Insect growth

Insect growth is discontinuous, at least for the sclerotized cuticular parts of the body, because the rigid cuticle limits expansion. Size increase is by molting – periodic formation of new cuticle of greater surface area and shedding of the old cuticle. Thus, for sclerite-bearing body segments and appendages, increases in body dimensions are confined to the postmolt period immediately after molting, before the cuticle stiffens and hardens. Hence, the sclerotized head capsule of a beetle or moth larva increases in dimensions in a saltatory manner (in major increments) during development, whereas the membranous nature of body cuticle allows the larval body to grow more or less continuously.

Studies concerning insect development involve two components of growth. The **first**, the molt increment, is the increment in size occurring between one instar and the next. Generally, increase in size is measured as the increase in a single dimension (length or width) of some sclerotized body part, rather than a weight increment, which may be misleading because of variability in food or water intake.

The **second** component of growth is the intermolt period or interval, better known as the stadium or instar duration, which is defined as the time between two successive molts, or more precisely between successive ecdyses.

The magnitude of both molt increments and intermolt periods may be affected by food supply, temperature, larval density, and physical damage (such as loss of appendages), and may differ between the sexes of a species.

In some pterygote taxa the total number of pre-adult growth stages or instars may vary within a species depending on environmental conditions, such as developmental temperature, diet, and larval density. In many other species, the total number of instars (although not necessarily final adult size) is genetically determined and constant regardless of environmental conditions.

Life-history patterns and phases

Growth is an important part of an individual's ontogeny, the developmental history of that organism from egg to adult. Equally significant are the changes, both subtle and dramatic, that take place in body form as insects molt and grow larger. Changes in form (morphology) during ontogeny affect both external structures and internal organs, but only the external changes are apparent at each molt. We recognize three broad patterns of developmental morphological change during ontogeny, based on the degree of external alteration that occurs in the postembryonic phases of development.

The primitive developmental pattern, ametaboly, is for the hatchling to emerge from the egg in a form essentially resembling a miniature adult, lacking only genitalia. This pattern is retained by the primitively wingless orders, the silverfish and bristle-tails, whose adults continue to molt after sexual maturity.

In contrast, all pterygote insects undergo a more or less marked change in form, a metamorphosis, between the immature phase of development and the winged or secondarily wingless (apterous) adult or imaginal phase.

The term exopterygote has been applied to this type of “external” wing growth. In the past, insect orders with hemimetabolous and exopterygote development were grouped into “Hemimetabola” (also called Exopterygota), but this group is recognized now as applying to a grade of organization rather than to a monophyletic phylogenetic unit. In contrast, pterygote orders displaying holometabolous development share the unique evolutionary innovation of a resting stage or pupal instar in which development of the major structural differences between immature (larval) and adult stages is concentrated.

The orders that share this unique, derived pattern of development represent a clade called the **Endopterygota** or Holometabola. In the early branching Holometabola, expression of all adult features is retarded until the pupal stage; however, in more derived taxa including **Drosophila**, uniquely adult structures including wings may be pre- sent internally in larvae as groups of undifferentiated cells called imaginal discs (or buds), although they are scarcely visible until the pupal instar. Such wing development is called endopterygote because the wings develop from primordia in invaginated pockets of the integument and are everted only at the larval–pupal molt.

Egg

With few exceptions, female Lepidoptera produce eggs that are deposited externally after fertilization in the oviduct. Moth and butterfly eggs vary enormously in size, shape, surface sculpture, and arrangement during oviposition. Within lineages such as families, larger species produce larger eggs, but depending upon the family, the sizes and numbers differ greatly. For example, females of hepialids, including some of the largest moths in the world, produce vast numbers of tiny eggs (20,000–30,000 or more by a single female) that are broadcast in the habitat. Conversely some small moths and butterflies produce few, relatively large eggs.

Embryonic development is related to temperature, proceeding more rapidly under warmer conditions, but the rate is physiologically and hormonally controlled in many instances. It requires 7–14 days in most Lepidoptera but may be delayed for many weeks or months in species that overwinter in the egg stage.

Micropyle

The shell (chorion) is soft during development and quickly hardens after oviposition, assuming a regular form consistent for the species and often characteristic for genera or families.

The chorion may be smooth or strengthened by raised longitudinal ribs or transverse ridges or both. At one end there is a tiny pore (micropyle), through which the sperm enters, surrounded by a rosette of radiating lines or ridges.

Two types of egg form are defined, those laid horizontally, with the micropyle at one end, which are usually more or less flat, and those that are upright, with the micropyle at the top.

Flat eggs are prevalent in the more ancestral lineages, microlepidoptera, while most derived groups, larger moths and butterflies, have upright eggs with more rigid and ornamented chorion.

Eggs of either type are laid singly or in groups; flat eggs are sometimes deposited shingle-like, with the micropylar ends protruding partway over the preceding row, while upright eggs are arranged side by side, like rows of miniature barrels.

Usually the eggs are glued to the substrate by a secretion of the female accessory (colleterial) glands, applied within the oviduct, sometimes forming a thick, paint-like covering to egg masses.

Eggs may be covered with debris collected by the female or hairs or scales from her abdomen or wings or may be surrounded by fences of upright scales, but lepidopteran eggs are not tended or guarded by the adults.

Typical insect eggs

Typical insect eggs contain nutrients to support embryogenesis and produce newly emerged first instars. Most eggs contain large amounts of lipid, for use as building material and energy, and yolk proteins, for the amino acids needed to build a larval insect body.

Types of insect eggs:

A- Singly laid eggs:

1- Sculptured eggs: chorion with reticulate markings and ridges for example Castor butterfly eggs.
2- Elongate eggs: eggs are cigar shaped ex. Sorghum shoot fly eggs.
3- Nit eggs: eggs of head louse is called Nit, it is cemented to the base of the hair. There is an egg stigma at the posterior end, which assists in attachment, while at the anterior end; there is an oval lid which is lifted at time of hatching.
4- Eggs with float: egg is boat shaped with a conspicuous float on either side, for example Anopheles mosquito eggs.

B- Eggs laid in groups:

1- **Pedicellate eggs**: this type of eggs laid in silken stalks of about 1.25 mm length in one groups on plants, for example Green lace wing fly eggs.
2- **Barrel shaped eggs**: these eggs are barrel shaped, they look like miniature batteries, and they are deposited in compactly arranged masses, e.g. stink bug eggs.
3- **Ootheca**: The word consist of (Oo= Egg and Theca= House). Eggs are deposited by cockroach in a brown bean like chitinous capsule. Each ootheca consists of a double layered wrapper protecting two rows. Oathecae are carried for several days protruding from the abdomen of female prior to oviposition in scheduled spot. Along the top, there is a crest which has small pores which permit gaseous exchange without undue water loss. Chitinous egg case is produced out of the secretions of collateral glands.
4- **Egg pod:**
Grasshoppers secrete a frothy material that encases an egg mass which is deposited in the ground. The egg mass lacks a definite covering. On the top of the eggs, the frothy substance hardens to form a plug, which prevents the drying of eggs.
5- **Egg case**: Mantids deposit their eggs on twigs in a foamy secretion

called spumaline which eventually hardens to produce an egg case or Ootheca. Inside the egg case, eggs aligned in rows inside the egg chambers.

6- **Egg mass**: Moths lay eggs in groups in a mass of its body hairs. Anal tuft of hairs found at the end of the abdomen is mainly used for this purpose, for example Rice stem borer eggs mass. Female silk worm moth under captivity lays eggs on egg card. Each egg mass is called a DFL (diseases free laying).

7- Egg raft: In *Culex* mosquitoes, the eggs are laid in compact mass consisting of 200-300 eggs called raft in water.

Insects from eggs without fertilization

The sex of hymenopteran insects normally is determined by the number of sets of chromosomes. Unfertilized, haploid eggs have only their mother's set and develop as males.

Fertilized, diploid eggs have chromosome sets from both their parents and develop as females. Mated females have control over when sperm is released from the spermatheca to fertilize eggs. Therefore, they can adjust their offsprings' sex ratio in response to a variety of cues. Hymenoptera are particularly susceptible to manipulation of sex determination by parasitic microbes. *Wolbachia,* for example, can alter sex determination so that haploid, and therefore unfertilized, eggs develop as females.

Organogenesis

When the germ band is fully segmented and gastrulation is complete, the remainder of embryogenesis involves the differentiation of the ectoderm and mesoderm into the organ systems of the larva or juvenile.

The ectoderm gives rise to the bulk of the larval or adult form. Most obviously the ectoderm forms the "skin" of the larvae, marked by numerous bristles and hairs. In **addition**, the nervous system develops from the ventral ectoderm, and the tracheal system develops from invaginations of the lateral ectoderm. Ocelli, salivary glands, a Prothoracic gland, corpora allata, molting glands, oenocytes, and silk glands also develop as ectodermal invaginations.

Finally, two additional invaginations of the ectoderm occur:

1. The stomadeum occurs in a central position near the anterior of the germ band, and once invaginated, these cells proliferate in a posterior direction to form the foregut.

2. The proctodeal invagination occurs in the terminal segment, and these cells grow anteriorly to form the hindgut.