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Symposium on "The Life Cycle in Insects."*

1. APTERYGOTA.

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In a discussion of the life cycles of insects it is logical to begin with Apterygota because their type of life cycle is the simplest, as it involves no metamorphosis.

Though Thysanura and Collembola undergo no changes that are sufficiently striking to constitute a metamorphosis, they nevertheless exhibit in their postembryonic development various minor changes of structure and coloration.

For example, *Lepisma saccharina* at hatching is whitish; is a slender creature, on account of its narrow thoracic segments; and does not have as yet the characteristic styli of the eighth and ninth abdominal segments. The antennæ have only 22 segments, though they later develop some 60 or 70 subsegments; and the lateral cerci have at first only 10 segments. Lepisma, as it emerges from the egg, has no scales. Even the first molt, which occurs seven days from the time of hatching, brings no change in these respects. (Heymons.)

In Collembola, at hatching, the head is large in proportion to the body—much as in a grasshopper. As the individual grows there are changes in the relative lengths of the segments of the body and of those of the appendages. Thus, in *Tomocerus vulgaris*, comparing small and large individuals:

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	SMALL	LARGE
Ratio, third to fourth antennal segment	1 : 1	2.9 : 1
Ratio, third to fourth abdominal segment	1 : 1	1.5 : 1
Number of intermediate teeth of mucro	1	8
Number of teeth of unguis	1	4 to 6

Intergradations in these respects occur in individuals intermediate between these two extremes. This variation, occurring during the growth of a single individual, is so extensive that one who studied only one of the youngest and one of the oldest specimens might easily mistake them for two distinct species. (Schäffer.)

In a few Collembola the number of antennal segments increases after birth. *Heteromurus*, for example, is born with four, but develops five by the division of the basal segment into two. *Orchesella* has at first four, and finally six, by the division of the two proximal segments. The fourth antennal segment may become subsegmented after birth, as in *Sminthurus* and *Heteromurus;* and numerous subsegments develop in the third and fourth segments in *Tomocerus.*

The postembryonic changes in coloration in Collembola are often striking. Collembola at hatching are usually white (sometimes yellow), except for the black ocular pigment, though most of them acquire pigments and color patterns later. *Anurida maritima* at first white, becomes dark blue. Species of *Sira* at birth lack their characteristic color patterns. *Calistella*, yellow at hatching, gradually develops its color pattern with each molt, and completes its pattern with the seventh molt. (Skorikow.)

Our knowledge in regard to seasonal histories in Apterygota is fragmentary. *Campodea fragilis* survives the winter and has been kept alive several months in captivity. *Machilis maritima* lives longer than one year, is sexually mature in spring, and does not molt in winter but molts at frequent intervals during the rest of the year. *Lepisma saccharina* is like *Machilis* in these respects. (Oudemans.)

Among Collembola, *Achorutes armatus* in Massachusetts has three generations during the year, and possibly four, which mature at intervals of about six weeks. *Achorutes packardi* in Massachusetts has two broods annually, the eggs being laid late in April and hatching in about one month. This species exhibits seasonal dimorphism; its variety *dentatus* laying eggs that produce *packardi.*

The following data were sent to me from Arnprior, Ontario, by Mr. Charles Macnamara, an exceptionally keen and thorough observer:

"Around here *Achorutes socialis* (the 'snow-flea') oviposits in spring, and the mature individuals have disappeared completely by June 1st. Well-grown individuals begin to appear again in September and October, but the very largest usually (not always) are to be found only in April and May. Apparently they grow all winter under the snow. As an exception though, I found some 2 mm. individuals (the maximum size) in late October, on a white birch.

"Eggs of *Achorutes socialis* hatch in 11 to 14 days, and in 9 to 10 weeks the young are .3 mm. to .5 mm. long, and fairly well pigmented. Another spring layer is *Onychiurus fimetarius;* eggs of which laid May 2, hatched May 22, period, 20 days.

"In my vials in the house, *Achorutes humi* and *Neanura muscorum* both oviposited in the early winter. Eggs of *A. humi* laid November 15, hatched December 7, period, 22 days. Those of *N. muscorum* laid December 4, hatched January 8, period 35 days. Under natural conditions outside, however, I doubt if the eggs of these two species would have hatched until spring.

"Specimens collected as well-grown adults survive in captivity for very various periods. *Sminthurus* and *Papirius* in my hands are always very short-lived—a few weeks at most. *Isotoma* may live for a couple of months, but the most resistant to captivity are *Achorutes socialis*, 5 to 6 months; *A. packardi*, 7 months; and *Xenylla maritima*, 12½ months. In estimating the length of life to these periods should be added the age when captured, and of course that is unknown to me.

"*Achorutes socialis* continues to grow long after it is sexually mature, and keeps casting its skin as long as it lives."

This is true of Collembola as a rule, which molt after growth has ceased. The total number of molts has not been ascertained in the case of any collembolan. *Tomocerus plumbeus* molts throughout the year at intervals of two to three weeks. (Sommer.) In *Tomocerus flavescens americanus* the intervals between successive molts increase with the age of the individual. Thus the youngest specimens molt every two days, and old individuals every six to eight days.

It remains to summarize the significance of these facts as follows: Apterygota at hatching are not structurally finished, or complete; but undergo further development in respect to various details of structure.

The postembryonic development of pigmentation in Collembola is (to judge from observations made on several genera) the direct result of exposure to sunlight, and may be prevented by keeping the insect in darkness, as in the case of *Anurida*. On the other hand, the embryo *Anurida* develops pigment prematurely if the egg is exposed to sunlight.

The colors and color patterns of Collembola are not known to have any adaptive significance. Many Collembola resemble their environment in color, to be sure, but there is no evidence that this resemblance is of any advantage to the organism.

The most conspicuous fact in regard to the seasonal history of Collembola is their tolerance of low temperatures. Many species are active in winter when most other insects are not. Some species grow and molt during winter, and lay eggs at low temperatures. Thus one species was seen to lay eggs at 0° C. The temperature-range of activity is lower than that of other insects. Thysanura, on the contrary, are far less tolerant of cold. Some of them hibernate but do not grow, molt, or lay eggs in winter. Thysanura are not known in the Arctic region; though the arctic and subarctic Collembola number some seventy species.

Apterygota molt at frequent intervals throughout life; are long-lived and have therefore many molts; the number being indefinite.

In Collembola, ecdysis is something more than a provision for growth; occurring as it does after growth has ceased; and being, in part at least, an excretory process. With each molt the inner half of the epithelium of the mid-intestine is cast off and discharged from the food canal, and with it are expelled pseudocrystals of sodium urate, which have previously accumulated in the epithelial cells. This process is correlated with the absence of Malpighian tubes in Collembola.

Apterygota best illustrate simplicity of the life cycle. They are relatively simple in structure, development and habits, in correlation with their environment, which is relatively simple and remains constant. The functions of growth and reproduction are not sharply separated as they are in Pterygota. Apterygota, being primitively wingless insects, show none of the specializations associated with the presence of wings; such as a firm integument, differentiation and consolidation of the thoracic segments, and the development of various thoracic sclerites in relation to muscles of locomotion. Neither are there found such extensive modifications of the abdomen in relation to reproduction, as occur in pterygote insects.

Thysanura and Collembola exhibit certain specializations of structure and function, but these are of minor importance—Apterygota being essentially the most generalized group of insects. They exemplify a life cycle without metamorphosis and are, so to speak, larviform, but with the power of reproduction.

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2. THE LIFE CYCLE OF THE ORTHOPTEROID ORDERS.

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The Orthopteroid insects (sens. lat.) include all such forms as have mouth-parts of the mandibulate type and undergo a gradual or "incomplete" metamorphosis.

As in other orders of insects, the extent to which the immature stages ("nymphs") diverge from the adult in form and structure is more or less proportional to the differences in environment and habits. Accordingly they may be divided into two groups, (1) those which are terrestrial throughout life, and (2) those in which the early stages are aquatic.

Group 1 includes the Blattoidea, Mantoidea, Isoptera, Zoraptera, Grylloblattoidea, Phasmoidea, Orthoptera, Dermaptera, Embiidina, Corrodentia and Mallophaga. Group 2 includes the Plecoptera, Ephemerida and Odonata.

In Group 1 the habitat and feeding habits are not materially altered during the life cycle, so that the same structural adaptations are present throughout life, and the metamorphosis is entirely gradual, except at the last moult, when the wings, if present, and the genitalia undergo more or less marked changes. There is, however, little or no histolysis of larval structures. The number of moults is comparatively small, so far as known, being usually four to six, but sometimes reduced to two or increased to seven or eight. A pronymphal stage is sometimes present. The nymphs resemble the adults except in size, details of proportion, chætotaxy, scuplturing and sometimes colour-pattern, and in the thinner cuticle. The number of antennal and occasionally tarsal joints sometimes increases with growth, and the ocelli, when present, may not appear until the last moult. The wings, when present, appear at an early stage,