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6. Insects of the Pond and Stream.

A HISTORY of the insect inhabitants of a pond or stream would deal largely in the tragic. The biography of one aquatic insect from the time of its birth till its death, provided it completed the usual round of existence allotted to its species, would be a long and perhaps tedious record of escapes from its enemies, of its methods of avoiding or repelling their attacks, while on the other hand the pages of its biography would be largely occupied with a list of those it had killed and wounded, not from the mere love of carnage, but from the simple necessity of maintaining its own existence. If we reflect for a moment on the fact that out of about one hundred eggs laid by the dragon fly, perhaps only one pair survive the following summer, and that the remaining ninety-eight young have afforded food for other dragon flies and insects of other species; and then consider the amount of insect-food required to maintain the pair of dragon flies from the larval to the winged state, we shall be impressed with the fact that the majority of insects are born to serve as food for the few that survive.

Life among the lower animals, as in human affairs, is an intense struggle for existence, resulting in a triumph of the favored few over the masses. These few perpetuate the qualities which gave them success, and so we have a constant progress upwards of life from lower to higher forms, a survival of those best fitted by physical and intellectual qualities to maintain themselves in the world. There is genius, or preëminence in intellectual qualities, among insects. Ants choose generals and master workmen, whose lead they follow in their wars and public works. The queen bee is mistress of the kingdom over whic she rules.

It is not, however, simply a record of the triumph of brute force. Intelligence is everywhere guiding the operations of these unconscious, or possibly conscious, agents. The great interest in studying the habits of insects results from this fact of the immanence of mind in the animal world. Insects and animals generally are not mere "animated machines," with a "blind instinct" alone, operating under the rule of so-called inflexible physical laws; for these very "laws," as we call them, are in a state of unstable equilibrium. There was a time, before life originated, when the world was forming by the agency of cosmical laws; the biological laws became developed with the rise of animal and plant life. The laws of life, the processes of evolution, have changed and become more complex, as forms of life beginning with the Vibrios, Moners and Amœbas became differentiated into the grand groups of the animal and vegetable kingdom.

So the life of the individual, of the species, of the animal world collectively, is a long record of feats of strength, of mere animal courage opposed to cunning, skill and sagacity. The strong are saved by their size and strength, while on the other hand, as in the parasitic species, the very weakness of the weak is often their defence. In past ages insects were gigantic and low in intelligence, judging by their surviving relations; while the insects of the present day, as a rule, have smaller, more compact bodies, with their appendages more under the control of their intelligence. The most fitting have survived. The families and orders of the Neuroptera which are least numerous at the present day are those which have succumbed in this struggle for existence. The Hymenoptera and beetles comprise the most intelligent of insects, and they are, perhaps, the most numerous in species.

Had one been born in the Silurian period he would be excused for being a materialist of the Büchner school, but man of the Quaternary period, *i.e.*, of the present day, who is able to reflect on this progress of life as the beneficent result of the struggle, mental and physical, for existence, of his own and other species; such an one, unless his faculties are quite unequally developed, cannot avoid a rational combination of materialism and spiritualism in his intellectual make-up. The very faculty he possesses of making this retrospect and studying his own mental operations, and of appreciating the Infinite Power working in material laws, separates him from the animals, and should teach him that he is not subject alone to physical, material laws.

So if, in looking back, the picture of the animal world evolving from a mere drop of protoplasm, of humanity struggling up from some ape-like form, seems sad, tragic, and gives a shock to the sensibilities of many, the final result is hopeful and inspiring. In connection with these profound problems of our own existence, the study of the habits, economy, structure and embryology of animals, their various contrivances for the maintenance of life, their evident enjoyment of life as long as it lasts, the gleams of intellect flashing out in their daily acts, all derive a fresh and startling interest.

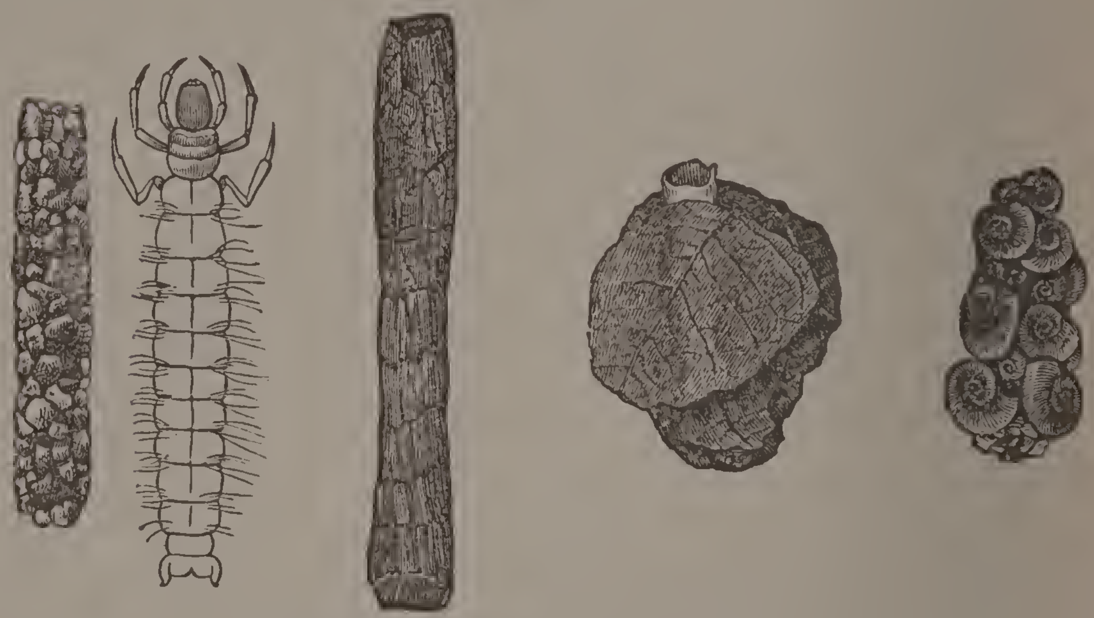
FIG. 91.

Gerris.

Among aquatic insects there are marvels of mechanical skill displayed in the construction of the bodies of the swimming and diving forms. The Gerris, or Wherryman (Fig. 91), of our streams, ages ago anticipated our racing boats and wherries. Our diving machines, whether known to their inventors or not, are modelled on the principle of the diving beetle and the diving spider. The mechanism of swimming in the Dytiscus engaged the attention of Straus-Durchheim, the famous French anatomist. Models of scissors, straight and curved, that would give new ideas to a Sheffield manufacturer, may be studied in the jaws of the young of these same diving beetles. The larval Corethra, a fly allied to the mosquito, is an excellent areometer, and other philosophical instruments have their counterparts in the special organs of insects adapting them for an aquatic life.

Cases of protective mimicry are afforded by the Caddis flies (Fig. 92), which move over the bottom, carrying about with them a movable *chevaux de frise* of sticks, behind which lurk a nimble pair of jaws; or they mimic innocent sticks, or build their cases of bits of moss and move about

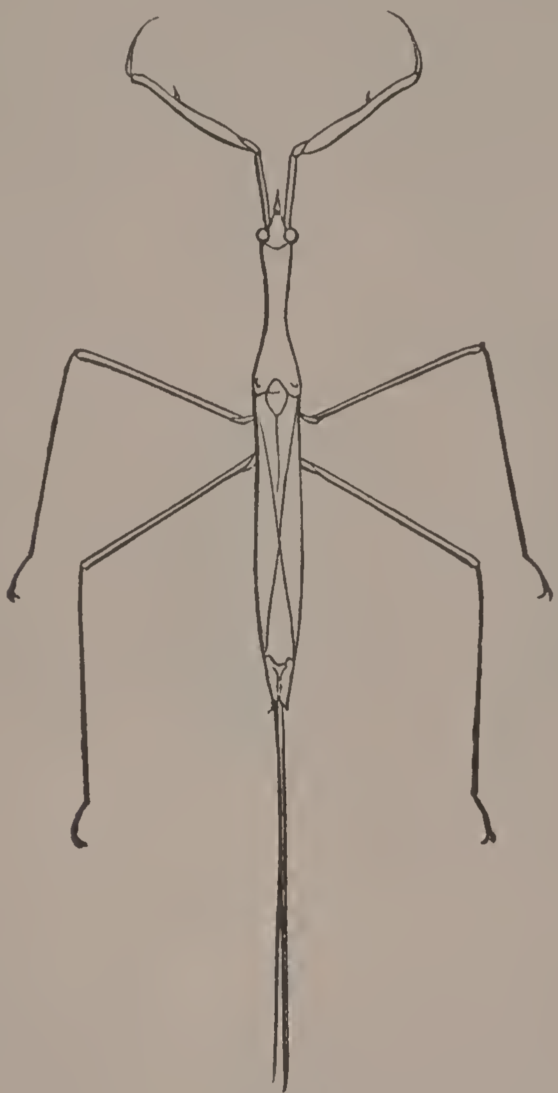
FIG. 92.



Different forms of Case Worms.

bearing, as it were, subaqueous Birnam forests; or when their tubes are built of sand imitate the irregularities of the bottom over which they creep, and thus living in ambush all the while, are protected in their turn by these disguises. As the Ranatra (Fig. 93) is noticed moving about slowly at the bottom of a pool, it would be easily mistaken for an ear of wheat moved accidentally. It is not so harmless as it looks, for its fore legs are held up in an attitude that will at least be deemed by its victims a striking one. When it strikes out those legs, the long claws close with a firm grasp on the struggling worm, which is nailed to the leg by a spine opposite the end of the claw. Why its body is so long and linear in shape, we cannot imagine, unless for the purpose of concealment and protection, as its movements are labored and slow, as are those of Belostoma, its near ally, which, as

FIG. 93.



Ranatra.

has been remarked by others, closely resembles a dead leaf, as it lies at the bottom of the pond in wait for its prey.

So small a proportion of insects are aquatic that the question arises whether those that do live in our ponds and streams may not be the descendants of terrestrial forms. The ocean is the parent of all life ultimately, but only a very few insects live in salt water, and it is easy to see that a maritime life is not a normal one to them. So in a less degree with the fresh water forms. The aquatic insects are representatives of scattered families, and though all are in various ways modified by their aquatic surroundings, yet so much do they differ in their modes of development and structure among themselves, that it is easy to see that they belong mainly to terrestrial types which have adopted an aquatic life after the type to which they had belonged had become fixedly terrestrial. For example, many beetles

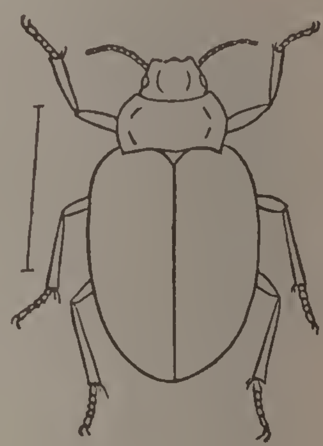
FIG. 94.

Dytiscus.

FIG. 95.

A Carabid.

FIG. 96.

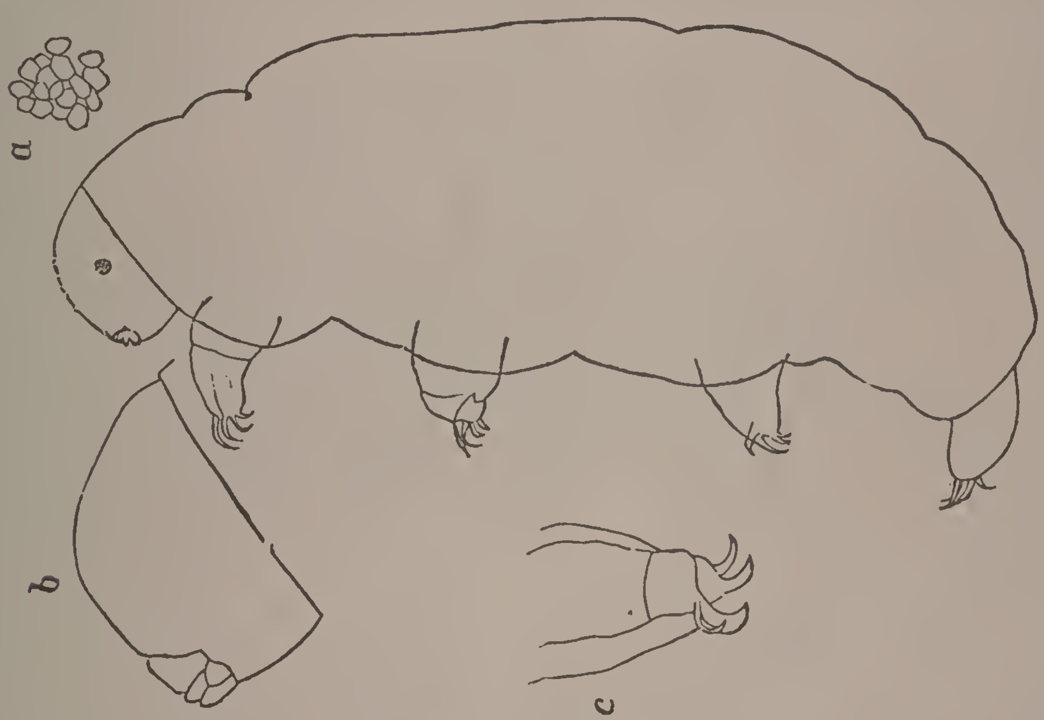


Amphizoa.

which are aquatic are allied to the carnivorous ground beetles. The Dytiscus and its allies are essentially aquatic Carabidæ, the family comprising the ground beetles. The larvæ of these water beetles have the same kind of feelers and mouth-parts as the land Carabids; the structure of the adult beetle is on the Carabid type, the body being, however, more ovate and modified for swimming. Both types (Figs. 94 and 95) may have been derived from ancestors of terrestrial habits. As proof of this we have the Californian Amphizoa (Fig. 96), which is said by Dr. Horn to be subaquatic, and in its structure and habits connects the Carabids with the Dytiscidæ.

Out of the immense number of species of butterflies and moths, but three or four genera are known to be aquatic. The larvæ of Hydrocampa, Cataclysta and Paraponyx, small moths of the family of Pyralidæ, live in the water on the leaves of aquatic plants, the caterpillar of Paraponyx being provided both with branchiæ and spiracles. M. Bar has lately discovered in French Guiana a hairy caterpillar which

FIG. 97.



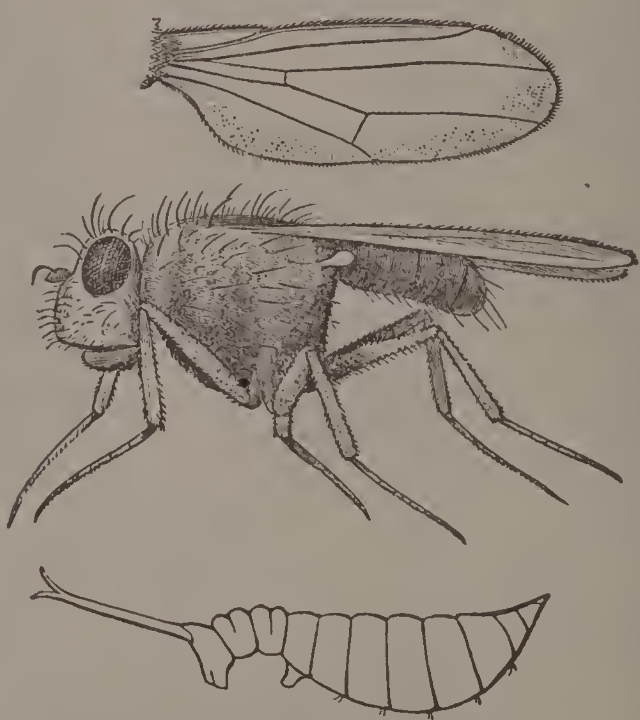
A Tardigrade.

lives in the water, and resembles that of our Arctia or "woolly bear." It has no tracheal branchiæ, and all the spiracles except those on the segment behind the head and a pair on the end of the body are smaller than usual.

There are no truly aquatic Hymenoptera or Orthoptera. The aquatic Hemiptera, such as Gerris, Notonecta, a Corixa and a few other forms, all breathe atmospheric air, though the stigmata may be elongated and otherwise modified for the purpose. One spider, the Argyroneta of Europe, is aquatic. We know of no other water spider. Certain mites are aquatic, but do not differ from land species in their mode of respiration. The Tardigrades (Fig. 97, *Macrobiotus Americanus*) are low microscopic mites, which live in water and are called water bears. They have no spiracles nor air tubes, and respire solely through the skin. The Pycnogonids, which live at all depths of the ocean, from low water to several hundred fathoms, and which are probably related to the mites, also breathe through the skin.

It is among the two-winged flies (Diptera) and Neuroptera

FIG. 98.



Ephydra and pupa case.

that we find insects with gill-like appendages penetrated by air tubes which supply fresh air to the blood. There are quite a number of aquatic larvæ of flies, but with few exceptions, such as those of the mosquito and black fly, they belong to families which also contain closely allied genera which live in the earth. For example, most crane fly larvæ are terrestrial, a few are adapted for aquatic life; some larval horse flies live in mould, some are known to be aquatic;

most of the Syrphidæ are Aphis-eaters in the larval state. Of that immense family Muscidæ, of which the house fly is a type, which are almost purely terrestrial, Ephydra (Fig. 98, fly and pupa case) is aquatic. It may be said on the whole that the aquatic larvæ of the Diptera were originally terrestrial insects, which have adopted an aquatic life and are exceptions to the rule.

In the Neuroptera, however, there are whole families which are aquatic both in the larval and pupal state, having external gill-like appendages in both stages, and in the case of

FIG. 99.

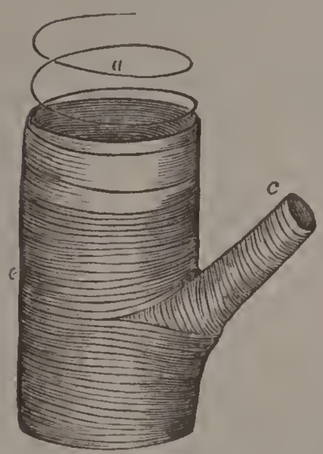
Perla.

Pteronarcys, which is closely allied to Perla (Fig. 99, from Figuier), they are retained in the winged fly. The Neuroptera are *par excellence* water insects, and yet it is doubtful even whether they have not originally assumed this exceptional mode of life, and, while the earliest of all insects, were not at first terrestrial. This is speculation and guesswork, but facts seem to point to this conclusion.

Now the changes in structure fitting the insect for a life in ponds and streams are to be found in the organs of locomotion and the breathing apparatus, and in this essay I shall endeavor to show how insects primarily adapted for breathing atmospheric air are enabled to breathe in the water; then I shall notice the various modes of swimming in aquatic insects.

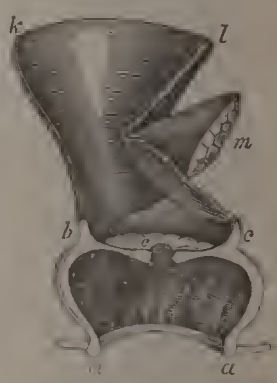
In the first place, how are insects fitted to live under water? It will be remembered that all insects breathe by means of air tubes called tracheæ (Fig. 100, trachea; Fig. 101, section of spiracle). These are tubes composed of three coats; the inner, a tube of mucous membrane surrounded by a spiral thread, formed originally out of a homogeneous membrane which ultimately splits up into these spiral threads, giving rigidity and toughness to the tube. There is a third loose investing membrane, the so-called peritoneal coat. A trachea originates from a spiracle or breathing hole, of which there are usually nine on each side of the body. These spiracles, or stigmata (Fig. 101, *aa*), open by a slit into an inner chamber (*e b*), guarded by a muscle (*m*). The air thus admitted is carried into every part of the body by the numerous fine subdivisions of these tubes, which form a beautiful net-work of silvery threads when filled with air. They are bathed by the blood which is everywhere oxygenated by the air in these fine tubes.

FIG. 100.



Trachea.

FIG. 101.



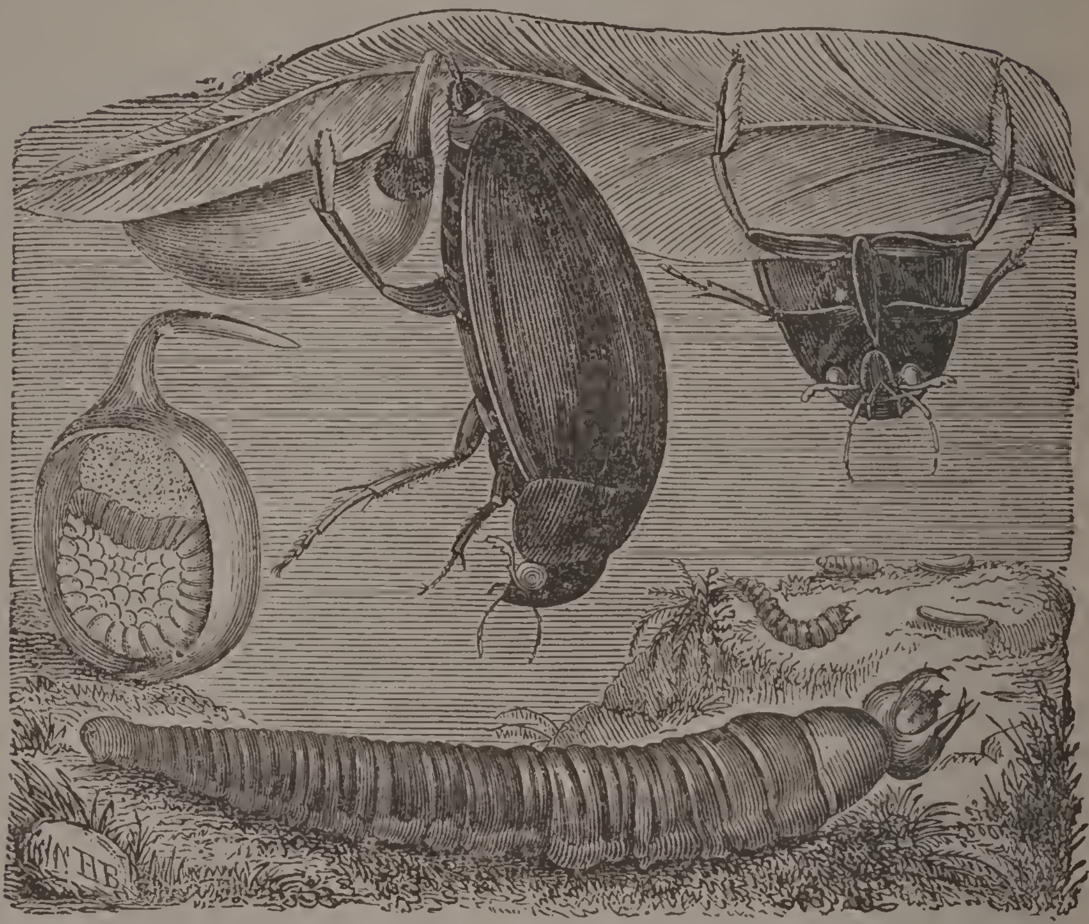
Spiracle.

Numerous beetles and water bugs have no special apparatus for breathing in the water. The Dytiscus when it wishes to breathe rises to the surface, tail foremost, bends the end of its abdomen so as to allow the air to pass into the spiracles under the elytra, and scuttles down to the bottom in great apparent haste, with a bubble of air attached to the tip of the body. When its supply of air is exhausted it is forced to rise for more. In the travels of Colymbetes, a near ally of Dytiscus, around the jar in which we have watched its movements, it often makes a squeaking sound, which we have heard at night as often as by day. This noise can be readily produced artificially by rubbing the end of the abdomen against the elytra, or wing covers. In this beetle there are six pairs of abdominal spiracles, but the basal pair are nearly three times as large as the others, and into these most of the air probably enters. In handling this beetle one is apt to be pricked by the sternal spine, which extends back of the insertion of the hind legs and is as sharp as a needle. How useful it may be to the insect in pushing its way through any obstacle may be demonstrated by holding it tightly between the fingers; here even it manages to push its way out and drop to the ground. All the water beetles fly about in the night, exchanging one pond for another, and they sometimes enter our windows.

Siebold says that *Hydrophilus piceus* (Fig. 102, from Figuier), the largest of all the water beetles, and belonging to a different group from Dytiscus, when it breathes, protrudes only its antennæ out of water, and, "bending them backwards, thus establishes a communication between the external air and that adhering to the under surface of the body."

In our *Notonecta undulata* (Fig. 103) the mode of taking aboard its supply of air before diving is most admirable. The deck of the boat, *i.e.*, the under side of the body (for the insect swims on its back) has a longitudinal ridge in the middle; a broad gutter between this ridge and the sharp edge of the body is bridged over from the head to the end of the abdomen by a layer of dark, coarse, oblique hairs, and a layer of less oblique hairs arises on each side from the middle of the ridge. These hairs thus form a false upper deck. The creature rises to the surface, the end of the body projecting slightly out of water; the air passes up on each side along the tunnel under the hairs and collects in bubbles above the base of the legs. Along the bottom of this

FIG. 102.



Hydrophilus piceus, eggs and larva.

tunnel are six pairs of spiracles into which the air passes. The air in the specimens we observed did not adhere to the hairs of the hind legs as Siebold says it does, nor, as he states in his "Comparative Anatomy," translated by Burnett, does the air for respiration as a rule pass under the elytra, since the spiracles are not situated on the upper side of the body but on the under, and quite a distance from the edge of the body. Nor does this insect breathe at all, as Westwood states, like Dytiscus, in which the spiracles are situated on the upper side of the body, so that the air enters readily under the elytra. When it takes in the air the tip of the abdomen is thrust up just above

FIG. 103.

Notonecta.

water and an orifice is formed by the separation of the hairs at the end of the keel, which form the larger part of the mouth of the orifice, the remainder being composed of the hairs fringing the movable terminal plates of the body. The air thus passes in between the false deck of hairs and the under side of the body. When the insect is taken out of the water the hairs cling to the sides of the body, revealing very distinctly the breathing holes. Some air occasionally penetrates under the elytra and remains there most of the time. Often the whole under side of the body between the pairs of legs is a continuous bubble, like a mass of quicksilver or molten lead. The Notonecta often rises for a new supply of air before the old is exhausted.

While handling Notonecta thoughtless of its reputed sting, in a quiet business-like way it inserted its beak in my thumb, the pain almost as severe as the sting of a wasp, and lasting for five minutes. The pain was too acute and benumbing not to be the effect of a poison. If no poison sac will yet be found in the head, then the saliva must be an acrid poison. By this poisonous sting it must paralyze its victims.

FIG. 104.

Corixa.

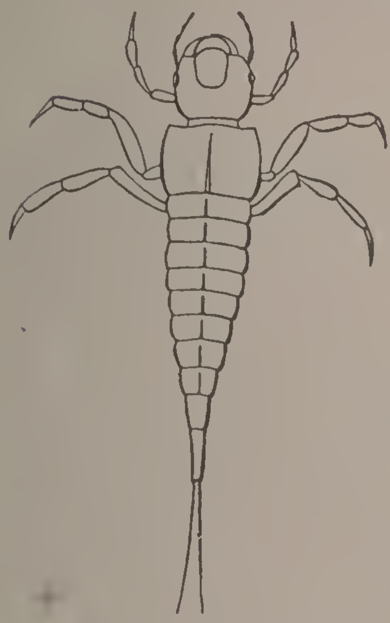
Another water bug, the Corixa (Fig. 104, enlarged), is less tame and does not come to the surface nearly as often as Notonecta. It receives its supply of air in an instant and darts down to the bottom. It does not swim in an inverted position. It takes in the air so suddenly that it is impossible without long and patient observation to see the mode, which we have been unable to find described. It rises to the surface in a horizontal position and no sooner is the surface reached than it darts to the bottom, and in one instance remained there for ten minutes by the watch, and then darted up again, leaving an air bubble in its wake, which rose to the top afterwards. It carries down with it a broad silvery streak along the side of the body. The air is really introduced under the head and front thorax. The head is large and very movable, as well as the prothorax. It slides back and forth on a thin membrane, from the surface of which it can be raised. So with the hinder edge of the prothorax, which rides over the membranous hind thorax, which it nearly conceals. When the Corixa rises to the surface it floats in a horizontal position, the hind edge of the head and the prothorax rising slightly above the surface. Now slightly raising the back of the head and the hind edge of the prothorax a space appears in front of and behind the prothorax, by which the air passes into the breathing holes beneath. This is proved by the small bubbles of air remaining in these two cracks. Two minute spiracles may be detected in deep pits, one on each side, just above the insertion of the legs, and from which the tracheæ arise, each one dividing into three irregular short branches, as may be seen by detaching the segment and holding it up to the light.

So much for those insects which simply rise to the surface and take in air without any special modification of the spiracles. We now come to a second group of adult insects which, by a change in the number, position and form of the spiracles, are provided with a special respiratory contrivance. A striking example is seen in Ranatra, the water stick bug. The end of this creature's body terminates in two thin tubes nearly as long as the insect itself, at the end of which are two spiracles, each connecting with a trachea. These long appendages, which are simply elongated spiracles, it thrusts out of the water, takes in its supply of air, and then goes on in its deliberate ramble. The Nepa of Europe has much shorter respiratory tubes than Ranatra, while those of Belostoma scarcely project beyond the body, though in *B. annec-*

tens, from Nicaragua, they are a quarter of an inch long and two tracheal branches can be distinctly seen in each of them. The other abdominal spiracles are wanting in these three forms, though three pairs, according to Schiödte, are present on the thorax.

There are a number of aquatic larvæ which breathe by similar respiratory tubes. Such is the young of Dytiscus

FIG. 105.



Dytiscus larva.

FIG. 106.

Eristalis larva.

FIG. 107.

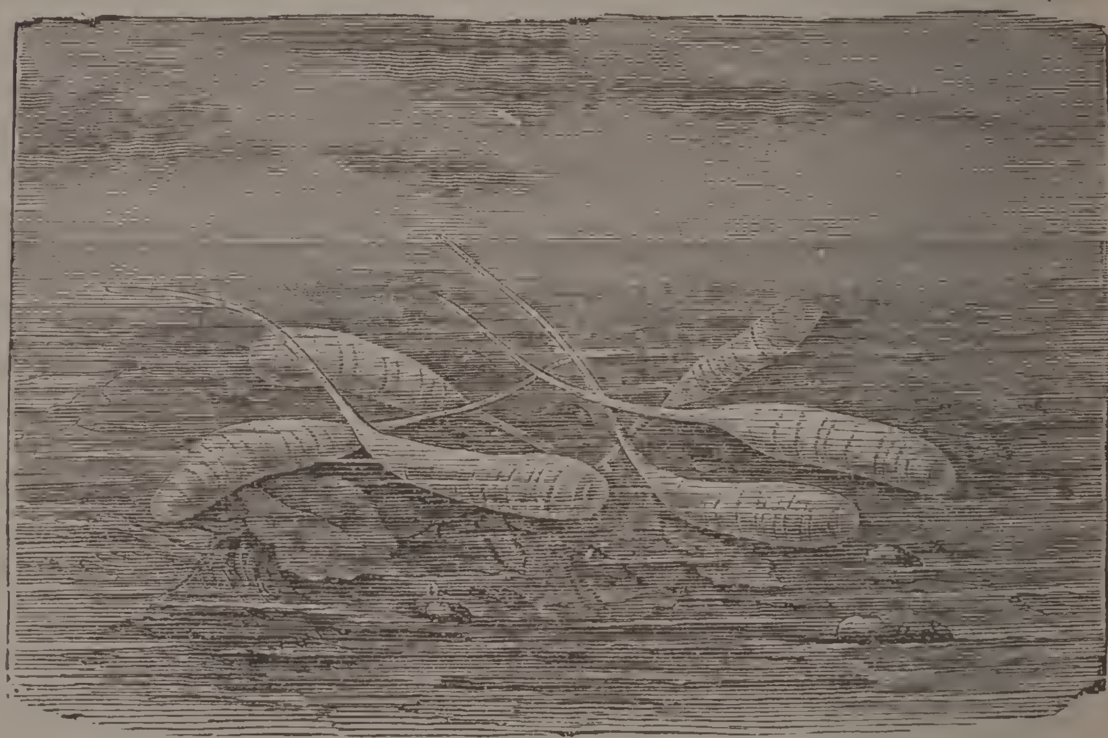
Merodon and larva.

(Fig. 105). It has to rise to the surface for air, which is inspired through the bristle-like tubes at the end of the body. So with the larval Eristalis (Fig. 106), and its ally *Merodon bardus* (Fig. 107; *a*, larva) and Helophilus (Fig. 108). These maggots frequent the most loathsome ditches, thick with mud and putrefying matter. Here they lie acting as scavengers and doing all they can to aid the State Board of Health. They wave their long flexible respiratory tubes aloft and drink in the pure air of heaven, not unmixed, perhaps, with the less than spicy odors emanating from their native puddle. Some of the Helophili frequent strongly brackish water, in fact almost purely salt water, while

Ephydra, with its rather short, thick tubes and fleshy feet, clambers over green sea weeds in salt pools removed above the reach of ordinary tides, or lives in the brine pools of Illinois, or the salt lakes of the West. The aquatic larva of one of the Tipulids or crane flies (Ptychoptera) has a long respiratory tube, while in the pupa there is one attached to the head and much longer proportionally than in the larval Helophilus.

Among those larval flies which are obliged to ascend to the surface to breathe, is the young Mosquito (Fig. 109; A,

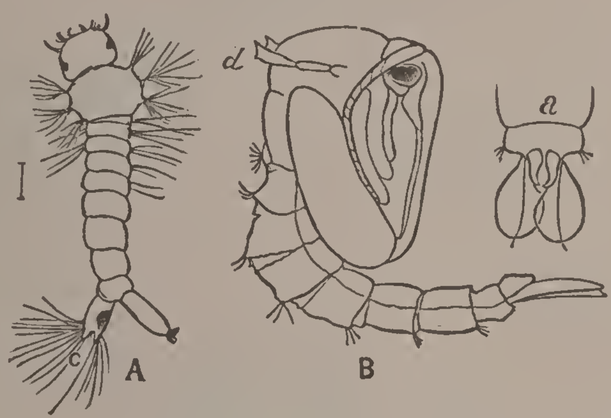
FIG. 108.



Helophilus larvæ (after Figuier).

larva; B, pupa; *a*, paddles at end of body of pupa). Its body is beautifully adapted for going through its aquatic evolutions. The head and thorax are so large and bulky that it cannot ascend and lie motionless in a horizontal position, as in the young Anopheles, which lies before us in a dish as we are writing; but it hangs head downwards and breathes by means of a spiracle lodged in one of the large tubes into which the end of the body subdivides, the position of this tube being maintained by a pencil of radiating hairs, attached to a shorter projection at the end of the body. The air is rapidly absorbed by the unusually large trachea, nearly filling the longer tube. After taking a fresh breath it often swings its head around, mouth upwards, its tail being the pivot, mowing the surface of the water, if clouded with decaying matter, with its jaws. The young Anopheles, the fly of which is the four-spotted mosquito found in houses late in autumn and early in spring, is a surface breather. But the head and thorax are scarcely heavier than the hind body, and along its whole length are tufts of hairs which spread out and act as floats to the body. The mouth-parts are tufted more distinctly than in the

FIG. 109.



Mosquito larva and pupa.

young mosquito. In this larva the body ends in four fleshy finger-like appendages, in which the tracheæ may be distinctly seen.

In its pupal stage the mosquito is quite a different being. Its life is regulated by a new code. It scorns food of all sorts, and like some religious devotee lives on air alone, and that in homeopathic doses. The enormous thorax is almost a deformity, and now, instead of breathing through its tail, it bears two club-shaped respiratory tubes on its back (Fig. 109, *d*). These are situated on the site of the future thoracic spiracles of the fly.

Of those insects which extract air from the water in which they live and are not obliged to ascend to the surface, is the young of the plumed gnat (Fig. 110, *Chironomus oceanicus*, male, and beneath, head of female; *a*, larva and head enlarged). These worms are very abundant in every mud puddle, but the species here figured lives at all depths in

FIG. 110.

Ocean Gnat; *a*, larva, and head enlarged.

the sea down to over a hundred feet. Some larvæ of another species were dredged in Lake Superior by Mr. S. I. Smith at a depth of one hundred and fifty-five feet. They are usually provided with two pairs of fleshy filaments, permeated by one or two slender tracheal twigs, connecting with a slender pair of tracheæ running through the body, and enlarging towards the head. So slightly developed, however, is the tracheal system in Chironomus, and so thin are the walls of the body, that I am inclined to think that these nearly transparent larvæ breathe in part through their skin.

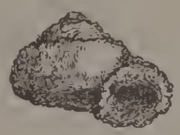
Now we have in the singular ghost-like larva of Corethra another plumed gnat, a being which has no spiracles nor tracheæ, and which breathes, as Weissmann says, through the skin. The air thus absorbed is contained in four reservoirs, forming swimming bladders, and thus the density of the water is measured by this living hydrostatic apparatus. Two of these kidney-shaped bladders are lodged in the thorax and are larger than the two near the end, in order to support the heavier front end of the worm. These singular larvæ may be found in winter in ponds by breaking through the ice, as well as the Belostoma and various water beetles, and can be kept alive in jars of water.

The finger-like appendages we have described in the larva of the plumed gnat afford the simplest form of "tracheal gill." Did the blood penetrate into them and accompany in closed vessels the air tube, it would be exactly comparable with the gills of fishes and larval amphibious reptiles; but it does not; it is not a true gill, and the term "false gill" or "tracheal gill" has been applied to this organ.

From the young Chironomus, with its four tracheal finger-shaped gills attached to the extreme end of the body, we may pass to a singular larva of a European crane fly, called Cylindrotoma, which according to DeGeer breathes by means of numerous hollow flexible filaments scattered over the body, and which, as Westwood says, appear to be traversed by tracheæ. A similar looking creature is the caterpillar of Paraponyx, which respires under water by means of a number of fasciculate filaments situated on the sides of the abdominal rings.

In fact this caterpillar has been anticipated by the case worms, the young of the Caddis flies, in which the caterpillar-like body is provided with white, slender filaments, arising in groups of from two to five and crossing over the back of the worm. When the case worms are about to transform

FIG. 111.



Case of Helicopsyche.

they close up the mouth of their case with a grating, or, as in the snail-like case-worm (Helicopsyche), whose case (Fig. 111) is made of grains of sand, they close the aperture by a dense silken lid, pierced by a slit through which the water enters. The only exception known to this mode of respiration in the large family of Caddis flies is Enoicyla, which is terrestrial, living in moss at the roots of trees, and consequently has no respiratory

FIG. 112.

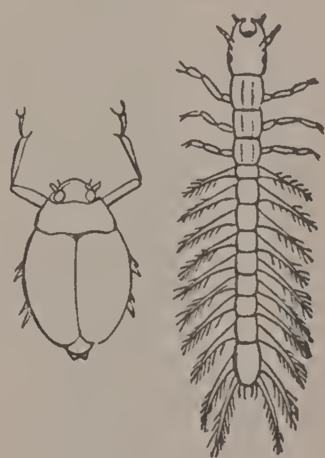
Nemoura and pupa.

filaments. Notwithstanding the submerged life of these case worms, they are attacked by ichneumon flies when in the larval state. How the young ichneumon lives in the submerged body of its host is not known.

The branchial gills in the Perla and its allies, Nemoura (Fig. 112, and pupa) and Pteronarcys, etc., which are flat-bodied insects living under stones in streams, have been investigated by Newport, the famous English anatomist, and quite recently by Dr. Gerstaecker of Berlin. Mr. Newport made the astonishing discovery that the winged adult Pteronarchys retains its larval tracheal gills, and Dr. Gerstaecker has lately discovered that this is also the case with a species of Diamphipnoa from Chili, and a European species of Nemoura. This is analogous to certain Tritons or Salamanders which retain their gills in adult life.

The larva of Hydrophilus, the large water beetle (Fig. 102), breathes by means of spiracles, but is probably aided by the lateral filaments along the abdomen. One would hardly suspect that the whirligig beetle which gyrates almost unceasingly on the surface of every roadside puddle or eddy of the stream, had young of such a singular appearance. They differ from all known coleopterous larvæ in the possession of eight pairs of large, long, thick, hairy appendages permeated by tracheæ. They would by some be mistaken for caddis worms, but their head is much larger and jaws much longer and sickle-shaped. In August the mature larvæ are said to creep out of the water and spin an oval cocoon attached to some plant, and then dropping their tracheal gills, with their larval skins, breathe through spiracles. After remaining a month in the pupa state it appears as a beetle, which lays its eggs in regular rows on the leaves of water plants, and in about a week after the larvæ are hatched.

FIG. 113.



Gyrinus and larva.

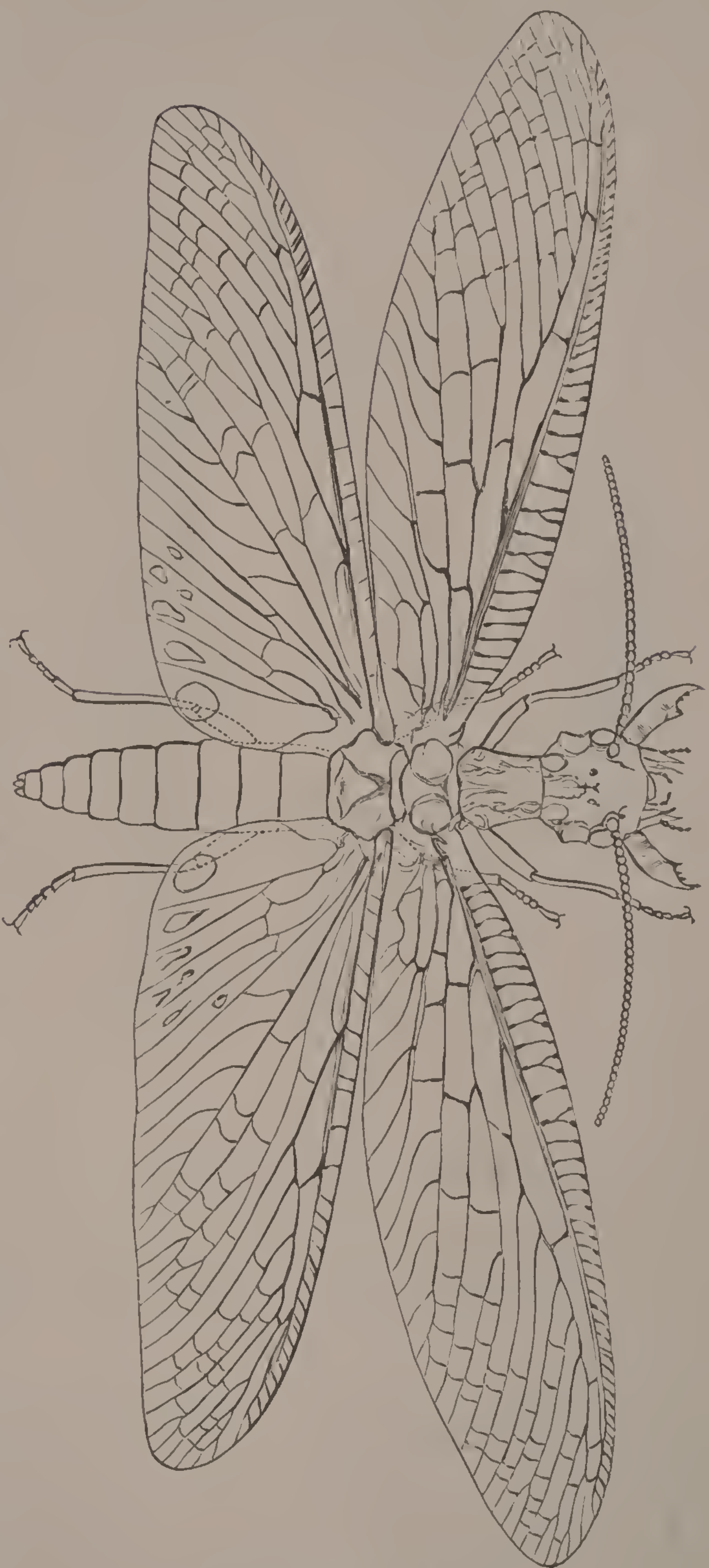
An interesting chapter might be written on the sense of sight in aquatic insects. In Notonecta and Corixa the eyes pass under the water level, so that they can see above and below at the same time. So with Gyrinus (Fig. 113). Its eyes are divided by the portion of the head that carries the antennæ, so that, as Wood says, the portion under the surface may be compared with a water glass used by fishermen for observing objects at the bottom. Our Gyrinus larva repeats with great exactitude the form of the young Corydalus (Fig. 114), which transforms into the large net-veined insect (Fig. 115) so formidable in appearance, and yet so harmless. A singular chapter in biology would be the life of this insect. The gigantic carnivorous larva, with its large head and enormous jaws, is provided with eight pairs of long, rather stiff, respiratory filaments. Dr. Hagen has called attention to the spiracles of this creature, which are not usually present with tracheal gills, and to the reason for their existence. It seems that like the European Sialis (Fig. 116, larva and pupa) it lives some weeks out of water before its transformation into the pupa, which rests in an earthen cocoon in the banks of streams above water. The eggs (Fig. 114, *a*) are very large, and are deposited in a squarish mass on the stems of water plants.

FIG. 114.

Corydalus larva and eggs.

There is no more beautiful object for low powers of the microscope than the larval May fly (Fig. 117). The body is so transparent that the movements of the heart, the play of its valves, the circulation of the blood, the distribution of the tracheæ, the digestive canal and its movements, as well as the action of the muscles controlling the jaws and other parts of the mouth, can all be watched with ease. The tracheal gills, like paddles, either round or long and leaf-like, are arranged in pairs along the hinder region of the body, and the tracheæ in them can be readily seen. These beautiful respiratory leaves are also paddles, and by their aid as well as by the undulations of the body the young May fly moves rapidly and gracefully through the water. It lives two years, while the winged fly (Fig. 118) but a day, rarely over twenty-four hours. The winged fly throws off the pupa skin in an instant. While holding a pupa in my hands the imago slipped out suddenly with wings fully formed. This

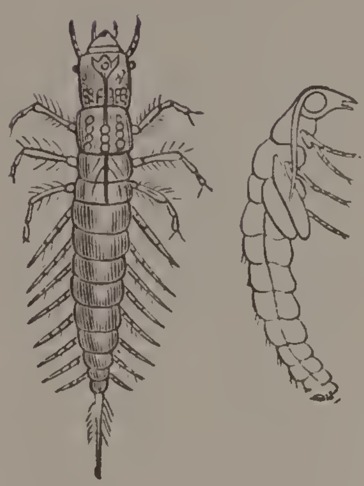
FIG. 115.



The Horned Corydalus.

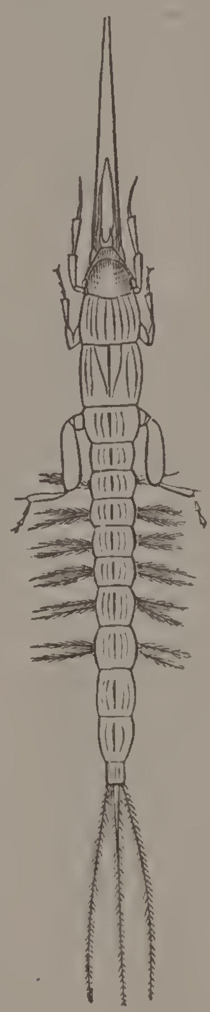
was the so-called sub-imago; after a few hours, if it had not been placed in the collecting bottle, it would have thrown off a thin pellicle, and then been sexually mature. It then

FIG. 116.



Larva and Pupa of Sialis.

FIG. 117.



Larva of Palingenia.

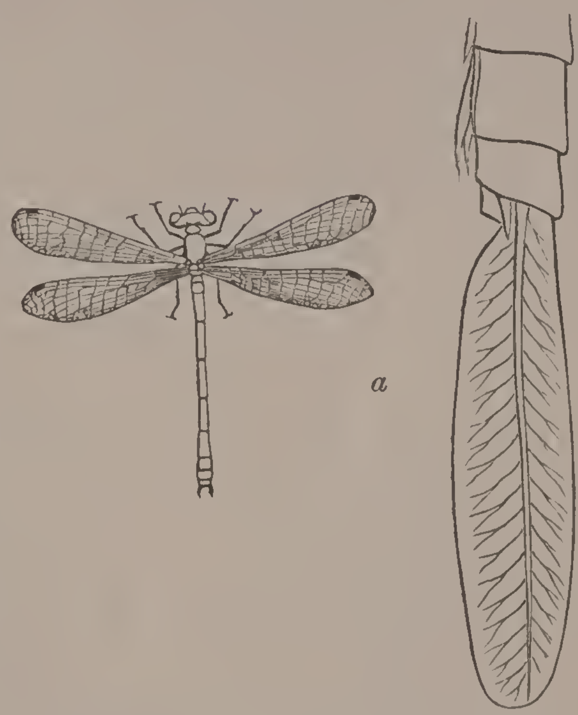
FIG. 118.

May Fly.

lays its eggs in a round mass and dies. Some of the larvæ live in burrows at the bottom of ponds, while others swim free.

Coming, lastly, to the family of Dragon flies, we find among the larvæ the most diverse means of respiration. In the young of Agrion (Fig. 119; *a*, respiratory leaf of larva) the body ends in three large leaves, through the middle of which runs a trachea which sends off a number of smaller branches. These larvæ when quite small are beautiful objects for the microscope, their bodies then are so transparent. Now in the young of the larger dragon flies, such as Diplax, Cordulia (Fig. 120), Æschna (Fig. 121), and Macromia (Fig. 122), the breathing process is carried on within the body. The terminal portion of the digestive tract is provided with ridges of mucous membrane. Into these folds or ridges numerous tracheal twigs penetrate (Fig. 123, *x*). The water is admitted through the conical valves at the end of the body; there it is deprived of its air, which is absorbed by the tracheæ and ejected in a gentle stream, or, if the creature is startled, it is driven out as if by a force pump or syringe, sending the insect forward several times its own length.

FIG. 119.



Agrion and Respiratory Leaf of Larva.

FIG. 120.

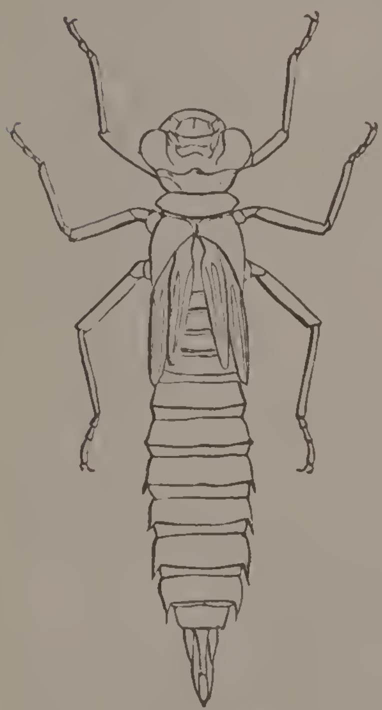
Cordulia lateralis.

Returning again to the May flies, Walsh has described a mode of respiration unique in that group, but which reminds us of the internal lung-like apparatus of the larval dragon fly. This curious form is otherwise an exception to all insects, in that its three thoracic rings above are, instead of being separate, consolidated into one plate which extends back half-way over the abdomen. Fig. 124, III, shows the position of the tracheal lungs in the end of the abdomen. We need further observations to show how the animal takes in and expels the water.

No Myriopods are aquatic, but a number of mites and allied forms live in water and extract the air mechanically mixed with the water, without having to rise to the surface. They have two spiracles and air tubes, but how they extract the air in the water is not known. Such are the Hydrachna and Atax, which live in their early stages as parasites between the gills of fresh water clams, while some species attach themselves to water insects.

Of the various modes of swimming among insects, the

FIG. 121.



Æschna.

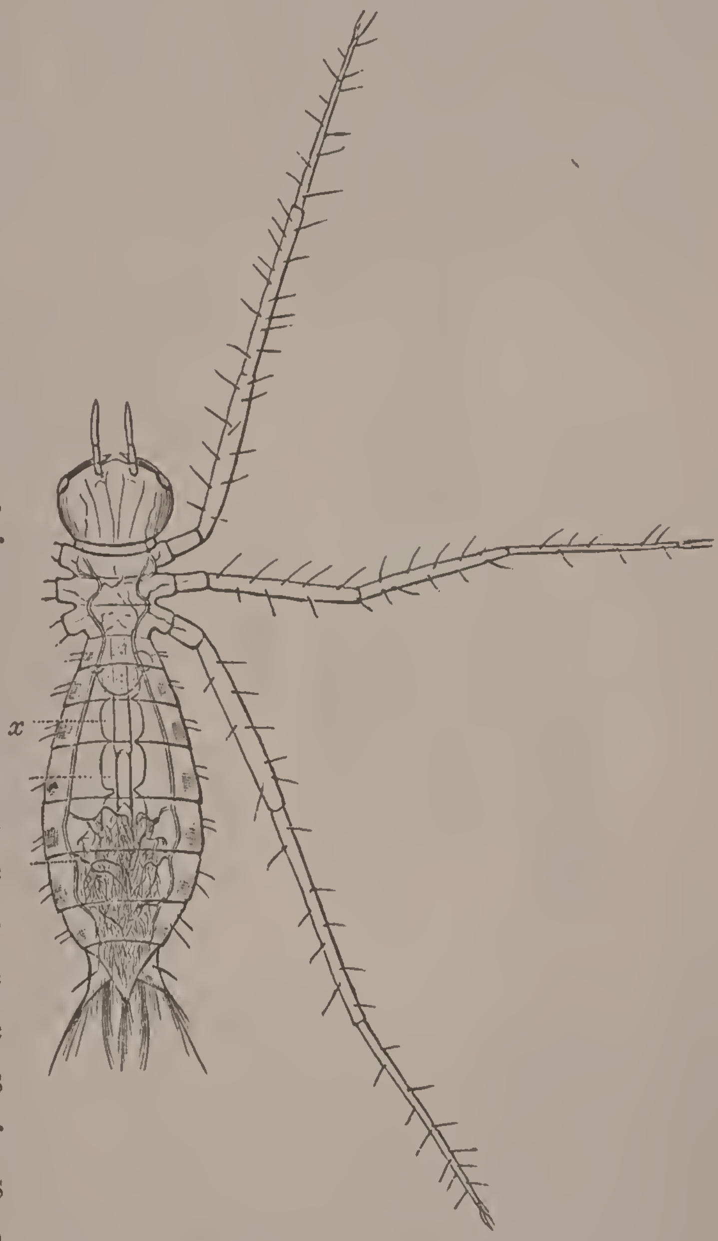
FIG. 122.

Macromia transversa.

simplest, though not the most graceful, is wriggling. By a series of contortions of the body the young Chironomus moves about without much apparent purpose. The twistings and turnings of the larval mosquito are anticipations in nature of the most laborious and complicated feats in gymnastics of the circus clown. The latter realizes the amount of muscular exertion and nervous strain expended in a two-minutes circumtorsion of the ring. The young mosquito, through its life of such violent undulations, knows no fatigue. A study, through the transparent skin, of the arrangement of the muscles of the body shows their wonderful adaptability for the production of these complicated movements.

Many aquatic insects are either "side wheelers" or propellers. The larval Ephemera, aided by the beautiful paddle-like tracheal gills along the sides of the body, moves through the water by a series of exceedingly graceful undulations; while the young Agrion propels itself, partly at least, by its large terminal respiratory leaves. How by a strange economy of nature the dragon fly larva combines the functions of digestion, locomotion and respiration in an organ which like a force pump ejects a powerful stream, and like a flash propels the creature many times its own length over the bottom of its pond, we have seen above.

FIG. 123.

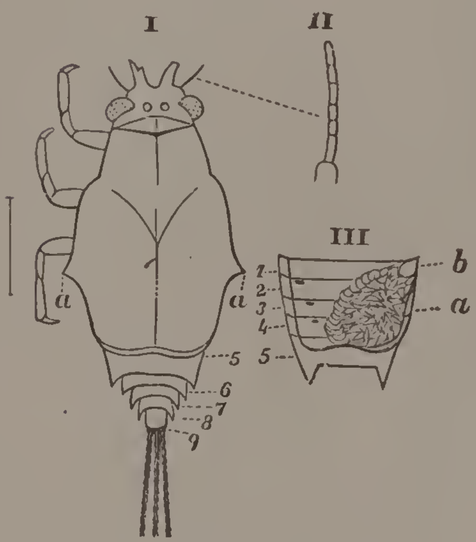


Diplax larva; *x*, mass of tracheæ.

One important result of the metamorphosis of the young mosquito into a pupa is that it is promoted from a wriggler to a paddler, paddling being a higher mode of aquatic locomotion. Our figure of the pupal mosquito shows in a rude way the two beautiful, thin, rounded paddles at the end of the body. By dexterous strokes, aided by a graceful but rapid bending of the body, it seeks the surface and inspires air through its thoracic respiratory tubes. In the same way it descends to the bottom.

The Corethra larva alters the specific gravity of its body during the course of its wriggling, but as a pupa all this is changed. It now resembles the mosquito pupa, has external thoracic respiratory tubes and well developed tracheæ; it loses its air bladders and swims by means of two terminal paddles like those of the mosquito.

FIG. 124.



Bætisca.

We now come to the water beetles and bugs, whose movements in the water are as graceful as they are awkward on land. Their whole organization, bodily and psychical, as thoroughly adapts them for the water as that of the seal or whale for the same element. They are the Amphibia of the insect world. Born as sailors, they take to the water on being hatched and there remain through their lives, only leaving one pond to seek another, impelled by a restless love of change, which unconsciously to themselves results in good to their race, preventing too close in-and-in breeding and the consequent deterioration of the stock. Look at the body of the Dytiscus (Fig. 125), so perfectly adapted for its aquatic life. Remember that it is in reality a modified ground beetle, such as Harpalus, the mouth-parts much the same, and that the changes in form are mostly, if not wholly, such as adapt it to its aquatic life. The body is oval, both ends alike, as in a boat, while the legs are perfect oars. The hind legs, instead of being broad and spiny towards the claws, as in the running ground beetles, taper to a point and are articulated by an exquisite mechanism to the body. They are edged on the inner side with a dense, long fringe of exceedingly fine, white hairs, forming, with the flattened leg itself, the blade of the oar; and thus by a series of rapid strokes the body is propelled onwards. The fore legs are short and thick, and in the males modified into a clasping organ, the three basal joints of the tarsus being broadly dilated and consolidated into a large disk, covered with "many minute funnel-shaped suckers, two or three of which are much larger than the others." The Gyrinus is less a

FIG. 125.

Male and Female Dytiscus.

diver than a surface swimmer. It is a very sociable insect, forming little swimming parties on the surface of the water. In the course of its gyrations it manages to pick up a comfortable livelihood of small beetles and flies which fall into the water. When disturbed it dives to the bottom. Unlike the other water beetles it has very large fore legs and remarkably short middle and hind legs, and flies about in the night, at daylight slipping quietly into some pool. On being handled it emits a disagreeable, whitish, milky fluid, which is probably distasteful to its enemies. All the other water beetles, so far as we have observed, secrete a similar fluid, but in less abundance.

Equally, if not more, perfect in its adaptability to aquatic life is the Notonecta, which, as its name implies, swims on its back. Now look at the form of the body. The back, usually broad and flat in the Hemiptera, is here rounded like the keel of a canoe, while the under side is flat, forming the deck of the boat, to which the oars are attached by a set of automatic row-locks. The head is bent over and submerged in front; the eyes are partly above and partly beneath the water, so that a double outlook into two worlds is secured. The antennæ are tucked away out of sight in a groove under the eyes. The end of the body is pointed, affording no resistance to the water, and the posterior half of the body is fringed with long spreading hairs, which aid in buoying the body up. The adjoining cut (126) gives an idea of the attitude of the Notonecta when at rest at the surface of the water, back downwards.

FIG. 126.

Notonecta.

The hind feet are beautifully fringed, and while swimming it feathers its oars, the hairs of the blade being pressed to the leg as it is drawn forwards, and again spreading out with the backward stroke of the limb. In this insect, as well as in Corixa, as Schiödte observes, the hind legs are moved both together, as in Dytiscus. In Belostoma, and probably Ranatra, they are moved alternately. When about to fly from its pool, which it does by day as well as by night, as is the case with Corixa, it dives a little way down, and then leaps suddenly straight up out of the water, and spreads its wings, flying rapidly off. All the water bugs and beetles are careful to keep themselves clean and smooth. Particularly necessary is it for the Notonecta to keep its keel smooth, and it may often be seen brushing its back with its hind legs, or where they will not suffice, using the middle and front legs for this purpose. It lays its long, cylindrical eggs on the stems and leaves of plants. The young hatch in about fifteen days, appearing in spring. They differ from their parent chiefly in wanting wings.

Corixa is in its form more like the slow moving punt, being rounded nearly alike at both ends. The head is still more bent and prolonged beneath, partly overlapping the thorax. Its beak is minute and hidden from sight.

So much for the swimming insects, of which we have mentioned the principal forms. There are a few of what may be called *skaters*. They move like the Wherryman, or Gerris, on the surface of the water, their feet being so constructed as to enable them to run upon the surface without wetting them. The middle pair of feet are longer than the hinder, and they mostly perform the work of skating, being covered with fine hairs which repel the water; and thus the insect skims over the surface with great rapidity, making very short twists and turns like a practised skater. The under side of the body is covered with short hairs like plush, forming a repellent surface to the water.

The fore limbs are much shorter and used at times in retaining their prey. Some of these Wherrymen will be found minus the hind wings, and are condemned to a life of comparative seclusion; though it is said that the winged individuals seldom take flight.

Far out in mid ocean in the tropics are found the oceanic water-skaters, the Hylobates. Their fore legs are short, outstretched, with thickened thighs. They are also wingless, the wing-covers alone being present. They course over the surface of the ocean in large swarms, and are seen from vessels many hundred miles from land. They are the true "toilers of the sea" among insects.

The only possible way to study the aquatic insects is to keep them in glass jars and bowls, where their habits can be carefully studied. An aquarium may thus be improvised which will last for several weeks without care, though it is better to add a few water plants, such as the water cress, the Valisneria, Callitriche, Duckweed and other plants, to keep the water oxygenated. By stocking the aquarium with the larvæ and pupæ of certain neuropterous insects at the time when the winged forms are most abundant, the immature forms can easily be kept long enough for us to determine the winged species into which they pass. In the autumn, as cold weather and short days keep us indoors, much profit and solid amusement may be gained by these studies of pond life within the house. Even in winter after the snow is on the ground, one can break through the ice of roadside ponds and with a small net capture nearly all the insects we have spoken of in this number, and keep watch upon their habits, and study their anatomy, with the aid of the needle and lens. He can also turn to the lower forms, such as the water fleas, rotifers, infusoria and rhizopods, with which the waters teem winter and summer, and find, with a few dips of the net, material for weeks of observation and study.

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