

1 Life History of Anax junius.

For the study of the life history of a dragon-fly, no better species can be chosen than the very common and widely distributed ^{big green, darker} Anax junius.

Anax junius. This is one of our largest dragon-flies and is so splendid a flyer, and so vigorous a competitor in the insect struggle for existence, that he well deserves his name, which is a Greek word meaning "king" or "lord". In appearance Anax cannot boast the beauty of some of the smaller dragon flies, or ^{of the} dainty and brilliantly colored damselflies. His sturdy, robust figure, his suit of olive green with trimmings of blue and brown, are eminently sedate and business like.

One's first glimpse of Anax might be as he flies in his regular beat around the pond or lake, which had been the scene of his nymphal life, occasionally darting from his line of flight to devour some small insect, or it might be far from water on some country road, where the air of a summer afternoon seems literally filled with the flying forms: all these are Anax triumphant and visible, and we should be giving ourselves fruitless trouble to attempt to catch a specimen while they are thus actively on the

wing. In the early morning or evening he is more approachable, and sometimes after a heavy rain storm, we may find him clinging to the shelter of a tree or even of a house, buffeted by the elements, drenched and drowned, and for the time being quite at our mercy.

If we take him then, lifting him by his wings, but carefully, so as not to injure their intricate and gauzy network, we can examine him at our leisure. There are three divisions of the insect body, the head, the thorax and the abdomen; we will begin our scrutiny by looking *Anax* squarely in the face. Our attention is first attracted by the enormous compound eyes, which compose more than two thirds of the head; these eyes with their thousands of facets are so set into the head as to give their possessor the advantage of an extraordinarily wide field of vision, an advantage which is most essential in ~~the~~ ^{our} consideration of his method of procuring food.

The face is olive green and the frons or forehead is marked with a dark spot on a yellow ground, the whole being surrounded by a bright blue ring. The mouth parts consist of a huge labium, divided at the tip into two lobes; the mandibles and the maxillae. The labium, which covers and

strokes of the cat's paw and the results for the victim are in each case equally unpleasant. This labium by means of which our Cuckoo nymph secures his food supply so quietly, cleverly and quickly is a wonderfully fine piece of mechanism. In Cuckoo we have it in a comparatively simple form but in some other families, notably in the Libellula, it is enormously developed and covers the face of the nymph up to the eyes, giving the creature a most ridiculous appearance, as if it were modestly concealing its face. At the tip the labium is divided into two lobes, equipped with strong hooks, and it is operated by two sets of powerful muscles, flexors and extensors. When the nymph is at rest the labium is folded so that the rear end extends back between the hind legs, but, when a blow is struck, the muscles, with lightning speed extend the labium to its full length, ^{while} at the same time the ~~abductor~~ ^{abductor} opens the labial lobes. These instantly shut down upon the body of the captive, and with the operation of the flexors the labium closes, bringing the prey into a position where it is easily torn up by the (mandibles and maxillae). If the insect thus captured be a large one the grip of the labium is shifted as much as is necessary to enable the nymph to begin his meal at the tail end of the creature; slender, soft-

bodied creatures, such as damselfly or may-fly nymphs are stuffed in, just as the nymph happened to seize them; head first, tail first, or even sometimes doubled in the middle. One may often see a damselfly nymph, the major portion of whose body has already been benevolently assimilated by an *Amelet* nymph, while his legs and head protruding from the jaws of the captor, wave a sad farewell to the watery world of which he has so recently been ^{an inhabitant} a member.

Wing cases, or strongly chitinized portions of the head and thorax are not devoured, but are discarded by the nymph and may be seen floating on the surface of the water.

Even the alert water boatman (*Corixa*) cannot long escape this sly hunter. On one occasion an *Amelet* nymph about 3c long, was placed in a bottle in company with nine damselfly nymphs of medium size and one water boatman. Altho' the *Amelet* nymph had fed abundantly the preceding day within twenty hours the damselfly nymphs had disappeared and four hours later, the wings and mailed head of the water boatman, floating on the surface of the water, mutely evidenced the fate which had overtaken him.

One readily realizes that the labium must be tremendously strong to enable the nymph to seize and overpower creatures as large as itself, and

Two slender, thread like antennae. - Labrum -
nearly conceals the other mouth parts, plays
an important part in the capturing of any
prey, and likewise holds the struggling
victim while the mandibles and maxillae
tear him in pieces. The thorax is the division
of an insect's body which bears the locomotor
appendages, these appendages in the case of a
dragonfly consist of three pairs of legs and two
pairs of wings. Each segment of the thorax,
the pro-thorax, the meso-thorax and the
meta thorax bears a pair of legs, and the
last two bear each a pair of wings.

The abdomen consists of ten segments and is
destitute of appendages if we except certain
sexual organs. The first two segments are larger
than the others and in the male accessory
genital organs are developed on the second segment.
The opening of the vas deferens is on the
ninth segment, while in the female the
vulvar opening is on the eighth. The female
Anax has an ovipositor and inserts her eggs
in masses of water plants or brush floating
on the surface of the pond.

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The dragon fly spends practically his
entire adult life upon the wing, his wings
are, in consequence, magnificently developed.
While his legs have ceased to be adapted for

walking and are useful only for clinging to a bush or twig during the brief pauses the insect takes for rest. They are also of assistance to the insect in catching his prey, in a way which will be explained in detail further on.

The existence of the dragonfly as an imago is brief, indeed, in comparison with the duration of its nymphal life. The adult life is variously estimated from a week to a month while the nymphal stage lasts ^{a year or more.} from one to four years.

In this brief existence as an imago, however, are comprised the acts essential to the preservation of the order — copulation and oviposition. The act of copulation and the laying of the eggs may be witnessed almost any time from early spring well up into the summer. Like most other phases of the imago's life, copulation takes place while the insects are on the wing. ^{In the case of the dragonfly describe the previous flight.} Among the Deschmuidae, the male grips the female by the rear of the head with his abdominal appendages, while she curves her abdomen forward until the vulvar opening on the eighth segment comes in contact with the accessory genital organs on the second segment of the male, to which he has previously transferred the sperm by curving his abdomen forward until

(make more general)

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the opening of the vas deferens on the ninth segment came in contact with the accessory organs on the second. The female proceeds with oviposition immediately after copulation; in the spring time she is often accompanied by the male, sometimes she is alone; sometimes she inserts merely the tip of her abdomen into the water and sometimes she descends entirely below the surface to insert the eggs in the stem of some plant. Early in the season the eggs are laid in floating masses of trash, but later they are placed in the tissues of growing aquatic plants. The development of the egg and the hatching of the nymph requires about three weeks.

"Dragon-fly nymphs", says Stellieth, "as well as the adults, exhibit the malignant side of that life that lived and sported about the marshes of the remote Tertiary period." If this be true of dragon-fly nymphs in general it is three and four times true of *Arix junius*. The appetite of an *Arix* nymph is absolutely insatiable, he is not dainty in his choice of food, he makes but the single proviso that his prey be living and moving, and any living thing that he is capable of handling will be devoured by him. If a number of dragonfly nymphs of

various ^{and species} sizes, be placed in a jar or bottle, the smaller ones will gradually disappear, until if there be two. One of nearly the same size the two, alone, will survive. If no more food be provided the nymphs will now undergo a prolonged fast, since neither is able to overpower the other, and this state of affairs will last until one or the other undergoes a molt. Then we have repeated the story of the "priest who slew the slayer, and shall himself be slain," for the nymph, wearied by the exertions of the molt, and protected only by a new and tender skin, is presently overpowered and devoured by the one who for long had been his companion in misery.

As a hunter, the Cuckoo nymph adopts methods much like those of a cat. The nymphs cling to the stems of aquatic plants, preferably hanging head downward, and conceal themselves as much as possible. If some hoppers chance fly or may fly nymph comes within his range of vision the nymph regards it with much the same air of calm unconcern with which a cat watches a mouse hole; when the prey comes within reach the swift stroke of the labium is irresistibly reminiscent of the

This may be interestingly demonstrated by suspending the nymph by the extended labium. It is able to draw itself instantly up to this support and to retain the position indefinitely, in which position, of course, the entire weight of the body is sustained by the muscles of the labium.

Another interesting adaptation of *Anax* for his lengthy existence as an aquatic insect, is found in his method of respiration. Scientists, at the present day, are agreed in the conclusion that all insects were primarily terrestrial forms and that their adaptation to aquatic life has been a secondary development. # There are many different methods by which aquatic insects secure air, the water beetles, for example, carry air with them, under their wings and on the ventral surface of the body and are obliged occasionally to return to the surface for a fresh supply; the damselfly, may-fly and stone fly larvae have developed external gills, containing tracheal branches and absorb the air directly from the water. # *Anax* has no external gills, but if we should dissect a nymph, we would perceive, upon opening the rear portion of the abdomen, a perfect network of trachea, lining the posterior third of the intestine. Water is taken into the intestine through its posterior opening, the dissolved oxygen is taken up by the trachea, the carbon dioxide

passes into the water, and the water is violently ejected from the same opening. When this is done violently, it serves as a means of locomotion, for the body of the nymph is driven some distance forward. The nymph does this when startled or frightened, so that it may perhaps serve ^{also} as a means of defense.

This arrangement enables the Anax nymph to remain continuously below the surface of the water, and to obtain a sufficient supply of air even when inhabiting very foul and stagnant ponds. The Anax nymphs, however, may be characterized as "climbers", in contra distinction to the Gomphines, which are "browsers", living almost buried in mud and ooze, and the Libellula, which are "bottom sprawlers", resting in the weeds on the bottom of the pond; consequently the Anax nymph is ordinarily supplied with purer and better oxygenated water, than are the nymphs of the other groups just indicated. simplify

The dragon-fly nymph grows through a succession of molts — that is, at a certain point in the development of the nymph, the old skins split and the nymph emerges in a new, clean suit a size larger than his discarded garment. When the nymph of Anax juvenis emerges from the egg it is a tiny object barely two millimeters in length, giving scant

promise of developing into the vigorous and aggressive personality of the later stages of nymphal existence. It is not known how many molts are required for the Cuax nymph to develop to full size, but it undoubtedly molts many times before attaining maturity. The full grown nymph is some twenty times the ^{length} ~~size~~ of the helpless little specimen just hatched from the egg. The body is smooth and slender, not broad and flat as in the Gomphines, and is marked in a pattern of pale green and dark brown in longitudinal streaks, which seems to be a scheme of protective coloration well adapted for the concealment of the nymph among the stems of the aquatic plants which form its favorite lurking place. The depth of coloring varies with the environment, and the nymph is also of much paler hue directly after molting, when the skin is likewise more tender and the nymph far less able to protect itself. The large eyes, ~~not, however, compound~~, as in the adult, almost cover the sides of the head, the long labium covers the other mouth parts and extends backward as far as the base of the hind legs, while the legs themselves are long and slender and fitted with strong tarsal claws as one would naturally expect in a nymph of the climbing habit of Cuax.

The duration of the nymphal life of Cuax has

not been definitely determined, but it is probably about a year. During that time then, with the exception of the very coldest winter season, we may picture Cixius living contentedly in his pond, eating voraciously when the food supply is abundant, and fasting expectantly when it is scanty. As one molt follows another, the size of the nymph rapidly increases; after the third or fourth molt the wing-covers appear and they, too, rapidly increase with each successive molt. With each molt, too, the nymph becomes more powerful and more ferocious, not hesitating to attack creatures nearly as large as himself, and proving a dangerous enemy to the small trout which inhabit the stream.

The time comes at last when the span of this nymphal life is at an end, and the marvelous change is at hand which completely alters every circumstance of the dragonfly's life. From an inhabitant of the water, he becomes a denizen of the air; from a quiet creature, clinging to the stems of water plants, he becomes a winged spirit, ever moving restlessly through space; from a lover of damp and coolness, he becomes a veritable embodiment of light and sunshine. In one respect, however, he is unchanged, his voracity is unaltered, and as in the

LIFE HISTORY OF ANAX JUNIUS

For a study of the life history of a dragonfly no better species can be chosen than the common and widely distributed big green darner, Anax junius. This is one of our largest dragonflies, and is so splendid a flyer and so vigorous a competitor in the insect struggle for existence, that he well deserves his name (Anax, a "king" or a "lord".) In appearance Anax cannot boast the beauty of some of the smaller dragonflies, or of the dainty and brilliantly colored damselflies. His sturdy, robust figure, his suit of olive green with trimmings of blue and brown, are eminently sedate and businesslike.

At no time during the warmer months is Anax far to seek; he is our earliest dragonfly to appear in the spring, being on the wing often as early as March, and he is the last to disappear before the rigors of winter. A first glimpse of him may be had as he flies around the pond or lake which had been the scene of his nymphal life. Sweeping in great circles, high above the water, he occasionally darts from his line of flight to seize and devour some small insect; or he may be far from pond or stream on some country road, where the air of a summer afternoon seems literally filled with the flying forms. We should be giving ourselves fruitless trouble to attempt to capture a specimen while thus actively on the wing. In the early morning or in the evening he is more approachable; and sometimes, after a heavy rain storm, we may find him, clinging to the shelter of a tree, or even of a house, buffeted by the elements, drenched and bedraggled, and for the time being quite at our mercy.

Practically the entire adult life of the dragonfly is spent on the wing. His strongly braced and well balanced body, the great

expanse of wings and the powerfly muscles which operate them, make the body of the dragonfly one of the most perfect of flying machines, capable of swift, sustained and certain flight. The green body and the gauzy wings gleam and scintillate in the sunlight, while the rustling of the wings as he darts close to one's face, is a sound quite in harmony with a drowsy summer day. When the dragonfly does stop to rest he perches lightly on a bush or twig in an attitude of alertness. His legs are not adapted for walking, but are most useful for clinging or perching. They also assist the darter to capture his prey.

The warmer the day, the more untiringly active is the darter, as if, after his life of seclusion in the watery depths, he wished to enjoy to the full every moment of sunshine. On cloudy days he is much less in evidence and is likely to be discovered clinging to a twig or to the underside of a leaf. The nights are, doubtless, passed in a similar way. Anax is one of the few species which fly until it is quite dusk, and he may be observed industriously collecting the early mosquito, long after most other light-loving insects have vanished.

The existence of the dragonfly as an imago is brief indeed, in comparison with the duration of its nymphal life. The adult life is variously estimated from a week to a month, while the nymphal stage lasts a year or more. Adult life is mainly concerned with reproduction. Copulation takes place while the insects are on the wing. It is preceded by a wild nuptial flight, and is followed by the laying of the eggs. The female Anax possesses an ovipositor. This instrument is adapted for cutting holes in the stems of aquatic plants. During the height of the season the eggs are usually laid in the stems of growing plants. Early in the spring they are deposited in masses of

floating trash and in pieces of dead cat-tail leaves. Sometimes the male accompanies the female when she flies to the pond to deposit her eggs; sometimes she is unaccompanied. Sometimes she inserts merely the tip of her abdomen beneath the surface of the water and sometimes she backs ^{down} the stalk which she has chosen, until she is completely submerged.

The eggs are about $1/25$ of an inch in length. A close examination of the stems of aquatic plants at the margin of a pond where Anax is abundant will often discover a stem which shows a double row of punctures, as even and regular as the stitching of a sewing machine. Within are the tiny, yellowish eggs, tucked carefully into the plant tissues.

This represents the only care which the mother gives her young, but as a very large number of eggs is laid by each female, so that in spite of the numerous accidents to which the eggs and the young nymphs are liable a great many may be destroyed without reducing the numbers of the species.

The development of the egg and the hatching of the nymph require about three weeks. When the nymph of Anax emerges from the egg it is a tiny, spider-like object, scarcely a tenth of an inch in length, and gives scant promise of developing into the vigorous and aggressive personality of later nymphal life. It is unknown how many moults are required for the Anax nymph to develop its full size but it undoubtedly moults many times before reaching maturity. After the third or fourth moult the wing covers appear and increase in size with each successive moult. The nymph grows rapidly, and with the increase in size he becomes more and more powerful and ferocious; not hesitating to attack creatures nearly as large as himself, he proved a dangerous enemy indeed

to the other inhabitants of the water.

Pale, almost transparent when he first emerges from the egg, Anax rapidly acquires his true nymphal coloring. The body is pale green marked in a pattern of dark brown in longitudinal streaks. This is a scheme of protective coloration well adapted to conceal the nymph among the stems of the aquatic plants which form his chosen lurking place. The depth of coloring varies with the environment in which the nymph finds himself. Directly after a moult the coloring is much paler; at this time, too, the skin is soft and tender, and the nymph is very likely to fall a victim to some one of his relentless enemies. The body of the nymph is smooth and slender; his legs, as one naturally expects in a creature of the climbing habit of Anax, are long and fitted with strong tarsal claws; but his most prominent feature is the huge labium which extends back as far as the base of the hind legs and completely covers the other mouth parts. This labium by means of which our Anax nymph secures his food, quickly, quietly, and cleverly, is a wonderfully fine piece of mechanism. It is operated by powerful muscles which extend it with wonderful quickness, and when it is extended it is nearly a fourth as long as the entire body. At the tip it is divided into two lobes, armed with powerful hooks. When a victim is sighted the labium is instantly extended to its full length, the lobes shut down upon the body of the captive, and the labium is closed, thus bringing the prey into a position where it is easily torn up by the powerful jaws. If the insect thus captured be a large one, the grip of the labium is usually shifted as much as is necessary to enable the nymph to begin his meal at the tail end; slender, soft-bodied creatures, such as damselfly or mayfly larvae, are

stuffed in just as the nymph happens to seize them - head first, tail first, or even sometimes doubled in the middle. One may often see a damselfly nymph, the major portion of whose body has already been benevolently assimilated by an Anax, while his head and legs, protruding from the jaws of his captor, wave a sad farewell to the watery world of which he has so recently been an inhabitant.

"Dragonfly nymphs" says Kellicott, "as well as the adults, exhibit the malignant side of that life that lived and sported about the marshes of the remote Tertiary period". If this be true of dragonfly nymphs in general, it is thrice true of Anax junius. The appetite of an Anax nymph is well nigh insatiable, he is not dainty in his choice of food, he makes but the simple proviso that his prey be living and moving, and apparently any living thing that he is capable of handling will be devoured by him. If a number of dragonfly nymphs of various sizes and species be placed in water in a jar or bottle, the smaller ones will gradually disappear, until if there be two Anax of nearly the same size, they alone will survive. If no more food is provided the nymphs will now undergo a prolonged fast since neither is able to overpower the other. This state of affairs may endure for a long time, but when one or another undergoes a moult, we have repeated the story of "the priest who slew the slayer and shall himself be slain", for the nymph wearied by the exertion of the moult and poorly protected by his new and tender skin, is presently attacked and devoured by the one who for a long time had been his companion in misery.

The Anax nymph is an exceedingly clever hunter. His shy, stealthy ways are much like those of a cat. He clings to the stems of aquatic plants, preferably hanging head downward and conceals himself

as much as possible. If some hapless damselfly or mayfly nymph comes within his range of vision, Anax regards it with an air of calm unconcern with which a cat watches a mouse hole. He does not stir, but watches immovably until the prey comes within reach; then a swift stroke of the labium like the stroke of the cat's paw captures it. Even the alert water boatman cannot long escape this shy hunter.

The duration of the nymphal life of Anax is not positively known, but under normal conditions it is probably about a year. During that time then we may picture Anax living contentedly in his pond, eating voraciously, when the food supply is abundant, and fasting expectantly when it is scanty. When the winter and spring have passed and the water is warm under the growing influence of the sun, the time comes at last when the span of his nymphal life is ended and the marvelous change is at hand, which completely alters every circumstance of the dragonfly's life. From an inhabitant of the water he becomes a denizen of the air; from a quiescent creature, clinging for hours in quiet contemplation to the stem of a water plant, becomes an aerial sprite, winging his way untiringly through space; from a lover of water and coolness, he becomes a veritable embodiment of light and sunshine. In one respect only he remains unchanged; his voracity is unaltered, and as, in the water he was the scourge of all living things smaller than himself, so in the air he is no less the dread and terror of the flies and mosquitoes.

He is, indeed, scarcely less dominant in the air than in the water, it would be a swift and clever bird that could capture an Anax,

excepting at the very moment of his emerging from the nymphal skin. Many females are taken by frogs when they descend to the water to deposit their eggs, but with these exceptions Anax is free to pursue his murderous career for the entire period of his adult life.

The spectacle of the transformation of a dragonfly nymph is a very wonderful one, but in spite of the great abundance of dragonflies transforming daily during the summer, it is witnessed comparatively seldom. This is because most species are accustomed to transform at night or very early in the morning and for this somewhat disobliging habit there is a most excellent reason. Fleet and strong although the dragonfly is, just at the moment of his emergence from the nymphal skin, he is at the mercy of his enemies. His body, just released from the confining nymphal skin, has not yet become hardened and toughened; his wings, which have been closely folded in the wing cases of the nymph are tender and easily torn, and are, moreover, too damp and crumpled to sustain the body of the dragonfly in flight. Consequently it is well that the dragonfly chooses for his transformation that period of the day when he has least to dread from enemies. Those which are most likely to prey upon him at this time are birds and other dragonflies; these last exhibit not the slightest hesitancy in attacking and devouring such newly emerged specimens of their own kind as they can overcome.

For some days before the time of transformation the nymph takes no food, but remains quietly clinging to his support until some mysterious impulse causes him to leave the water and crawl up on a reed or the strong stem of some other plant. He grasps the reed firmly with his sharp tarsal claws, for a fall after the transformation

had begun would mean the death of the insect. When he has established himself firmly on the reed, he remains for some time motionless; after a time slight movements of the head and wings are noticed and then a split appears in the nymphal skin just behind the head of the dragonfly. The back of the emerging adult is first drawn through the opening, then the head, the legs and wings and lastly the long abdomen. Even when he is thus quite free from the old skin the insect is extremely soft and helpless, so he remains for a long time clinging to the cast skin, while his wings and body become drier and stiffer. After an hour or so the wings are quite dry and completely expanded and the dragonfly flies away. He is now a full-grown insect and has completed the interesting cycle of his life, but he still has the pale coloring which characterizes the newly emerged insect. It is not until somewhat later in his adult life that the coloring of his body becomes brighter and assumes its maturer tints.