INSECT MORPHOLOGY - EGGS & DEVELOPMENT

* **Size of Eggs** - Eggs can be a multitude of sizes. Generally, those of parasitic species such as some Hymenoptera are smaller than non-parasitic species. Some can be relatively large (up to 8mm in length in some grasshoppers) or they can be quite small (less than 0.1mm in some parasitic Hymenoptera).

* **Color of Eggs** - They can also be of a multitude of colors - dull or bright, simple or intricate, but they are usually fairly constant within each species.

* **Shape of Eggs** - They can also be quite variable in shape. Commonly, they are sausage-shaped such as in Orthoptera and Hymenoptera. Sometimes they are conical to rounded as in Lepidoptera and Hemiptera. Some Diptera and the family Nepidae (Hemiptera) have eggs with extensions of the chorion which form one or more horns. Many parasitic Hymenoptera have a projection at one end called a pedicel. Eggs of the genus *Encyrtus* (Hymenoptera) consist of two bladders (a proximal and a distal bladder) connected by a tube.

* **Number and Egg-laying** - The number of eggs laid by one insect is as varied as their shape and size. A single female may lay as few as 1 egg (in exceptional cases, like the true females of certain aphids), or at the other extreme 1 million or more. The honeybee queen lays 2,000 to 3,000 eggs a day. The termite queen may lay as many as 60 eggs a minute. In general the average number for all insects is probably greater than 100. The eggs may be all laid at one time (tussock moth); they may be laid a few a day for many days (some lice); or they may be laid in batches of eggs at intervals (house fly).

* **Coverings and cases** - Egg laying is usually accompanied by the exudation of sticky or cement-like substances for attaching the eggs to one another and to the plant, for protecting the eggs, for serving as floats in aquatic forms, and for many other purposes. Eggs may be deposited in a matrix of cement or in an egg capsule or **ootheca**, covered with a felt-like material composed of cement and hair and scales of the female's body; in floating rafts or in sacs; in gelatinous strings and masses; in thick silken webs; in woolly waxy secretions; and in many other ways.

* **Parts of the Insect Egg**
    1. The **chorion** or **eggshell** is a tough, nonchitinous, protective covering, secreted by the cells lining the ovarian follicles. The chorion is of two layers, a thick inner **endochorion** and an extremely thin outer **exochorion** which is composed of a chemical substance, **scleroprotein**, which is similar to the cuticulin of the insect epicuticle, and is also sometimes called **chorionin**. Usually some part of the chorion contains extensive airspaces with chorionic struts.
    2. The **micropyle** is one or more small openings through the chorion usually at one end of the egg, through which the sperm may enter the egg.
    3. Eggs of many insects are furnished with a lid or cap commonly referred to as the **operculum** by means of which the young escape.
    4. The **vitelline membrane** or **cell wall** of the egg is a delicate membrane completely lining the shell within, and enclosing the following parts:
        a. The **cytoplasm** or general living substance of the cell, the "cell sap".
        b. The **yolk** or **deutoplasm**, or lifeless food material, which is not usually assembled into one mass as in bird eggs, but rather is scattered throughout the egg.
        c. The **nucleus** is a highly organized dynamic part of the cell which among other things contains the **chromatin**. The chromatin at times forms minute bodies called the **chromosomes** which are composed of **genes**.

* At the time of oviposition the cytoplasm of the egg forms a bounding layer called the **periplasm**, and there is an irregular **cytoplasmic reticulum** within the yolk. The zygote nucleus occupies a posterior position. Around the outside of the ovum are the **vitelline membrane** and the **chorion**, or shell, with a layer of wax on the inside.

Parts of the Sperm

* The sperm of insects are quite similar to sperm of other animals. They are elongate, slender cells, with a whip-like, vibratile tail, by which they may swim actively to find an egg. When examined at high magnifications, 3 different parts may be distinguished:
    1. A slender, rod-like **head** which contains the nucleus and carries the chromosomes and is believed to be the part that bears the hereditary characters of the male parent to the egg.
    2. A **middle piece** which is thought to contain an "attraction sphere," of significance in the division and development of the egg after fertilization.
    3. The **tail**.

Development

* All that takes place between fertilization of the egg and the perfection of the full-grown insect is call **development and growth**. This can be divided into 2 phases: that part of the development that occurs before hatching from the egg is called **embryonic development**; that which takes place after hatching is called **postembryonic development**.

* After fertilization the zygote nucleus begins to divide. Nuclear division is not accompanied by cell division, but each daughter nucleus is accompanied by a halo of cytoplasm and each such unit of nucleus and cytoplasm is called an **energid**. The energids move apart and eventually they reach and enter the **periplasm**, and then the nuclei spread entirely around the periphery of the egg. Plasma membrane then forms between the nuclei to form a layer of cells surrounding the undivided mass of yolk. This layer of cells is called the **blastoderm**, and the mass of yolk in the central cavity is called the **blastocoele**. This stage is called the **blastula**. Cleavage of this type in which only the peripheral layer of cytoplasm divides is known as **superficial cleavage**. Not all of the energids migrate to the periplasm; some stay behind and form yolk cells in the center of the eggs called **vitellophages**. The vitellophages may be involved in the break down of the yolk, and they may play a role in forming the midgut.

* Along the ventral side of the egg some of the blastoderm cells become thicker to form the **germ band** or **ventral plate**; the remainder of the **blastoderm** remains extra-embryonic. This germ band is the future site where the embryo begins to develop. The early embryo has an enlarged head region, called the **protocephalon**, and a narrower tail region, called the **protocorm**. The primitive "creature" then takes the form of a double-walled sac. This stage is called the **gastrula** and the outer layer is the **ectoderm** and the inner layer is the **endoderm**. **Gastrulation** is the process by which the **mesoderm** and **endoderm** are invaginated within the **ectoderm**. These form the **mesoderm**, while those remaining in a superficial position are known as the **ectoderm**. Folds of the blastoderm now grow over the germ band from each side to form a double protective covering, the **embryonic membranes**. When these folds meet and fuse, the outer layer of the folds forms the **serosa** and the inner layer forms the **amnion**. Thus the developing insect becomes covered or separated from the vitelline membrane by two other cell layers.

* The next developments occur rapidly and in synchrony with each other. Transverse furrows of the germ band divide it into a series of segments. The whole outer wall of the embryo is ectoderm and by outgrowths of the ectoderm the appendages are formed. The nervous system is also formed from the ectoderm. Cells break off from the ectoderm called **neuroblasts** and form the nervous system. The tracheal system is also of ectodermal origin. Invaginations or ingrowths from the ectoderm form the fore- and hind-intestine, while internally the endoderm develops the tube known as the mid-intestine to connect the other two. From the mesoderm develop the muscles, the heart, and the coelomic cavity walls. From the ectoderm the body wall is formed, and all the appendages are evaginated; from invaginations of the ectoderm develop the central nervous system, the tracheal tubes, and the salivary glands.

General Comments:

* In general, reproduction in most insects is **oviparous**, that is they lay eggs which then hatch into the immature forms of the insect. In contrast, animals in which live young are born is called **viviparous**. In a few insects

the eggs are retained within the body of the female and actually hatch inside the female parent. She then lays active young. This is called **ovoviviparous** reproduction.

* In certain parasitic chalcid wasps many embryos may develop from a single egg and give rise to adults of just one sex. This is called **polyembryony**.

* In some insects reproduction is accomplished without the fertilization of the eggs (called **parthenogenesis**). Parthenogenesis in which only males are produced is called **arrhenotoky**; in which only females are produced is called **thelyotoky**; and in which individuals of either sex may be produced is called **amphitoky** (or **deuterotoky**).

* In other insects the immatures may become capable of reproduction usually due to a hormonal imbalance. This type of reproduction is called **paedogenesis** (or **neoteny**).

Postembryonic Development

* The young escape from the egg by eating through the shell, by pulsating the body to burst the shell, and by the use of special hatching spines, teeth or ridges situated on the head and called **egg-bursters**.

* Molts - usually more molts in primitive groups. Some Ephemeroptera may have 30-40 molts; Hemiptera usually have 5 molts; Nematocera have 4 molts.

* During larval development there is usually no marked change in body form, each successive instar being essentially similar to the one preceding it, but the degree of change from the last instar larva to the adult varies considerably and may be very marked. This change is called **metamorphosis**. There are 3 types of metamorphosis: **ametabolous (no metamorphosis), paurometabolous (gradual metamorphosis), and holometabolous (complete metamorphosis)**.

* **Ametabolous** - no metamorphosis, the adult form resulting from a progressive development of the immature form. This is characteristic of the Apterygota.

* **Paurometabolous** - the immatures hatch in a form that generally resembles the adult except for their small size and lack of wings and genitalia. Found in the following orders Orthoptera, Isoptera, Heteroptera, and Homoptera, and their relatives. **Hemimetabolous** is a subset of this type of metamorphosis in which the aquatic immatures do not look like the adults; found in Plecoptera, Ephemeroptera, and Odonata.

* **Holometabolous** - the immatures are quite different from the adult and a pupal instar is present between the last larval instar and the adult. Found in Neuroptera, Trichoptera, Lepidoptera, Coleoptera, Hymenoptera, Diptera, Siphonaptera, Thysanoptera, and some Homoptera.

* The main difference between paurometabolous and holometabolous larvae is from the development of the wings. In the paurometabolous immatures, the wings develop as external buds which become larger at each molt. In the holometabolous immatures, the wings develop in invaginations beneath the larval cuticle and so are not visible externally. The invaginations are finally everted so that the wings become visible externally when the larva molts to a pupa.

Types of Immature forms:

* Immature forms of ametabolous insects are called **young**; of paurometabolous insects are usually called **nymphs**; of hemimetabolous called **naiads**; and of holometabolous insects are called **larvae**.
* Larvae of holometabolous insects can have several different forms:
    1. **oligopod** - hexapodous form (6-legged) with a well-developed head capsule and mouthparts similar to the adult, but no compound eyes. There are 2 forms:

a. **campodeiform** - well sclerotized, dorso-ventrally flattened and is usually a long-legged predator with a prognathous head. Occurs in Neuroptera, Trichoptera, Strepsiptera, and some Coleoptera.
b. **scarabaeiform** - fat with a poorly sclerotized thorax and abdomen, and which is usually short-legged and inactive, burrowing in wood or soil. Occurs in some Coleoptera.

2. **polypod** - this in addition to the thoracic legs also has abdominal prolegs. It is generally poorly sclerotized and is a relatively inactive form living in close contact with its food. Occurs in some Lepidoptera, Mecoptera, and Hymenoptera. Sometimes called **eruciform**.
3. **apodous** - has no legs and is very poorly sclerotized. Several forms:
   a. **eucephalous** - with a well-sclerotized head capsule. Found in Nematocera, Buprestidae, Cerambycidae, and Aculeata.
   b. **hemicephalous** - with a reduced head capsule which can be retracted within the thorax. Found in Tipulidae and Brachycera.
   c. **acephalous** - without a head capsule. Found in Cyclorrhapha. Often called **vermiform**.

Pupae:

* **exarate** - pupae in which the appendages are free from the body.
* **obtect** - pupae in which the appendages are glued down to the body by a secretion produced by the larva-pupa molt.
* **decticous** - pupae in which articulated mandibles are present. Decticous pupae are always exarate. Found in Megaloptera, Neuroptera, Trichoptera, Lepidoptera.
* **adecticous** - pupae in which immobile mandibles are present. Some adecticous pupae are also exarate, but some are obtect.
* **coarctate** - pupa within the last larval skin. Diptera - often called a **puparium**.