Development, Growth, and Molting

Insect Eggs
- chorion (outer shell),
- micropyle (area where sperm penetrates)
- ovoviviparity – eggs retained until the point of hatching, e.g., some cockroaches and their egg cases, also aphids, thrips, etc.
- viviparity, e.g., female tsetse fly even have uterus and milk glands
- eggs commonly overwinter
- many have a plastron (trapped layer of air for underwater respiration)

Embryogenesis:
- embryonic development of insects is not especially remarkable-see paragraph on page 145
- optional text box 6.1 (pages 148-150)
- zygote divides mitotically to yield many nuclei which migrate to the outside of the yolk
  * lots of nuclei but few cell membranes, syncytium is formed
  * cell boundaries are not established deep within the yolk → thus "superficial cleavage"
    (only in myriopods and Collembola do we see holoblastic division, through yolk)
- early on in embryo development see short abdominal appendages that are later reabsorbed

Development Following Eclosion: three principal types of metamorphosis

A. Ametabolous: "without change"
   - almost no changes in form
   - molts result in growth and ultimately sexual maturation
   - molting is indeterminate, even molt after sexual maturity
   - Thysanura and Archaeognatha

B. Hemimetabolous = incomplete metamorphosis
   - three stages: egg, nymph, and adult
   - nymph and adult rather similar in morphology
   - biology & ecology are very similar
   - external wing development
   - new term: naiad: aquatic nymphs
     * separate term because often radically different in morphology from adults
     * Odonata, Ephemeroptera and Plecoptera

C. Holometabolous = complete metamorphosis
   - four stages: egg, larva, pupa, and adult
   - larva wholly unlike adult
     * thus radically different habitats may be occupied
       e.g., caterpillar to adult
       e.g. mosquito: aquatic filter-feeder to nectar or blood feeder
     * planets four "megaorders": Coleoptera, Diptera, Hymenoptera & Lepidoptera
       [= 87% of insect diversity is holometabolous]
   - pupa: vehicle for nearly complete tissue turnover
     * paradoxically: physically looks inactive but physiologically….
* little is kept intact: heart, tracheae, & nervous systems
* larval features histolyzed
* many adult structures exist as anlagen (embryonic buds)—see Figure 6.4 from text

Wing Development
most Hemimetabola have external wing development (= Exopterygotes)
most Holometabola have internal wing development (= Endopterygotes)
exceptions, a few Exopterygota that have complete metamorphosis
  * male coccids
  * Thysanoptera
  * Aleyrodidae

Hypermetamorphosis
two or more larval forms (in post-embryonic development)
two forms in the development of a single insect...always indicates two different ways of life

Outline of Molting Sequence:
1) Apolysis:
   - separation of old cuticle from epidermis
   - secretion of molting fluid (inactivated chitinolytic and proteolytic enzymes)

2) Epicuticle formation
   - chemically inert layer (resistant to enzymes)
   - laid down in folds

3) Procuticle deposition and digestion of old cuticle
   - secretion of procuticle
   - activation of molting fluid (new epicuticle protects new underlying procuticle)
   - old endocuticle digested and reabsorbed

4) Ecdysis:
   - separation of old cuticle from newly formed cuticle
   - exuviae = remains: old epicuticle and exocuticle
   - cuticle breaks along ecdysial lines: pre-ordained areas of thin exocuticle

5) Expansion
   - unfolding and stretching of new epicuticle & procuticle by
   - intake of water and air

6) Hardening and darkening
   - quinone release and tanning of exocuticle

7) Additional deposition
   - endocuticle deposition and differentiation to exocuticle
   - waxes added to epicuticle
Hormonal Control of Insect Molting: Brain controls molting sequence via neuropeptides and the neurohemal organs, especially cells in the brain that secrete prothoracicotropic hormone (PTTH) and the corpora allata (CA) and corpora cardiacum (CC). The latter two structures, located behind the brain, store and release a number of important insect hormones.

1) Prothoracicotropic hormone (PTTH), a short polypeptide, is released from brain.
2) PTTH collects in corpora allata (CA)
3) PTTH is released into blood and picked up by the prothoracic glands.
4) Prothoracic glands then secrete alpha-ecdysone (derived from dietary steroid precursors).
5) Conversion of alpha ecdysone to beta ecdysone in target tissues triggers molting.

Ecdysone levels in the hemolymph rises before each molt. In the Hemimetabola there is a sharp rise in ecdysone titer prior to the imaginal molt; in the Holometabola there are two sharp rises in ecdysone concentrations: one prior to pupation and the other preceding the imaginal molt.

Every year new hormones are being discovered that regulate and affect molting processes; many differ among from taxon to taxon. A few of principal insect molting hormones:

*Ecdysis triggering hormone* (ETH)
neuropeptide
from epitrachael glands
stimulates pre-eclosion behavior

*Crustacean cardioactive peptide* (CCAP)
triggers abdominal contraction, accelerates heartbeat, etc.

Prothoracicotropic hormone (PTTH)
neuropeptide released by cells in protocerebrum
master molting hormone: stimulates release of ecdysone from prothoracic gland

**Ecdysone** titer controls steps 1-3 in molting sequence above

**Juvenile Hormone** (JH)
terpene found in CA
modulates effects of ecdysone, i.e., it prevents molt or it results in the maintenance of
nymphal/larval stages
in Holometabola JH titers drop off prior to molt, and especially, the pupal and imaginal
mols

**Eclosion hormone** (EH)
neuropeptide secreted by cells in brain
stored in CA
triggers eclosion (ecdysis)(step 4)
facilitates coordinated movements associated with eclosion

**Bursicon**
polypeptide secreted by brain
titer controls steps 5-7 in molting sequence above
involved in expansion, e.g., of wings
also facilitates tanning
post-molt deposition of endocuticle

**Stimuli that trigger molting:**
1. photoperiod
2. physical stretching of body (e.g., abdomen) (size, blood meal, etc.)

**Insect Hormone Analogs:**
Much plant defense and insect control based on disruption of the hormonal balance of insect
molting:
A. Phytoecdysones:
   - cause insects to molt prematurely
   - many ferns, mulberry trees, etc.
B. Juvenile Hormone analogs
   - juvabione in balsam fir
   - balsam fir used to make paper toweling
   - JH analog is presently used in houses to control fleas (in homes)