate in detail.

2. In the larval or maggot stage they are undoubtedly, as a family, not open to the attacks of the Odonata, and, consequently, only such habits of life which place them in the enemy's reach need be discussed.

3. In the imago state the most casual observer has a fair opportunity to judge for himself just how far the house fly

is liable to attack from insect enemies ; such liability can be left to another chapter for discussion.

As an introduction to our consideration of these insects it is well to premise our account by the statement that we will take *Musca domestica* as the type of its group, and all that hereafter follows will apply to that species, unless it is otherwise stated.

M. domestica of this country is undoubtedly the same insect as the *domestica* of Europe, its identity and introduction to this country having furnished the systematists much food for interesting discussion in the past.

One peculiar item of its systematic position is that the name is misleading ; Prof. Snow¹⁵² has pointed out that *Domestica* is the first visitor at any camp in our backwoods in North America, no matter how remote from civilization ; and in using the sweeping net for minute insects in grass, shrubs, or trees we find *Domestica* well represented ; and it can as well be called the commonest insect away from domestic surroundings as in our houses. Packard¹⁰⁸ has given us a full description of the oviposition of *Musca*, the principal facts gleaned from which are as follows : Fresh horse manure, with plenty of heat and moisture, furnishes the best food for the young maggot. From a hundred to a hundred and fifty eggs are deposited in irregular, loose sacs, usually within eighteen hours, and hatching in twenty-four hours or less. The maggots moult twice ; the three stages of larval development being of the following periods : first stage, one day ; second stage, from twenty-four to thirty-six hours ; third stage, three or four days. To this maximum period of seven days is to be added the same length of time for the pupal life ; thus it will be seen that fifteen or sixteen days

are required for the entire development from egg to imago.

These stages are illustrated in Plate IV., Figs. 8 and 9.

The rapid changes following so rapidly in generation after generation make it impossible for the student to separate broods, and it is therefore easy to account for the immense numbers of house flies which are everywhere and always present. Even in years when flies are, by comparison with former seasons, said to be scarce, they are still present in sufficient numbers to be safely considered the most plentiful insect in America. Harrington⁵² in a readable, popular account quotes Linnè to the effect that three flesh flies "with their progeny could eat up a dead horse as quickly as a lion could." This truth, impossible as it seems at first, coming as it does from the great naturalist, explains why, when the season favors and its natural enemies are greatly abated in numbers, these insects—the whole tribe of *Muscinae*—are to be found in swarms defying computation. S. A. Stewart¹⁵⁹ speaks of a "plague of flies" in Ireland in 1878, so extensive that stones and plants for about one and a half miles along the Bann were completely covered with the pupa cases, from which "they issued in millions and attacked both men and cattle." In a few days the ground was strewn with the dead flies, in some places lying three inches deep. J. H. Smith¹⁴⁸ writes of a column of flies, thought to be *M. domestica*, issuing from a crack in the wall of the palace at Delhi, India. In a band about seven inches wide they marched out of the shadow of the building, and as soon as their wings dried in the warm sunlight took flight. They could not be made to alter their course by any form of tormenting or destruction which occurred

to the narrator. "Nature"¹⁸¹ published a résumé of the newspaper accounts of the fly plague which occurred during August and early September, 1880, in Canada and northern New York. The buzzing of these swarms was distinctly heard by many who missed seeing them. The swarms resembled dark clouds and lasted many hours while passing. The steamer "Martin," on the Hudson, near Newburgh, New York, encountered what seemed a "great drift of black snow, reaching from shore to shore, as far as the eye could reach. There were millions upon millions of these flies, and they hurried northward as thick as snowflakes driven by a strong wind."

The popular and semiscientific journals abound with accounts like the above, and many references could be made; but these will suffice. When we come to that phase of its life histories in which the testimony for or against the unobstructed existence of *M. domestica* is to be gleaned, we find that comparatively little has yet been discovered. In our chapter on the medical and economic character of the subject a full discussion will be found.

"Doubtless the great majority of people," says Harrington,⁵² "would affirm that the house fly is in the habit of biting persons. But, from the formation of the fly's proboscis (Plate IV., Fig. 5) with its feebly developed mandibles, it hardly seems probable that the skin could be punctured. * * * However this may be, it appears that the culprit who thus assails, especially during showery weather and late in the season, is a distinct species, although it so closely resembles *M. domestica*. Its name is *Stomoxys calcitrans*, and it is distinguished by its long horny beak, which, as pointed out by De Geer, has a "long and very sharp lancet sliding in a groove, while the fleshy

sucking disks at the extremity of the proboscis are small and inconspicuous as compared with those of the house fly."

Plate IV., Figs. 4, 6, gives an idea of the differences between this savage genus of biters and the more numerous, but less rabid, *Musca*. In describing the wonderful adaptability of the mouth parts, Packard (Guide, page 409) says: "In the proboscis of the house fly the hard parts are obsolete, and instead we have a fleshy, tongue-like organ (Plate IV., Fig. 5), bent up underneath the head when at rest, the maxillæ are minute, and the palpi (mp) are single jointed, and the mandibles (m) comparatively useless, small, and short compared with the lancet like jaws of the mosquito or horse fly. The structure of the tongue itself (labium, l) is most curious. When the fly settles upon a lump of sugar, or other sweet object, it unbends its tongue, extends it, and the broad, knob like end divides into two flat muscular leaves (l), which thus present a sucker-like surface, with which the fly laps up liquid sweets. * * * The inside of this broad, fleshy expansion is rough like a rasp, and, as Newport states, 'is easily employed by the insect in scraping or tearing delicate surfaces.'"

The foregoing graphic description of this organ, the accuracy of which we have carefully verified by minute examination, seems to demonstrate that the house fly is not a biter.

Alluding to its *raison d'être*, a subject which fittingly closes this chapter, the same author¹¹¹ (page 479) writes: "It should be remembered that flies have an infancy as maggots, and the loathsome life they lead as scavengers cleanses and purifies the August air, and lowers the death rate of our cities and towns. Thus the young of the

house fly, the flesh fly, and the blow fly, with their thousand allies, are doing something towards purifying the pestilential air and averting the summer brood of cholera, diphtheria, and typhoid fevers which descend like harpies upon the towns and cities. This useful species, to which man owes more than he can readily estimate, and with which he can dispense only when the health of our cities and towns is looked after with greater vigilance and intelligence than is perhaps likely to be the case for several centuries to come."

As belonging less to life history and more to the domain of the medical question, we omit from this portion of the essay all mention of such species of Diptera as *Cestrus*, *Anthomyia*, et al., which are known to be inimical to the health and comfort of man by reason of the hypodermic or intestinal habits of their larvæ.

Several continental writers believe that the oily papillæ which enable flies to adhere to smooth surfaces, are the means of transporting disease. The fly's foot is illustrated Plate III., Fig. 4.

III.

LIFE HISTORIES AND STRUCTURE OF THE ODONATA.

IN approaching the life histories of the Odonata, we find ourselves confronted with a more complicated series of events, and a far more difficult problem to solve.

While the preparatory stages approximate those of the Culicidæ, the imagos, on the other hand, are possessed of habits which, on account of their powerful flight and wary nature, are extremely hard to observe.

Much which is now known is the result of chance observation, and the patient research of several seasons is needed to throw light on the subject now under our consideration. In their habits of flight the Odonata may be divided into three groups, and these are nearly classificatory in value, though not absolutely so. The first group, comprising such genera as *Agrion*, *Lestes*, *Calopteryx*, et al., usually known as the "hammer headed dragon flies" (Plate VI, Figs. 4, 5), frequent the grassy margins of pools and ponds, and the low bushes and shrubbery by swamps. Flying from stalk to stalk, darting after insects, they are typically the hawks of the minuter insect world. The second group, with true *Æschna* and *Corduligaster* as its principal representative genera (Plate I, Fig. 2), are high fliers and mighty knights of the upper air. They are the largest of their suborder. They haunt the tall shrubbery, the middle and upper portions of the trees, seldom come within easy reach of the collector, and are less frequently seen over the ponds and waterways. They are preëminently the enemies of all juicy winged insects which leave the lower levels in their flight. Seemingly, no insect is too large to tempt them to an onslaught, and this rapacious disposition is often the cause of many a midair conflict between two or more of their own kind. Their flight is more sustained than others of the Odonata; they seem to be absolutely untiring. From early morn until evening they are constantly on the wing, seldom resting save to devour their prey, and not always stopping for that. On account of their later hours it would seem that this branch of the family are best suited for an untiring warfare against the evening flying Diptera.

The third group, with the genera *Gomphus** and *Anax*† of the *Æschmina*, and *Cordulia*, *Tramia*, *Libellula*,* *Diplax*,* etc., of the *Libellulina*, is far the most diversified in its habits and numerous in both species and individuals. These dragon flies are nearly as swift on the wing as *Æschna*, but not capable of the sustained and lofty flights. Sunset finds most of them safely ensconced for the night, and they do not leave their dew bespangled couches as early as either the "hammer heads" or "high fliers." In their methods of oviposition there is but little latitude for variation. Uhler (Packard¹¹⁴) has observed *Libellula auripennis* drop a bunch of eggs while balancing herself just above the surface of the water, and the same insect he has seen settled upon the reeds in brackish water with her abdomen submerged and there attach a cluster of eggs. Others of the same genus fly at the water with a dash, striking the end of the abdomen, and deposit eggs on the surface. Todd,¹⁰² calling attention to this habit in a species of *Æschna*, suggests that it may serve as a bath to rid them of parasites. Davis,²² Dunn,²⁸ Weir,¹⁷⁰ Todd,¹⁰² and Aaron¹ have all noted the habits of various species which go beneath the water for some distance. Todd has seen a *Libellula* remain under water for half an hour depositing eggs on a stem. M'Lachlan⁹⁵ has called attention to *Agrion mercuriale* with a part of the abdomen incrustated with mud, caused by sinking its eggs in the mud left from dried up pools. Packard has observed *Perithemis domitia* depositing its eggs on floating refuse on a pond. Lacaze-Duthiers is quoted by Packard,¹⁷⁴ as authority for the fact that the *Agrions*

* See Plate VI, Figs. 4, 1, and 2.

† See Plate I, Fig. 1.

make a little notch in the plant for their eggs. With the exception of this last habit, all that has been narrated has been verified by our personal observation.

On the 12th of October five pairs of *Diplax rubicundula* were all together in a little bay hardly two feet square, which ran in from a reedy pool, depositing eggs so earnestly that the observer was allowed to approach very close. Two downward strokes of the abdomen seemed to be necessary to deposit the eggs, which floated for an instant, although some went at once to the bottom. We are of the opinion, based on personal observation, that this habit of ovipositing very materially aids the female in flight and thus enables her to elude the everwatchful frogs which lie in wait at such times. Many a hapless female and her carefully deposited cluster of eggs disappear down the cavernous gullet of the frog.

It is evidently with the view of preventing this catastrophe that the female of a species of *Æschna*, as related by Marchal,⁸⁸ has been observed to plaster its eggs with sand or mud at the margin of the pool. For the purposes of study, the eggs of the Odonata are readily obtained; gentle pressure on the abdomen of an egg laden female will furnish a few.

Owing to the protracted development, we have been unable to determine the exact length of time required for the eggs to hatch.

European entomologists give periods varying from six days to several months, the latter being the case when the winter is passed in this stage. A lot of *Diplax rubicundula* eggs obtained early this fall are yet unhatched and will probably pass the winter so. Packard¹¹⁴ has described

the egg development of *Diplax* minutely, and we can add nothing to his full details.

Odonat larvæ are sluggish and unable to make quick, well directed movements of the whole body. The powers of locomotion are very poor when their predatory habits are considered; the legs are feeble and used for crawling and burrowing in the mud. The larva, however, possesses a locomotory power which is derived from its ability to suddenly force out the water contained in its abdomen, thereby propelling the body forward for some distance; but this function is not entirely under control, the larva cannot always strike the desired point. It is here that a most remarkable structure plays an important part. On turning over one of these insects it will be found that the under lip is greatly enlarged and is folded over the mouth parts so as to earn the name of "mask." Plate V., Figs. 3 and 5, show how it is hinged, and the formidable extremity. It seems that all the muscular energy and powers of quick perception were attached to this organ. Nothing can exceed the rapidity with which the mask is shot forward and its helpless prey is seized. Then this arm-like lip is used as a fork to hold the food which it slowly feeds into the capacious jaws. The size and structure of this "mask" clearly indicate, in our opinion, that such puny victims as Culicid larvæ were never intended as the natural food to be seized by an appendage which is capable of catching and firmly holding prey quite as large as the insect to which the mask belongs. Packard¹¹⁴ regards the Odonata as scavengers; he says: "In the water they prey upon young mosquitoes and the larvæ of other noxious insects, * * * and cleanse the swamps of miasmata." If, as stated by the same author, mosquitoes

also destroy miasmata, the fact that Odonats feed upon them would seem to remove them from the category of useful scavengers. As a matter of fact we have been unable to get them to eat anything in the least decayed. Their preference is for fresh and living food. The Italian entomologists recommend pieces of fresh fish for feeding Odonata in captivity, but urge that they be supplied with fresh sweet food. Biro⁷ states that nearly fifty thousand young fish were destroyed by a species of Libellulina in a pond in Hungary. Riley and Howard¹³⁴ mention a case, on the authority of Mr. W. L. Jones, of Atlanta, Georgia, where the larvæ of *Anax junius* were found feeding on young carp. In our several aquaria we have studied the appetites of our larvæ under varying circumstances, and feel prepared to state that, even with thousands of *Culex* larvæ provided for them, the young Odonats will exhaust every other source of food first and then attack each other. This latter habit is a serious one when artificial propagation is to be considered. Poulton¹²⁰ thinks that cannibalism among larvæ frequently arises from scarcity of food, but our experience leads us to believe that they are cannibals from choice.

Species of *Agabus geoffria* and allied genera, and *Notonecta undulata*, furnish the young dragon fly with dainty food, and while there remain any of these the *Culex* larvæ are unmolested. The slender, soft bodied "wrigglers" usually succeed in eluding the rather ponderous apparatus evidently intended for larger, hard bodied game.

As the Odonat grows towards maturity (Plate V., Fig. 2) its form becomes more graceful and its movements less clumsy, but it is still sluggish and prefers to remain at the muddy bottom. Butler¹¹ thus describes this habit:

“When you have brought yourself to perform the disagreeable task of hauling out of a dirty pond a mass of slimy weeds and fetid mud, and have deposited it on the bank, you see the mass here and there heaving with the struggles of these ugly brutes as they work their way into daylight and drag their grimy bodies out of the tenacious and unsavory mess. What a contrast between this sordid life and the gay and brilliant existence of the shiny winged adult.”

How these creatures breathe is almost a mystery. Hagen⁴⁸ has described the wonderful apparatus which enables them to respire under any circumstances. Cabot¹² and Packard¹⁰⁷ also give details of the same, which are so full it is only necessary to refer the reader to those authors.

The duration of the stages from the egg to the imago has not been determined.

Enough is known, however, to lead us to believe that very few species, if any, are two brooded. Most of the species are known to live in the imago state a long while, and oviposition is carried on for a number of days by the same individual. Larvæ of the same brood develop unequally, some far out-tripping their fellows in rapid growth and utilizing their tardy companions as the principal articles in their bill of fare. From nine to ten months is required to perfect the dragon fly, whose winged existence is enjoyed but for a few weeks at most.

When the time for the imago to emerge arrives, the pupa climbs out of the water on some stalk or dry place; the back yawns and the perfect insect, a knight in mail, a very prince of the insect realm, emerges, ready to “tilt against the field.”

Now our Odonats have reached the period in their

tedious and varied existence when, if ever, they are to do the most effective work in thinning the Culicid ranks. Enough has been written of the hours and habits of flight. The season of their usefulness is for the most part restricted to the warm weather. They become rarer about the time that mosquitoes are the most obnoxious.

In the matter of flight they are very local, seldom straying from their accustomed haunts, save in case of migration. To us it seems impossible to conceive that they could ever be brought to frequent deep woods or city streets; yet these widely dissimilar localities are each fertile breeding places for *Culex*.

In their feeding habits the Odonats are very difficult to watch. Our experiments and observations lead us to believe that they prefer robust, meaty insects, such as grasshoppers and bugs. The study of their food preferences in confinement is most misleading. So rapacious are they, so fierce in disposition, and so well adapted for any kind of chewing, that they will eat anything which is forced upon their notice. In one case an *Anax junius* devoured with evident relish seven of its own abdominal segments which were severed from the rest of its body.

The habit of migration among dragon flies will militate against their efficiency as mosquito destroyers. This peculiarity has drawn the attention of entomologists for many years past. Newton,¹⁰² Van Hasslet,¹⁶⁶ Kuwert,⁶³ Van Bemmelen,¹⁶⁵ and Chyzer¹⁵ have all noted extensive migrations in Sweden, Denmark, The Hague, Rotterdam, and Hungary; in one instance lasting four days. Matthew,⁹⁰ Schaupp,¹⁴³ and Fromont⁴⁰ have observed migrating swarms at sea, far from land. Torrey¹⁶³ gives an account of a flight at Weymouth, Massachusetts, extending

a quarter of a mile wide and lasting from 8 A. M. until it was too dark at night to see them. A close observer watched a flight at Cape May this season, and adds very pertinently, "The mosquitoes were as plentiful at the time and afterwards."

Southeastern Texas and east Tennessee are localities where migrating Odonats are no uncommon spectacle.

Several of the above writers have attributed this most interesting habit to the fact that the ponds drying up in the neighborhood caused them to abandon their haunts in self defense. Such an explanation must surely fail near the seaboard, where many of these swarms occurred. Be the cause what it may, it will be a difficult habit to overcome in case these insects are bred in wholesale quantities.

Finally, we must consider the enemies of the Odonata. In the egg state we have found a small red mite, an Arachnid, which skims rapidly over the water in search of an Odonat egg, upon which it either deposits an egg or excavates it for immediate nourishment. A minute Diptron, genus unknown, was also seen to oviposit on the egg of *Diplax*.

In laying her eggs the dragon fly has always to guard against frogs, as we have already noted. In the larval state their enemies are considerably multiplied. *Belostoma*, *Notonecta*, and *Ranatra* and insects of that ilk all prey upon the young larvæ; they in turn return the attention when they reach the latter stages. Forbes³⁹ points out their liability to attacks from fish. The fact that they are in this stage their own worst enemy has been mentioned.

To the perfect dragon fly, we have been unable to find any constant enemy save the birds; even they do not seem to select this food with much relish.

Hersey⁵⁴ considers them favorite food with the fly catchers; McLachlan⁹⁴ believes these attacks only incidental; and Thomas discusses the swallow in this capacity.

IV.

THE MEDICAL PROBLEM.

THE disagreement between the two schools of students relative to the annihilation of *Culex* and *Musca* seems to be an almost irreconcilable one with the present light which we now possess.

A large and eminent school of scientists believe it unsafe to overthrow the equipoise of Nature, or, more properly speaking, that due proportion of individuals in the animal kingdom. They urge that Nature has eliminated all useless species and that there is no safety in destroying any living thing, lest we annihilate some function which will leave us far worse off for the need of it.

But an equally numerous school take the ground that it is incumbent upon man to first ascertain the exact nature of any creature, and utilize or destroy as in his judgment may seem best. With such creations as the Canada thistle, the potato beetle, or the Colorado grasshopper they hold no parley. Without stopping to question its place in the economy of Nature, they simply treat such pest as unalloyed evil, to be exterminated as quickly as possible, gladly risking the effects of the outrage thus offered, that the great evils worked by the species may be prevented.

Whether the mosquito or house fly is to be treated as an evil it is hardly possible to decide. If the more harmful relatives of the house fly could be separated from

it and proceeded against as a distinct class, the problem would be capable of solution.

The obscurity of the facts having to do with human parasitism and the difficulty of following the feeding habits of the mosquito and fly in Nature make it very difficult to come to any definite conclusions. The medical literature on this subject is too conflicting to guide the student in forming a final judgment.

The principal charges against *Culex* are as follows: (1.) Its female is an unalloyed pest in the imago state, by reason of its acquired fondness for human blood. (2.) It is a harbinger of *Hæmatozoæ* and consequently a constant menace to man by virtue of the fact that, as host of these dread enemies, it helps them towards a period of development where they become a serious visitant in the human system. (3.) It is argued that if it can harbor and transmit such diseases as arise from *Filaria* and other forms, it may also be the means of inoculating with malaria and other diseases. In other words, if *Filaria sanguinis hominis* can be passed into *Culex*, the far smaller germs believed to be the prime cause of these other diseases can easily be transmitted in the same way or by the more direct method of inoculation by puncture with the proboscis.

There is room for much useful research in this *Filaria* problem. Our present knowledge may be epitomized as follows: Lewis⁷³ has found twenty female mosquitoes out of a hundred and forty to be infested with *Hæmatozoa*; McLeod, commenting on this, states that the diseases arising from *Filaria* in the blood "are very serious." Manson⁸⁶ estimates that the blood of one man may at one time contain at least two million embryo *Filariæ*. As the individuals of such a brood could not attain any size

within one human, it becomes necessary for them to have an intermediary host or "nurse," as it has been termed. In this capacity *Culex* is said to act; the theory further calls for the death of *Culex* and the taking into the human system the further matured *Filaria* through water in which *Culex* has died. Manson's experiments are interesting. They are commented on by Dr. Cobbold, who was strongly impressed. Sansino¹⁵⁴ has also written on this theory.

King⁶¹ has, in a very readable way, brought charges against *Culex* as the cause of malarious diseases. He reasons on the fact that mosquitoes are found where malaria abounds. It seems to us, as it does to Stebbins,¹⁵⁷ that the reasoning should have proceeded in the reverse direction. Malaria and *Culex* are widely separated at the seashore, as many can testify who leave their city homes to escape the former and are persecuted by the latter.

Liegard narrates the symptoms produced by *Culex pungens* in France, and an account of the serious effects of an unknown species in the city of Mexico is given in "Science."¹⁸²

Vague and unsatisfactory as these charges seem to be, they are sufficiently suggestive as to warrant greater attention than they have yet received.

Against *Musca* we find much graver charges and more direct evidence.

The published researches of Grassi⁴³ have been of recent years the most important, and those on which other papers have been based. Packard¹¹³ abstracts the above, and states that they "go to show that flies are agents in the diffusion of infectious maladies, epidemics, and even infectious diseases."

Grassi's experiments consisted principally in placing the eggs of a human Nematoid (tape worm) parasite on a plate, from which the flies sucked them up, for they were found in the excreta spots on sheets of white paper hung up for that purpose. The same results were obtained with the ripe segments of *Tania solium*, another tape worm.

"E. P. W.,"¹⁷⁶ reviewing the discoveries and speaking of the fly's food, says: "It may be the expectoration of a phthisical or the ejecta of a typhoid patient, but, irrespective of the material, their next visit may be to the moist lips or eyes of a human being." He adds: "It seems scarcely doubtful that in Egypt ophthalmia is constantly carried by such winged visitors." Taylor,¹⁶⁰ Girard,⁴² and Leidy⁶⁹ record instances in which flies have spread gangrene and other diseases.

We may dismiss *Musca domestica* with a plea in its behalf, that as a well known scavenger it is far too useful to man to warrant its extermination without mature deliberation.

Leaving the sucking group and coming to the biters, we have to deal with a very different state of things.

Stomoxys calcitrans is the species of the biters which is most frequently taken for *Domestica*, as it is a common visitor in our houses. It is referred to on page 40, and its proboscis is illustrated on Plate IV., Fig. 4. Riley and Howard¹³⁵ bear testimony to its powers as a biter. Akin to it is the recently imported horn fly, *Hæmatobia serrata* (Plate IV., Fig. 1), which has been quite common in houses during the rainy season this fall; we apprehend that it will soon be one of our "house flies."

Anthrax, or malignant pustule, a disease much dreaded in certain countries, has, according to Macleay,⁸⁰ been

traced to the bite of an unrecorded species of fly which has feasted on animals dead from splenic fever, anthrax, charbon, or Cumberland disease—all names for one malady affecting cattle.

“*Bacillus anthracis*, the organism which is the cause of the disease,” says Macleay, “is most tenacious of life; it has been known to retain its vitality in dried bones and skins for years. Where a carcass has been buried a depth of twelve feet, the Bacilli will in course of years find its way to the surface in the bodies of earth worms.” On the other hand, Taschenberg believes that anthrax is not conveyed by flies. Both sides are in need of much added research.

Various species of *Hypoderma* larvæ are occasionally addicted to burrowing beneath the human skin, though the lower animals seem to be their natural prey. *Hypoderma bovis* (Plate IV., Fig. 2) is supposed to be the species which Allen⁸ found under the skin of a lad who had been bathing in a stream running through a pasture. The symptoms caused by these insects are called “warbles” or “bots.” Schoyen,¹⁴⁵ Ormerod,¹⁰⁴ and others allude to similar attacks.

Of the same origin is the disease known as “myiasis,” caused by the screw worm, the imago of which is *Macil-laria hominivorax*. (Plate IV., Fig. 7.) Marchi, Löw,⁷⁵ and Williston¹⁷⁹ all remark on this disease. Snow¹⁵³ gives full details of our present knowledge of this terrible species. Matas⁸⁹ says it is the habit of this insect to fly suddenly into the ear, nose, or mouth, or light on a sore, and quickly deposit a few eggs. These soon hatch and the screw like worms (Plate IV., Fig. 7) begin at once their task of eating away the tissues until removed or the death of the patient ensues.

An occasional fly gets into the human nose or ear (Laboulbène⁶⁵); but this is so infrequent as to indicate that it is probably as much a surprise to the fly as to the victim.

Maddox⁸⁴ finds that if a bit of sugar well saturated with a bacilliated fluid, is placed in the reach of flies, they will partake of it, and be attacked with violent dejections, in which bacilli will be found in motion.

Anthrax rods, *Bacillus anthracis*, were also taken up in the same way. Balbiani⁵ and Forbes³⁷ have each written of the flies' susceptibility to inoculation by bacilli. Schoch¹⁴⁴ and Taschenberg have treated of these insects as the cause of malarious diseases.

Williams¹⁷⁸ queries whether it is not better to bear these evils than to run the risks incident to their removal.

Riley¹²³ shows how easy it is to mistake a useful scavenger for a harmful parasite.

The sudden appearance in new localities, and the injurious habits assumed by certain species, are illustrated by Riley and Howard¹²⁶ in the case of the horn fly; the mosquito, "Science"¹⁸²; and the buffalo gnat, Buck.¹⁰

Brauer⁹ treats of *Cestrus*, and its attacks on man, bibliographically; Jacobs⁵⁶ also writes of these insects.

Diptera have frequently been cast up by vomiting. Laboulbène,⁶⁶ Packard,¹¹⁴

Spicer¹⁵⁵ has published and illustrated interesting material on human flesh-eating flies.

The foregoing, but a brief indication of what has been written, will give the reader an insight into this most interesting phase of medico entomological research. A full bibliography of the subject will be found in the Catalogue of the Library of the United States Surgeon-General.

V.

THE POSSIBILITIES AND COSTS.

THE insecticide substances and other means for arthropod extermination now known to economic science are legion. An acquaintance with their properties, and a knowledge of the experiments which have been made with them, require years of study and research. It is not our design to treat of the methods of the work already done, or the nature of most of these remedies. A fair understanding of the former may be obtained by consulting Comstock,¹⁸ and the latter by referring to Riley.¹²⁴⁻¹³²

There are some insecticides which can best be discussed at this time. They are substances as will by their union with water destroy larval life. Chief among these is the well known pyrethrum or Persian insect powder. That it is one of our most important insecticides may be judged from the prominence given it in all our Government reports. But it is far too expensive to be of practical value in the cases now under our consideration. To mix it in ponds or pools, or heaps of compost, in sufficient quantities to overcome dipterous larvæ, is quite beyond our calculations. To attempt to use it against the adult fly or mosquito is equally visionary. Various insecticides which come next in importance, as best adapted to the conditions in which larval *Culex* and *Musca* are to be found, are naphtha, sulphurous exhalations, ammoniated water, and naphthalin. None of them, however, are sufficiently cheap or easy of application to answer our purposes. The reader may consult Cornelius,¹⁹ Riley,¹²⁹ Gratacap,⁴⁴ and Miot.⁹³ As partaking of the nature of the above, and being cheap

and readily applied, petroleum in its various prescribed dilutions may be given a very important place in this list. Its many qualities commended themselves to us early in our search after the possibilities, and the great measure of success met will be discussed further on. Petroleum compounds have had favorable mention from several writers in our bibliography—notably, Cornelius,¹⁹ Riley,^{126,127} and Miot.⁹³

Leaving the inorganic insecticides, we come to a class of vegetable poisons belonging to the fungoids. Here we find at once a most difficult, yet promising field; one that seems to us to be a more promising one than any yet explored. As an introduction to this subject we may mention that classic of scientific research by Pasteur¹¹⁵ on the diseases of the silk worm. So suggestive is this work, so full of food for thought, that it is surprising to note how very little has really been accomplished in the study of these insecticides.

The Entomophthoræ, fungoid growths upon insects, are undoubtedly a potential class of insecticides, with great recuperative and reproductive capacities, and are seemingly so organized as only to need a thorough introduction into a colony to enable them to carry on their death dealing mission. Hagen,^{46,49} quoting from the late Dr. Bail, of Germany, asserts that the common Entomophthora musca, or "Fly fungus," is none other than the still more common fungus of yeast fermentation. It is also said to be identical with the common "mould" so annoying to housekeepers. In several papers^{46,47,49} he enlarges considerably upon this theory, and is answered in the negative by Lancaster⁶⁸ and Prentiss,¹²¹ both of whom state that yeast fungus is not a reliable insecticide.

On the other hand, Leidy,⁷⁰ Pasteur,¹¹⁵ Giard,⁴¹ Bessey,⁶ Comstock,¹⁷ and many others have testified to the deadly effects of the various species of the Entomophthoræ.

All observers are familiar with the sight of a house fly fastened to a window pane by a filmy fungus or cobwebby growth, or with a caterpillar covered with little vegetable growths, both members of this insect killing group. Very little is known of the methods by which insects may be made to inoculate each other with these germs. Our own bibliography must not be taken as an indication of the number of papers written on the subject, as we have only included a few representing epochs in this research, and for additional literature we refer to Forbes'³⁸ most complete list.

We regret that our experiments have been unproductive of anything new, and have contributed nothing to set at rest the dispute as to their effectiveness.

We believe that the propagation of such forms as attack the house fly should receive more attention from experimenters; that is, if the extermination of *Musca domestica* is to be regarded as a wise move.

Packard¹⁰⁹ has pointed out that Nature's means of preventing the too rapid increase of insect life is largely through the medium of parasitic insects. There are several insects which prey upon both families of Diptera now under consideration, but none of them to such an extent as do the various species of the Odonata.

The preparatory stages of the Culicidæ and Muscidæ are passed under such widely diverse conditions, the Odonata will have to be considered under different heads.

There are other problems yet untouched by investigators. Prominent among them is that of solar physics,

to which Riley, Packard, and Thomas¹³⁹ have given some attention in the case of other insects.

The multiplication of electric lights may hold forth some promises, as urged by some writers, though we believe that neither *Culex* nor *Musca* is likely to be greatly decreased by this method.

Having discussed those insecticides which are generally applicable to this work of extermination, we come now to more specific considerations, to be taken up in detail.

The Culicidæ are much more vulnerable in their larval state, and a consideration of their early stages yields several new points. The means for extermination may be divided into natural and artificial insecticides and destructive methods. Under the former may be classed all chemical or animal enemies, aquatic Hemiptera and Coleoptera, fish, Odonata larvæ, etc. Of the latter class, flushing the breeding places with water, draining swamps, and creating active artificial currents may be mentioned. Aquatic predatory insects may be dismissed at once; while such have been observed to be inimical to the Odonata while in their earliest stages, such genera as *Notonecta*, *Ranatra*, *Geoffria*, et al., do not bother themselves with the slender Culicidæ, which lacks substance and pulpiness.

Fish are active and untiring in their efforts to thin out the Culicid ranks. A small sunfish taken from our aquarium and put into one of our many tanks of water well filled with these larvæ, had soon to be removed, as he reduced the ranks too rapidly. Unfortunately it is seldom that fish can be utilized, as *Culex* usually selects for oviposition those pools and stagnant ponds where fish cannot live. Where the breeding ponds or marshes are near the seashore or inland bays, flushing these pest holes will

be found an excellent remedy. If plenty of rapidly running water can be forced into these places and cause them to overflow into main waterways, the Culicids will be devoured by minnows and other small fish to a great extent. For this purpose we would recommend windmills. The farmer or neighborhood which is annoyed by the proximity of a mosquito rendezvous can, by means of a windmill pump the stagnant pools into the stream, or, if there be no nearby running water, the pools or marsh can be drained to one point by digging a small pool at a lower level. From this the water can be pumped and thrown back upon the land. In this way a circulation of rapidly moving water may be maintained, and in it *Culex* cannot live. In addition to ridding the neighborhood of mosquitoes, this plan will also purify the atmosphere of much of the miasmatic influences which arise from swamps and stagnant bodies of water.

Where the area of mosquito breeding territory is large, it will be necessary to drain on a large scale. When the infested ponds are near the sea, the waves may be made to communicate their resistless power to a large float, the rising and falling of which will set in motion the plunger of a mammoth pump. Very many swampy tracts may be filled in with earth. If this is done systematically in connection with these other methods, many a neighborhood now almost uninhabitable will find a rising market.

In the imago state, *Culex* is much more difficult to reach with destructive agents. To prevent mosquitoes from biting, various washes and decoctions have been well tried. Quassia water and oil of pennyroyal are strongly recommended. Outside of houses at night time the principal enemies of *Culex* are probably night hawks, whippoorwills,

and bats. Harvey⁵³ has found six hundred mosquitoes in the crop of a night hawk; evidently these birds are worthy of encouragement.

We know that mosquitoes are attracted to our houses by the illumination from within; therefore, if lights are placed away from our habitations, in suitable localities near marshes and ponds, and arranged as in Plate VI., Fig. 2, with petroleum in the tray, they may be the means of destroying myriads of these tormentors. Fungoid growths have not been tried upon *Culex*; we observed, however, an interesting species of *Algæ* on the head of many larvæ.

No very promising methods remain to be discussed, save the Odonat cultivation and the oil treatment.

The former is of the most importance from the standpoint of this essay, as it is the plan which brought forth the call for the contest. We regret that our careful and continued study under all conditions and favorable circumstances show that the habits of the Odonata remove them from the possibility of close contact with the Culicidæ and their tastes are such as to make the latter unsatisfactory food for them. However, with a view to the possibility that others may not look upon this problem as we do, we give the outcome of our experience in rearing the Odonata. They must be kept in slowly running water, and the tanks in which they are bred must be free from all aquatic predatory insects, and so screened as to prevent the ingress of these or of frogs. Fish must be kept out, and netting should be spread so that birds may not attack them when they emerge from the pupæ. Owing to their cannibalistic tendencies, the larvæ should be placed in large tanks with a limited number in each, and fed care-

fully with pieces of fresh fish. Allowing for five broods of mosquitoes in a summer, and that one hibernated female may be responsible for at least ten thousand larvæ by the time the Odonats appear, it will be seen that the one brooded enemy will need to be produced on an enormous scale. Liberated in great quantities, as they would be if bred in sufficient numbers, the dragon flies might migrate to less crowded localities.

The question of transporting the young larvæ from the breeding tanks to the mosquito infested ponds is to be considered; although they are tough and can stand jostling, only a few can be carried in one receptacle. Twenty put in one jar would be found to be an inextricable kicking mass of cannibals after a mile's transportation.

We have failed to find the natural enemy of the mosquito to be the dragon fly, and have intentionally reserved to the last that remedy which to us seems to far outrank all others of which we have any knowledge or have been able to devise, viz., the oil treatment.

The United States Department of Entomology and the various State Reports, as well as numerous economic entomologists abroad, have long recommended the use of petroleum in some form for the extermination of plant lice and many other noxious insects. Petroleum emulsion, sprayed petroleum, the naphtha compounds, and others from the same source, are prompt and deadly insecticides. With this in mind we early began a series of tests with common illuminating oil on Culicid larvæ under all circumstances. The narration of one series of experiments, typical of all, will illustrate the efficacy of this treatment. Into a shallow pool of water with an area of ten square inches, five pupæ, two grown larvæ, and about sixty others in various

stages of development were put. With them were also two immature Odonats and a number of Cyclops and Cypris. On the surface ten drops of oil were placed, and were observed to cover the entire area in ten minutes. At once great uneasiness was manifested by the larger larvæ. Then they all began cleaning off the breathing tube with their jaws, with apparent discomfort.

The very evident effect of the oil was to coalesce the cilia at the tip of the tube, thus making respiration difficult or impossible. The annoyance, fear, agony, and, finally, desperate frenzy were clearly depicted by their actions. The two grown larvæ were dead in eight minutes; several of the half grown died in ten minutes; at the end of twelve minutes most of the remainder, save the very smallest, had succumbed. The pupæ had both expired in fifteen minutes. In an hour and a half everything was dead except the Odonata and minute Crustaceans; the former seemed to be in perfect condition, owing to their multitudinous breathing appliances. After the oil had been put on the above area, it was at once seen that the proportion was too great. A second pool of the same dimensions was tried with one drop of oil, which was quite enough to have the same deadly effect, though the results were not so rapidly attained. The all pervading nature of the oil was shown by the fact that one of the larvæ removed to a pool of eight square inches of surface took enough oil with it to cause almost instant uneasiness to the inhabitants of the otherwise fresh water.

These experiments were tried time after time, always with the same result, and show conclusively to us that oil is the great hope of nearly every mosquito infested district, for the following reasons: (1) Its cheapness; (2)

its deadly nature when applied to the Culicidæ; (3) its comparatively harmless nature as applied to other forms of aquatic life; and (4) the ease with which it can be applied.

Of the first claim we only care to say that three dollars' worth of the crude oil will suffice, according to our estimate, to cover an area of one hundred acres of water surface five times in one season. In this way every brood would be greatly retarded or entirely destroyed in that area. In illustration of the second claim we may state that mosquito larvæ lived as long in pure Brown's Jamaica Ginger as they did in water covered with a film of oil. The depth of the water does not signify. *Culex* must come to the surface to breathe. If the oil is sprayed, as illustrated in Plate VII., Fig. 2, it need not interfere with the herbage. Odonat larvæ will not be found in stagnant water, and fish must have fresh water, but oil may be carefully sprayed over any surface however small. The tube may be attached to a fishing pole in order that a spray may be thrown some distance. A Riley or Cyclone nozzle is best adapted to this purpose. In closing this account of Culicicides it is well to call attention to a paper by Dogiel,²⁶ in which a description of the effect of twenty-two poisons on *Culex* are given.

The possibilities for destroying members of the Muscidæ are not so promising as are those of the Culicidæ, owing to their hidden habits and the repulsive nature of their breeding places.

Under the discussion of general insecticides at the beginning of this chapter, the treatment of pyrethrum, gases, certain parasites, yeast, and other fungi have special bearing on the fly problem.

As it appears to us, the only very promising methods are cultivation of fly fungus and the oil treatment.

On page 58 will be found a résumé of the present knowledge of the subject of fungoid growths likely to affect the fly.

The application of oil can only be made during the larval and pupal stages. Spraying petroleum on compost heaps and other breeding places will be effective. The methods of applying are described on page 65. We believe that, after much study and experience, the Odonata cannot be considered a formidable enemy. The method of breeding them, however, has been described on page 62.

A FINAL SUMMING UP.

To gather together the weight of the testimony in the foregoing chapters, and to clearly set before the reader what, in our opinion, may be the best exterminators to use against Culicidæ and Muscidæ in their various stages, we close with the following table:—

CULICIDÆ: Larva and pupa.

1. Sprayed petroleum.
2. Flushing, circulating, grading.
3. Odonat culture.

Imago.

1. Pennyroyal vapors.
2. Odonat culture.

MUSCIDÆ: Larva and pupa.

1. Sprayed petroleum.

Imago.

1. Cultivation of fungoids.
2. Odonat culture.

The compilation of a bibliography, including papers produced in the domain of medicine, biology, insect classification, and economic entomology, is not the work of a day nor the outcome of a simple searching in the index of one or a dozen standard authorities. Nor does the mere enumeration of a list of the leading text books suffice, for the bulk of the literature is found scattered through the pages of the scientific periodicals of the last twenty-five years. The "Zoological Record" and "Zoologische Anzeiger" have been invaluable aids in this work. It has been necessary to look carefully in books and papers where the title afforded the least hope that pertinent matter would be found. It was not, however, alone difficult to compile this list on account of the scarcity of works having reference to the subject, but it was quite as perplexing to eliminate from the list those references which were either duplicates or such as were condensed from more comprehensive productions. It may be urged against this list that too much has been excluded, but, in order to make it of the greatest possible worth to students, writings of the following classes have been eliminated:—

1. Pertaining to distribution, migration, and habits in countries very remote from the United States.
2. Abstracts of papers already published in more accessible form, or abstracts in languages not so generally read as that in which the originals were published.
3. Publications of a popular nature, in which the information is given at second hand, and not in such a way as to make it as accessible as others of a similar nature.
4. Publications in languages such as Russian, Dutch,

Hungarian, Scandinavian, et al., and which have been abstracted in papers more accessible to all.

It is believed that all separate papers or works which have a direct bearing on this general subject, and which are not excluded by the foregoing rules, will be found in the list, if they were published during the last twenty-five years. In selecting papers of an earlier date, greater freedom has been taken in rejecting such as seemed purely introductory and elementary. The combined results of most of these are now found in our standard text books on the classification of insects. Medical works and journals frequently contain many references to insects attacking the health of man; such allusions are not noted, unless the habits or appearances are sufficiently indicated to determine the genus.*

*The plates and bibliography prepared by Mrs. Aaron, and accompanying her essay, will be found at the close of the volume.

III.

UTILITY OF DRAGON FLIES AS DESTROYERS
OF MOSQUITOES.

BY A. C. WEEKS,

SECRETARY OF THE BROOKLYN ENTOMOLOGICAL SOCIETY.

REPLY TO A "CIRCULAR NOTE TO WORKING ENTOMOLOGISTS."

IN replying to the question propounded by Mr. Robert H. Lamborn, whether dragon flies may not be artificially multiplied to such extent as to become an important factor in the destruction and consequent diminution of flies and mosquitoes or other noxious insects, the entomologist finds himself confronted at the threshold of the discussion by the necessity of making special investigations into the life histories, and relations to man under his present conditions of civilized existence, to Nature in general, and to each other, of each of the insects above named before definite conclusions can be reached.

The artificial rearing from generation to generation of any insect requires the duplication, or some equivalent, of the following natural conditions:—

1. OVUM.

1. Conditions under which copulation and fertilization of ova occur.
2. Conditions under which oviposition will occur.
3. Conditions under which ova will hatch.

2. LARVA.

4. Conditions necessary to afford food supply to larvæ.
5. Conditions for maintenance of natural element or surroundings of larvæ.

3. PUPA.

6. Conditions favorable to formation of pupæ.
7. Conditions favorable to pupal existence and maturity.

4. IMAGO.

8. Conditions favorable to perfection of imago.
9. Conditions under which imago will partake of nourishment.

These conditions vary generally in the same ratio as the number of transformations, and are frequently wanting in the transformations themselves; each insect is in fact *sui generis* as respects these conditions, which can only be determined by personal observation. Inasmuch as a failure to satisfy any one of these particulars or conditions, so far as they may be requisite to any insect, will defeat the rearing, the elimination of any one of them will operate to destroy; the result attained being the same, however opposed the intention.

Bearing these principles and the object to be accomplished in mind, the discussion of the question may be considered under the following divisions:—

I. Natural conditions under which the insects in question breed, with life history so far as applicable or known.

II. Experiments in rearing in imitation of natural conditions.

III. Habits of insects in question.

IV. Relations to each other.

V. Conclusions.

DRAGON FLIES.

I. NATURAL CONDITIONS UNDER WHICH THEY BREED,
WITH LIFE HISTORY SO FAR AS APPLICABLE OR
KNOWN.

In the vicinity of New York the perfect insects appear among a few species as early as the latter part of May in a favorable season, increasing in both numbers and variety of species until about the middle of August, and decreasing rapidly until their disappearance, which may be extended as late as October 1st.

The following table of time, of appearance, and locality frequented, prepared from data upon specimens collected by myself, will be interesting and valuable in this connection, only those species being included which, from my personal knowledge of their habits, would seem at all available for the purpose suggested. No accuracy is claimed for it beyond my personal observation.

SPECIES.	EXPANSE OF WING.	STRENGTH OF WING.	CHARACTER OF FLIGHT.	VELOCITY (ESTIMATED).	FREQUENCY OF OCCURRENCE.	LOCALITY MOST FREQUENTED.	LOCALITY OCCASIONALLY FREQUENTED.	LOCALITY IN WHICH SELDOM OR NEVER OCCUR.	SEASONS OF GREATEST ABUNDANCE.
<i>Tramea carolinæ</i>	3½-4'	Medium.	Rapid.	Fair.	Not rare.	Marshes near seacoast.	Upland near coast.	Inland.	July-Aug.
" <i>laccata</i>	3½-4'	"	"	"	" (local)	"	"	"	"
<i>Libellula auripennis</i>	3'	"	Medium.	"	Common.	"	"	"	"
" <i>pulex</i>	3¼-3½'	Superior.	Rapid.	Great.	Very common.	" generally.	"	"	"
" <i>luctuosa</i>	3¼'	Medium.	Medium.	Fair.	Common.	Inland ponds and streams.	"	"	"
" <i>quadrimaculata</i>	2¾'	"	"	"	Rather rare.	Marshes generally.	Neighboring woods.	"	"
" <i>semifasciata</i>	2½-2¾'	Superior.	Rapid.	"	"	Marshes near coast.	"	"	"
<i>Plathemis trimaculata</i>	2½'	Medium.	Medium.	"	Common.	Inland ponds.	Upland roadsides adjacent to ponds.	Remote from water.	June-July.
<i>Celithemis crenina</i>	2½-2½'	"	"	Limited.	"	"	"	Far from edge of pond	July-Aug.
<i>Mesothemis simplicicollis</i>	2½'	Superior.	Rapid.	Fair.	Rather rare.	Streams, ponds.	Fields bordering on streams.	"	"
<i>Diplax rubicundula</i>	2'-2¼'	Feeble.	Feeble.	Limited.	Very common.	Meadows generally.	Fields.	"	"
" <i>heretica</i>	2'-2½'	"	"	"	Not rare.	"	Fields and upland adjoining water.	"	June-Aug.
" <i>elisa</i>	2'-2¼'	"	"	"	Very common.	Inland ponds.	"	"	July-Aug.
<i>Anax junius</i>	4'-4½'	Superior.	Very rapid.	Very great.	"	Generally distributed.	Generally distributed.	"	Aug-Sept.
<i>Eshna constricta</i>	3¾-4'	"	"	"	Common.	Borders of woods and streams.	Vicinity of dwelling.	"	July-Aug.
" <i>heros</i>	4½'	"	"	"	"	Generally distributed.	"	"	"

By the foregoing table it will be seen that the species most likely to be of service are *Anax junius* and *Eshua constricta* and *heros*, which appear in July and August and may occur as late as the middle of September, a period comprehending some two months, when their usefulness as destroyers of other insects ceases. The pairing of the sexes may be readily observed during the months above named, occurring just over the surface of some fresh water stream or pond, during rapid flight, which, broken to make connection, continues uninterruptedly except for rest in some adjoining thicket or the deposition of eggs. These eggs sinking, lodge among water plants and débris at the bottom of the stream and hatch within a short time into insect devouring larvæ, which upon attaining full growth enter into a semipupal stage, in which they are still active. What the combined duration of the larval and semipupal stages is I am unable to state, but it is certainly not less than one year, and it is quite possible that it may be longer. (*Diplax berenice*, from specimens taken by me in both June and August, may be an exception, and produce two broods. It is, however, of rather infrequent occurrence, closely confined to its birthplace, and rather feeble in motion.) The knowledge we already have upon this point is sufficiently definite for our purposes.

II. EXPERIMENTS IN REARING IN IMITATION OF NATURAL CONDITIONS.

An insufficient period to satisfactorily test the question of breeding in all its phases was allowed by the terms of the circular—for the reason stated above, that dragon flies require, with few exceptions, at least a year in which to complete their transformations, and, like their cousins, the

May flies (Ephemeriidæ), seem only to reach the last stage for the purpose of procreating their species, so comparatively short is its duration. The writer has, however, some years previously made some experiments at carrying the larvæ of many aquatic neuroptera through to the perfect stage; and the results of these, coupled with some subsequent attempts to obtain oviposition, may serve to answer the present purpose.

In the spring and summer of 1875, while at home upon my father's farm in Suffolk County, Long Island, which borders for some half mile upon the Connecticut River, I constructed three cages for the rearing of any insect whose larval stage was confined to the water. The sides of two of these were of board, sixteen inches in width and five feet in length, placed one foot apart and kept in position by four narrow pieces of scantling nailed at right angles to the ends, top and bottom. Painted wire cloth was fastened to the ends of the cages by wooden cleats, to allow the passage of water. Escape of the larvæ by burrowing was prevented by a fringe of tin projecting several inches from the bottom of the cages; and the cover of each consisted of two painted wire screens which could be raised independently for the purpose of keeping a portion of the imagines confined while others were being removed. The third cage was similar in construction, but having three times the width. Weights prevented the cages from floating when in position. One cage was placed in a shallow arm of the river, so that the current would readily flow through it, leaving some four or five inches projecting above the surface, affording space for the imagines to expand their wings. The second cage was similarly placed in the stagnant water of a wide, shallow ditch in an adjoining bog

meadow, from which the surface peat or turf had been removed. Rough stones, decayed sticks, cress, and eel grass were placed in the former, while the latter stood on the bottom of the ditch enclosing such organic material as happened to be within its sides, together with two or three pieces of turf. The widest cage was placed so that it might enclose a section of the water and adjoining bank of a small stream which drained the meadows.

Numbers of the larvæ of the dragon fly, caddis fly, and even some Diptera were netted out of the adjacent streams and ditches with a large net of unbleached muslin having a wire cloth strainer in the bottom, collected in tin pails, and emptied into the cages, care being taken to return each species to the cage more nearly corresponding in situation to that from which it was taken. The ends of the cages were frequently cleared of the accumulation of floating material, to permit the easy entrance of such insects as might serve for food. The result was very satisfactory. The caddis flies emerged during May and June and occasionally thereafter during the summer. The dragon flies appeared sparingly at first, but during the latter part of July and early part of August readily crawled up the rough sides of the interior of the cages, emerged from their pupal cases, and expanded their wings by suspending themselves from the under side of the covers. Several species of *Diplax* were abundant, of *Anax junius* only a few were obtained, while *Libellula pulchella* was fairly numerous. Other genera, which I do not now remember, were represented by an occasional specimen. Not a single instance of pairing was observed, and some little time was required in drying wings after full expansion before the insects were able to use them.

The next experiment was undertaken for the purpose of testing the willingness of the dragon fly to mate or to oviposit while in partial confinement.

A portion of the upper story of my house on Prospect Heights, in Brooklyn, consisting of bath room with large skylight, hall with skylight, and adjoining hall room with southern exposure, was utilized as a temporary nursery for dragon flies during August and again in September of this year, my family being absent. Every article of furniture was removed, the carpet covered with newspapers, the bath tub filled nearly to the brim with water and plentifully fringed with rushes and aquatic grasses, the roots of which were inserted in several pans of previously well washed sand placed on the bottom of the tub; some boxes and water jars containing large weeds transplanted from an adjoining field were distributed at intervals along the hall and hall room, and a wire fly trap was set in the kitchen to provide a supply of food for such dragon flies as might be taken.

In the afternoon of that day (August 17th) some brackish pools a quarter of a mile from the beach at Coney Island were visited, and between thirty and forty specimens of *Libellula pulchella* and *Diplax rubicundula* were captured with a large net (eighteen inches diameter), care being taken to secure some pairs in copulo. These were immediately inserted, according to size of insect, in one of two confectionery boxes lined with mill net, with sliding covers, each having a hole one and one-half inches in diameter, through which the dragon flies could be thrust without removing the cover. The darkness of the box as well as the lateness of the hour prevented the insects from attempting to fly and thus injuring themselves,

and so far as could be perceived they rested quietly in the interior of the boxes upon the net. (As a matter of fact, the rushes, etc., were gathered in a basket at this time and placed in the tub on my return that evening.) The collecting boxes and fly traps were also placed in the bath room that evening, so that the insects could liberate themselves the next morning. The floor below was darkened by closing the shutters, in order that none of the insects should be induced by the light to pass down the stairway. The next day was Sunday, August 18th, a bright, pleasant day, and soon after dawn I stationed myself at convenient points of observation, remaining as motionless as possible consistent with an occasional change of position. The result was a disappointment, so far as pairing, ovipositing, or even the destruction of the flies were concerned. The flies began to circle around the rooms as soon as they were fairly light, and as morning advanced flew towards the windows seeking an outlet, and alternated between the windows and the objects in the room, crawling over the walls and ceilings, lighting on the plants, and apparently searching for food. The dragon flies were indisposed to activity until the sun began to heat and light the rooms, about 10 A. M., when they, too, flew toward the windows and skylights, and though frequently flitting around the ceilings always returned to the former, and when apparently fatigued with their exertions, or convinced that their efforts to escape were futile, would remain resting on the sills, unless disturbed by the buzzing flies, which crawled fearlessly over them. There were no attempts at ovipositing or pairing, and the improvised pool with its rush lined banks seemed to offer no attraction, probably because it was lacking in three particulars, viz., a muddy

bottom, a swarm of gnats, and a vertical sun. The insects were confined in this way for several days, until many of the flies and dragon flies perished, and out of feelings of compassion the survivors were allowed to escape. Frequent and prolonged visits during the period of confinement failed to show any attempts to oviposit, and a careful scrutiny of the water plants failed to show a single egg. The following week a pair of *Anax junius* in copulo and several single specimens were captured, and placed in the rooms with a number of fresh flies, with the same lack of success ; and again in September, with a similar result.

III. HABITS OF DRAGON FLIES LIMITED TO SCOPE OF OBJECT TO BE ACCOMPLISHED.

The most important results to be attained in the rearing of any insect is the fertilization and deposition of ova. With this paper in view, during the month of August, in addition to the foregoing experiments, I visited a number of small ponds, marshy pools, and other places frequented by these insects, to ascertain if possible the necessary conditions under which these acts occur, with the following result : The greatest activity was developed under a vertical sun, in a quiet atmosphere ; a fair breeze slightly diminished this, a strong breeze greatly reduced it, while the passage of a cloud over the sun with a cool breeze brought it to a minimum. The insects do not take flight at an early hour, and, with the exception of *Anax junius* and *Aeshna constricta* and *heros*, cease from flight as the sun approaches the horizon. A solitary specimen of one of the three species above named may be occasionally observed

flitting around the sides of buildings and hay ricks, or skirting the borders of a piece of woods at or shortly after sunset. All dragon flies are distinctively diurnal, however, and night finds them totally inactive. The summer sun is their god; when he shines every element in their being is alive as if in homage to him, when his light and heat are obscured by clouds or diminished by chilling winds their worship ends. They are short lived and frequently destroyed in large numbers by heavy showers and winds through their inability to properly shelter themselves from the weather. After a severe storm their numbers are greatly diminished for several days, until renewed by fresh emergings. Dragon flies with a few exceptions (see table) confine themselves to the vicinity of their place of birth, and even if removed therefrom quickly return. They require in pairing and feeding, ample space and great freedom. The dragon fly does not consider man and his convenience in satiating its appetite, but destroys every soft bodied insect which is unfortunate enough to fall in its way, and the destruction of flies and mosquitoes is merely incidental. I have seen *Anax junius* chasing and even capturing small butterflies which happened to ascend to its elevation while hovering over a clover field.

FLIES.

I. NATURAL CONDITIONS UNDER WHICH HOUSE FLIES BREED, WITH LIFE HISTORY SO FAR AS IS APPLICABLE.

The number of living North American species of Diptera is estimated to be about ten thousand, with an equal number in Europe. Only about one-fifth of these numbers comprise the family Muscidae, some of the members

of which are known under various names, as House fly (*Musca domestica*), Bluebottle fly, Green fly (*Musca cesar*), Meat fly (*Musca vomitoria*), etc., and which are the most common species which infest our houses, and, attracted by the odors and refuse of the kitchen, out-houses, stables, and poultry and cattle yards, fearlessly invade the privacy of our dwellings and rudely trespass upon our persons and food. On the other hand many of the *Muscidæ*, as *Tachina*, are parasitic upon caterpillars and coleopterous larvæ, and so beneficial are they in this respect that, so far as my experience goes, it is not extravagant to say that without their aid there would be no crops to harvest nor forests for timber. A single female *Tachina* will destroy an entire brood of one hundred *Datana* larvæ, each one of which is from twenty to thirty times heavier than herself—a fact which I myself have witnessed. Out of three hundred larvæ of *Danaus archippus* collected this summer, only about one hundred were free from *Tachina*, and these escaped very largely by being taken during the first moult. Again, there are *Diptera* (*Asilidæ*) which, though not parasitic as the *Tachina*, are direct destroyers of other insects and are of equal value with dragon flies in this respect. The largest and most voracious species of this family are found in the fields adjoining our dwellings, where they are distributed in great numbers, every step arousing one or more. Bee and butterfly alike are palatable morsels to them, and, as they never rise from the surface of the ground, they catch many insects which the dragon fly is unable or unwilling to take. Besides the *Muscidæ* there are many families of *Diptera* (*Cestridæ*—bot flies, etc.) which are very annoying to man and the lower animals, but, as the dragon fly

is obviously incompetent to destroy them, it is useless to speak of them further. Flies breed in organic matter of every description, animal as well as vegetable. The large majority of them are limited in their destructive effects, filling humble offices in the great scheme of Nature, and unrecognized and unrecorded except in the collection of the specialist, check lists, and agricultural reports. Many species of Muscidæ are able to retain their fecundated eggs until hatched in a receptacle provided for that purpose, and are able to excrete the living maggot directly and in considerable and surprising numbers. I have seen a female of this family rapidly moving over a small quantity of freshly deposited dung, and voiding maggots at intervals of several seconds, until at the expiration of two or three minutes the entire surface of the material was plentifully sprinkled with their writhing forms.

The house fly breeds in freshly deposited stable manure, and its four stages or transformations occupy, at most, some fifteen days; *M. cæsar* and *vomitória* occupy about the same period. There is practically no stated limit to the number of broods in a season, and it is probable that every hour of the day, from April to December 1st, the several transformations are occurring contemporaneously among the different broods.

II. EXPERIMENTS IN REARING.

To satisfy myself on the question of the rapid development of the house fly, a quantity of horse manure was, in the latter part of August of this year, placed on the surface of loose soil with which a soap box was partially filled, and exposed to the sun in my back yard for one day, at the end of which time a glass pane was placed

over the box, which remained standing in the sun. Twelve days afterward the first imago was noticed, and the numbers increased until the sixteenth day, when quite a swarm of these flies with some others filled the box.

In crossing a plowed field about the same time I found the carcass of a large rat which had been crushed by a farm wagon. A strong wind was blowing at the time, and the number of meat flies attracted by the odor thus wafted almost concealed the body from view. A number of the flies were secured and preserved, and the rat taken home and after a few hours' exposure confined as the horse manure had been. In the course of two weeks the perfect flies appeared.

MOSQUITOES (Culicidæ).

I. NATURAL CONDITIONS UNDER WHICH MOSQUITOES BREED.

The life history of these insects is so well known, and has been so frequently described at length, that it would be a vain repetition to insert any extended account of their transformations here. The eggs are laid in or near fresh or brackish water, in which the larval stage is passed, and a new brood appears about every three or four weeks. Their period of aggressive activity is not nearly as extensive as that of house flies, but, like them, all the stages exist contemporaneously, from the frequency and interlapping of the broods.

II. EXPERIMENTS IN BREEDING IN IMITATION OF NATURAL CONDITIONS.

None were made, for the reasons stated in I.

FLIES AND MOSQUITOES.

III. HABITS OF INSECTS IN QUESTION.

Flies are the scavengers of the earth and air, mosquitoes of the water; and both are exceedingly abundant wherever the continents extend from the northern frigid zone to the southern extremities of their great peninsulas. As soon as the rays of the returning sun unclasp winter's icy grip, from every sheltering crack and crevice creep forth hibernating flies, others emerge from their well-protected larval cases, while mosquitoes arise in myriads from every marsh and pool—a vast army of Nature's faithful servants—to consume and destroy corruption and render the earth a healthful habitation for man. No decaying substance is too trifling to be a nursery for a maggot, no pool or water-holding-stump too limited to afford a domicile to the larvæ of a mosquito. Not a day has passed during this present month, November, but I have noticed house flies, singly or in swarms, in my kitchen and dining room flitting around the room as sprightly as if the summer solstice had just commenced, though the dragon fly and all its congeners have for many weeks ceased their aerial flights, and their graceful forms are no longer recognizable.

IV. RELATIONS TO EACH OTHER OF THE INSECTS
IN QUESTION.

It would seem an unnecessary task to recapitulate the facts above cited relating to the life history of dragon flies, flies, and mosquitoes, to show how impracticable would be the attempt to artificially multiply the former for the purpose of destroying the two latter. So far as

the experiments herein described show, it is impossible to fulfill, in respect to dragon flies, many of the conditions essential to rearing, viz., pairing and fertilization and deposition of ova. It is generally easy to carry an insect through the larval and pupal stages and obtain the imago or perfect insect, but this is not breeding; and while the larvæ of dragon flies may be captured and carried through the larval and semipupal stages in limited numbers (a portion will certainly die), this is not rearing, in the sense in which fish or silk worms are bred. A negative reply, therefore, to Mr. Lamborn's proposition could be made at this point, provided the experiments above described in the direction of rearing dragon flies were accepted as exhaustive and conclusive; and it is to meet that exigency that so many apparently disconnected details relating to the life history of each of the insects above named have been narrated. Irrespective, then, of the question of rearing, we may ask, what chance has an insect producing a single brood in a year, or even longer, highly sensitive to every change of temperature, and whose actual existence in the imago is confined to a few days, to destroy one to whom every year adds a long line of generations, whose egg producing capacity is reckoned by the thousands, and to whom only the severest weather has any terrors? How can an insect handicapped as above stated, whose early stages must be confined to an element in restricted positions, such as rivers, ponds, ditches, and marshes, where the water is constant for a considerable period, compete in numbers with or annihilate the mosquito, a habitant of the same element, to whom not only such waters, but every transient puddle, clay pit, pool, hollow stump, or rocky depression affords a "coign of vantage" to rear

its young, and whose generating powers are a thousand fold greater; or, again, the omnivorous fly, whose subsistence, in both of the active stages, drawn from the sources of unceasing decay, is comparatively flung broadcast over the earth?

It is safe to say that, were the destruction of flies and mosquitoes, through the agency of dragon flies, a vital necessity to the preservation and continuation of the human race upon the earth, every dollar of wealth represented, whether by men, machines, or money, could be expended in vain.

Let us assume, for the sake of meeting every objection, that dragon flies could be multiplied indefinitely by artificial means—

1. At the time of their natural annual appearance.
2. At all seasons.

1. AS TO INDEFINITE MULTIPLICATION AT NATURAL SEASONS.

As has been shown, dragon flies are incapable of domestication. No matter how many may be introduced within or in the neighborhood of a dwelling, their natural instincts would prompt them to instantly betake themselves to the vicinity of the nearest marsh or body of water, while the flies and mosquitoes which most annoy us and frequent our houses would be unmolested. (This fact would absolutely dispose of the question of their utility as destroyers of flies and mosquitoes in houses, in cities, or in neighborhoods.) The vicissitudes of temperature would soon terminate their existence, brief at the most, and the relief afforded, at best, provided they were able to measurably destroy other insects, would be but temporary. In short, there is no creature which is really so unable to

cope with the mosquito and fly as the dragon fly. Both of the former remain, for the most part, close to the ground, concealed among the heavy foliage of summer, and comparatively few fall a prey to the dragon fly, which is able to capture only those which inadvertently thrust themselves in its way.

In the early part of July, both by day and night, when mosquitoes swarm in myriad millions, making the life of the average man miserable, scarcely a dragon fly is to be seen; and, even at its most plentiful season (July 15th to August 15th), the few hours in the daytime limited to fine weather render it a feeble combatant against mosquitoes, which, largely concealed during the day, pour out in countless hordes at night, in all changes of temperature, while the members of their giant enemy are stiff with the evening dews. Many other objections to dragon flies as a means for the destruction of other insects are readily deducible from the facts already stated.

2. AT ALL SEASONS.

The reasons stated in 1 apply with equal force to 2, except so far, of course, as continuity of appearance is concerned; but it is proper to add that, however easy it might be to produce the mature dragon fly at any particular season, its activity would be regulated by the weather, and it is doubtful if the period of its usefulness could be greatly extended. Assuming that it would be content to remain within a dwelling and capture such insects as might be attracted thereto, refraining from passing through an open window or door, even then the disagreeable rustling of its wings, multiplied six or seven fold, would be an intolerable nuisance, and the bodies of these short

lived insects falling behind furniture or other inaccessible places would attract a brood of *Dermestes*, the next generation of which would be nourished on the family furs.

Before drawing any conclusions upon the foregoing, it is necessary to reply to some of the premises set forth in the circular. The question is raised, why it is not as easy to breed dragon flies as it is fish, silk worms, bees, etc.? Let us ask ourselves the question, why it is not as easy to produce herds of tigers, lions, and some other carnivorous and herbivorous quadrupeds as it is cattle, sheep, and horses? We know that there is a difference; that this difference is inherent in the habits and instincts of these animals as shown by experience; and yet why this difference no one will ever be able to satisfactorily explain until the relation between the organs of generation and the instinctive action of the motor nerves can be discovered. As among quadrupeds there are species which can be easily bred in captivity from generation to generation, and others which cannot, so there exists among insects the same difference. To illustrate: Of the nocturnal *Lepidoptera*, nearly all the species of *Bombycidae* readily mate in captivity. So much so, that in the case of the silk worm (*Bombyx mori*) pairing will inevitably occur if specimens of both sexes be confined in any space, however limited, oviposition will as surely follow upon any material within a definite period thereafter, irrespective of fertilization. The same fact is true of a large number of the silk spinners, such as *Callosamia promethea*, *Hyperchiria io*, and *Samia cynthia* (Japanese silk moth, feeding upon the *Ailanthus*, acclimated here), while on the other hand the species of *Sphingidae* and many of the *Noctuidae* and *Geometridae* can only be mated with extreme difficulty.

The breeding of diurnals is seldom attended with success, and, even under the most tempting imitations of Nature, with the auxiliaries of light, heat, flowers, and food plant, fertilization is rarely effected. This summer I bred some hundreds of *V. antiopa*. Many of the insects emerged simultaneously within a small box, but not a pair mated; and, later, the same box was similarly filled with *D. archippus*, with a similar result. These facts are only quoted by way of contrast in this connection. Of the thousands of diurnal Lepidoptera which I have reared by capturing the larvæ, not one pair ever mated, and artificial fertilization of the ova is out of the question. The same difference exists among other orders of insects. Among the Hymenoptera, bees may be reared in swarms from year to year, but it is doubtful whether a "hornet" or "yellow jacket," both assiduous destroyers of flies, could be; and the very nature of the Ichneumonidæ and Tachina, useful as they are, forbids any artificial multiplication.

A request is made in the circular that the reply contain a suggestion as to what insects may be utilized for the purpose therein named. My own large local collection, embracing all orders, and well represented in species, with scarcely an exception the result of my personal labor, and with the life history of each of which species I am measurably familiar so far as the requirements of this paper are concerned, has been carefully examined to the above end, and as a result of such examination I am compelled to admit that there is not a single insect, from among the scores of insectivorous species, which can be recommended as advisable to breed artificially—practicability, economy, and convenience considered.

It may be laid down as an axiom that in general no insect destroying insect can be artificially propagated without multiplying its often injurious prey; the Australian *Coccinella*, used to devour the plant lice on the Florida orange trees, requires no artificial aid in rearing.

It may be interesting to note in this connection one insect whose value as a domestic fly destroyer is probably not appreciated. I refer to a species of *Cermatia*, probably forceps, a spider-like centipede having extremely long and slender legs, the body of which is about two inches in length, and its speed marvelous. It is of frequent occurrence in dwellings in New York City and Brooklyn. During the day it retires to the darkness and dampness of closets, leaky basins, and cellars, but at night issues forth, traversing the entire house, and frequently stations itself head downward along the upright "trim" of the kitchen or wherever flies are abundant, and with members extended seizes and mercilessly slays every fly passing within its reach. If unable to devour all its captures, the first is allowed to drop to the floor after receiving a fatal bite and another substituted of the several simultaneously imprisoned and buzzing at different points between its legs. Its appetite does not seem to become readily satiated, one specimen capturing flies for an hour and a half, when my patience became exhausted and it was taken into custody. One day's confinement in a dry box caused the insect to shrivel and die. In spite of its usefulness, I have not encouraged it in my house, preferring a whitewashed cellar with dry cement bottom and sanitary plumbing to its company. (According to Latreille the bite of insects of this genus is poisonous.)

Inasmuch as the result of my investigation has failed to

produce a realization of the expectations raised by the circular, it would not be proper to conclude this paper without suggesting methods of destroying or limiting the number of flies and mosquitoes.

At the outset the principle is enunciated that in order to compass the destruction of any insect it is only necessary to interrupt or break the chain of conditions which are inseparably connected with its life history. It follows, then, that we may absolutely destroy any insect by removing every particle of the material which serves it for food or as a home during its larval period. If there be wanting such material or home, no egg will be laid, no larva will hatch, and no pestering imago will be perfected. The powders, washes, and mixtures which the housewife and the farmer are constantly wasting time and money in distributing and applying, only bring other annoyances. The bed bug will leave a house in one season if, after the beds and clothing are thoroughly cleaned of nits and mature individuals, the posts are isolated by being placed on bricks set in vessels of water; the potato beetle in the State would disappear for a considerable period if the farmers should unanimously omit to plant that vegetable for one season; the phylloxera would instantly perish if the vines were totally cut down and burned. Millions of dollars could be expended in apparatus for the breeding of dragon flies, while the filthy little duck pond or marsh, which a few dollars would fill up, and costing nothing but indifference to maintain, would supply mosquitoes enough to satisfy the voracious appetite of all the dragon flies that such apparatus could produce.

How shall houses, cities, and neighborhoods, then, be freed from the house fly and his congeners? I answer :

by affording him and his tribe no inducements to stay. In rural districts, householders should allow no kitchen refuse or other organic material to decay in the vicinity of a dwelling, nor permit the malodorous compounds of the stable, pig pen, cow yard, and poultry house to accumulate in an exposed condition. In cities, householders should burn every particle of kitchen refuse and garbage in the range so far as practicable, and remove all decaying organic matter from the premises, and thoroughly cleanse cellars and waste pipes. The accumulation of festering filth in the streets, and of nauseating barrels of garbage, should not be permitted, or their prompt removal facilitated. The cellars and back yards of all tenements (used in a technical sense) should be subject to frequent periodical visitation by a sanitary inspector with power to order removal of filth in his discretion. No slaughter house or kindred business should be maintained within the city limits, and, what is most important, the keeping of every stable should be either prohibited entirely or else confined to a certain locality, and cleanliness and the daily removal of the accumulations enforced under stringent police or sanitary regulations. The disappearance of the house fly under such circumstances would be an insignificant item compared with the decrease in the prevalence of deadly and contagious fevers.

To banish the mosquito, drain meadow, bog, swamp, and marsh, fill up stagnant ponds and pools, and level rain holding hollows contiguous to dwellings, and in the same proportion as the foul murderer of sleep departs, so will malarial and miasmatic exhalations.

ONE WORD AS TO THE BIRDS.

Instead of devising methods to artificially breed disproportionate numbers of insectivorous insects, why is it not much more advisable to foster and preserve with little expense the means which we have at hand? I refer to the various species of insectivorous birds, which used to remain with us throughout the year, with the exception of two or three of the colder months, the most short lived of which would be more effective in the destruction of noxious insects than ten thousand dragon flies. Not a Sunday passes in the woods and fields adjacent to our cities but dissolute boys and men are maiming, killing, or frightening away every innocent bird within the range of their guns. If the farmer be so blind to his own interests that he will not assist in the enforcement of laws for the protection of song birds, and the consequent preservation of his crops, at least there should be aroused a public sentiment demanding the adoption of a more competent law than prevails at present.

It is simply absurd to provide, as the statute now reads, that the destruction of birds should be permitted to every collector or so called scientist. Our local birds are well known, their habits and peculiarities have been described hundreds of times, specimens are to be found in every museum, where they can be readily inspected, and there is not the slightest necessity for the satisfaction of the thirst of acquisition of every tyro in making a collection of either local birds or their eggs, or of swelling the stock in trade of the taxidermist or milliner. As a matter of fact, this wholesale and criminal destruction of birds has made them so scarce that an observation of their natural habits by the general public is an impossibility. A law should

be passed prohibiting the killing of all insectivorous birds, under a heavy penalty, unless a person has obtained and paid for a license, to be not less than twenty-five dollars per annum, the fees to be used toward the compensation of game constables, and such license to be granted only after approval by a competent board of officials.

V. CONCLUSIONS.

1. An attempt to destroy flies and mosquitoes by the artificial propagation of dragon flies or any other insect, would be unprofitable, unadvisable, and impracticable.

2. That if such attempt were both practicable in operation and profitable as to numbers produced, it would still be unadvisable from a sanitary point of view (the annihilation of every house fly would breed a pestilence).

3. That if the natural conditions under which dragon flies are produced could be totally eliminated, mosquitoes would be greatly diminished.

4. That a proper enforcement and observation of sanitary laws, and the passage of a proper law for the protection of birds, afford the best solution of the question.

IV.

ESSAY ON THE DESTRUCTION OF THE
MOSQUITO AND HOUSE FLY.

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ESSAY ON THE DESTRUCTION OF THE MOSQUITO.

PREFATORY NOTE.

THE following essay must be regarded as a provisional and introductory treatise. It is quite impossible to cover the entire ground, or even part of it, with details of experiments and observations such as would place any one's conclusions beyond criticism or reversal.

The short time given for its preparation has not permitted me to make the experiments necessary for arriving at any very original suggestions, though I have been led to notice in the course of its writing how unoccupied the ground is, and what interesting questions it opens.

The discussion of the house fly as a mischievous nuisance, and of methods for its destruction, has been almost abandoned by me, but I have made a short separate notice which at present incorporates the most that now occurs to me that can be said on this subject.

The far more important weight to be given to the problem of freeing our communities of the mosquito has received recognition, and this essay is in consequence almost entirely devoted to its discussion.

It will be seen that I have furnished throughout the essay a series of original observations, which I regard as useful contributions to science.

It is certainly to be hoped and expected that Dr. R. H. Lamborn's public spirited inquiries and attention to this subject will result in securing some alleviation from the persecution of the irrepressible and vicious *Culex*.

My thanks are due to Mr. L. P. Gratacap for his numerous suggestions and assistance he has given me in the preparation of this work.

NOTE.—The plates and catalogue prepared by Mr. Beutenmuller, and accompanying his essay, will be found at the close of the volume.

THE MOSQUITO.

IT would be difficult to overestimate the amount of distress and positive injury inflicted by mosquitoes. Their monotonous and droning song drives sleep from the eyes of nervous and exhausted patients, and the sharp puncture of their industrious lancet introduces in the arteries of their victims a subtle poison that inflicts an unendurable irritation. To some its consequences are truly baneful, and from many, to whom rest brings the refreshment of renewed strength necessary for their daily toils, it robs of vitality and energy; the sleep of babyhood is disturbed by the mosquito, by the mosquito the sufferings of the sick are intensified, the heat of summer becomes more wearisome under their exasperating inflictions, and the beauty of Nature itself wanes before their vexations and murderous attacks.

In view of such facts and consequences Dr. Lamborn has prepared a circular, in which he formally invites the attention of scientific entomologists to this problem, and opens the discourse by some practical suggestions; and these effective inquiries are made urgent to-day, when, in the neighborhoods of our large cities, useful and inviting tracts of country become almost uninhabitable by the presence of mosquitoes. In the suburbs of New York City the mosquito forms a veritable barrier to occupation. Many portions of New Jersey are deserted by desirable residents because of the great numbers of mosquitoes, and

when the land wind prevails at some of the summering resorts along the shores of this State the terrible hordes of this persecutor depopulate the hotels and cottages. The annals of travel record the wide distribution and un-failing activity of this abominable tormentor. The genus *Culex* belongs to the order of Diptera, family Culicidæ, which contains only a small number of genera, but a large number of species. The genus *Culex* is distributed over the entire globe.

The name Mosquito has been used in popular parlance for the genus *Culex*, and derived from the Spanish, signifying little fly. The vernacular of many nations varies exceedingly in the designation of these insects. In France they are known as Cousins; in Germany as Schnacken, Stiehmücke, Singmücke, and Gelse; in England as Gnats; in America and hot countries as Mosquitoes (sometimes spelled Mosquites, Moustiques, Mousquites, or Mosquilles); and in the Antilles as Maringouins.

Upward of thirty species are found in North America. *Culex ciliatus*, a large species found in the Atlantic States, bites very severely, but fortunately is comparatively rare, and does not appear in swarms as *Culex tæniorhynchus* (*C. damnosus* Say), which invades our brackish and salt water marshes. Although the mosquitoes are present all summer, there are four distinct broods in the Middle States, which only swarm at intervals of one month. According to my friend Mr. W. T. Davis, the first brood makes its appearance in the latter days of May or early in June; the second, third, and fourth broods appear early in July, August, and September.

In the Arctic region, where the larvæ of the mosquito constitute the principal food of the trouts that inhabit the

lakes, they are apparently double brooded; the first brood appearing in July and the second in August.¹ During the hot weather of July and August the mosquitoes are most numerous, and more annoying than during the cooler weather. The life duration of the mosquito in the imago state lasts about one week. A few individuals of the last brood hibernate over the winter. The food of the mosquito, besides blood of human beings and animals, consists of the sweets of flowers and other vegetable juices. (I have often taken mosquitoes with a mixture of molasses and rum used as a bait for capturing moths at night.)

MOUTH PARTS.

In this inquiry it is necessary to treat at some length the disposition and arrangement of the mouth parts, the contents and structure of the poison glands, which together constitute the offensive and injurious portion of the mosquito.

The mouth parts of *Culex* have received the careful study of many observers, who vary considerably in their results and give different enumerations of this complicated mechanism. From Dimmock (*Anat. of the Mouth Parts, etc., of Diptera*, pages 9-22, pl., 1881), the latest writer on this subject, I extract the descriptions (with some condensation) essential for the purpose of this paper. I have further restricted these extracts to the mouth parts of the female *Culex*, as it seems as yet doubtful whether the male mosquito possesses the sanguinary tastes of its truculent companion. The difference that obtains in the mouth parts of the male and female is chiefly comprehended in the absence from the former of the mandibles, and the

¹Ross, *Append. Second Arct. Voy.*, page lxxvi.

unbarbed characters of the maxillæ, and by having the antennæ plumose. The mouth of the female *Culex* consists of two groups of appendages, the elements of punctation and suction, with which are connected the adjustments for the secretion and emission of the poison, and the parts which enclose these and form around them a natural sheath.

The first group, which are surgical in character, embrace the epipharynx, second, the hypopharynx, two mandibles, and two maxillæ; and the second group comprises the labrum (upper lip), and the labium, which receives them into a groove on its upper side. (Dimmock.) The epipharynx is slightly attached to the labrum, and this combination, termed the labrum epipharynx, tapers uniformly from the base to the apex. It forms an unfinished tube, being completed along its inferior surface by the oppression of the hypopharynx to the narrow slit between its separated edges. The channel thus made is the avenue by which the juices of its host passes to the œsophagus, which is the postpharyngeal passage, and which acts like a suction pump for the imbibition of the nourishing liquids, being expanded into a bulb behind a valvular constriction of the pharynx. This action is performed by muscles attached to the epipharynx "having their insertions on the upper side of its wings or lateral portions" and extending upward and backward over the inner surface of the clypeus, the chitinous escutcheon above the labrum. The hypopharynx is a linear lanceolate, transparent lamellæ of chitin, and is the element needed to complete the tube of the epipharynx, which it effects by being placed in apposition with the inferior margins of the latter. Dimmock discusses the difficult question, whether

this appendage may be considered a rod or a tube, and, if the latter, whether it is not a duct for the injection of poison. He is in no doubt as to the actual effusion of a poisonous fluid, but, from the extreme delicacy of the microscopic examination, is unable to reach a definite result as to whether the hypopharynx is its channel. The later examinations (alluded to under "Poison Glands") of Macloskie seem to place this trying question in a clearer, if not certain, light. At any rate, the hypopharynx acts in conjunction with the epipharynx as an instrument of suction, and both are complementary organs.

The mandibles are the most delicate of the mouth parts of *Culex* and are composed of "two very thin, linear lanceolate lamellæ of transparent chitin, which rest with their inner edges beneath each half of the hypopharynx, their outer edges projecting beyond its outer edge, on each side." (Dimmock.) Dimmock describes them but does not seem to have discovered their significance or suspected it.

The maxillæ are also lamellæ of chitin serrated with a minute corrugation, which varies in different species in its inclination to the strengthening chitin rod on the inner side of the maxillæ. In some species it is at right angles, in others obliquely inclined. At the extremity of the maxillæ is a row of papillæ, varying in their number both in different species and different individuals. The papillæ have been regarded as serrations, by some observers. The maxillæ are accompanied by the maxillary palpi at their bases, which are four or five jointed flexible and abbreviated stalks. Dimmock considers the office of the maxillæ to be the drawing into the perforated skin of the other mouth parts, but Macloskie expressly alludes (Science, X., 106) to their cutting action as the actual or

accessory apparatus by which the perforations of the skin are made.

The second group of mouth parts, the invaginal or sheathing parts, consists of an upper lip (labrum) and an under lip (labium) with its accompanying setae, which latter according to Dimmock form the aggressive cutting or piercing organs of the mosquito.

The labrum is a thin, lanceolate lamellæ of chitin, concave along the under side from the basal portion to the tip, and its concavity rests upon and fits to the convexity of the tubular parts of the epipharynx. It is provided with its own muscles and possesses some independent motion. It serves the purpose, together with the labium, of framing the tensile and extended group of parts just described.

The labium is a long, tapering channel, annulated, and covered with fine hair and scales. At its extremity it carries two lobate appendages—the labelle—which are furnished with muscles by which these latter can be dilated or contracted. When the combined parts of the surgical group of instruments are entering the skin, they pass between the opened angle of the spread labelle while the labium itself “is seen to be flexing backward in its middle, the labelle holding the clustered file of setae as they pass inward through the tissues of the victim. Reaumur, Mem., plate iv., gives a very good illustration of the bent labium holding in position the other mouth parts in act of stinging.

POISON GLANDS.

This description is found in a letter to Science (Vol. X., page 106, and Vol. XII., page 144) from Professor Macloskie, of Princeton College.

The hypopharynx, which acts as the poison fang, is connected with a poison duct which has two branches running backward into the prothorax. The secreting glands are in two paired systems, one on each side of the prothorax. Each system consists of three trifoliate glands, the mid-gland being poisonous and the lateral salivary; the three ductules uniting into the branch of the poison duct of its own side.

LIFE HISTORY AND DEVELOPMENT.

THE breeding grounds of the mosquito embrace the swampy hollows of low grounds, shallow rain pools, cisterns, ponds, and the wide expanse of salt or brackish marshes extending up along the estuarine banks of sluggish rivers and the tide-invaded shores of sandy peninsulas, and also the wet area in thick woods.

The first stages of the mosquito are found in the small floating or suspended raft composed of an assemblage of many hundred eggs, each subconical in shape, tapering to a somewhat rounded or obtuse point notched at the apex. The number of eggs in these rafts reaches as high as three hundred, and become cemented together by the glutinous substance secreted at the oviposition. The period of hatching extends about five or six days, when the young larva makes its appearance after cutting through the under surface of the egg. (Plate VIII., Fig. 2.)

The young larva remains in the water for about twenty days, passing through a series of three or four moults.

The larva when full grown is about five millimetres long, and is of a semitranslucent, grayish blackish color. The head is small, subglobose. The first, second, and

third segments are about twice as broad as the remaining ones; each segment along the sides is furnished with a bunch of very short bristles. The anal segment is provided with a rather long tube, through which it breathes by rising to the surface of the water. Its well known rapid oscillating movement through the water is performed by the quick lateral pulsations and lashes of its tail, while it will often remain motionless for many moments at the surface of the water, hanging head downward from the liquid floor. Their food consists of minute organisms and animal matters, and it has been suggested that they free the stagnant swamps of miasmatic regions of their malarial and zymotic germs.

The pupa stage lasts about four or five days. The pupa is of a blackish color, with the wing cases and thoracic segments enormously developed and the thorax provided with two respiratory tubes. The abdominal segments are considerably narrower than the thoracic ones, and become slightly smaller towards the posterior end of the body, which is furnished with two oar like appendages used for swimming. (Plate VIII., Fig. 3.) Length about three millimetres. After this stage succeeds the emergence of the imago from its encasement. The delicate shell of the pupa is ruptured by a short split near the head, when the adult mosquito presses through the orifice, and remains upon its fairy like boat, drying its wings and gathering strength for its aerial or terrestrial life

DISCUSSION OF THE PROBLEM.

THE actual injury inflicted by the mosquito can only be approximately estimated; the numerous instances, which must escape all record, wherein the mosquito inflicts the

most serious discomfort, and its sanguinary appetite, can be imagined rather than described when we are made familiar by personal experience with its habits. The gradations, too, between such mere inconvenience or irritation, and serious consequences arising from its bite, can be indefinitely expanded. The wound that brings about a temporary inconvenience may, under other circumstances, become a swelling, lasting for some time, tending to diminish vitality or retard recovery from disease. These effects can become more and more important, more and more permanent and pernicious, until we reach such a possibly aggravated state of things, wherein exhaustion may disturb the delicate balance between life and death.

Dr. Findlay, of Havana (see *Science*, Vol. VIII., page 279), has brought the more unnatural charge against the mosquito, that it is an agent in spreading yellow fever. Dr. Findlay asserts that it is his belief that the insect, after puncturing the skin of a yellow fever patient, retains some of the germs of the disease, which are communicated to its next host. Similarly the young of mosquitoes breeding in neighborhoods afflicted with the disease would even become the carriers of its germs. So convinced is Dr. Findlay of this that he avers that the mosquito is the active, if not the sole, agent for the dissemination of yellow fever, and he believes that where the mosquito cannot live, or, at the season when it decreases in numbers, the yellow fever simultaneously disappears. In corroboration of this he says that in the summer of 1885 mosquitoes were scarce in Havana, but were very numerous in the autumn; and that yellow fever cases were few in number, but in October and November they increased considerably, at which times the mosquitoes appeared. In confirmation of this view

Mr. H. Hammond (Science, Vol. VIII., page 436) says: "In 1839, during a yellow fever epidemic in Augusta, Georgia, no cases originated at Somerville, a neighboring suburb, among the sand hills. There were no mosquitoes at Somerville, which was approached by a rather circuitous route from Augusta. Some years after, a straight broad road was built through the swamps directly to the sand hills; cisterns were also built; and mosquitoes appeared and became an intolerable pest. During the yellow fever epidemic of 1854 a number of cases originated at the sand hills abounding with mosquitoes."

I think that, while it may be true that the mosquito as well as other predaceous Diptera can carry germs of yellow fever, it would be rather a strained and unreasonable complaint to urge that they are the sole causes of that epidemic. These instances, however, emphasize the noxious character of the mosquito and make the inquiries and suggestions of Dr. Lamborn of very essential value.

Again, the mosquito has been accused of further mischievous activity in spreading entozoic diseases. According to the researches of Drs. Mason and Cobbold (P. Lin. Soc., pages 304-311, 1878, and Trans. Linn. Soc. Lond., 2 ser., Vol. II., page 367, 1884) and others, it appears certain that these insects disseminate the parasite *Filaria sanguis hominis* by absorbing them into their system when imbibing the blood of their prey, and afterwards, by their death, contaminate drinking waters into which they fall with these entozoa imprisoned in their bodies. Sonsino in Egypt (Med. Times and Gaz., May 13, 1883, page 494, and Sept. 22, page 340, 1883) and Lewis in India (14 Rep. Sanit. Com. India) have both confirmed Mason and Cobbold statements as to the entrance of *Filaria* into

the mosquito. *Filaria sanguinis hominis* is a minute nematoid embryo—which in certain warm countries is found in the blood of man.

Taking into consideration all the reports against the mosquito, Dr. Lamborn is undoubtedly correct in his timely suggestions that any effort toward the extermination or reduction of the numbers of this pest should be followed with all possible skill and patience. But, lastly, consider how many houses in summer-time, at the hottest and most trying season of the year, are rendered almost useless; how much attractive land is made uninhabitable; how many furious and debilitating nights and days are passed in agony from the attacks of this insupportable winged fiend, and the question of its suppression becomes one of economic and social importance. To be sure, there is the revers de medaille claimed for the mosquito.

It has been claimed in his behalf that in its larval stages it destroys the germs of miasma. The plea is futile and misleading. The germs of miasma are very problematical and indefinite organisms, and the radical methods of the extermination of miasma are well known and far more efficient than any supposititious relief to be expected from the larvæ of mosquito. Drainage and clearance and sunlight are the scientific methods to overcome this difficulty. Besides, J. W. Slater (Ent., page 87) is of the opinion that "aquatic dipterous larvæ appear to render stagnant waters more corrupt." While Dr. A. F. A. King, in a paper read before the Philosophical Society of Washington, D. C., endeavors to sustain the thesis that malarial disease is produced through the instrumentality of mosquitoes, which by their punctures inoculate the body with the malarial poison.

It is absolutely certain that as a preliminary conclusion I can confidently assert that the mosquito is injurious and that its extermination or its abatement is a benefit.

In discussing this problem we are compelled to avoid any collision between the achievement of the desired end by such means as we may employ and usages or comfort of society.

A remedy which considered in itself might be quite efficacious is debarred from consideration if it interferes with social usages or is a nuisance. In the discussion, even, we should be inclined to reject any suggestion which was recommended simply on the score of its being less aggravating than the scourge. The remedy should be complete in itself and harmless in its results, inoffensive, and if possible attractive, so that with the eradication of a pest we may substitute a pleasure or an ornament. Further, we must select by preference all such remedies as are the least exhausting, the least expensive, most readily obtained, and most easily maintained. Furthermore, we should inspect the various stages in the life history of the mosquito and observe the requisite, feasible, or known devices for its extermination at each stage. In this way it might be possible to find a method which, applied at one stage, was many times more effective, owing to the conditions then prevalent, than a more difficult or costly one used at a later or different period.

There are obviously two distinct paths of experiment in reaching practical results: first, by natural methods, and, secondly, by artificial; and as between these, other things being equal and the results the same, the natural methods are to be preferred if it can be shown that they will continue in action automatically after their introduction, or

will require but little outside encouragement or renewal. Dr. Lamborn brings one of the most interesting of these natural methods forward to notice, and I have considered it at length in the succeeding section upon remedies.

It is also requisite to examine the divers conditions of different places, and to adapt as far as possible remedies most suitable, adequate, and attainable for the places under consideration.

Further, it is well to draw attention to the desirability of a general and consolidated effort on the part of communities in these enterprises, or even to enlist the assistance of local governments towards securing some means for the eradication of the pest.

With these preliminary observations, and speaking under the influence of a firm conviction that the mosquito is a serious and avoidable nuisance, I pass to the consideration of the possible remedies.

NATURAL REMEDIES.

THE DRAGON FLIES—ODONATA.

THE first measure which promises relief is the creation of a sufficient number of the natural destroyers of the mosquito; that is, to set in motion an organic device, or an arrangement of organic machinery, which will work smoothly and effectively.

This plan is fascinating in itself and is in accordance with scientific principles, for it invokes the activity of Nature to amend or repair her own mistakes and injuries, and appears comprehensive and economical. It introduces that balance of opposite agencies which Nature uses everywhere to repress her own.

The dragon flies (Odonata), especially the *Æschnina*, *Gomphina*, and *Libellulina*, are the natural enemies of the mosquitoes; they are voracious, they sometimes appear in great numbers, and as a matter of fact the mosquito disappears before them, while their breeding grounds are in many respects similar, so far as fresh and brackish water habitats are concerned; and, finally, in the metamorphoses of the dragon fly we meet conditions which introduce it in antagonism to the mosquito at the same stages of development.

The voracity of the dragon fly has been frequently reported, and it is an old fact that the dragon fly will eat its own body when offered to him. I have experimented with *Æschna heros*, which ate forty flies inside of two hours, while *Libellula pulchella* devoured twenty-five flies in the same period.

MIGRATION.

That the dragon fly does naturally occur in great numbers at favorable moments is also a matter of scientific record. Mr. E. T. Koppen (*Stett. Ent. Zeit.*, pages 183-188, 1871) gives a chronological résumé, from 1494 to 1868, of records of flights and swarms of species of dragon flies, especially *Libellula quadrimaculata* Linn. (See Appendix B for further information on migrations of dragon flies.)

That the mosquitoes actually diminish in the presence of the dragon flies seems in a measure authenticated. Dr. Edgar A. Mearns informs me that while he was stationed at Fort Snelling, Minnesota, the mosquitoes appeared in vast swarms, to be shortly after followed by large numbers of dragon flies (*L. pulchella*?), at whose appearance the numbers of mosquitoes, which were at that time a pest,

were considerably reduced. I had a similar experience last summer at Sandy Hook, New Jersey, where the mosquitoes are always abundant. Last season immense numbers of *Diplax berenice* appeared and but few mosquitoes were to be found. Mr. W. T. Davis met with the same fortune at Perth Amboy, Long Island. From Dr. Lamborn's circular it is also seen that he has been struck by the same coincidence. Mr. Pryer (*Journ. N. Branch Roy. Asiatic Soc.*, IV., pages 75 and 76) also noticed great abundance of dragon flies in Japan, where they seemed to keep down the numbers of mosquitoes.

BREEDING GROUNDS, HABITS, ETC.

The breeding grounds of the mosquito and dragon fly are similar in some respects. The larvæ and nymphæ are found in sunny places, shallow and especially still pools, and in swampy areas. But they are different in this respect, that the dragon fly cannot be raised in waters of deep or shady woods, having a propensity for the sunlit areas, both aquatic and terrestrial.

The metamorphoses of the dragon fly, passing as it does through an aquatic existence, adapt it possibly for contest with the mosquito life in the larval stage of both, though on this point more precise information is needed. The voracity of both larva and nymphæ of the dragon fly is well known. It has been asserted by Mr. L. Biro (*Rov. Lapok. I.*, pages 251-253) that "the larvæ of some species of dragon fly was destructive in the piscicultural establishments in Hungary. Fifty thousand young fish were placed in a pond in spring and in September only fifty-four remained, and there were immense quantities of

dragon fly larvæ." This inference needs corroboration, as the fish may have died from other causes.

In view of all these facts, I believe it is a feasible plan to pursue the directions for relief indicated by Dr. Lamborn, in an experimental manner; but I am led also to conclude that remedies less elaborate will yield quicker results. For there are difficulties to be encountered at the outset which only patience and ingenuity can surmount, and patience and ingenuity demand time and money for their exercise. The difficulties connected with this are in the breeding stages and the somewhat different habits of dragon flies and mosquitoes.

Whether the dragon fly can be artificially bred so as to use the same against the mosquito is a matter for experiment. Their life histories are not yet sufficiently known to make positive statements in this direction. (Although I made a series of experiments last summer in breeding *Libellula auripennis*, *L. pulchella*, *L. semifascia*, *G. trimaculata*, *Diplax rubicundula*, and *D. berenice*, yet lack of time prevented my giving it proper attention, and I failed to rear these species.) The principal difficulty will be found in the protection of the different stages of dragon flies against mutual depredation and injury; I am inclined also to think that the larvæ of the dragon fly will succumb far more quickly than the mosquito, and that the delicate conditions requisite for its growth are not always easily attained. But I would recommend for experiment *Libellula quadrimaculata*, which is found in North America, Europe, and Asia, as a species easily obtained and noticeable for its appearance in immense swarms.

Furthermore, it is to be remembered that the mosquito is partially a nocturnal insect, while the dragon fly is

diurnal ; that the mosquito nestles in tall grass, seeks the protection of trees and shrubs, and is practically hidden in the edges of copses and woods.

Under these circumstances the dragon fly will not find its prey. Great numbers will escape ; only those encountered in its busy flight through the air will be captured, for the dragon fly does not hunt for its booty nor scour the forbidden shadows of woods and forests, and at nightfall the mosquito will elude his pursuer and rise to his murderous intent.

Besides, as I pointed out in the Discussion of the Problem, the remedy should be complete and unassailable and fit the widest variety of conditions. The dragon fly may in some genial locations suit the elements of the question and be of practicable service ; it may, indeed, be more widely beneficial than we suspect, as the references above made would seem to show ; but the preliminary experimental stage of rearing dragon flies and studying their preparatory stages must be first successfully examined.

For this purpose I have given in Appendix B a bibliographical catalogue of all the known transformations of the Odonata of the world, and have also inserted in the same place a short sketch of the mode of oviposition and description of the egg of *Libellula*, *Plathemis*, and *Diplax*. I have also, for the convenience of collectors, added a list of species of Odonata found in New York State, with special reference to those found in the vicinity of New York City.

FISH AND WATER FOWL.

I consider, in the second place in natural remedies, the importance of fish and water fowl for the subjection of

the mosquito. These instrumentalities I regard as of very considerable importance, and amongst natural remedies place them as the equivalents, and, possibly, of more interest than the dragon fly. For in this connection it must be remembered that a method which attacks at its inception is more likely to lead to radical results than one applied later, after the scourge has reached considerable dimensions and is not so readily grasped. If the larval stages of the mosquito can be reached effectively we have nipped the disorder, as it were, in the bud. It is true that distinguished entomologists state that the dragon fly in its water life attacks and destroys the larvæ of the mosquito, but I have no information on that point, though, from the manner in which the larvæ of the dragon fly destroy each other, it seems probable that their carnivorous propensities might lead them to attack the young of mosquitoes. Yet, in this case, I think the injury inflicted on mosquitoes would be slight, and the larger number would escape. But young and old fish, and also aquatic birds, will devour them in great numbers where they occur in large masses, and the cultivation of these denizens of our pools and lakes is, therefore, most advisable, as striking means for the diminishment of these pests.

Mr. Ludwig Riederer, of New York, informs me that he has dissected a fish caught in a fresh water lake, and found in its stomach hundreds of mosquito larvæ and pupæ.

I said in the discussion of the problem (ante) that we might find it well to use some remedies, in some circumstances, that would preclude the use of others equally effective, while these latter would be again valuable under different conditions. Here is an illustration: Aquatic

birds can be adopted for the purpose of destroying mosquito larvæ in ponds, rain pools, etc., near houses, and in ponds in well cleared fields, rolling and cultivated land, where there is no extent of wood and management of the fowl can be made simple and their breeding profitable; and fish can be introduced in our public lakes. In these different provinces the different agents of this compound remedy will effect beneficial changes. It has been observed by myself how infrequent the larvæ are in the Central Park (New York City) lakes, and that their absence is due to the industry of the fish and water fowl, though there is another suspected cause which I will mention in a succeeding section.

The obvious dissatisfaction over these remedies is their probable insufficiency; but as helpful and useful, in the absence of more perfect means, there is in my mind no doubt.

Third, this group of natural remedies comprises the dissemination of parasitic fungus and the cultivation of fresh water algæ to such an extent as to prevent or retard the development and health of the mosquito larvæ. Dr. Hagen calls the attention of entomologists to the use of beer yeast for destroying greenhouse pests, which proved to be successful against plant lice (aphidæ) and potato beetles. But as this process is so uncertain to use against the mosquito, I only suggest that experiments in this direction may be made for the observation and record of facts which may lead to results which are of practical usefulness.

Mr. L. P. Gratacap, of the American Museum of Natural History, has suggested that the increase of fresh water algæ would greatly impede the progress of the mosquito

larvæ in the water and by entanglement effect their destruction before they could rise to the surface for the respiration of air. This suggestion appears to me important, and I am inclined to agree with Mr. Gratacap that the vast numbers of the fronds of *Oscillatoria* in the Central Park lakes have had a deterrent effect upon the propagation of mosquitoes in those localities. The requisition here is a largely disseminated mass of algæ, which, in such rod-like forms as *Oscillatoria*, will float through the water and by its intermixed and diffused stipes embarrass the development and movements of the mosquito larvæ. I cannot lay especial stress on this suggestion, but regard it as a very interesting field for practical experiment.

ARTIFICIAL REMEDIES.

The second class of remedies are those which involve the use of artificial means, chemical, physical, or mechanical, and which ingenuity has proven to be effective. They are, first, those which aim directly at effecting the destruction of the mosquito; and, second, those which are simply deterrent or protective to the individuals attacked by mosquitoes, and therefore of limited and strictly adventitious usefulness.

The use of coal oil in swamps, by filming the ground, odorizing the air, and floating upon the surface of the water itself, is a very practical and energetic remedy. It has its disadvantages, and I recall the principle I laid down in the "Discussion of the Problem," that no remedy should be recommended which replaced the scourge we endeavor to eject by an obnoxious substitute. Yet, in many places removed from general habitations, this remedy can be safely employed. It acts destructively upon

the early stages of the mosquito. The use of poisons or uncongenial admixtures in the breeding grounds of the mosquito is to be avoided.

The use of lanterns so arranged as to attract and destroy the mosquitoes. The lamps I recommend are illustrated on Plates VIII. and IX. Their action is simple and adequate. The mosquitoes are attracted to them, and are destroyed in the pans of coal oil or kerosene, or other strong mixtures which may be used. They should be placed around houses, hotels, and in marshes. The expense and trouble with their management is inconsiderable, as their use is discontinued, of course, during a large part of the year.

General and scientific drainage of swamps is a very radical and intelligent course of operation. It goes even further back than the larval stage, for it precludes the incipient acts of the mosquito at propagation. It robs her of the congenial nidus for the development of her eggs.

Finally, I beg to emphasize the extreme aid which village authorities might render in this matter. A small general fund appropriated to experiments would be of great assistance in helping to solve the problem. At the same time no isolated and forlorn unsupported attempts on the part of a few localities will be of any use. Coöperation, combination, unanimity, and persistence are the needed factors, and only in such consolidated efforts can we look for any encouragement in freeing ourselves from this formidable pest.

MEDICINES.

I append a list of more or less helpful medicines or deterrents for individual protection: lemon juice, vinegar,

oil of peppermint, and oil of pennyroyal. A very strong infusion of roots of *Triticum repens* is successfully used at Simbirsk as a preventive against the attacks of mosquitoes, etc. (Ross. Ent. Soc., X., page 10. A weak solution of quassia wood boiled in water has also been recommended against bites of mosquitoes. (Nat., XXII., page 11, 1880.)

CONCLUDING RECOMMENDATIONS.

The results of this examination of the problem laid before the scientific world by Dr. Lamborn, and recommendations flowing from these results, are :—

1. A closer study of the life history of the dragon fly, which invokes for its objects the exact determination of the period of the larval condition, habits, etc.

2. I recommend the employment of the lamps mentioned (see Plates VIII. and IX.) in swamps and along coast marshes, in damp woods, and about houses and hotels.

3. The raising of fish in ponds and the encouragement of raising water fowl in regions where fresh water is abundant.

4. Where the conditions are favorable and their use will not lead to the interference with health, I believe the use of coal oil in the waters of the estuaries of our rivers and on the rain invaded areas of deep woods will be effective in destroying the mosquito in its larval stages. Astringents, as logwood or alum, will also prevent the growth of the mosquito in its incipient stages.

5. Drainage of swamps. This is of immense value and probably a complete remedy where it can be inexpensively used.

Finally, the question of mosquito extermination or abatement, I believe, can only be satisfactorily settled by a conducted movement over wide tracts of land. The arrest of the plague in one portion of the country, when the next section makes no effort to suppress its own annual contingent, can only lead to discouragement and ridicule. The approval of local authorities and the appropriation of a fund for the purpose will greatly aid the cause of mosquito extermination, and especially the location of the worst infected regions, whose baneful progenies are carried far and wide over their afflicted vicinities.*

THE DESTRUCTION OF THE HOUSE FLY.

I DO not think it is possible to introduce the dragon fly into the streets and houses in cities for the purpose of using it as an instrument of attack against the house fly (*Musca domestica* L.). The latter, from habits, has become completely domesticated, while the former retains all its wild nature unsubdued and unchanged, has undergone no experience which would tend to divorce it from its outdoor life, and probably it cannot be modified in this respect, even after long habituation to new conditions. Its natural voracity might disappear under such circumstances, or its tastes be altered. Its aerial and sunny existence could hardly submit to such a violent change without some corresponding modification of its nature.

*Prof. R. P. Whitfield informs me that some years ago while he was staying at Atlantic City, N. J., he noticed that people of that town were using an astringent in the water to kill the mosquito larvæ which were at the time very numerous, and upon inquiries made by him was informed that the chemical used for the purpose was copperas (ferrous sulphate).

That the house fly is in some ways a menace to health may be readily allowed. Scientific literature contains many instances illustrating this fact. Dr. B. Grassi's experiments (*Archiv. Ital. Biol.*, IV., pages 205-208, and *Am. Nat.*, XVIII., page 1267) show that flies are agents in the diffusion of infections, maladies, epidemics, and even parasitic diseases. Drs. Spillman and Hanshalter, in a report made to the French Academy, have come to similar conclusions. (*Science*, X., page 214, 1887.) Leidy (*Proc. Ac. N. Sc. Phil.*, 140, 1874) found a thread-like worm infesting the house fly. This parasite was first discovered in the house fly of India by Mr. H. J. Carter, who described it under the name *Filaria muscæ*, and suggested that it might be the cause of the Guinea worm, *Filaria medinensis*, in man.

The house fly in its larval stages lives in manure and other decaying vegetable matters. I would suggest the speedy removal of all such matters in cities, and also the refuse in houses, and under no circumstances should our Board of Health allow the accumulation of manure for shipment along our river fronts, as has been done in certain parts of New York City.

Stables are the principal breeding grounds of the house fly. Kerosene sprinkled over the floor in stables is said to be an excellent remedy to keep flies away.

The various instruments and methods to trap flies in houses are too well known to discuss here. As a self-perpetuating remedy, and one allied to the natural means discussed in reference to the mosquito, the fly fungus (*Sporendonema*) might be employed and established to destroy the house fly by inoculation.

MODE OF OVIPOSITION OF CERTAIN SPECIES OF ODONATA.

THE female of *Libellula*, when laying eggs hovers over the surface of the water, and, coming in close proximity of the same, balances herself by the very rapid motion of the wings, curves her body downward, and dips the tip of her abdomen into the water at short intervals, and at the same time deposits from twenty-five to forty eggs, which are surrounded by an invisible glutinous substance secreted at oviposition, by means of which they adhere to aquatic plants, sticks, stones, or any other object they may come in contact with at the bottom of the water. In order to ascertain the number of eggs laid each time the female *Libellula* dips her abdomen into the water, I captured at different times several specimens of *Libellula auripennis* and *L. pulchella* in act of ovipositing and held together their fore wings, allowing the hind wings to remain free and in action while I dipped the tips of their abdomens into a small vial filled with water, and invariably at each dip about the same number of eggs were deposited as alluded to above. This experiment I repeated until the supply of eggs of my specimens for the time being was exhausted, and the results were always the same. As regards my observations of *Libellula*, they agree with those made by Siebold. (Germ. Zeit. Ent. II., page 421.) The male of *Libellula*, as is stated by Siebold, retains its hold to the female and directs her movements while ovipositing. Müller (Ent. M. Mag., VIII., page 127) confirms the assertions made by Siebold. Although I have seen scores of *L. pulchella*, *L. auripennis*, *L. semifascia*, and

other species in act of oviposition, the females were always destitute of the male, and only in one instance I saw a male retain its hold to the female while laying eggs. The egg of *Libellula auripennis* is irregularly oval, with very fine granulations, sordid white and semitranslucent, becoming amber yellow before the young larvæ emerges. Length, one-third millimetre; width, one-fourth millimetre. A number of eggs which were laid on July 23d, at 6.30 P. M., disclosed the young larvæ on August 1st. The egg of *Libellula pulchella* is very similar to that of *L. auripennis*, in fact cannot be distinguished from it, except that it is a little more irregular in shape. Length, one-third millimetre; width, one-fourth millimetre. Laid July 23d at 6 P. M.; young larvæ emerged August 31st.

The mode of oviposition of *Plathemis* (*P. trimaculata*) and *Diplax* (*D. berenice* and *D. rubicundula*) is identical with that of *Libellula*. The egg of the former is elliptical or subelliptical, granulated, semitranslucent, pale yellowish white, becoming amber yellow before hatching. Length, one-half millimetre; width, one-third millimetre. Laid July 13th, at 5 P. M.; young larvæ emerged July 23d. The eggs of the two latter species are oval, yellowish white, semitranslucent, and slightly granulated. Length, one-half millimetre; width, three-tenths millimetre. Laid August 12th; young larvæ emerged August 22d.

Calopteryx (*C. virgo*) deposits her eggs on the under side of leaves of aquatic plants. (Brandt, Mem. Ac. Sc. St. Petersb., 1868.)

The habits of *Agrion* and *Lestes* differ entirely from that of *Libellula*. They deposit their eggs in a groove made by their ovipositors along the stems of water plants.

Both *Agrion* and *Lestes* sometimes also go beneath the surface of the water to lay their eggs. Siebold (Wiegmann. Archiv. Plate I., page 205, 1841) has observed the female of *Æschna* clinging to a plant, dipping her body beneath the water and rubbing it up and down along the stem. Mr. W. T. Davis once saw a female *Æ. verticalis* descend beneath the surface of a slow flowing spring, but he has not seen the species deposit an egg as is stated in one of the volumes of the "Zoological Record." I have seen, at Sandy Hook, N. J., a species of *Æschna* laying eggs in the same manner as *Libellula*, with the male directing her movements.

The best time I found to make observations and to capture the different species of Odonata is between sunset until dusk or on a day partly clouded. In the hot rays of the sun the insects are too active and shy to make observations about their breeding habits; while during sunset or on a cloudy day, when the sun is less torrid, they are less active and rather sluggish in their movements.



V.

DRAGON FLIES AS MOSQUITO HAWKS ON
THE WESTERN PLAINS.

A LETTER FROM

C. N. B. MACAULEY,

CAPTAIN AND ASSISTANT SURGEON, UNITED STATES ARMY.



DRAGON FLIES AS MOSQUITO HAWKS ON THE WESTERN PLAINS.

THE following letter from an officer in the United States Army gives valuable information as to the good service rendered by dragon flies against the mosquitoes of our Western States :—

In the summer of 1885 I was on duty at Fort Abraham Lincoln, Dakota. The post is on the Missouri River, west side, about six miles below Bismarck. On my arrival I was told long yarns about the thickness of the mosquitoes.

I was not inclined to believe them, as I had served on that river before and had not been troubled at all, except when I went into the brush on the bank. However, the “yarns” were more than fulfilled towards the latter part of June. People who went up the river to Fort Buford and above—nearly five hundred miles—told the same story. The pests were so thick that I could hear the horses and mules in the Quartermaster’s corral crying from irritation. Both in the officers’ quarters and the enlisted men’s barracks, thick “smudges,” made by burning half dried grass, were the only things that rendered our quarters inhabitable. On the target range during the end of June and about three weeks in July I could not stay, unless I had on heavy boots—such as are used out there for riding, thick trousers, leather gauntlets, and a thick “cache nez” tucked under my helmet and collar of my tunic.

My friend Lieut. H. O. S. Heistand, Eleventh Regiment of Infantry, U. S. Army, told me he had seen mosquitoes quite as thick at Camp Poplar River, Montana, a few years before, and had seen them disappear as if by magic. He said there suddenly appeared a species of "devil's darning needle" or dragon fly, of rather a large size. These insects flew in lines slowly. At first he did not think they had anything to do with the mosquitoes' disappearance, but the change was so sudden, and without sufficient change in the temperature to account for it, that he was forced to the conclusion that this insect was at the bottom of it. This, he said, was corroborated by some "squaw men" and Indian traders who had been at Camp Poplar River for several years. They said these flies did not appear every "mosquito year," but when they did they came in droves and cleared the place out. They called them "mosquito hawks."

While sitting on the target range one day in July, toward the end of the third week, I think, with the mosquitoes as thick as ever, we were talking about the mosquito hawk, and wishing he'd hurry up. Just then Lieutenant Heistand shouted, "There's one now!" For some time before this I had given up slapping myself, as I had not been so much troubled. On looking around I saw a number, about a dozen, of the largest dragon flies I ever saw. If I remember correctly, they had four wings, six legs, were about two inches long, and of a dark brown color. I picked up a dead one some time later, and was about examining it when I was called away. I lost the specimen, and so cannot be certain of my description. The wings had a fine network of blood-vessels (?) and had the faintest kind of an emerald green

tinge. I am not an entomologist, I am sorry to say, so I cannot describe the "bug" more exactly.

From Mr. Heistand's enthusiastic description of these mosquito hawks I was curious to see how they caught their food. I noticed that they flew in an irregular kind of skirmish line, moved slowly, and every now and then made what he described as short "dabs" at apparently nothing. Mr. Heistand said that "each one of these dabs means a mosquito." It was curious to see how deliberate they were about it, and how fairly aligned this skirmish line was. They appeared somewhere about 11 A. M., and when I went into the post later I crossed the parade ground and saw detachments of about half a dozen flying slowly about. They stayed at about an average of three feet from the ground. I do not know how late they kept it up or how early they began. They stayed until all the mosquitoes appeared to be gone. I intended catching one and chloroforming it for examination—I even made a net for the purpose—but I hadn't the heart to do it, because of the business like way they made life bearable. I do not remember how long they stayed—maybe a week—but I know that at the end of three days the change was so great that head nets were no longer needed, and existence was bearable once more. At the end of September of that year I was ordered to Poplar River, where the mosquitoes had been just as bad, and I have a dim recollection of hearing of the appearance of these mosquito hawks. The following year we had a few mosquitoes, but as the summer was unusually dry, even for that comparatively arid country, they were few and did not last long. The next year they appeared and were very bad again, but I was ordered to the Indian

Territory at the end of July; I did not see any of the "hawks." I heard from time to time that mosquitoes were very thick there, but how long they stayed, or whether these dragon flies appeared or not, I do not know.

I am sorry I cannot make a more scientific account than this, but between an epidemic of measles that broke out in the post about that time—and as the post surgeon was away I had all I could do to attend to the cases—and a number of other things that occurred, my letter is simply a "recollection." Of this I am certain, that for a time head nets, mosquito bars, and the best way of making "smudges" were about all I could think of, and that on and after the appearance of these "mosquito hawks" the above mentioned articles sank into an "innocuous desuetude."

They might be bred in the East, but they are an erratic insect. As I said before, they do not appear every "mosquito year," and it was just my good fortune that I happened to see them. Officers who were with me in that garrison, who had been stationed there years before, told me that it was almost worth a man's life to attempt to walk up to Fort McKean (a small infantry post on the foothills behind Fort Lincoln), not so much from the Sioux, as from what they (the officers) termed the Sioux's allies—the mosquitoes.

TO DR. R. H. LAMBORN, New York.

PHILADELPHIA, PA., 22d January, 1889.

VI.

CAN THE MOSQUITO BE EXTERMINATED?

BY HENRY C. McCOOK, D. D.

FROM THE NORTH AMERICAN REVIEW, SEPTEMBER, 1889.



CAN THE MOSQUITO BE EXTERMINATED?

NATURAL science has taught the world modesty in its judgments. Many things thought impossible have been done, and the imaginary achievements of the genii and magicians of earlier ages are the workaday deeds of modern times. Therefore one may well hesitate to say that the extermination of the mosquito is impossible; yet the facts seem to point that way. The mosquito is an ancient inhabitant of this globe of ours, being found among the fossil insects, and is as catholic in its distribution as venerable in its descent. Having thus far held a place among the myriad creatures of our globe, it is likely to continue its generation. Let us, then, accept it as inevitable that the mosquito cannot be exterminated.

Can the mosquito pest be mitigated? That is quite another question, which has just been raised by a philanthropic gentleman with strong scientific tastes. Dr. Lamborn, who has recently offered a prize for a preliminary study of the habits of dragon flies, with a view to their propagation as destroyers of mosquitoes, has found the ready ear of the American nation. His manifesto was a "touch of nature" which has proved our New World "kin," for, alas! there are few portions of this beautiful domain where the mosquito has not piped her war song and drawn blood from human victims. I am constrained by truth, despite the seeming discourtesy, to say

“her.” It is the female mosquito that does all the damage! Her spouse is a harmless creature. Without claiming any knowledge as a specialist of these very interesting but disagreeable insects, I may offer a few suggestions intended to encourage public sympathy and coöperation with an enterprise which may seem to many chimerical. Certainly nothing is ever done by attempting nothing; and if we wish to rid ourselves of what is an undoubted pest in certain localities, we must at least “make an effort.” Success in limiting the number of mosquitoes pivots upon two points: Hostile Environment and Natural Enemies.

I.

Where the conditions are favorable for propagation and growth, the mosquito, like other creatures, will flourish. If those conditions can be made unfavorable, the insect must decrease. This compels us to ask, what are favorable conditions for the mosquito's development?

The question is easier asked than accurately answered. In point of fact, the mosquito has a cosmopolitan distribution. It is supposed to have its paradise in tropical countries, but it flourishes in Labrador. It affects low lying positions, but lovers of the Adirondack Mountains will recall visions of “smudges,” and cheese cloth canopies on rustic bunks, and battles with swarms of Culicidæ amid the sighing of pines and the sweet fragrance of the balsam. It loves the interior, and many a veteran may recall the days when he hunted prairie chickens on the plains of Illinois with mosquito netting twisted around his hat and face; yet it is said, though good testimony could be drawn to the contrary, that “a few” mosquitoes have habitat along the seashore of New Jersey! But, wherever found,

one condition seems to be essential to its active development. It must have water.

The mother mosquito deposits her eggs in minute boat-like masses upon the surface of water. From these eggs come little larvæ, or worms, or maggots, to use popular words. These wee things inhabit the water, living most of the time at or near the bottom, where they are said to feed upon decaying matter and the micro-organisms that swarm in such conditions. The question has often been asked me, "What were mosquitoes made for, anyhow?" If those who have specially studied the habits of the insects are correct, they certainly render important and useful service during their larval stage by cleansing swamp lands and stagnant pools from the miasms which plague mankind with various forms of fever. Let this much be said to the credit of this dreadfully maligned insect, for it behooves the naturalist, at least, to give "even the devil his due." If our mosquito were only pleased to confine its existence to this stage, there would be no need to write this paper, for it would be numbered among the benefactors of our race, or, perhaps, like many another benefactor, be utterly unknown.

The mosquito's brief period of larval life is divided between feeding upon the aforesaid micro-organisms, etc., and occasional excursions to the surface for a breath of air. Unfortunately, the larva soon becomes a pupa with a greatly enlarged thorax, which gives the body a club shaped appearance. Two broad paddles or caudal swimming leaves are fixed at the apex of the body, by which the mosquitoes can wiggle their way through the water. They are active in their habits, but they do not eat. Perhaps their larval diet of miasms proves too much for

them. Soon they awake, at the call of Nature, to another element and another sphere of activity.

It may shock the æsthetic sensibilities of the general public to speak of anything beautiful or fairy-like in the natural history of the mosquito; but really such terms are truly applicable when the mosquito pupa begins to transform. Let me briefly describe the process as entomologists have observed it. These little fish-like larvæ have spent their first stage of being swimming about in stagnant water, devouring the living atoms that swarm therein. They reach their second stage by casting off the larval skin and becoming pupæ. In this stage they remain rolled up like a ball, and float at the surface of the water for the purpose of breathing through the two respiratory tubes on the top of their backs. If disturbed by any unwonted agitation of the water, they suddenly uncurl their bodies and whirl over and over from side to side. This Turn Verein existence, spent with no sustaining nutriment but atmospheric air, terminates in the course of a few days.

Now the little water tumblers are ready for another transformation. The skin splits on the back between the breathing tubes, and a little boat is thus formed, as gracefully curved at the bow and poop as the imperial barge of Cleopatra. Out of this fairy bark there suddenly issues a winged creature. The head, the body, the limbs, burst from the opening in the hard skin. The slender legs are raised on the edges of the empty bark until, spreading its wings and pluming itself for flight into sunlight and air, the insect rises, while by the reflex of its upward bound its tiny bark is overset and sinks beneath the wave. If the poet or artist were to catch this vision at the moment the insect leaves its abandoned bark and stretches its wings

for flight, he might well imagine that he had obtained a glimpse of the good old days when one might see "old Proteus" or young Venus "rising from the sea." Alas, that Professor Gradgrind, the naturalist, should be compelled to tell him that he had only seen a mosquito transforming!

This is the natural history of the animal's environment. The practical question is, How can one so control these conditions as to limit the multiplication of the insects? Obviously the answer is, Limit their natural breeding grounds! When swamps are dried up, when stagnant pools are filled up, when brackish lakes and sluggish streams are drained and dredged and graded so as to give free current to their waters, when the swamp grasses, weeds, sedges, and various plants in which mosquitoes find refuge after transformation are cut down and cleared away—when, in short, the scythe, lawn mower, grubbing ax, and gardener's hand of diligence, thrift, cleanliness, and care have turned our country into a cultivated garden, the days of the mosquito as a pest will be numbered. *Culex pipiens* and all the other species of Culicidae (the family of mosquitoes and gnats) will still have their representatives in the land; but they will be short of their power to deplete the veins of summer cottagers and guests and the purses of summer landlords.

II.

The second factor in limiting the number of mosquitoes is that of natural enemies. Of these only two may be mentioned—the dragon fly and the spider. It is a strange illustration of human perversity that these two animals,

whose lives are spent in serving man, should be largely under the ban of human prejudice. The dragon fly is dreaded; the spider is hated; and yet they are Nature's checks upon the mosquito and other insects that otherwise would make our earth well nigh uninhabitable.

Is it practicable so to develop the dragon fly and spider that their special gifts from Nature can be further used in the service of man by directing them especially against the mosquito? The first step in the practical consideration of such a question, of course, is that human prejudice should be set aside and these two animals recognized in their true relations to the insect world.

Dr. Lamborn's circular concerning the propagation of the dragon fly, which has evoked this inquiry, will doubtless call forth a great deal of valuable information from entomologists better equipped for treating the subject than myself. But a few words on this point may not be out of place. "What is a dragon fly?" asked an intelligent city gentleman who had read Dr. Lamborn's note. I attempted to explain, and, indeed, took the pains to show him a figure of the insect. "Oh!" was the exclamation, "that's a devil's darning needle!" Yes; and the name is expressive of the attitude of English speaking people towards this serviceable insect. I have read of a school—if memory serves me truly, it was situate in that highly developed centre of American civilization, New York City—whose session was broken up by the advent of an innocent dragon fly through an open window. An alarm raised by one scholar passed through the entire room: "A devil's darning needle! A devil's darning needle!" The ominous phrase, piped in the shrill quaver of terrified childhood, alarmed the teacher, and

the agitation became so general that the school had to be dismissed as an act of humanity.

Again, I well remember, when a small boy upon the hills of eastern Ohio, gazing with open eyed wonder upon the beautiful forms of these insects as they flitted to and fro, and heard my older companions speak of them as "snake feeders." "Look out! There's a snake somewhere near! Here's a snake feeder!" I do not even now know the origin of that term, or the meaning attached to it by people generally; but to my child's imagination there came up a picture of these strange insects haunting some shady nook by running streams, where, under the shelter of limestone rocks, the serpent reared his head and thrust out his quivering tongue to receive his daily supplies of food from his servant, the "snake feeder." Is it strange if boyish fancy somehow associated the incident with all sorts of demoniac folklore and ghost stories? And yet, within two weeks from the date of this writing, a well informed gentleman who did not know this insect by the name of dragon fly recognized it at once when I spoke of it as a "snake feeder." With a keener sense of the beautiful, the French have called this insect *demoiselle*. But for the most part English terminology expresses superstitious fear or ignorance.

There is, however, another popular name which shows that the kindly service of these beautiful Neuroptera, the Libellulidae, is known and appreciated. It is "the mosquito hawk." Those who have watched the dragon fly's habits must have noticed that, as it flits here and there, it is engaged in seizing and devouring various insects. In regions infested by mosquitoes, those creatures contribute

largely to the dragon fly's appetite. This deadly war, waged in its perfect estate upon the perfect form of mosquito, is only a continuation of the habit of larval life. Like the mosquito, the mother dragon fly oviposits in the water, and its young are reared under similar conditions. The dragon fly larva is as voracious as the imago, and destroys enormous numbers of the aquatic larvæ of other insects, including, of course, the larvæ and pupæ of mosquitoes. Thus it comes about that in both stages of their development dragon flies are the natural enemies of the mosquito in both stages of its life.

Now emerges the query, can this "mosquito hawk" be propagated in such numbers, in regions most frequented by the mosquito, as materially to contribute to the mitigation of the pest? The question is one that can only be answered by experiment, and certainly the interests involved to both human property and human comfort are sufficient to justify the undertaking. There appears to be no difficulty in rearing the aquatic larvæ and pupæ of dragon flies in artificial conditions. An ordinary aquarium, a good sized jar, or a glass tumbler will suffice for a successful experiment. The matter which needs most to be attended to in such primitive undertakings is to separate the more ferocious forms from the less.

Dr. Lamborn's offer of a prize for a paper upon the methods of propagating dragon flies is intended simply as a preliminary step. If the inquiry should develop facts that seem sufficient to justify further experiments and researches, no doubt there will be money enough forthcoming to enter upon this larger undertaking. In the meantime let us encourage the endeavor. It can certainly do no harm. It will, beyond doubt, develop many interest-

ing facts in natural history ; and if it shall fail to reach its objective point, it will at least have enlightened the nation somewhat as to the real character of one of the most beautiful and serviceable inhabitants of our insect world.

I now come to another natural enemy of the mosquito, concerning whose habits I can speak with something more of authority. The spider is Nature's chief check against the undue increase of insects. Despised *Arachne* is entitled by her services to occupy the chief place among invertebrate philanthropists. It is, I might almost say, absolutely harmless to mankind. With the exception of an occasional alleged "spider bite" issuing in suffering or death, and delivered by the traditional and indefinite "black spider," I know of no evil that can be charged against the spider. True, as, long ago, the wise Proverbialist said, "She taketh hold with hands, and is in king's palaces." She builds her cobwebs in our homes, but there is no harm in that. If one will take the pains to study the cobwebs, they will be found beautiful structures ; and, at all events, the housewife can brush them away without encouraging hatred for the harmless creature that makes them. For, be it considered, the spider only comes into our homes because mosquitoes and other insects also come ! She comes, not seeking to harm us, but to help us ; and, therefore, for the sake of her motive, if she be not welcome, let her, at least, be thought of kindly.

The number of insects of all sorts and sizes destroyed by spiders simply passes calculation. If one will walk out on a dewy morning, with his eyes open for spider webs, he will be surprised to find how many there are,

and how various, too, the forms of spinningwork that meet him. All over this new plowed field he will find them; in yonder meadow, also, hanging by myriads upon myriads on the grasses. Along that hedgerow they are nested and have woven their dainty snares. In the branches of these shrubs and on the foliage of yonder trees are other hosts. If one will push back the foliage he will see yet others, spiders of the wandering group, that stalk their prey as do the wild beasts of the forests, crouching on trunk and branches and lurking among the leaves. If one turns to the earth other myriads are seen whose homes are on the ground or who build slight webs close to the surface. These have laid the ax at the very root of the tree, and are destroying the insects ere they rise from the surface to visit our homes. All these unnumbered multitudes of spiders are engaged during every moment of their existence in waging relentless war upon the insect world. When one considers how many spiders there are, and that they all thus feed upon their natural food, the insects, he may form some just conception of how needful they are to mankind. I do not hesitate to say that, unless Nature should provide some equivalent in the way of check upon insects, man could not dwell in many inhabited parts of the world, were it not for the friendly service of spiders.

But do the spiders have a special taste for mosquitoes? it may be asked. They take what comes to them, and when mosquitoes are abundant mosquitoes are taken. I have counted in an orbweaver's snare, spun upon the railing of the long bridge over Deal Lake, New Jersey, thirty-eight mosquitoes at one time hanging entangled upon the viscid spirals. Times without number have I seen like

destruction wrought to mosquitoes by spiders' webs ; for it is a fact that, even after the araneid has satisfied its appetite, its snare continues to capture insects. On one occasion I took the pains to count the number of insects of various species upon one large web, which was spread in a favorable position, and found that there were two hundred and thirty-six. It is a most common thing to observe three, four, or half a dozen flies or other insects trussed up upon the viscid orb of some of our orbweaving species. It is needless to add the conclusion from the above facts : if people would decrease the number of mosquitoes, let them encourage the multiplication of spiders.

The writer of this paper has not aimed to enter learnedly or exhaustively upon the subject, but simply to give a few hints by way of indicating the lines along which we may successfully consider the question, Can the mosquito be exterminated ?



VII.
APPENDIX.



A.

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B.

RECORDS OF MIGRATIONS OF DRAGON FLIES, ESPECIALLY *LIBELLULA QUADRAMACULATA*, FROM 1868 TO 1888.

BY WILLIAM BEUTENMULLER.

Since the paper on migrations and swarms of dragon flies by Mr. E. T. Koppen, published in the *Stett. Ent. Zeit.*, pages 183-188, 1871 (ante, page 21), I am not aware that a continuation of this paper appeared. I therefore add the following records:—

1761. Abbe Chappe (*Journ. to Siberia*, pages 236 and 237, 1770) notices, on July 2d, an immense swarm of dragon flies migrating from north to south.
1867. Pryer (*Journ. N. China Branch Roy. Asiatic Soc.*, vol. iv., pages 75 and 76) notices great swarms of dragon flies in Japan.
1872. Kuwert (*Stett. Ent. Zeit.*, xxxiv., pages 374 and 375) notes on great swarms of dragon flies observed in Prussia in May.
1878. Thomson (*Ent. M. Mag.*, xvi., page 280) notes on the abundance of dragon flies at Zanzibar.
1880. Schaitter (*Sitzb. z. b. Ges. Wien*, xxx., page 40, and *Ent. Nachr.*, vi., pages 133 and 167) notes on great swarms of *Lib. 4-maculata* and *L. depressa* observed in Galicia, in May.
1880. Anony. (*Feuill. Nat.*, x., page 15) record of a great swarm of *Libellula* observed at Havre, on October 7th.
1880. Torrey (*Am. Nat.*, xiv., page 132) records an enormous swarm of dragon flies at Weymouth, Mass., on June 2d. The column was at least a quarter of a mile in width and the migration lasted all day. On the 23d of the same month a similar swarm was observed near Boston. Both swarms were flying westward.
1880. Van Bemmelen (*Tijdschr. Ent.*, xxvii.; *Verslag*, page 91) records a swarm of dragon flies in the Rotterdam Zoological Garden in June.
1880. Chyzer (*Rov. Lapok.*, i., page 125) records a swarm of *Lib. depressa* and *Agrion pulchellum* in Hungary, May 8th.
1880. Eimer (*Biol. Centralb.*, i., pages 549-557) notes on a migration of *Lib. scolica* in September, and also refers to a swarm

- seen in the Engadine (Reprod. in Stett. Ent. Zeit., xliii., page 260, and abstr. in Jahrb. Verh. Wurtb., xxxviii., pages 105-113.
1880. Godlin (Zoo. Gart., xxv., page 125) records *Calopteryx virgo* in a migratory swarm at Lake Neuchatel on September 17th, flying from northeast to southeast.
- 1880 (?) Glulian (Bull. Ent. Soc. Ital., vi., pages 227 and 228) record of the invasion of *Anax ephippigera* in Italy.
1881. Torrey (Am. Nat., xiv., page 594) records a migration of dragon flies, on May 24th, at West Hill, in Melrose, Mass.
1881. Mundt (Can. Ent., xiv., page 56, and Rep. Ent. Soc. Ont., page 31, 1882) records migration of a swarm of *Aeschna heros* in Illinois, and also the abundance of *Anax junius* Drury.
1881. Landwehr (Ent. Nachr., vii., page 280) records an immense swarm of *Lib. 4-maculata* at Bielefeld on May 30th, flying towards the northwest.
1881. Weidinger (Ent. Nachr., vii., 187) records an immense swarm of *Lib. 4-maculata* that passed over Dresden on May 28th.
1881. Ent. Nachr., vii., page 216, note on swarms of *Lib. 4-maculata* in the Neisse Valley, one of which took two hours to pass.
1881. Blasius (Jahrb. Ver. Braunsch., iii., pages 72-77) records on a large swarm of *Lib. 4-maculata* through North Germany.
1882. Riveau (Feuill. Nat., xii., page 123) records that every year large migrations of *Lib. 4-maculata* take place in Charente Inferieure at the end of September.
1882. Fokker (Tijdschr. Ent., xx.; Verslag, page 16) records an immense swarm of *Lib. 4-maculata* which appeared on May 30th in Zierikzee, Holland, from 11 A. M. till 11 P. M.; they came from southwest.
1883. Newman (Nature, xxviii., page 271) records immense swarms of *Lib. 4-maculata* which appeared at Malmo, Sweden, from June 25th to the 27th.
1884. Van Hasselt (Tijdschr. Ent., xxviii., Verslag, page 12) records a migratory swarm of *Lib. 4-maculata* seen at the Hague, on July 10th.
1885. Campbell (Ent. M. Mag., xxi., page 192) records a migratory swarm of *Aeschna mixta* observed along the banks of the Gironde, in France.
1888. Pender (Ent. M. Mag., page 96) record of a migratory swarm of *Libellula 4-maculata*.

MACROMIA.

M. transversa Say.

EPITHECA.

E. tenebrosa Say.

CORDULIA.

C. lepida Sely.

C. uhleri Sely.

TRAMEA.

* T. carolina Linn.

CELITHEMIS.

* C. eponina Dr.

PLATHEMIS.

* P. trimaculata De G.

LIBELLULA.

* L. quadrimaculata Linn.

* L. auripennis Burm.

* L. semifasciata Burm.

* L. quadrupla Say.

* L. pulchella Dr.

* L. plumbea Uhler.

L. basalis Say.

MESOTHEMIS.

* M. simplicicollis Say.

* M. longipennis Hagen.

DIPLAX.

* D. rubieundula Say.

* D. berenice Dr.

* D. vicina Hagen.

* D. elisa Hagen.

D. semicineta Say.

PERITHEMIS.

* P. domitia Dr.

NANNOTHEMIS.

* N. bella Uhler.

* All species marked with an * are found in the vicinity of New York City.

PRELIMINARY CATALOGUE OF THE DESCRIBED TRANSFORMATIONS OF THE ODONATA OF THE WORLD.

BY WILLIAM BEUTENMULLER.

CALOPTERYX.

1618. Larva. (Fig.) Aldrovand, De Animalibus Insectis, pl. 15.
1671. Larva. (Fig.) Redi, Experimenti circa generat. Insect., page 319 (as *Scorpio marinus*).
1742. Larva. (Fig.) Reaumür, Mem., vi., pl. 38, Figs. 1-8.
1744. Larva. (Fig.) Roesel, Insect. Belust., ii., pt. ii., pl. ix.
1782. Larva. (Fig.) Harris, Exposit. Ins., pl. 30.
1835. Larva. (Brief.) Stephens, British Ent., vi., page 78.
1852. Nymphæ. (General.) Dufour, Ann. Sc. Nat., xvii., 3 ser., page 71.
1853. Nymphæ. Hagen, Ent. Zeit. Stett., xiv., pages 260 and 269.
1857. Nympha. Brauer & Low, Fauna Austriaca, page xvi.

CALOPTERYX VIRGO Linn.

1806. Larva. (Brief.) Shaw, Gen. Zoo. Insecta, ii., page 246.
1840. Nympha. (Fig.) Westwood, Intro. Ins., ii., page 38.
1852. Nympha. (Fig.) Dufour, Ann. Sc. Nat., xvii., 3d ser., page 71, pl. 3. (Probably *C. hæmorrhoidalis*, according to Dr. Hagen.)
1855. Egg. Meissner, Zeit. Wiss. Zoo., vi., page 283.
1868. Embryology. (Figs.) Brandt, Mem. Ac. Imp. Soc. St. Petersburg., xiii., page 2.
1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 20, page 162. Hab., Europe.

CALOPTERYX SPLENDENS Harris.

1888. Nympha. Roster, Bull. Soc. Ent. Ital., 20, page 163.

AGRION.

1555. Larva. (Fig.) Rondelet, Univers. Quat. Hist., ii., page 213.
1700. Larva. nympha. Coedart, Met. St. Hist. Ins., Lister Edition, iii., page 129, 1700.
1696. Larva. (Fig.) Swammerdam, Hist. Insect., pl. xii.

1742. Larva. (Figs.) Reaumür, Mem., vi., pl. 36, Figs. 5 and 6; pl. 38, Fig. 2; pl. 41, Figs. 1, 2.
 1744. Larva. (Figs.) Roesel, Insect. Belust., ii., pt. ii., pl. 10 and 11.
 1770. Larva. (Fig.) Drury, Illust. Exotic Ent., 1, page 112, pl. 47.
 1776. Larva. (Fig.) Harris, Exposit. Ins., pl. 29.
 1806. Nympha. (Brief.) Latreille, Hist. Nat. Crus. and Ins., xii., page 398.
 1835. Larva, nympha. (Brief.) Stephens, British Ent., vi., page 71.
 1837. Larva. (Figs.) Westwood, Drury Exot. Ent., i, page 108, pl. 47.
 1839. Larva. (Brief.) Burmeister, Handbuch, ii., page 812.
 1844. Nympha. (Fig.) Ratzeburg, Forstins., iii., page 236.
 1852. Nymphæ. Dufour, Ann. Sc. Nat., 3d ser., xvii., page 72.
 1853. Nymphæ. Hagen, Ent. Zeit. Stett., xiv., page 311.
 1867. Egg, nympha. (Brief.) Packard, Am. Nat., i, page 306.
 1867. Egg, nympha. (Brief.) Packard, Guide, pages 599 and 601, Fig.
 1873. Oviposition. Dunn, Am. Nat., vii., page 489.
 1885. Oviposition. McLachlan, Ent. M. Mag., xxi, page 211.

AGRION PUELLA Linn.

1806. Larva. (Brief.) Shaw, Gen. Zoo. Insecta, ii., page 246.
 1840. Nympha. (Brief.) Westwood, Intro. Ins., ii., page 39.
 1868. Embryology. Brandt, Mem. Ac. Imp. Soc. St. Petersb., xiii., page 2, pl. i. and ii.
 1888. Nympha. Roster, Bull. Soc. Ent. Ital., 20, page 168. Hab., Europe.

AGRION CYATHIGERUM Charp.

1771. Larva. (Fig.) De Geer, Mem., ii. Hab., Europe.

AGRION SCITULUM Ramb.

1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 20, page 169. Hab., Europe.

AGRION GENEI Pict.

1886. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 18, page 254. Hab., Europe.

AGRION ELEGANS Vander L.

1886. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 18, page 241. Hab., Europe.

AGRION PUMILIO Charp.

1886. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 18, page 243. Hab., Europe.

AGRION VIRIDULUM.

1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 20, page 168.
Hab., Europe.

AGRION LINDENT Sely.

1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 20, page 169.
Hab., Europe.

AGRION PULCHELLUM OR HASTULATUM.

1853. Larva. Hagen, Ent. Zeit. Stett., xiv., page 312. Hab., Europe.

LESTES.

1827. Young larva. Carns, Entdeck. eines Blutkreislaufs, page 10.
1835. Larva. (Brief.) Stephens, British Ent., vi., page 77.

LESTES NYMPHA Sely.

1841. Egg, young larva. Siebold, Wieg. Archiv, vii., pt. i., pages
205 and 211 (as *A. forcipula*).
1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 312.
1857. Nympha. Brauer and Low, Fauna Austriaca, page xvi. Hab.,
Europe.

LESTES VIRIDIS Vander L.

1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 20, page 164.
Hab., Europe.

LESTES BARBARA Fab.

1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 20, page 165.
Hab., Europe.

LESTES VIRENS Charp.

1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., 20, page 165.
Hab., Europe.

PLATYCNEMIS PENNIPES Pall.

1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., xx., page 167.
Hab., Europe.

SYMPYCA FUSCA Vander L.

1888. Nympha. (Fig.) Roster, Bull. Soc. Ent. Ital., xx., page 166.
Hab., Europe.

ANAX JUNIUS Dr.

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 15 and
36, pl. i. Hab., United States, Mexico, China, West Indies,
and Sandwich Islands.

ANAX FORMOSUS Vander L.

- Nympha. (Fig.) Muralto, Ephem. Nat. Cur., Dec. ii., ann. 2, page 194, as Phrygan perle.
 1852. Nympha. (Fig.) Dufour, Ann. Sc. Nat., 3d ser., xvii., page 60, pl. 3, as *Æschna grandis*.
 1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 266.
 1857. Nympha. Brauer and Low, Fauna Austriaca, page xvi.
 1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 13 and 315, pl. i. Hab., United States, Europe.

ANAX JULUS.

1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., pages 16 and 36. Hab., Japan.

ANAX GUTTATUS Burm.

1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., pages 16 and 34. Hab., Oceanica.

ANAX AMAZILI Burm.

1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., pages 17 and 36. Hab., West Indies, South America.

ANAX MAURICIANUS (?)

1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., pages 14 and 36. Hab., Africa.

ANAX sp.

1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., pages 17 and 36. Hab., East Indies, Central and South America.

ÆSCHNA.

1634. Larva. (Figs.) Mufet, Theat. Insect, pages 321-322 (as *Laensta aquatica*, *Pulex*, and *Scolopendra*).
 1706. Nympha. (Brief.) Anonym., Hist. Acad. Sc., Paris, page 9.
 1730. Nympha. (Fig.) Frisch, Beschreib. all Ins., viii., pl. x., page 70.
 1742. Nympha. (Fig.) Reaumür, Mem., vi., page 456, pl. 36, Figs. 3 and 4.
 1770. Larva. (Fig.) Drury, Illust. Exot. Ent., i., pl. 47, Fig. 3.
 1804. Nympha. (Brief.) Latreille, Hist. Nat. Crus. and Ins., xii., page 398.
 1816. Nympha. Latreille, Diet. Hist. Nat., i., page 181.
 1826. Nympha. (Fig.) Kirby and Spence, Intro. Ent., iii., page 125, pl. 16.
 1837. Larva. Westwood, Drury's Exot. Ent., i., page 108, pl. 47.

1839. Larvæ. Burmeister, Handb., ii., page 835.
 1840. Nympha. (Brief.) Westwood, Intro. Ins., ii., page 39.
 1852. Nymphae. Dufour, Ann. Sc. Nat., xvii., 3d ser., page 67.
 1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., pages 260 and 266.
 1867. Nympha. (Fig.) Packard, Am. Nat., i., page 309.
 1869. Nympha. (Fig.) Brehm, Thierleben, vi., page 451.
 1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., pages 18 and 36.

ÆSCHINA CONSTRICTA Say.

1863. Nympha. (Fig.) Sanborn, 10th Rep. Mass. Bd. Agricult., page 149 (as *Æ. clepsydra*).
 1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 24 and 38, pl. iii. Hab., United States.

ÆSCHINA EREMITICA Scud.

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 23 and 37, pl. ii., Fig. 2. Hab., United States.

ÆSCHINA HEROS Fabr.

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 30 and 39, pl. i., Fig. 3. Hab., United States.

ÆSCHINA CYANEA Müll.

1742. Nympha. (Fig.) Beaumür, Mem., vi., page 39, Figs. 1-9.
 1852. Larva. (Fig.) Dufour, Ann. Sc. Nat., xvii., 3d ser., page 69, pl. 3, Fig. 5 (as *Æ. innominata*).
 1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 267.
 1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., page 20, pl. iv., Fig. 3. Hab., Europe.

ÆSCHINA RUFESCENS Vander L.

1852. Nympha. (Fig.) Dufour, Ann. Sc. Nat., xvii., 3d ser., page 69, pl. iii. (as *Æ. De Geerii*).
 1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 267.
 1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 4 and 36, pl. v., Fig. 4. Hab., Europe.

ÆSCHINA AFFINIS Steph.

1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 267.
 1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., page 23, pl. v., Fig. 3. Hab., Europe.

ÆSCHNA MIXTA Latr.

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 21 and 37, pl. v., Fig. 2. Hab., Europe.

ÆSCHNA VIRIDIS.

1879. Nympha. (Brief.) Poletajwa, Tr. Ent. Soc. Russ., xi.
 1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 21 and 37, pl. v., Fig. 5. Hab., Europe.

ÆSCHNA JUNCEA Linn.

1879. Nympha. (Brief.) Poletajwa, Tr. Ent. Soc. Russ., xi., page 15.
 1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., page 21, pl. iv., Fig. 1. Hab., Europe.

ÆSCHNA GRANDIS Linn.

1744. Nympha. (Fig.) Roesel, Insect. Belust., ii., pt. ii., pl. 3 and 4.
 1771. Nympha. (Fig.) De Geer, Mem., ii., pl. 19, Figs. 12-19.
 1782. Larva. (Fig.) Harris, Exposit. Ins., pl. 12, Fig. 3.
 1806. Nympha. (Fig.) Shaw, Gen. Zoo. Insecta, ii., page 242.
 1845. Nympha. Latreille, Cuvier Regne Anim. Ins., page 87.
 1852. Nympha. (Anatomy.) Dufour, Ann. Sc. Nat., xvii., 3d ser., pages 73-108, pl. 3, 4, and 5.
 1853. Nympha. (Anatomy.) Hagen (quotes Dufour), Ent. Zeit. Stett., xiv., pages 313-325 and 334-346 and 368.
 1879. Nympha. Poletajwa, Trans. Ent. Soc. Russ., xi.
 1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., pages 19 and 37. Hab., Europe.

ÆSCHNA sp.

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 25 and 38, pl. 1, Fig. 4. Hab., Brazil.

ÆSCHNA sp.

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 25 and 38, pl. 4, Fig. 2. Hab., Himalaya.

ÆSCHNA ?

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 32 and 39, pl. iii., Fig. 3. Hab., Venezuela and Chili.

ÆSCHNA ?

1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., page 31. Hab.

NEURESCHINA VINOSA Say?

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 29 and 39, pl. ii., Fig. 3. Hab., U. S.

GOMPLESCHINA FURCILLATATA Say.

1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 28 and 38, pl. ii., Fig. 4. Hab., U. S.

GYNACANTHA sp.?

1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 268. Hab., Brazil.

GYNACANTHA sp.?

1881. Nympha. Cabot, Mem. Mus. Comp. Zoo., pages 11 and 35. Hab., Brazil, United States.

ONYCHOGOMPHUS LINEATUS Selys.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xvii., page 253. Hab., East India.

HERPETOGOMPHUS COMPOSITUS Selys?

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 4 and 16, pl. ii., Fig. 6 (as Gomphus sp).
1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 256. Hab., United States.

HERPETOGOMPHUS DESIGNATUS Selys.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 255. Hab., United States.

HERPETOGOMPHUS MENETRIESII Selys?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 256. Hab., Guatemala.

OPIOGOMPHUS OCCIDENTIS Hagen.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 259. Hab., United States.

OPIOGOMPHUS COLUBRINUS Selys.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 257. Hab., United States.

OPIOGOMPHUS CAROLINUS Hagen?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 258. Hab., United States.

OPIOGOMPHUS SEVERUS Hagen.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 259.
Hab., United States.

? OPIOGOMPHUS sp.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 259.
Hab., Himalaya.

? CYCLOGOMPHUS sp.

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 5
and 16, pl. ii., Fig. 2 (as Gomphus sp.).
1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 271.
Hab., Himalaya.

BRACHYTRON PRATENSIS Müll.

1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 268.
1857. Nympha. Brauer & Low, Fauna Austriaca, page 16.
1881. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 27
and 38, pl. v., Fig. 1. Hab., Europe.

GOMPHUS.

Nympha. Burmeister, Handb., ii., page 831.

1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 263.
1872. Nympha. Cabot, Mem. Mus. Comp. Zoo., page 15.
1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 260.

GOMPHUS PILIPES Sely.

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 2
and 15, pl. 1, Fig. 3, a, b, c. Hab., United States.

GOMPHUS ADELPHUS Sely?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 262.
Hab., United States.

GOMPHUS EXILIS Sely.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 263.
Hab., United States.

GOMPHUS SPINICEPS Walsh.

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 5-16,
pl. ii., Fig. 1 (as Macrogomphus).
1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 270. Hab.,
United States.

GOMPHUS VASTUS Walsh.

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 3 and 15, pl. ii., Fig. 4, b (as *Gomphus* sp.).
 1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 265. Hab., United States.

GOMPHUS PALLIDUS Ramb.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 266. Hab., United States.

GOMPHUS PLAGIATUS Selys.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 269. Hab., United States.

GOMPHUS GRASLINELLUS Walsh?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 264. Hab., United States.

GOMPHUS OLIVACEUS Selys?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 271. Hab., United States.

GOMPHUS NOTATUS Ramb.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 270. Hab., United States.

GOMPHUS VULGATISSIMUS Linn.

1744. Nympha. (Brief.) Roesel, Insect. Belust., ii., pt. ii.
 1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 263.
 1857. Nympha. Brauer & Low, Fauna Austriaca, page 17.
 1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 3 and 15, pl. 1, Fig. 1, b, c.
 1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 261. Hab., Europe.

GOMPHUS sp.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 254. Hab., Himalaya.

GOMPHUS sp.

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 4 and 15, pl. ii., Fig. 5. Hab., United States.

GOMPHUS sp.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., pages 261, 262, 263, and 265 (four species described). Hab., United States.

GOMPHUS sp.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 268 (two species described). Hab., Brazil.

GOMPHUS sp.

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 8 and 16, pl. 1, Fig. 5, a, b, c, d. Hab., Brazil.

GOMPHUS sp.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 264. Hab., India.

PROGOMPHUS obscurus Ramb.?

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 6 and 16, pl. ii., Fig. 3.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 274. Hab., United States.

PROGOMPHUS sp.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 275. Hab., United States.

GOMPHOIDES sp.

1872. Nympha. (Brief.) Cabot, Mem. Mus. Comp. Zoo., pages 9 and 16.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 277. Hab., Brazil.

GOMPHOIDES sp.

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., page 8, pl. 1, Fig. 5.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 276. Hab., Brazil.

ASPHYLLA PRODUCTA Sely?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 277. Hab., United States.

HAGENIUS BREVISTYLUS Sely.

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 9 and 17, pl. iii., Fig. 4, a, c, d.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 279. Hab., United States.

HAGENIUS JAPONICUS?

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 10 and 17, pl. iii., Fig. 5, c.
 1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 280. Hab., Japan.

HAGENIUS NANUS?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 281. Hab., Japan.

TACHOPTERYX THOREYI Selys?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 281. Hab., United States.

CORDULEGASTER DORSALIS Selys?

1885. Nympha. (Brief.) Hagen, Trans. Am. Ent. Soc., xii., page 289. Hab., United States.

CORDULEGASTER SAYI Selys.

1872. Nymphae. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 13 and 17, pl. iii., Fig. 2.
 1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 290 (as *C. diastatops*?). Hab., United States.

CORDULEGASTER OBLIQUUS Say?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 291. Hab., United States.

CORDULEGASTER DORSALIS Selys?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 289. Hab., United States.

CORDULEGASTER ANNULATUS Latr.

- Nympha. Scopoli, Faun. Carn., page 259 (is surely an *Aeschna*); Cabot, page 2.
 1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 14 and 17, pl. iii., Fig. 3.
 1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 289. Hab., Europe.

CORDULEGASTER BIDENTATUS Selys.

1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 265.
 1857. Nympha. Brauer & Low, Fauna Austriaca, page 19.
 1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 14
 and 17, pl. iii., Fig. 1, a, b, c, d.
 1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 287. Hab.,
 Europe.

EPIGOMPHUS? PALUDOSUS Selys?

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 1
 and 15, pl. ii., Fig. 2 (as *Herpetogomphus*).
 1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 272. Hab.,
 Brazil.

ICTINUS PRÆCOX?

1872. Nympha. (Fig.) Cabot, Mem. Mus. Comp. Zoo., pages 11
 and 17, pl. 1, Fig. 4, a, c.
 1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 283. Hab.,
 Himalaya.

ICTINUS PUGNAX Selys?

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 285. Hab.,
 Africa.

ICTINUS sp.

1885. Nympha. Hagen, Trans. Am. Ent. Soc., xii., page 285. Hab.,
 Himalaya, India.

MACROMIA TRANSVERSA Say.

1871. Nympha. (Fig.) Packard, 1st Rep. Ins. Mass., page 319, pl.
 1, Fig. 11.
 1871. Nympha. (Fig.) Packard, Am. Nat., v., page 427 (as *Didymops*
sp.). Hab., United States.

EPITHECA BIMACULATA Charp.

1730. Nympha. (Fig.) Frisch, Beschreib. all. Ins., viii., page 20,
 perhaps not this species.
 1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 263.
 1881. Nympha. Borre (quotes Hagen), Comp. Ent. Soc. Belg., xxv.,
 page lxx. Hab., Europe.

CORDULIA METALLICA Vander L.

1844. Nympha. (Fig.) Ratzburg, Forstins, iii., pl. xvi., Fig. 3.
 1853. Nympha. Hagen, Ent. Zeit. Stett. xiv., page 263.
 1881. Nympha. Borre (quotes Hagen), Comp. Ent. Soc. Belg., xxv.,
 page lxxix. Hab., Europe.

CORDULIA JENEA Linn.

1744. Nympha. (Fig.) Roesel, Insect. Belust., ii., pt. ii.
 1826. Nympha. Kirby & Spence, Intro. Ent., iii., page 128.
 1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 263.
 1881. Nympha. Borre (quotes Hagen), Comp. Ent. Soc. Belg., xxv.,
 page lxxix. Hab., Europe.

CORDULIA CYNOCURA Say.

1871. Nympha. (Fig.) Packard, 1st Rep. Ins. Mass., page 30, pl. 1,
 Fig. 10 (as *C. lateralis*).
 1871. Nympha. (Fig.) Packard, Am. Nat., v., page 427, Fig. 93 (as
C. lateralis). Hab., United States.

LIBELLULA.*

1555. Nympha. (Fig.) Rondelet, Universæ Aquat. Hist., ii., page
 212.
 1634. Larva. (Fig.) Mouffet, Theat. Insect., page 137.
 1635. Larva. (Fig.) Jonston, Compl. Theat. Insect., page 201,
 pl. 27.
 1710. Larvæ. Ragus, Hist. Insect., page 48.
 1718. Larvæ. Ruysch, Theat. Anim., ii., pt. 3, pl. xxv.
 1732. Larvæ. Roberg, Libell. Lacustri, Upsaliæ, page 9.
 1842. Larvæ. (Fig.) Lyonet, Theolog. des Insect., i., page 156.
 1743. Larva. (Fig.) Hebenstreit, Insect. Natalibus.
 1752. Oviposition. Bartram, Phil. Trans., 46, page 323.
 1770. Larva. (Fig.) Drury, Illust. Exot. Ent., i., pl. 47.
 1804. Larvæ, nympha. Latreille, Nat. Hist. Crus. and Ins., xii.,
 page 396.
 1817. Larva, nympha. Latreille, Dict. Nat. Hist., xvii., page 546.
 1835. Nympha. Stephen, British Ent., vi., page 80.
 1837. Larva. (Fig.) Westwood, Drury, Ill. Exot. Ent., i., pl. 47.
 1840. Oviposition. Westwood, Intro. Insects., ii., page 38.
 1841-45. Larva, nympha. Latreille, Cuvier Regne Anim. Insecta,
 page 4.
 1852. Larva, nympha. Dufour, Ann. Sc. Nat., xvii., 3 ser., page 70.
 1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 261.
 1856. Nymph. V. d. Hoeven, Handb. Zoo., ii., page 421.
 1868. Larva. Packard, Am. Nat., i., page 307.
 1880. Egg, young larva. (Figs.) Gerard, Am. Ent., i., 2 ser., page 174.

* Many species described by older authors cannot be identified and placed in their proper positions and, only for convenience' sake, have been put in the genus *Libellula*.

PLATYTHEMIS TRIMACULATA De G.

1890. Egg. (Fig.) Beutenmüller. Ante, page 126. Hab., United States.

LIBELLULA PULCHELLA Dr.

1890. Egg. Beutenmüller, ante, page 126. Hab., United States.

LIBELLULA AURIPENNIS Burm.

1890. Egg. (Fig.) Beutenmüller, ante, page 125. Hab., United States.

LIBELLULA PECTORALIS Charp.

1760. Larva, nymph. (Figs.) Lyonet, Recherches, pages 197-200. (1823.)

1853. Larva. (Brief.) Hagen, Ent. Zeit. Stett., xiv., page 262. Hab., Europe.

LIBELLULA DEPRESSA Linn.

1742. Larva. (Fig.) Reaumur, Mem. des Ins., vi., pl. 36, Figs. 1, 2.

1744. Larva, nymph. (Figs.) Roesel, Insect. Belust., ii., pt. ii., pl. vii.

1763. Larva. Scopuli, Ent. Carn., page 260.

1766. Larva, nymph. (Figs.) Harris, The Aurelian or Nat. Hist., pl. 26.

1806. Larva. (Brief.) Shaw, Gen. Zoo., ii., Insecta, page 245.

1823. Larva. (Fig.) Dumeril, Consid. Gen. Class Ins., page 71, pl. 28.

1826. Larva. Kirby & Spence, Intro. Ent., iii., page 128.

1840. Nympha. (Fig.) Westwood, Intro. Ins., ii., page 38.

1841-45. Larva, nymph. Latreille, Cuvier Regne Anim. Insecta, page 86.

1852. Nympha. (Fig.) Dufour, Ann. Sc. Nat., xvii., 3 ser., page 70, pl. 3, Fig. 7. Hab., Europe.

LIBELLULA CANCELATA Linn.

1685. Larva, nymph. (Figs.) Menzel, Ephem. Nat. Cur. Dec., ii., ann. 3, page 117, pl. vi.

1744. Larva. (Fig.) Roesel, Insect. Belust., ii., pt. ii., pl. vi. (probably a Gomphus). Hab., Europe.

LIBELLULA FULVA Müll.

1693. Life history. (Figs.) Swammerdam, Hist. Ins., pages 79 and 173, pl. 8. Hab., Europe.

LIBELLULA FERRUGINEA Ramb.

1852. Nympha. Dufour, Ann. Sc. Nat., xvii., 3 ser., page 71. Hab., Europe.

LIBELLULA QUADRIMACULATA Linn.

1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 262.
1857. Nympha. Brauer & Low, Fauna Austriaca, page 13. Hab., Europe.

LIBELLULA sp.

1853. Nymphae. Hagen, Ent. Zeit. Stett., xiv., page 262 (three unknown species described). Hab., Brazil.

DIPLAX BERENICE Dr.

1890. Egg. Beutenmüller, ante, page 126. Hab., United States.

DIPLAX RUBICUNDULA Say.

1890. Egg. Beutenmüller, ante, page 126. Hab., United States.

DIPLAX SCOTICA Don.

1853. Nympha. Hagen, Ent. Zeit. Stett., xiv., page 262.
1857. Nympha. Brauer & Low, Fauna Austriaca, page 16. Hab., Europe, Asia, United States.

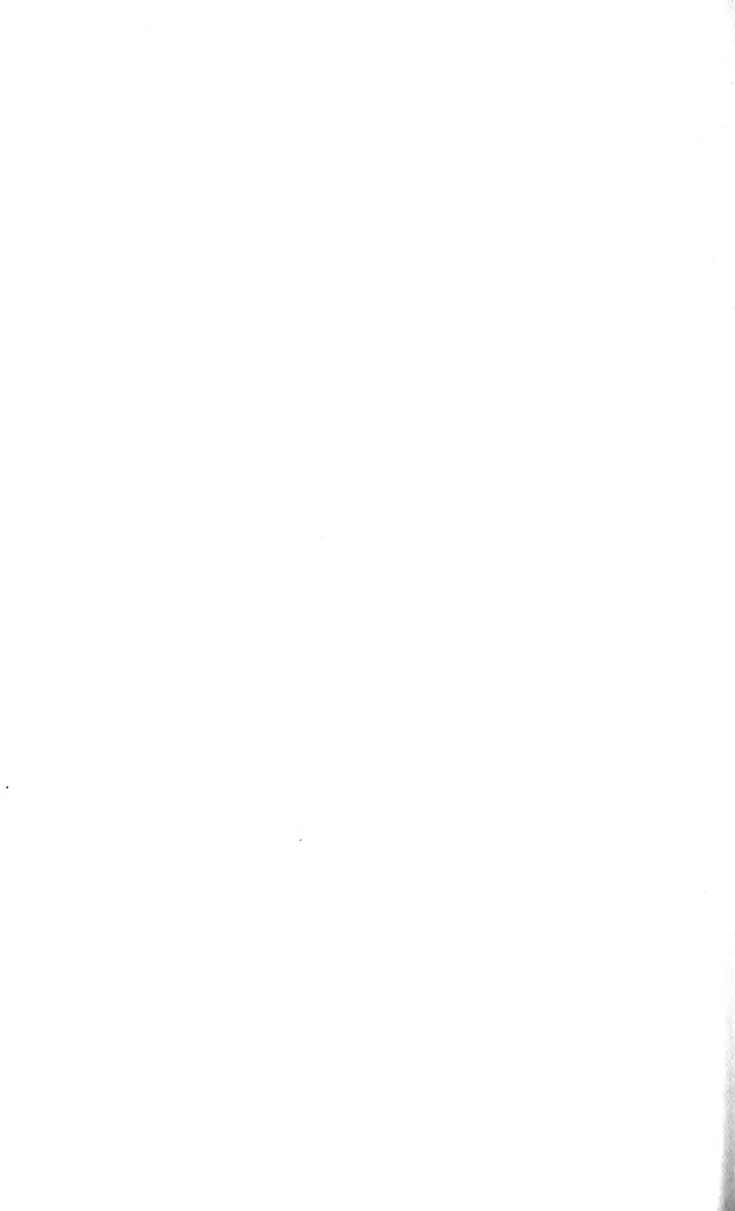
DIPLAX VULGATA Linn.

1744. Larva. (Fig.) Roesel, Insect. Belust., ii., pt. ii., pl. xviii. Hab., Europe, Asia.

DIPLAX sp. (BERENICE?)

1868. Embryology, young larva, pupa. (Figs.) Packard, Am. Nat., 1, pages 311, 391, and 676.
1868. Embryology, young larva. Packard, Proc. Bost. Soc. N. Hist., xi., pages 365, 372.
1869. Embryology, young larva, pupa. (Figs.) Packard, Guide, pages 55, 60. Hab., United States.

Mr. Beutenmüller wishes to state that he was unable to gain access to Mr. Cabot's recent work, "On the early stages of the Libellulidae," for the preparation of the foregoing bibliographical catalogue.—[Ed.]



VIII.

PLATES AND EXPLANATIONS.

PLATE II.

- FIG. 1. Adult larva of *Culex damnosus*; from Nature.
2. Deflected pupa of *Culex damnosus*; from Nature.
3. Natural attitude of pupa of *Culex damnosus*; from Nature.
4. Breathing attitude of larva of *Culex damnosus*; from Nature.
5. Imago of ♀ *Culex damnosus*; from Nature.
6. Head of ♂ *Culex damnosus*; from Nature.
7. Head of ♀ *Culex rufus*; $\times 20$; after Dimmock.
8. Median cross section of proboscis of ♂ *Culex rufus*; after Dimmock.
9. Median cross section of proboscis of ♀ *Culex rufus*; after Dimmock.

EXPLANATION OF LETTERING.

a, six piercing members.	d, hypopharynx.
b, labium.	e, mandibles.
c, labrum epipharynx.	f, maxillæ.

♂ Male.

♀ Female.

PLATE II.

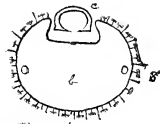
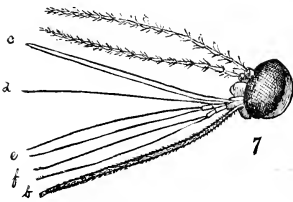
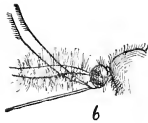
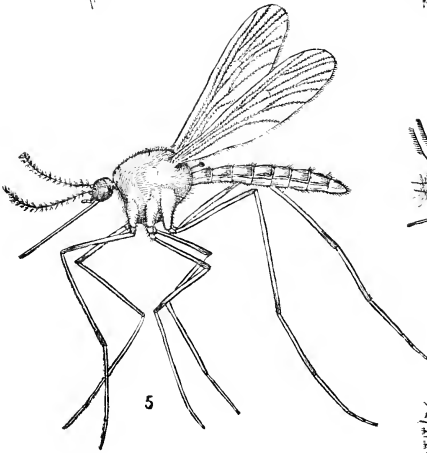
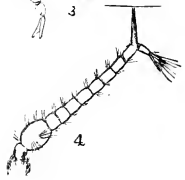


PLATE III,

- FIG. 1. Longitudinal section of head *Culex teniorhynchus*; after Macloskie. ce, cesophagus; cb, cerebrum; m, muscle; n, nerve commissure; du, venomo salivary duct; l.e, labrum epipharynx.
2. Venomo salivary duct of the same, with upper nest of glands; after Macloskie. sg, salivary gland; pg, poison gland.
3. Head of *Aeschna heros*; front view; after Packard.
4. Foot of *Musca domestica*; $\times 200$; after Roubouts.

PLATE III.

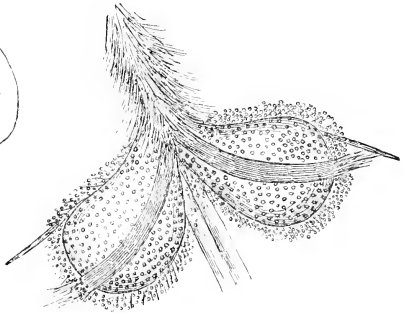
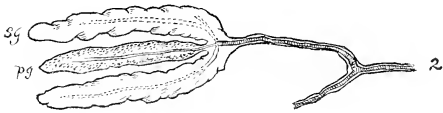
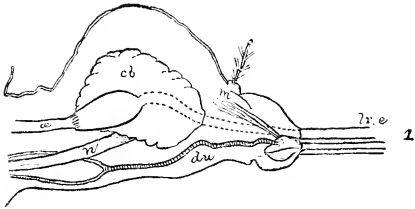


PLATE IV.

- FIG. 1. Head of *Haematobia serrata*; front; after Riley and Howard.
2. *Hyperderma bovis*; after Packard.
4. Tongue of *Stomoxys calcitrans*; after Meigen.
5. Tongue of *Musca domestica*; after Packard. mp, palpi;
m, mandibles; l, labium.
6. Tongue of *Musca domestica*; after Meigen.
7. *Macillaria hominivorax*; after Coquerel.
8. Larva of *Musca domestica*; after Packard.
9. Pupa of *Musca domestica*; after Packard.
10. Larva of *Musca vomitoria*; from Nature.
11. Larva of *Lucillia hominivorax*; after Packard.

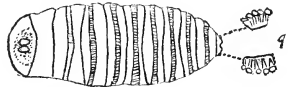
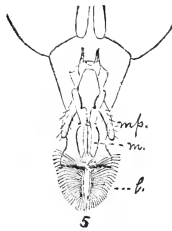
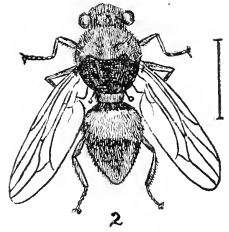
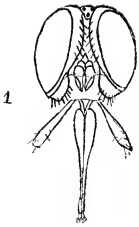


PLATE V.

- FIG. 1. Nearly adult larva of *Anax junius*; from Nature.
2. Pupa of *Anax junius*; after Cabot.
3. Pupa of *Anax junius*; from Nature, showing the mask partly extended.
4. *Culex ciliatus*; from Nature.
5. Mask of *Anax junius*; from Nature.

PLATE V.

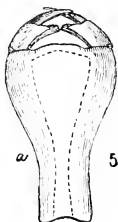
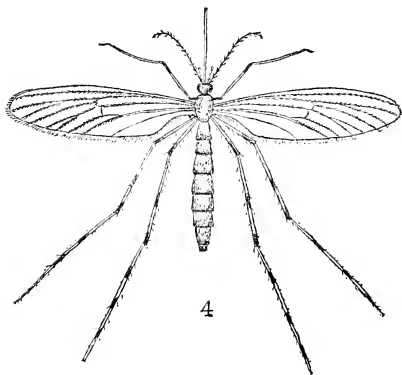
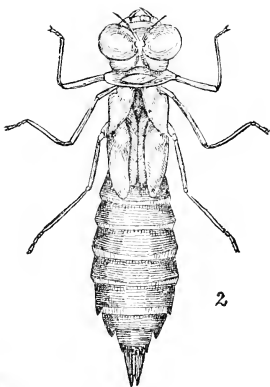
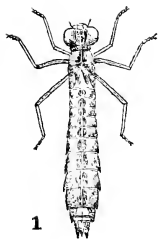


PLATE VI.

All these figures are from Nature.

- FIG. 1. Imago of *Libellula pulchella*, ♂.
2. Imago of *Gomphus exilis*, ♂.
3. Imago of *Calopteryx maculata*, ♀.
4. Imago of *Diplax rubicundula*, ♀.
5. Imago of *Agrion civile*, ♂.

♂ Male.

♀ Female.

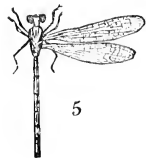
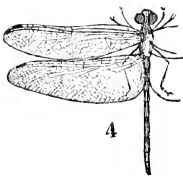
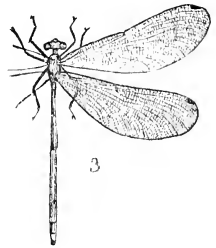
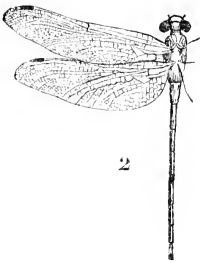
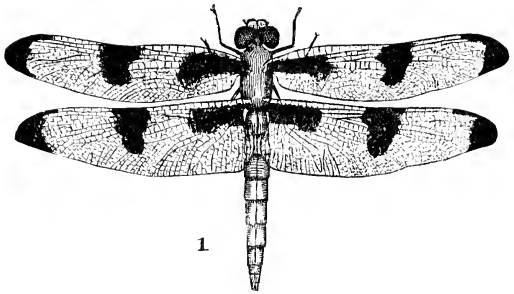


PLATE VII.

FIG. 1. Lantern trap for mosquitoes ; after Riley.

2. Apparatus for spraying petroleum ; after Riley.

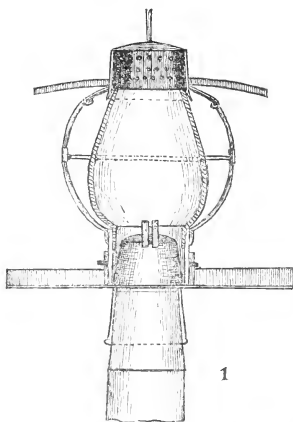


PLATE VIII.

FIG. 1. Lantern trap to hang from trees.

2. Eggs of mosquitoes.

3. Pupa of mosquito.

Original drawings by William Beutenmüller.

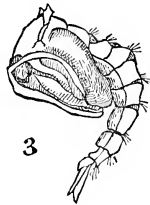
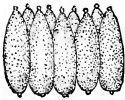
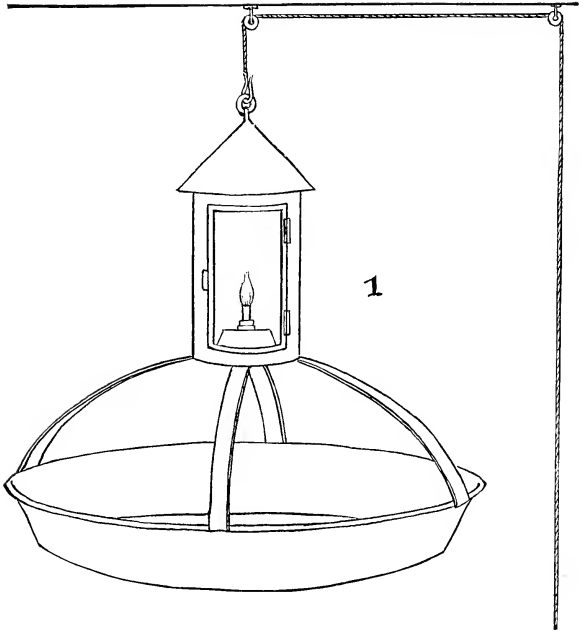
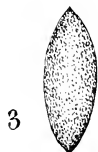
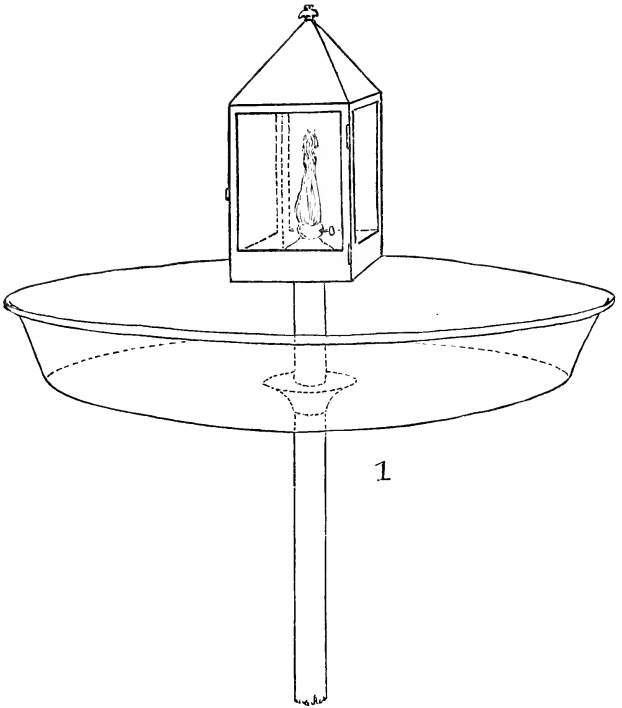


PLATE IX.

- FIG. 1. Lantern and pan on post to be placed in swamps.
2. Egg of *Libellula auripennis*.
3. Egg of *Plathemis trimaculata*.

Original drawings by William Beutenmüller.



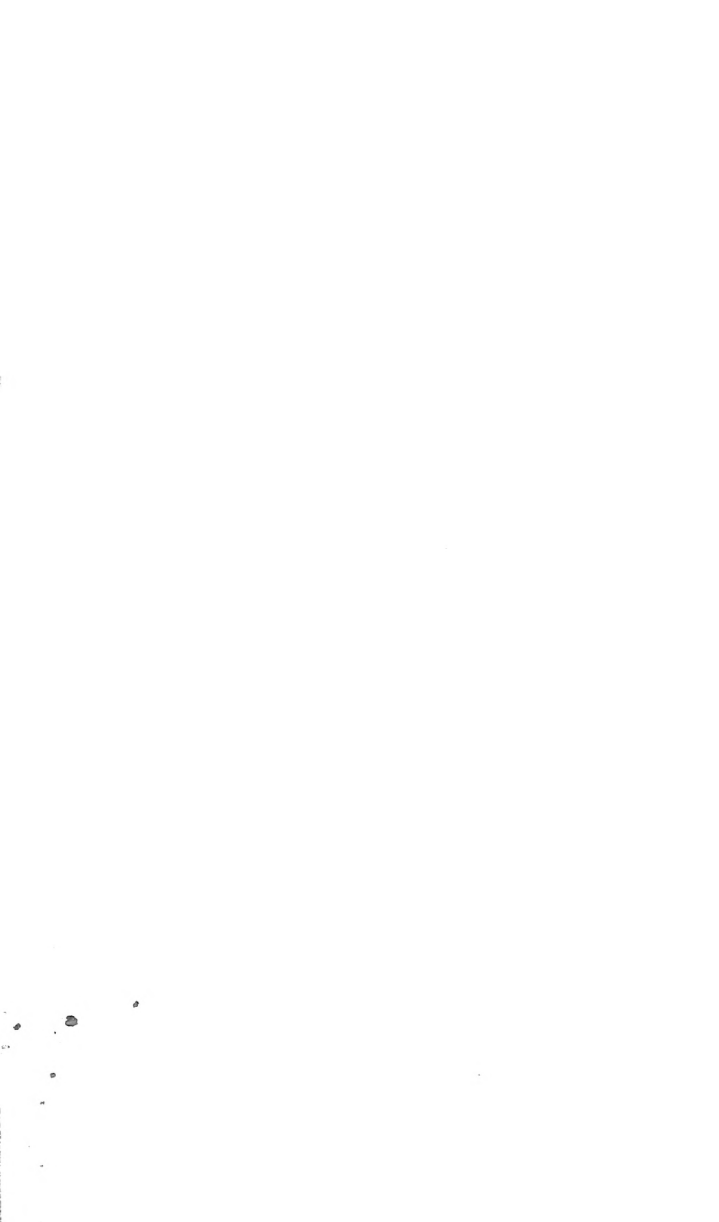
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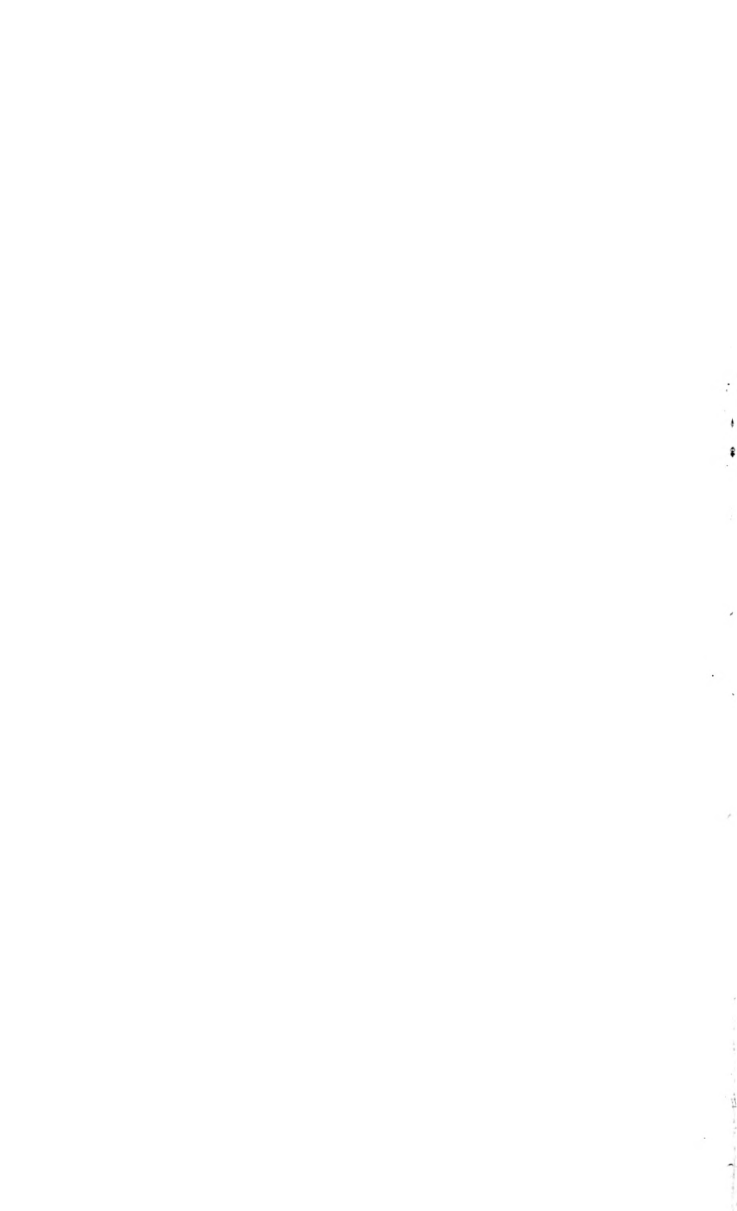
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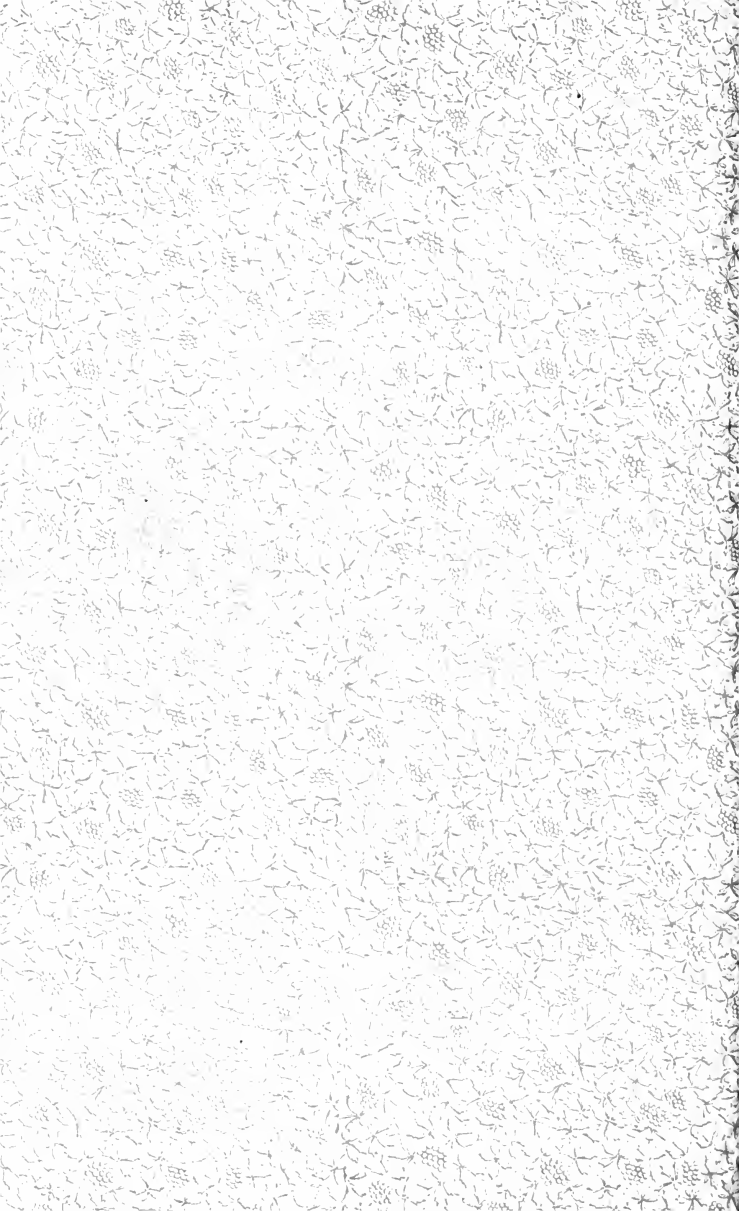
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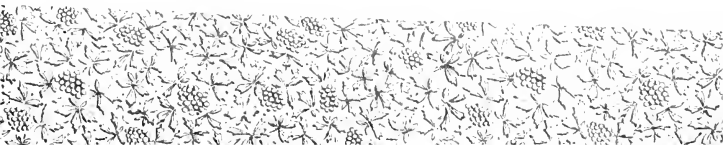
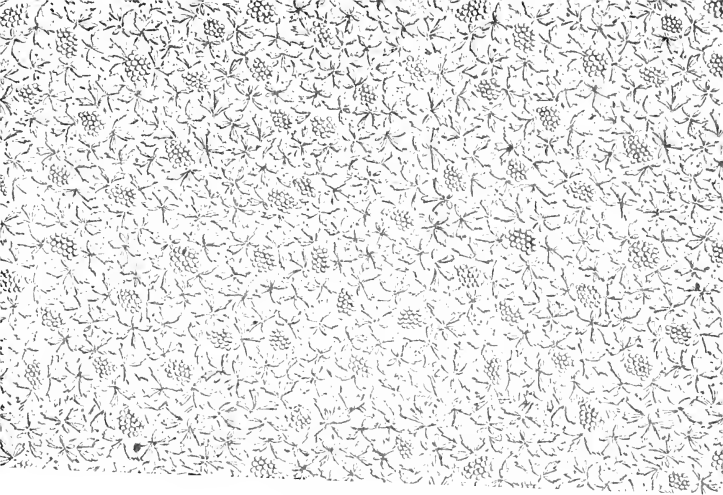
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