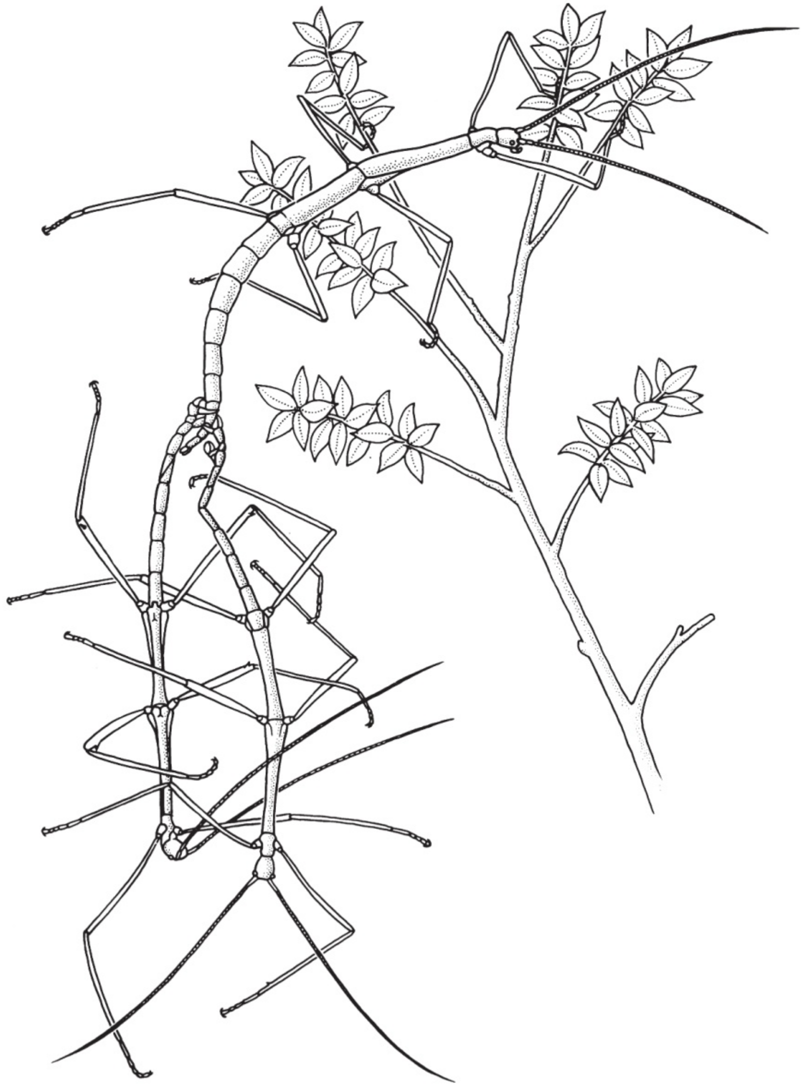
Reproduction and development

Yong-Chao Su
KMU



Two male stick-insects fighting over a female. (After Sivinski 1978.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects

WILEY Blackwell

Reproductive organs of insects

- Similar to vertebrates: male->sperm; female ->eggs.
- Most insect species reproduce sexually
- There are also many species (eusocial bees) that reproduce by **parthenogenesis**, asexual reproduction in which there is growth and development of an unfertilized egg.

Prior mating
(before mating)

Sexual dimorphism and Sexual selection

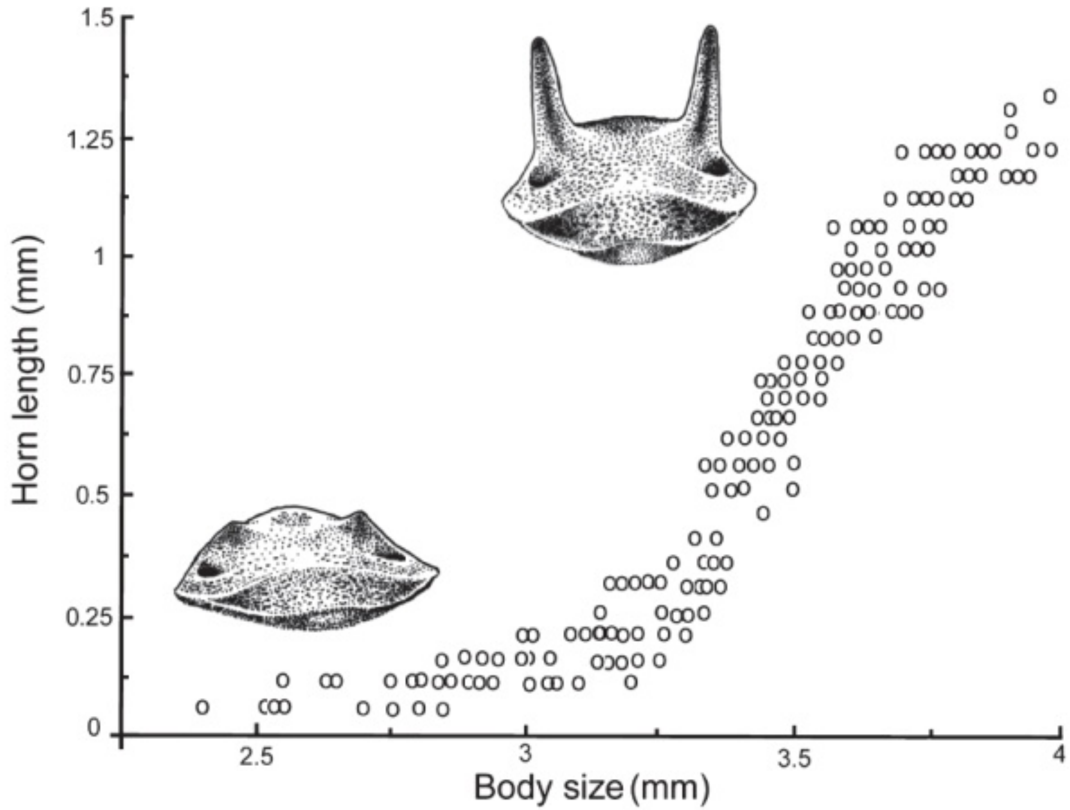


Fig. 5.2 Relationship between length of horn and body size (thorax width) of male scarabs of *Onthophagus taurus*. (After Moczek & Emlen 2000; with beetle heads drawn by S.L. Thrasher.)

Male-male competition and Sexual selection

Fig. 5.3 Two males of *Phytalmia mouldsi* (Diptera: Tephritidae) fighting over access to the oviposition site at the larval substrate visited by females. These tropical rainforest flies thus have a resource-defence mating system. (After Dodson 1989, 1997.)

Nuptial gift giving behavior of Mecoptera (長翅目)

Box 5.1 Courtship and mating in Mecoptera

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects

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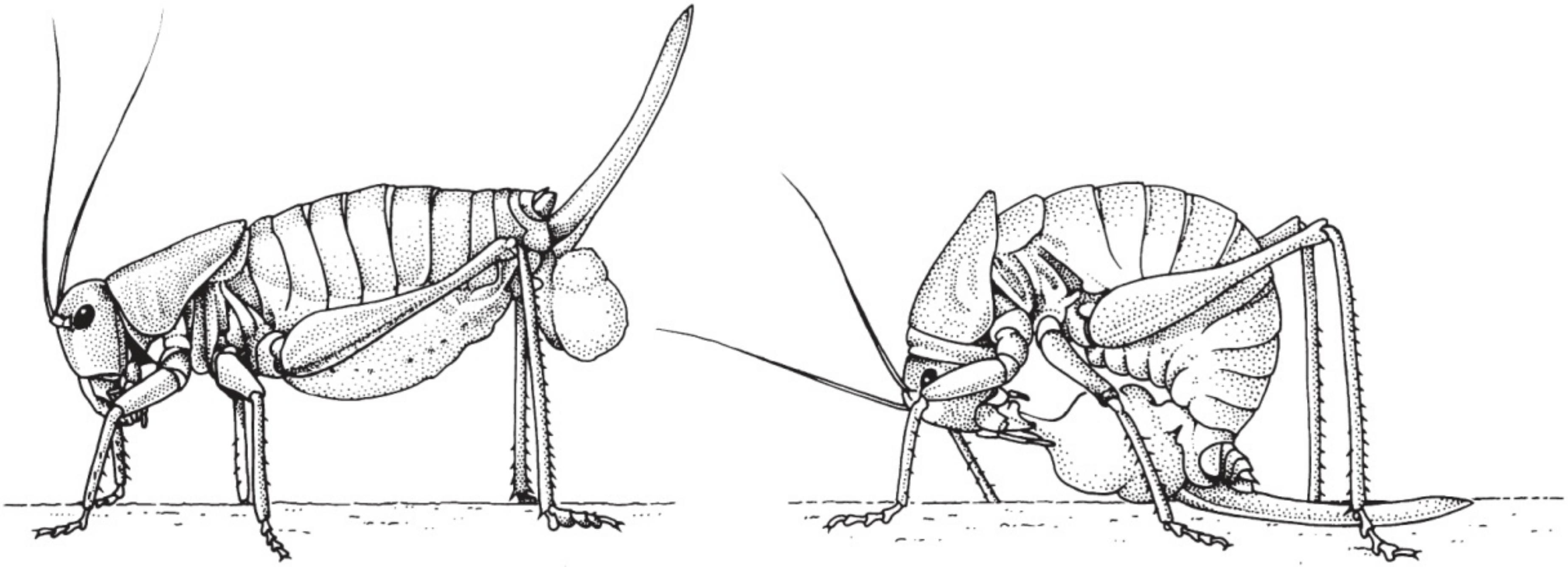
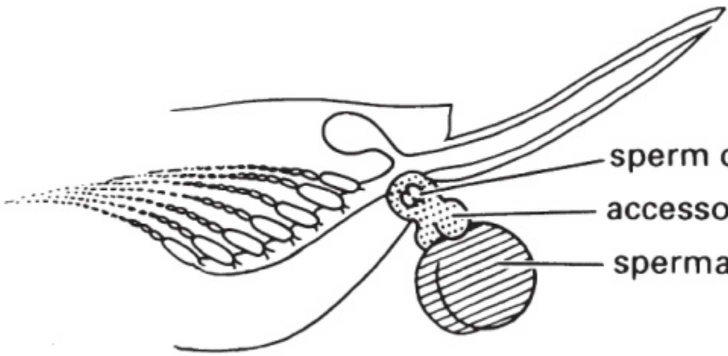
Nuptial gift giving behavior of *Anabrus*





Box 5.2 Mating in katydids and crickets

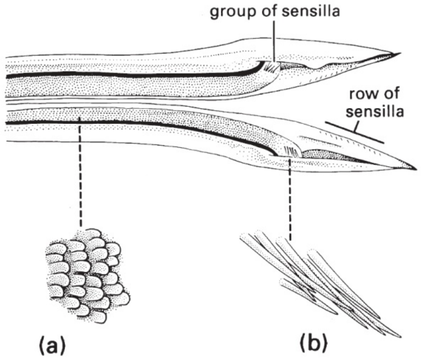
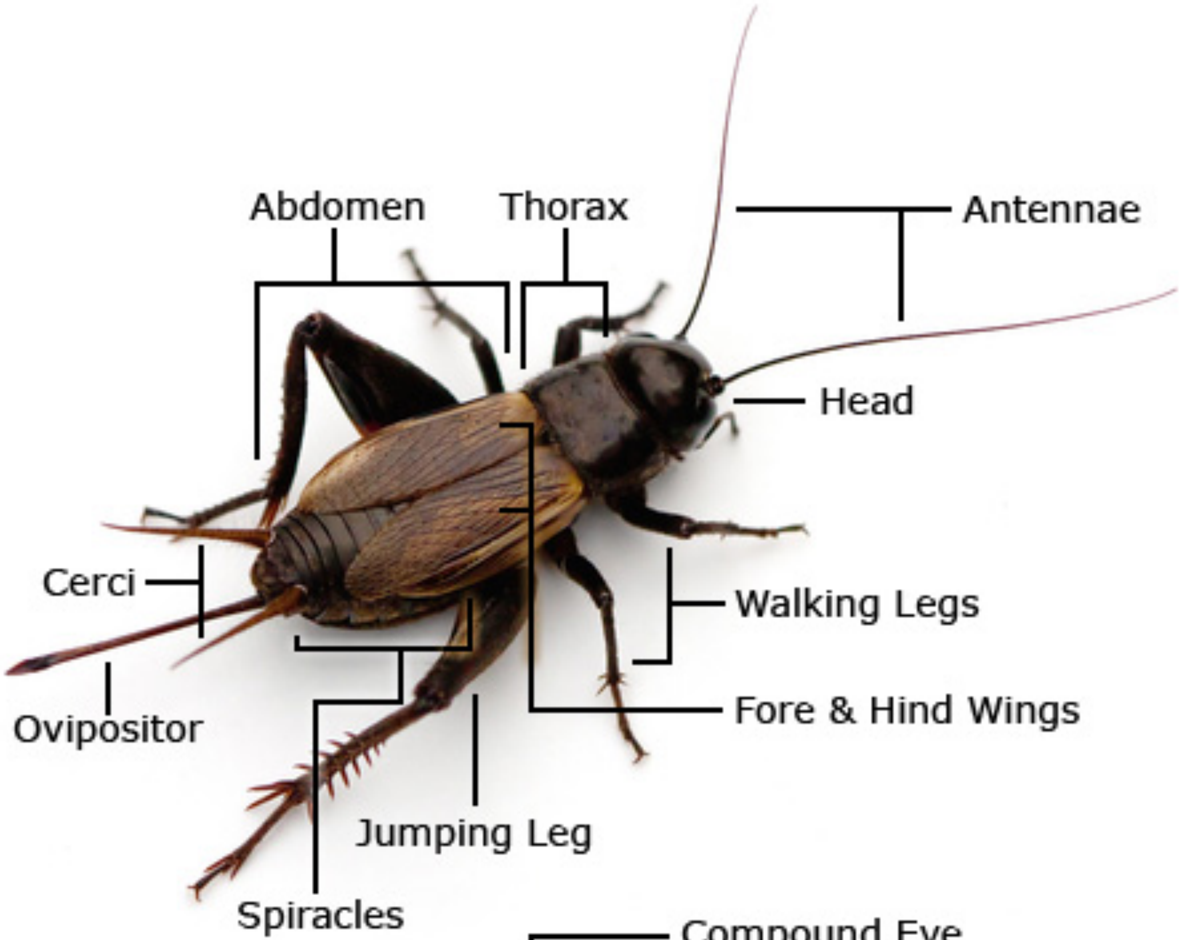
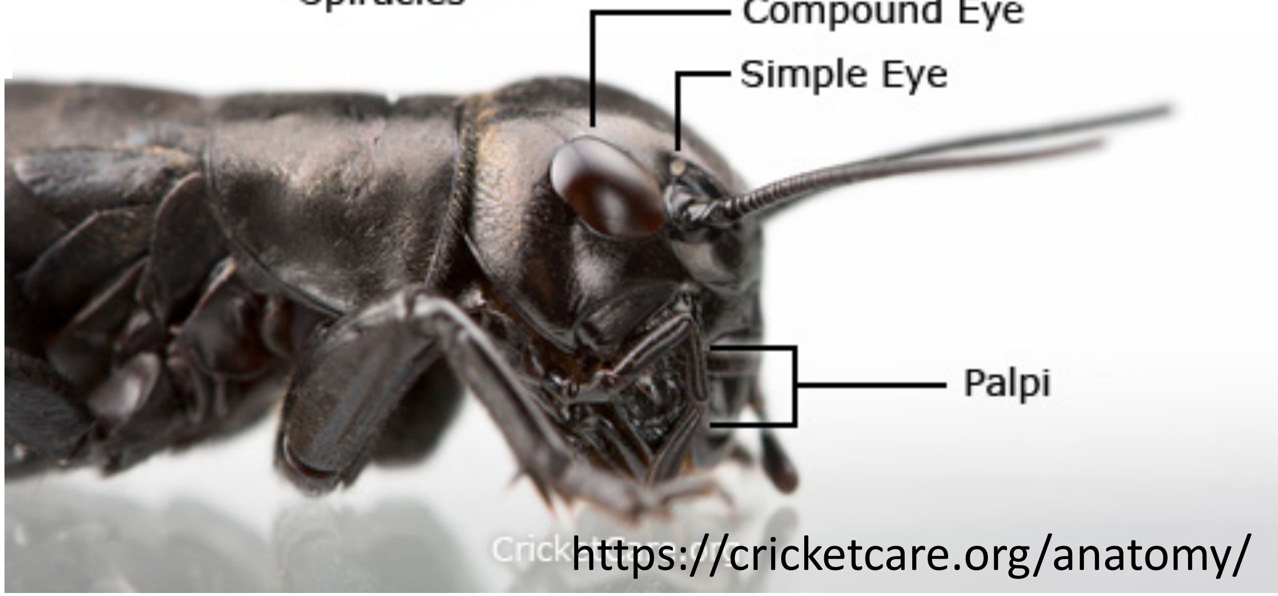


Fig. 5.12 Tip of the ovipositor of a female of the black field cricket, *Teleogryllus commodus* (Orthoptera: Gryllidae), split open to reveal the inside surface of the two halves of the ovipositor. Enlargements show: (a) posteriorly directed ovipositor scales; (b) distal group of sensilla. (After Austin & Browning 1981.)





Sexual selection --- swarming

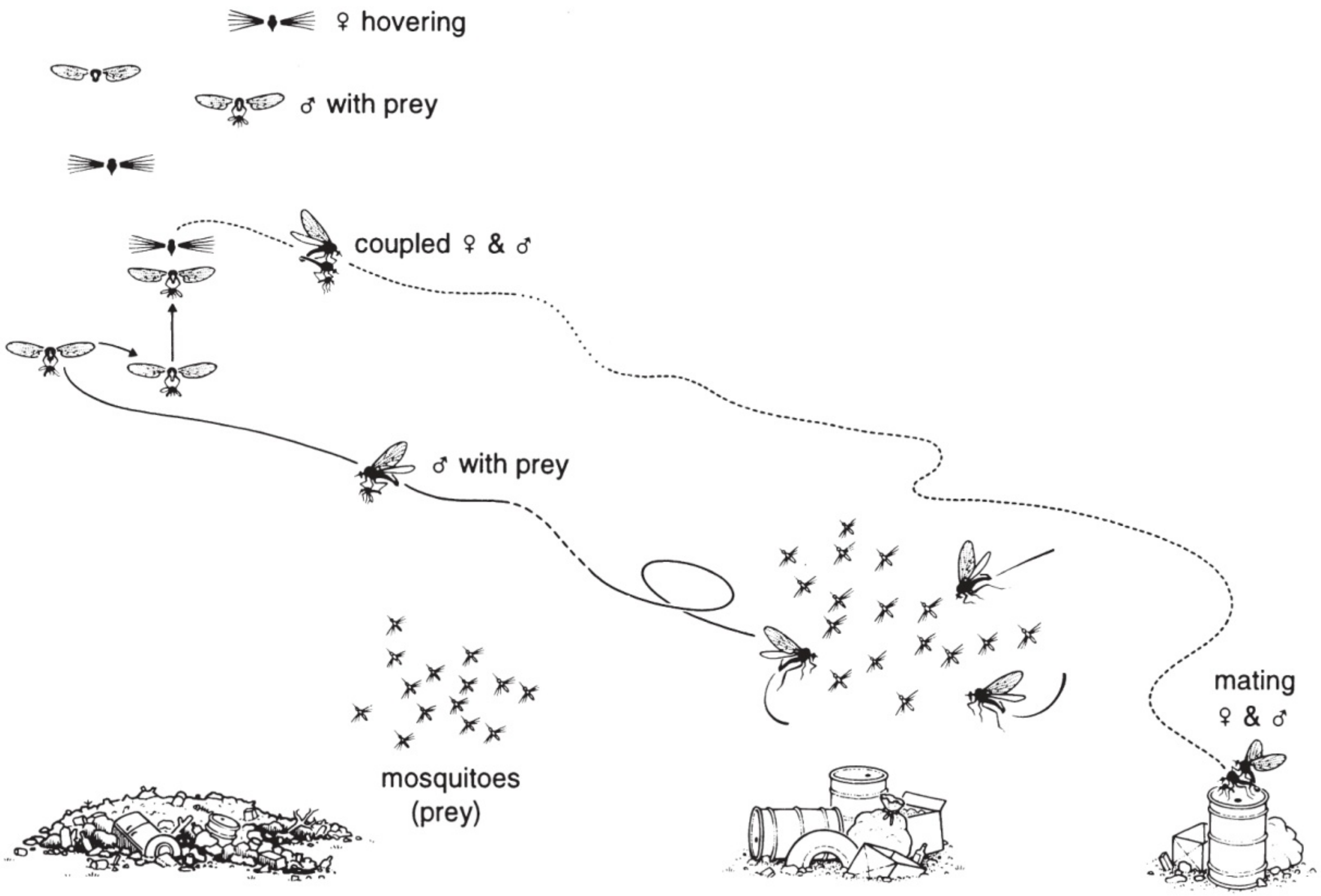
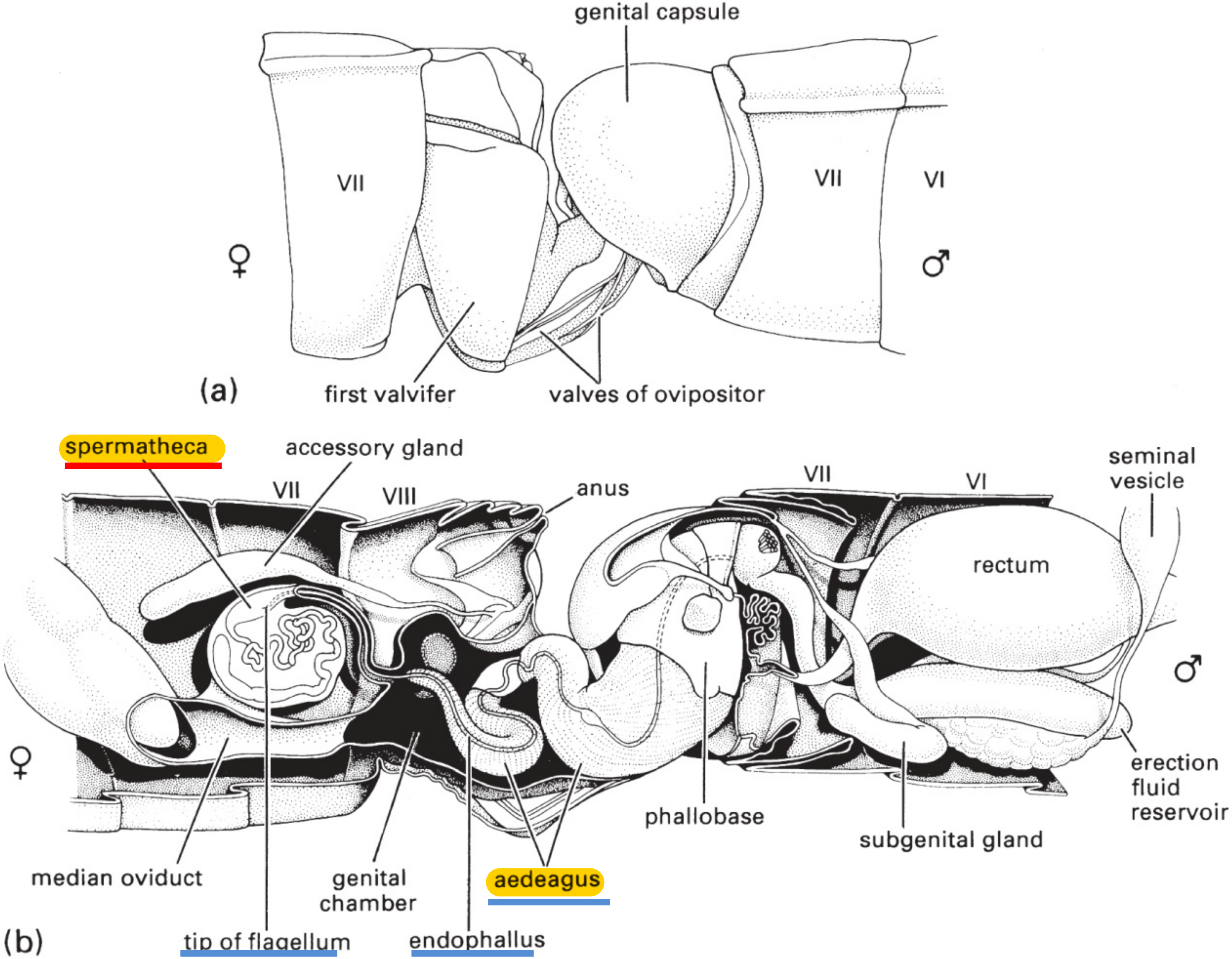


Fig. 5.1 Males of the Arctic fly, *Rhamphomyia nigrita* (Diptera: Empididae), hunt for prey in swarms of *Aedes* mosquitoes (lower mid-right of drawing) and carry the prey to a specific visual marker of the swarm site (left-hand side of drawing). Swarms of both the empidids and the mosquitoes form near conspicuous landmarks, including refuse heaps or oil drums, which are common in parts of the tundra. Within the mating swarm (upper left), a male empidid rises towards a female hovering above, they pair, and the prey is transferred to the female; the mating pair alights (lower far right) and the female feeds as they copulate. Females appear to obtain food only via males and, as individual prey items are small, must mate repeatedly in order to obtain sufficient nutrients to develop a batch of eggs. (After Downes 1970).

Mating
(during mating)

Copulation



Female

Male

Do all insects copulate?

- NO.
- Wingless orders Archeognatha and Thysanura used indirect sperm transfer
- The thing they use is spermatophores to transfer sperm
- Females gather spermatophores, lay eggs

Species specific male genitalia
(so is good character for diagnose species)

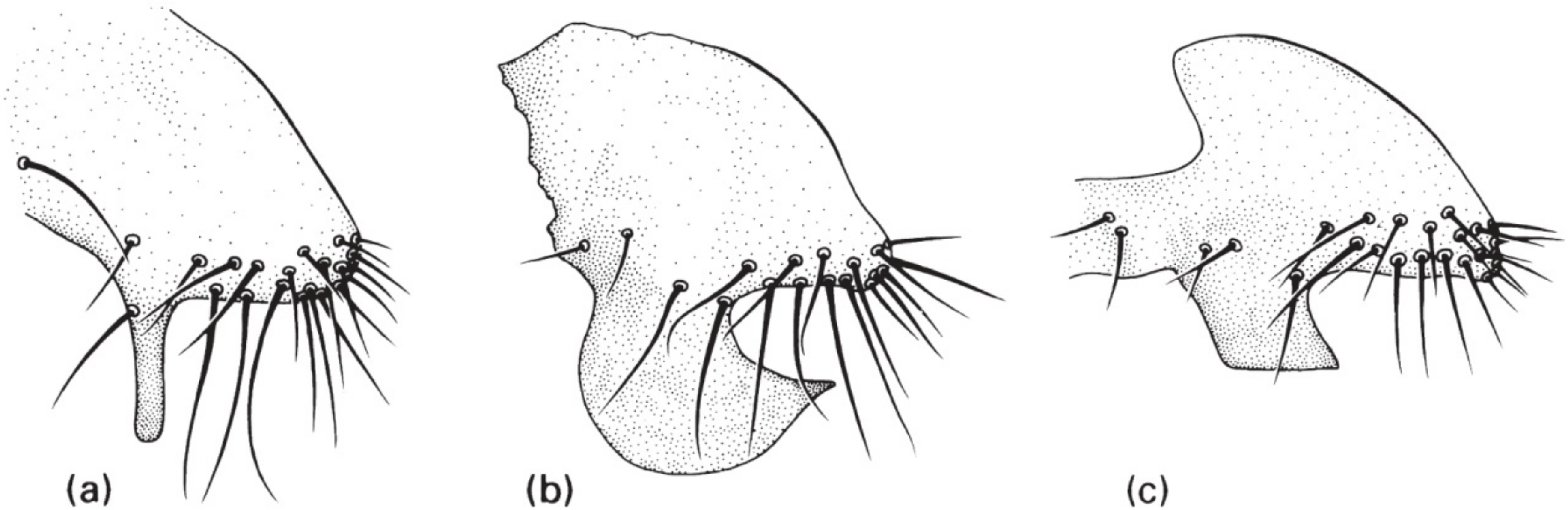


Fig. 5.5 Species-specificity in part of the male genitalia of three sibling species of *Drosophila* (Diptera: Drosophilidae). The epandrial processes of tergite 9 in: (a) D. *mauritiana*; (b) D. *simulans*; (c) D. *melanogaster*. (After Coyne 1983.)

Species specific female genitalia
(so is good character for diagnose species)

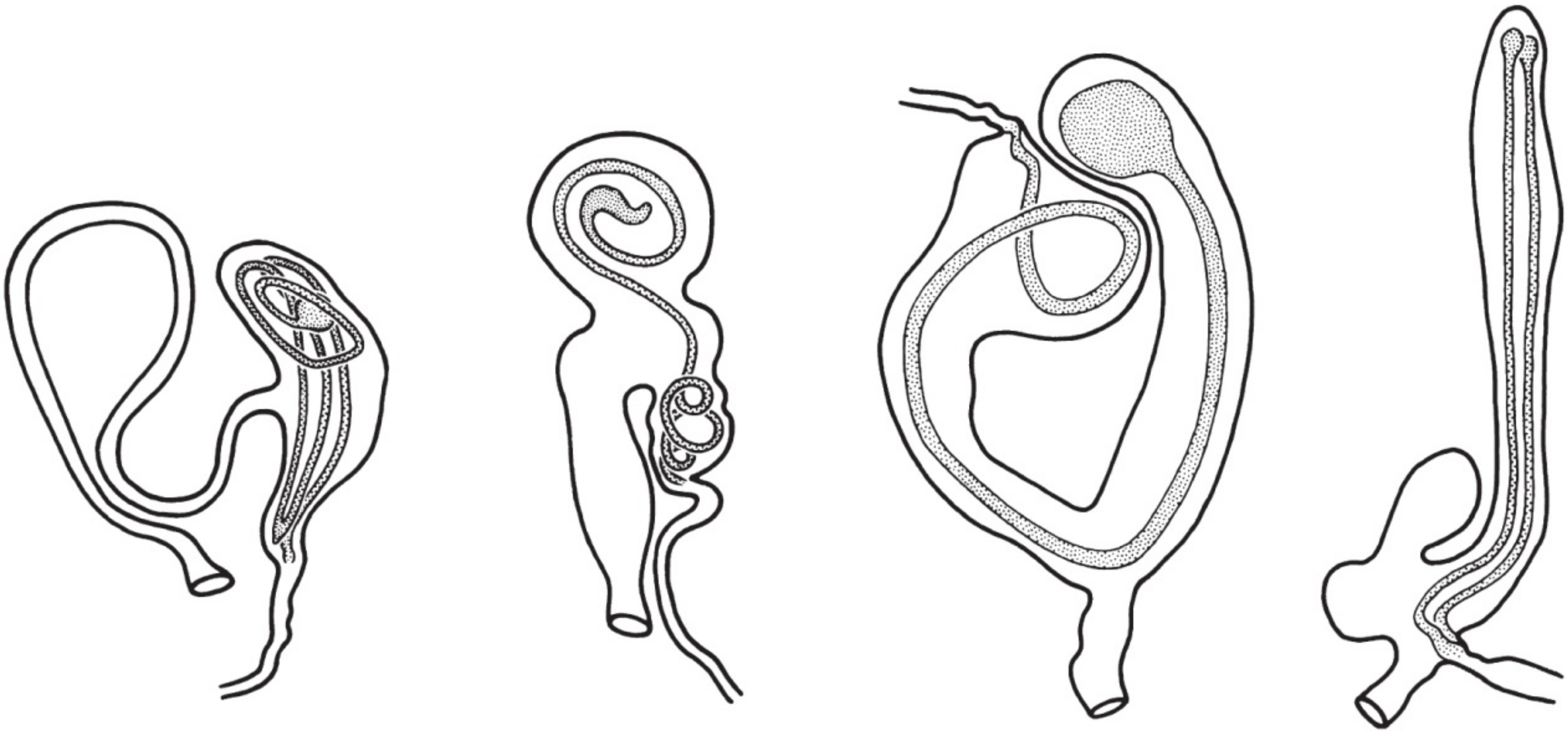


Fig. 5.6 Spermatophores lying within the bursae of the female reproductive tracts of moth species from four different genera (Lepidoptera: Noctuidae). The sperm leave via the narrow end of each spermatophore, which has been deposited so that its opening lies opposite the "seminal duct" leading to the spermatheca (not drawn). The bursa on the far right contains two spermatophores, indicating that the female has re-mated. (AfterWilliams 1941; Eberhard 1985.)

Other characters to avoid matting with wrong species (so are good character for diagnose species)

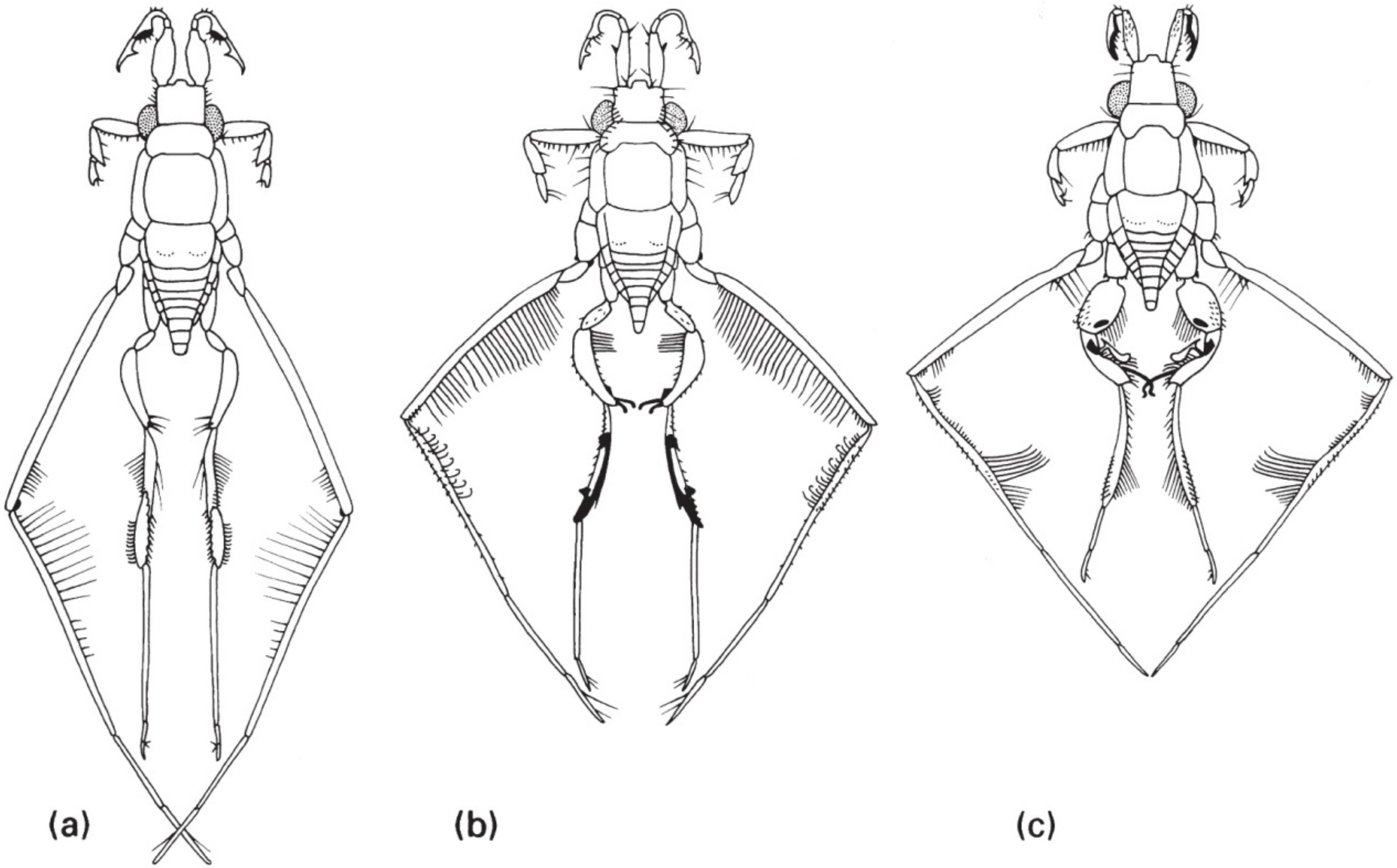
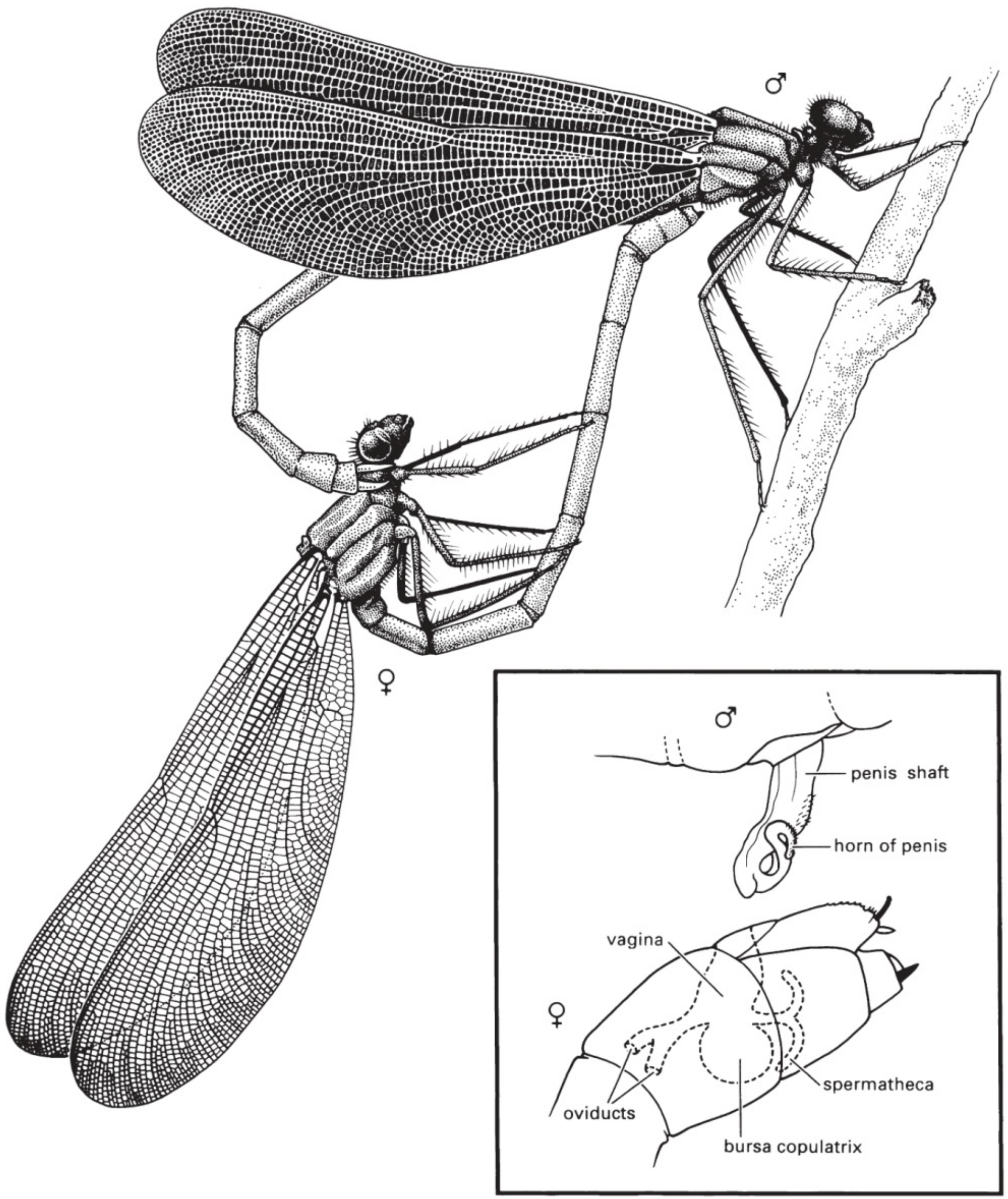


Fig. 5.7 Males of three species of the water-strider genus *Rheumatobates*, showing species-specific antennal and leg modifications (mostly flexible setae). These non-genitalic male structures are specialized for contact with the female during mating, when the male rides on her back. Females of all species have a similar body form. (a) *R. trulliger*; (b) *R. rileyi*; (c) *R. bergrothi*. (After Hungerford 1954.)

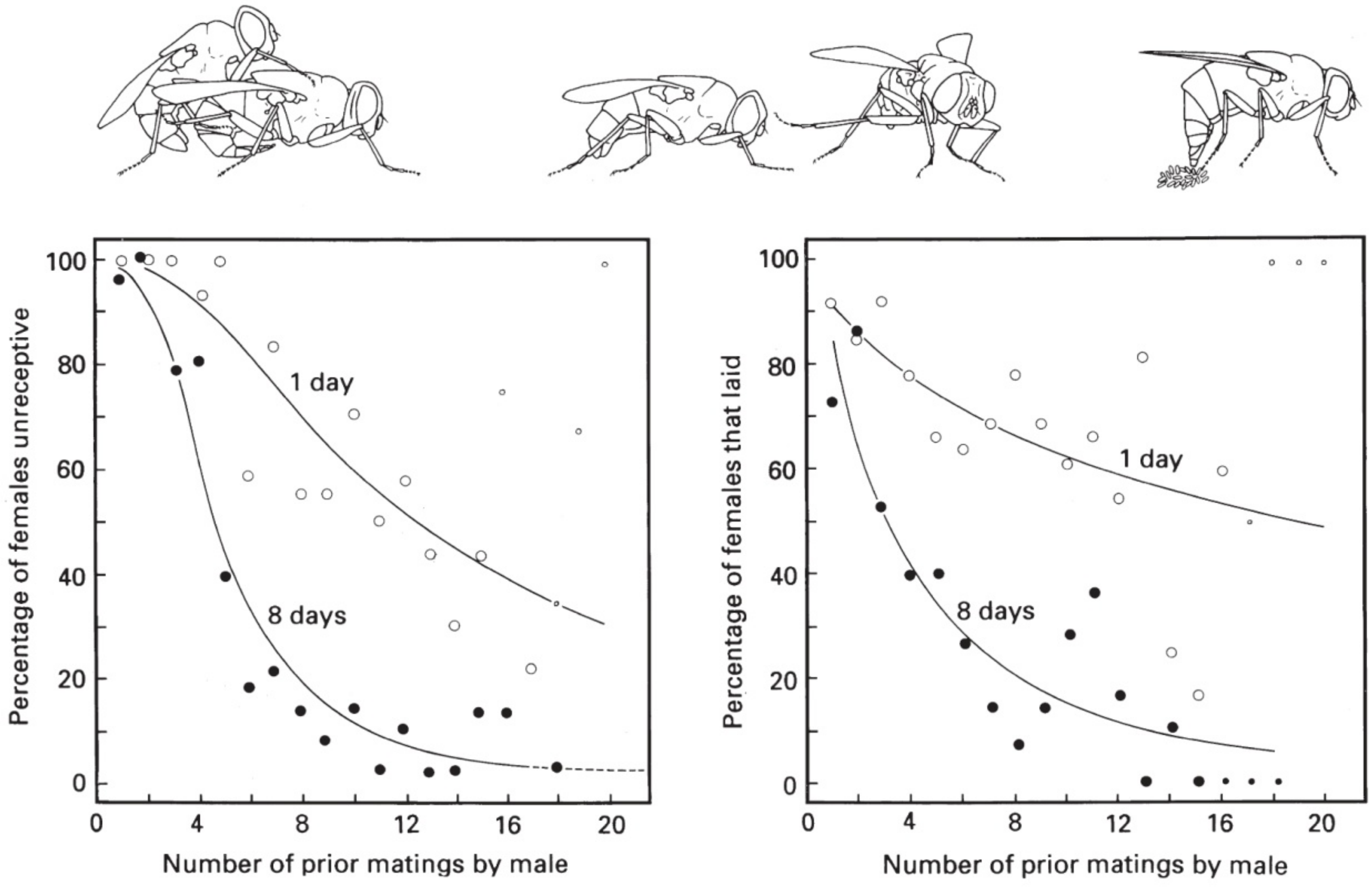
Post-mating
(after mating)

Post mating competition – sperm removal



Box 5.5 Sperm precedence

Post mating competition – sperm competition



Box 5.6 Control of mating and oviposition in a blow fly

Post mating competition – female guarding

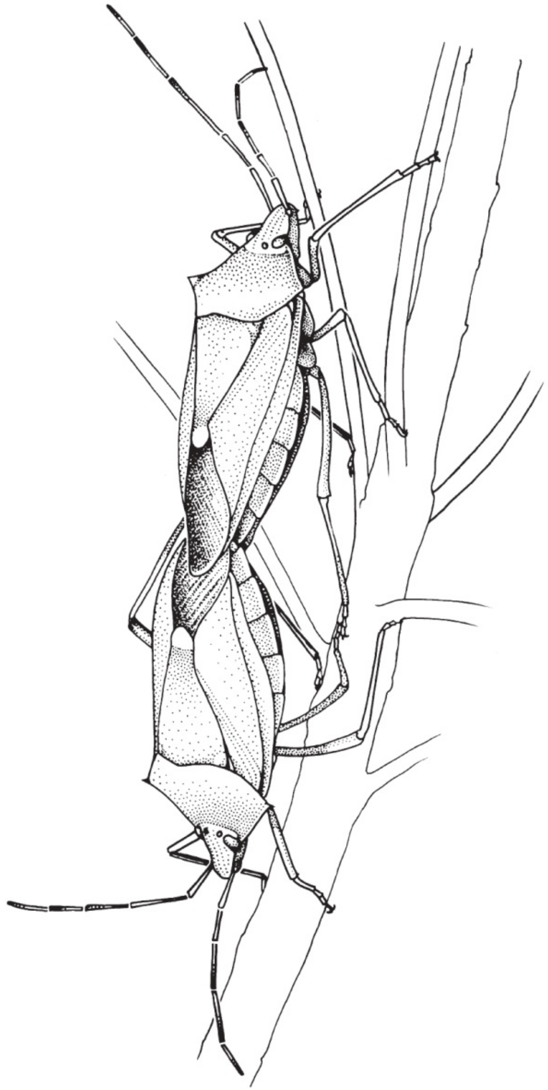


Fig. 5.8 A copulating pair of stink or shield bugs of the genus *Poecilometis* (Hemiptera: Pentatomidae). Many heteropteran bugs engage in prolonged copulation, which prevents other males from inseminating the female until either she becomes non-receptive to further males or she lays the eggs fertilized by the "guarding" male.

Post Oviposition

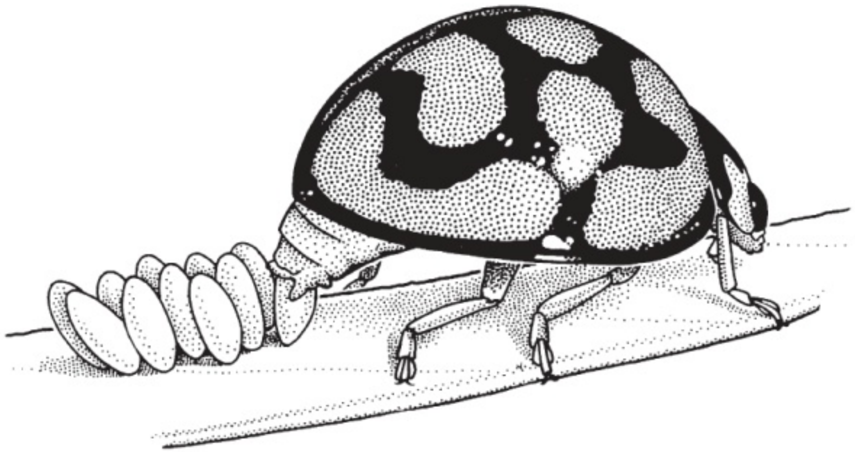


Fig. 5.9 Oviposition by a South African ladybird beetle, *Cheilomenes lunata* (Coleoptera: Coccinellidae). The eggs adhere to the leaf surface because of a sticky secretion applied to each egg. (After Blaney 1976.)

Post Oviposition-- egg investment

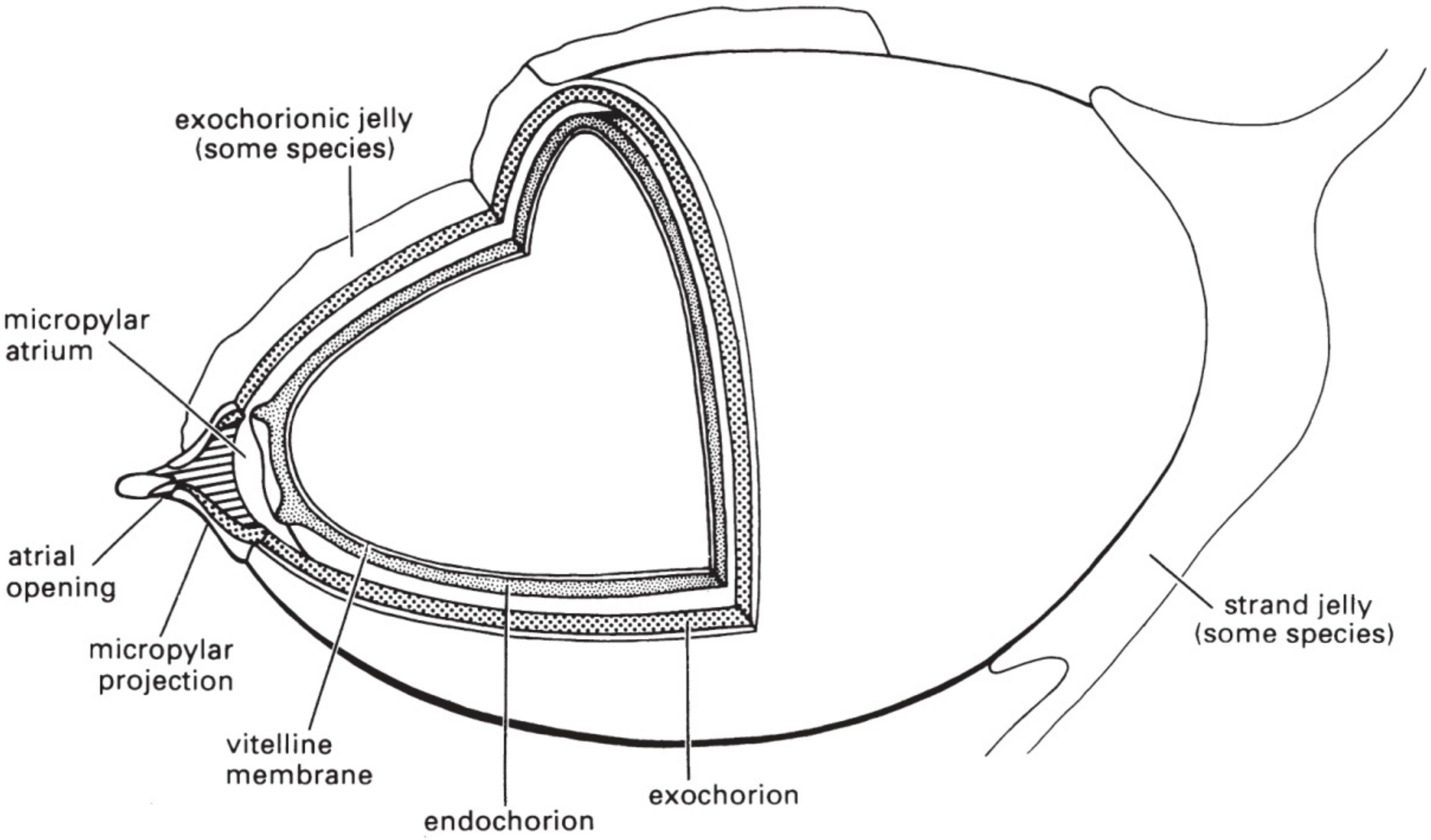
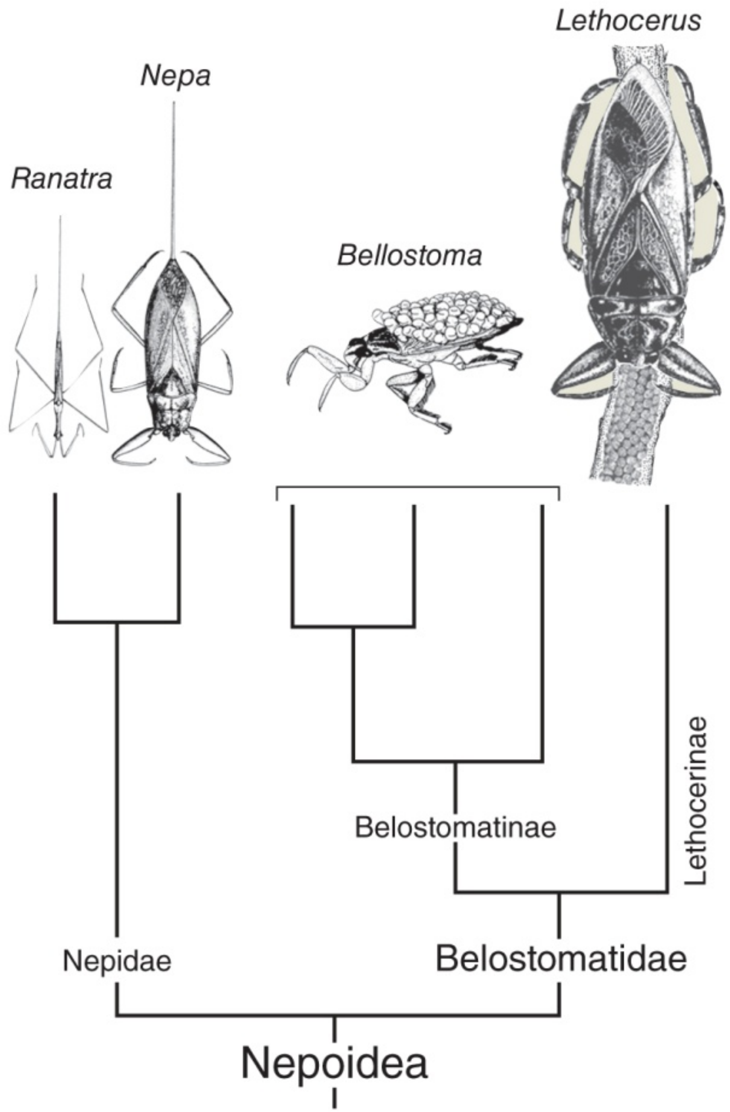


Fig. 5.10 The generalized structure of a libelluloid dragonfly egg (Odonata: Corduliidae, Libellulidae). Libelluloid dragonflies oviposit into freshwater but always exophytically (i.e. outside of plant tissues). The endochorionic and exochorionic layers of the eggshell are separated by a distinct gap in some species. A gelatinous matrix may be present on the exochorion or as connecting strands between eggs. (After Trueman 1991.)

Post Oviposition– Paternal care



Box 5.8 Egg-tending fathers – the giant water bugs

Post Oviposition– Maternal care (parasitoid)

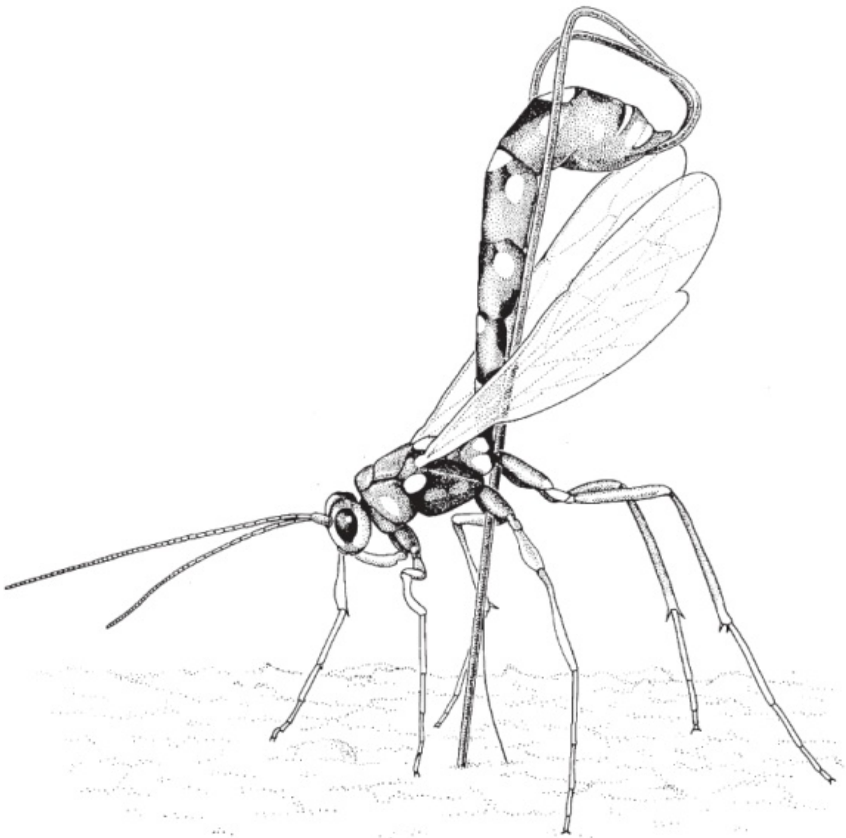


Fig. 5.11 A female of the parasitic wasp *Megarhyssa nortoni* (Hymenoptera: Ichneumonidae) probing a pine log with her very long ovipositor in search of a larva of the sirex wood wasp, *Sirex noctilio* (Hymenoptera: Siricidae). If a larva is located, she stings and paralyzes it before laying an egg on it.

Physiology of insect reproduction

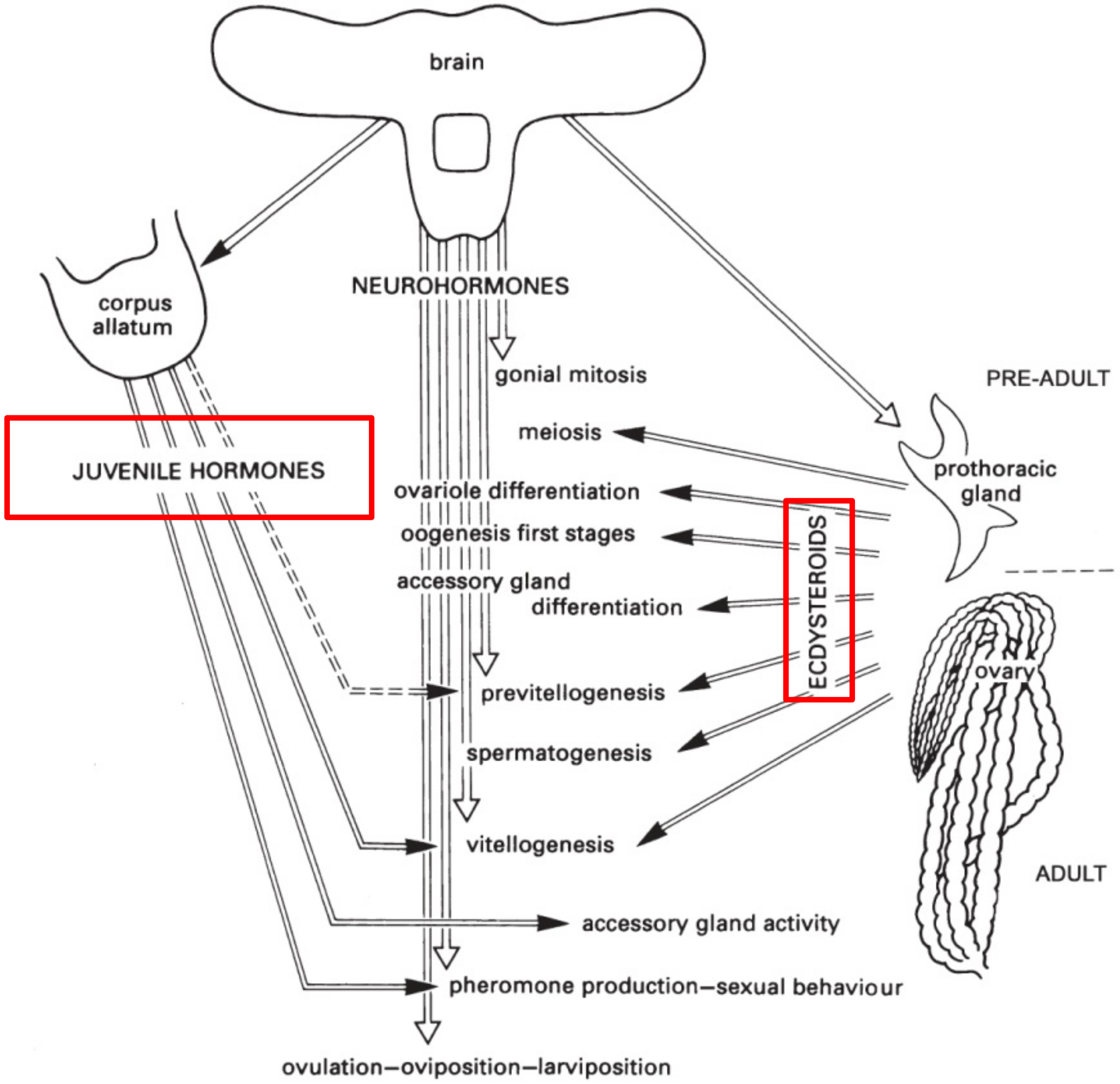
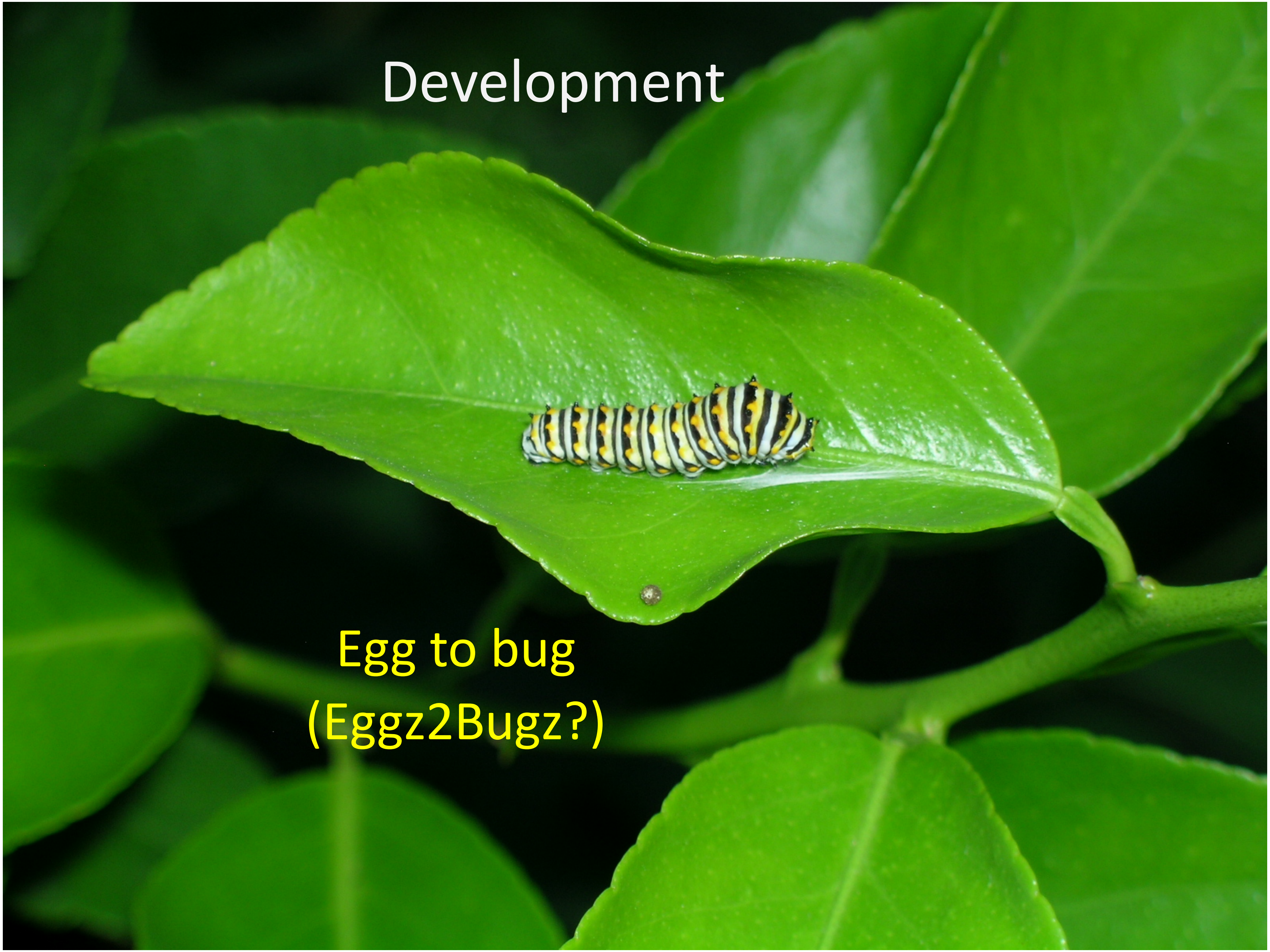


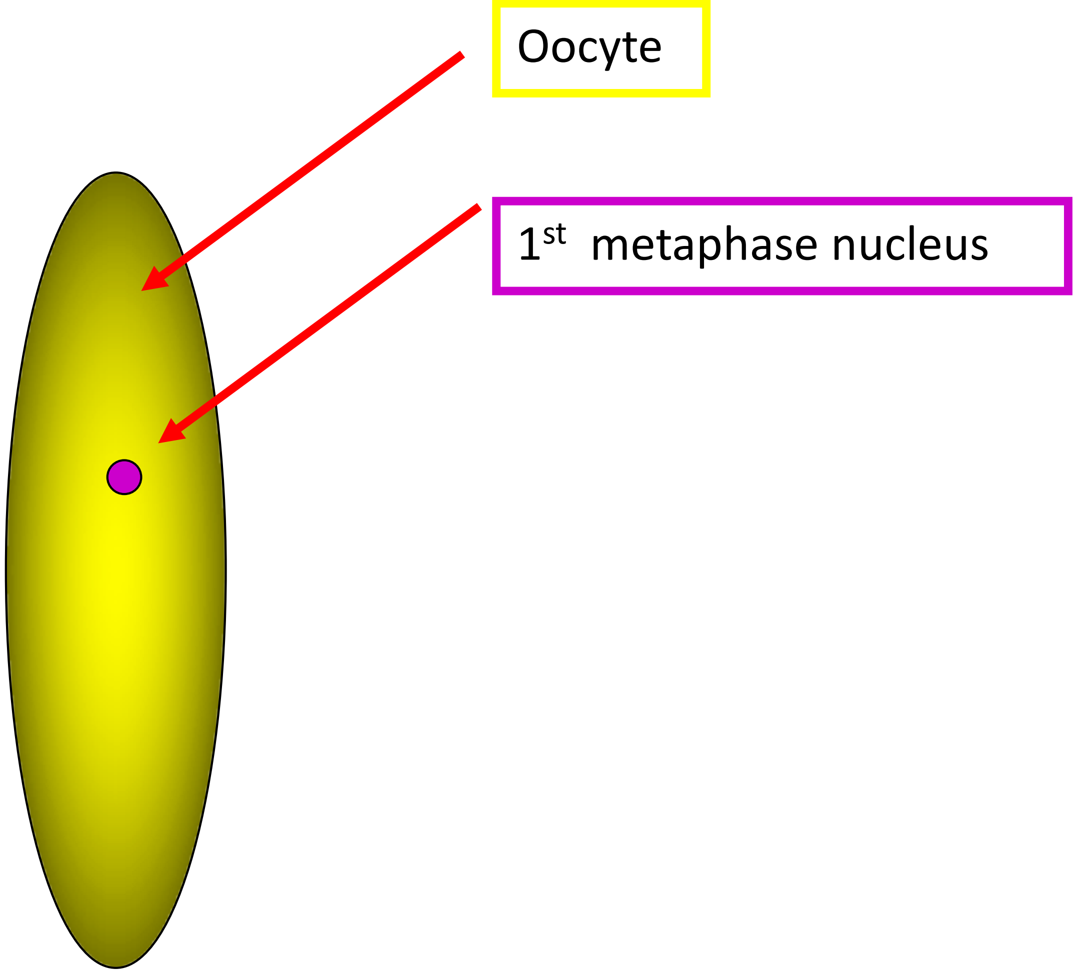
Fig. 5.13 A schematic diagram of the hormonal regulation of reproductive events in insects. The transition from ecdysteroid production by the pre-adult prothoracic gland to the adult ovary varies between taxa. (After Raabe 1986.)

Atypical modes of reproduction

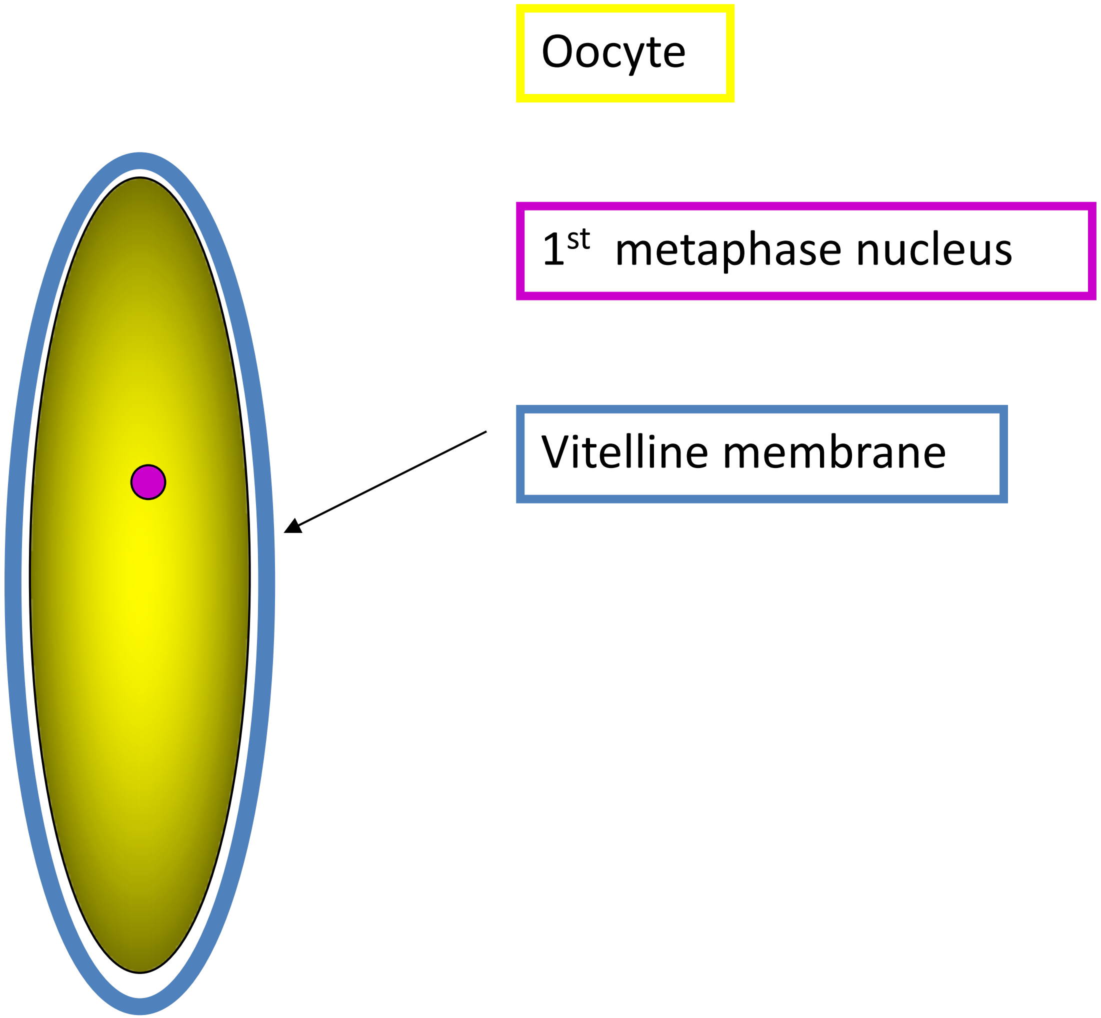
- “Normal” reproduction: gonochorism, amphimixis, diploidy.
- Atypical reproduction:
- Parthenogenesis (孤雌生殖) - Aphids
- Paedoyenesis (幼體生殖)- Diptera
- Neoteny (幼態成熟)- Hemiptera


Development
Egg to bug
(Eggz2Bugz?)

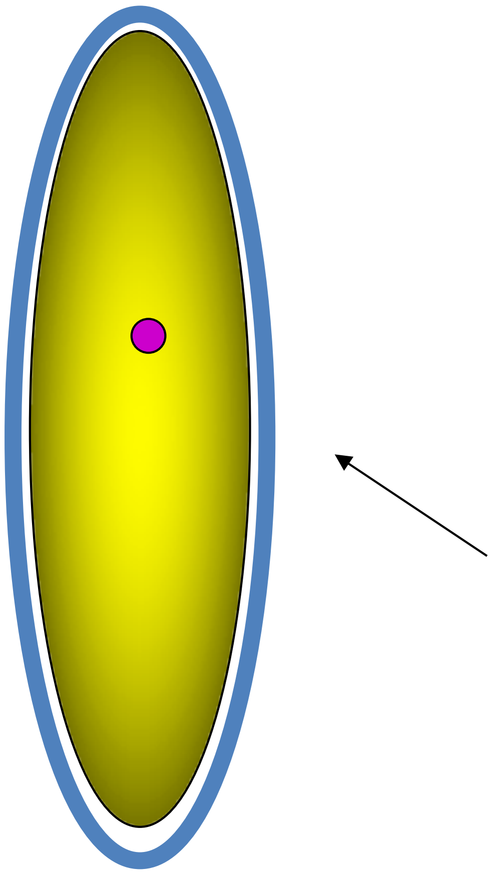
The insect egg



The insect egg



The insect egg



Oocyte

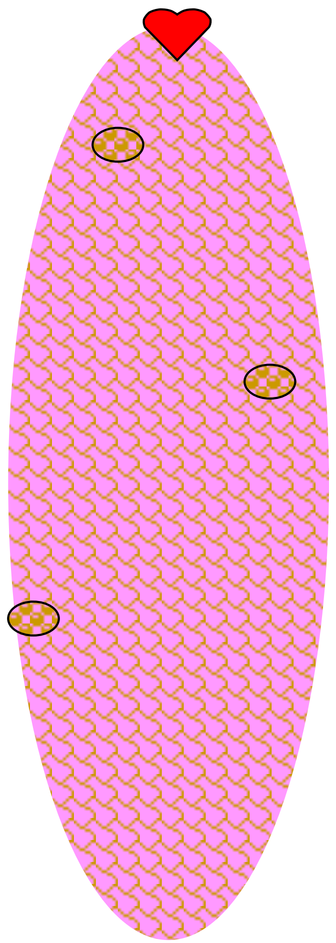
1^{st} metaphase nucleus

Vitelline membrane

Protein fibers, sperm recepters

Chorion

The insect egg



Oocyte

1st metaphase nucleus

Vitelline membrane

Chorion

Micropyle

Aeropyles

The insect egg

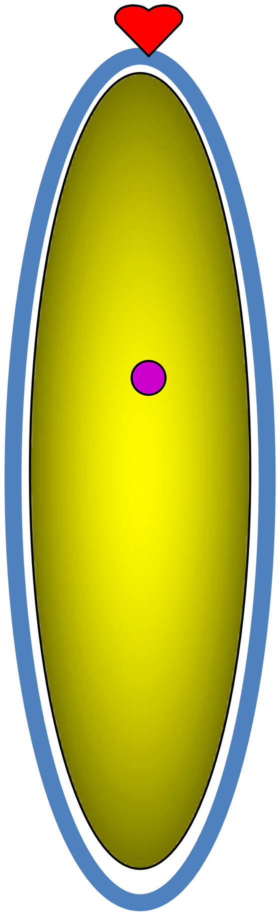
Micropyle –a site spermatozoa can enter

Oocyte

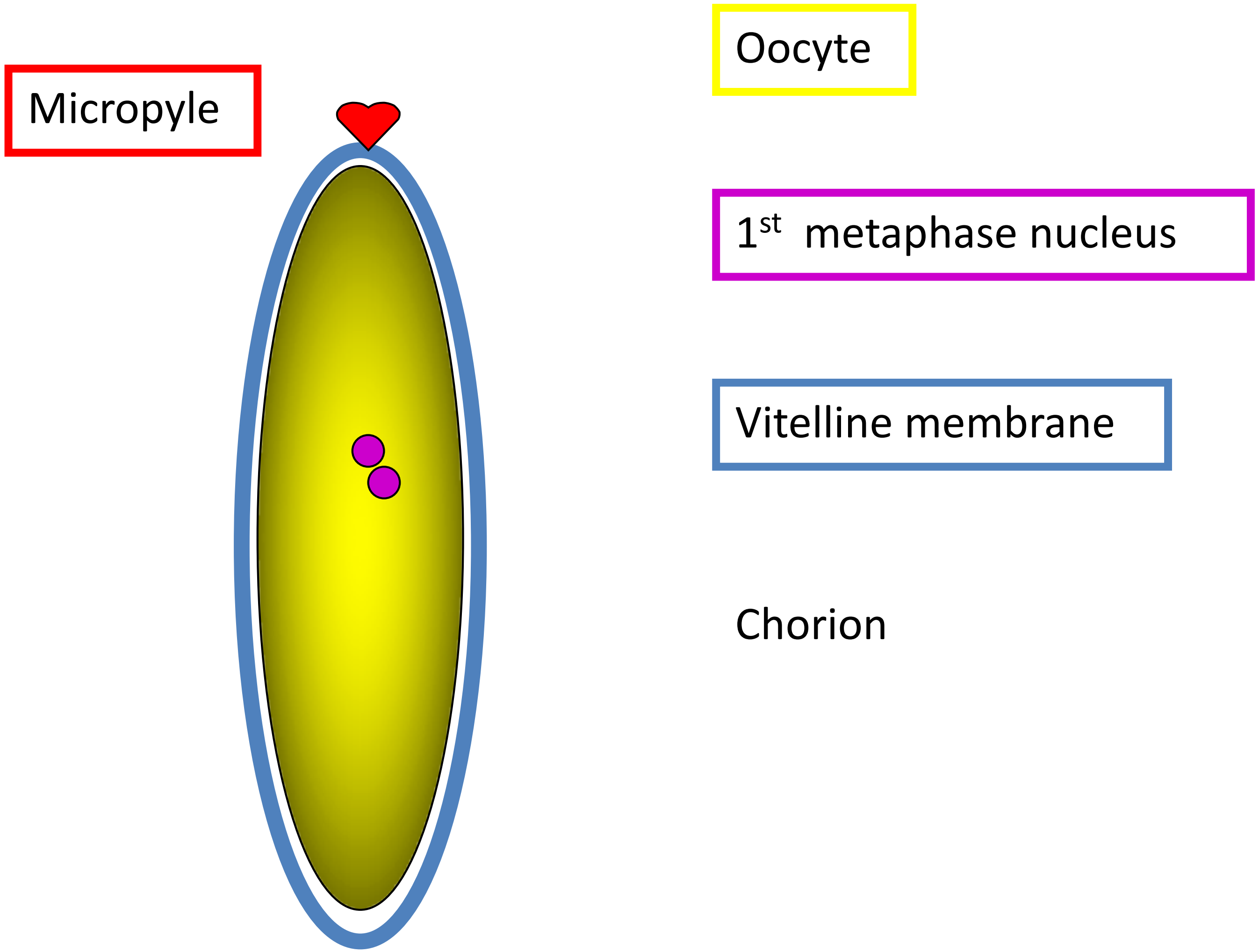
1st metaphase nucleus

Vitelline membrane

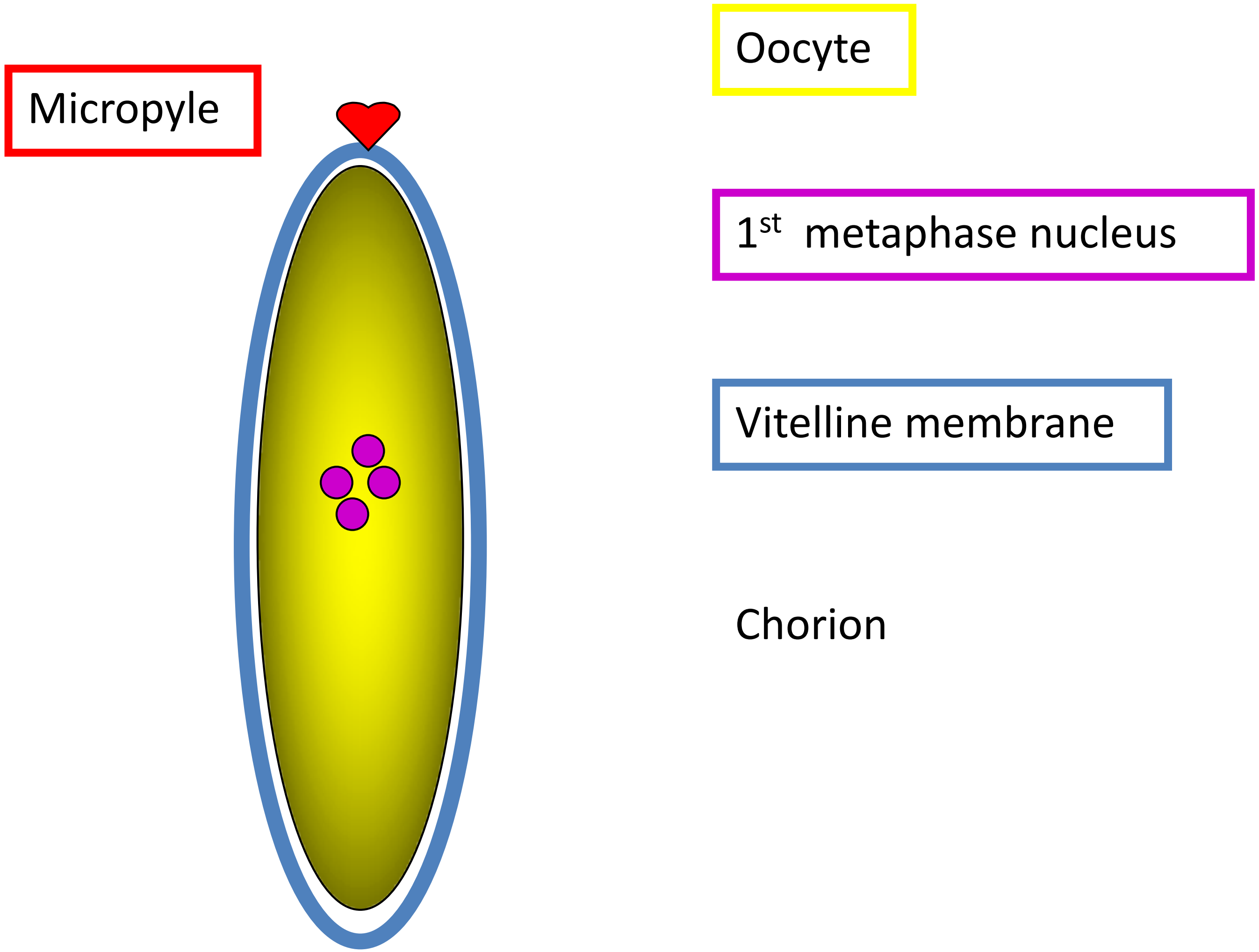
Chorion



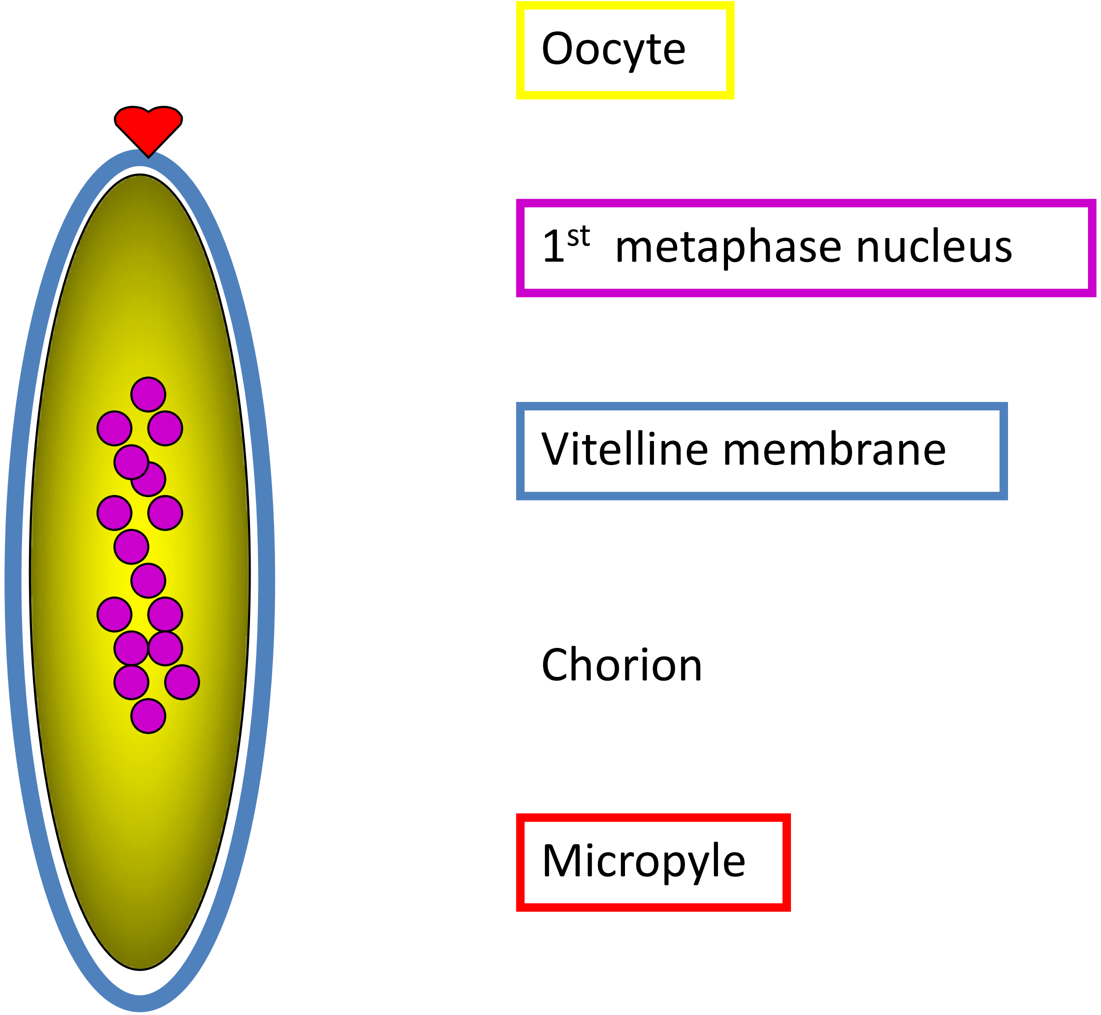
The insect egg



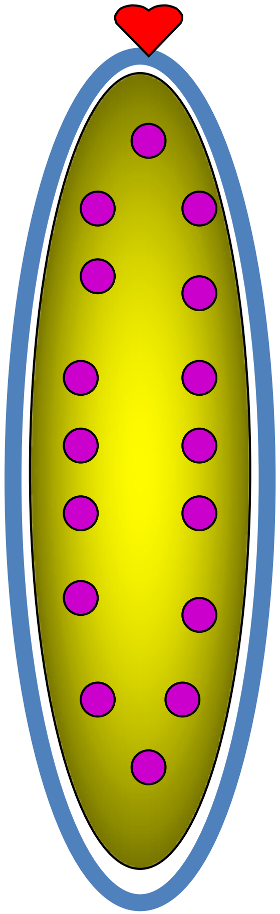
The insect egg



The insect egg



The insect egg



Oocyte

1^{st} metaphase nucleus

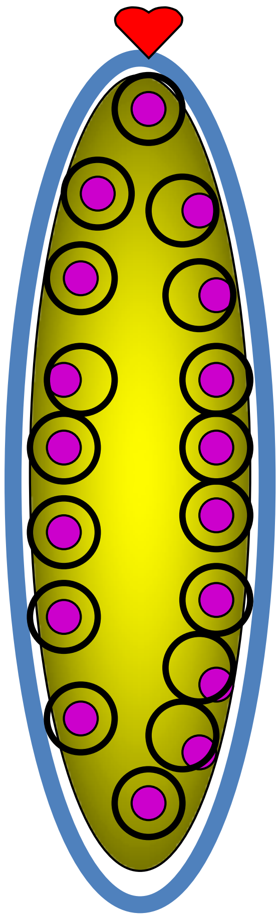
Vitelline membrane

Chorion

Micropyle

The insect egg

Cross section



Oocyte

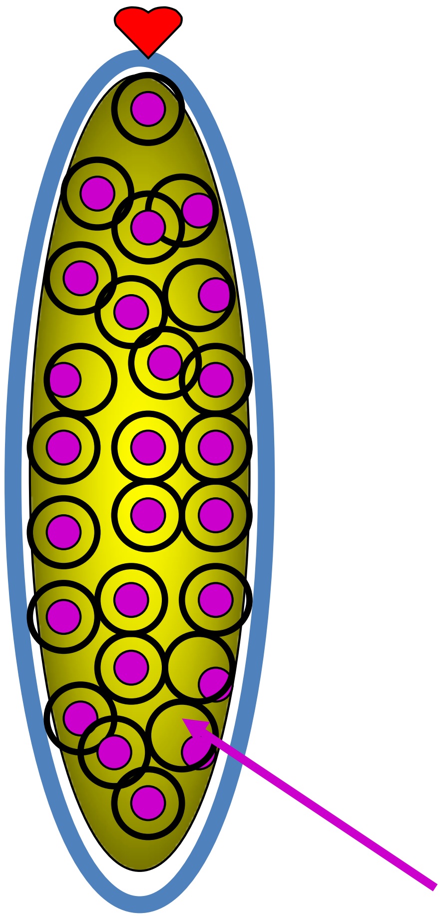
1st metaphase nucleus

Vitelline membrane

Chorion

Micropyle

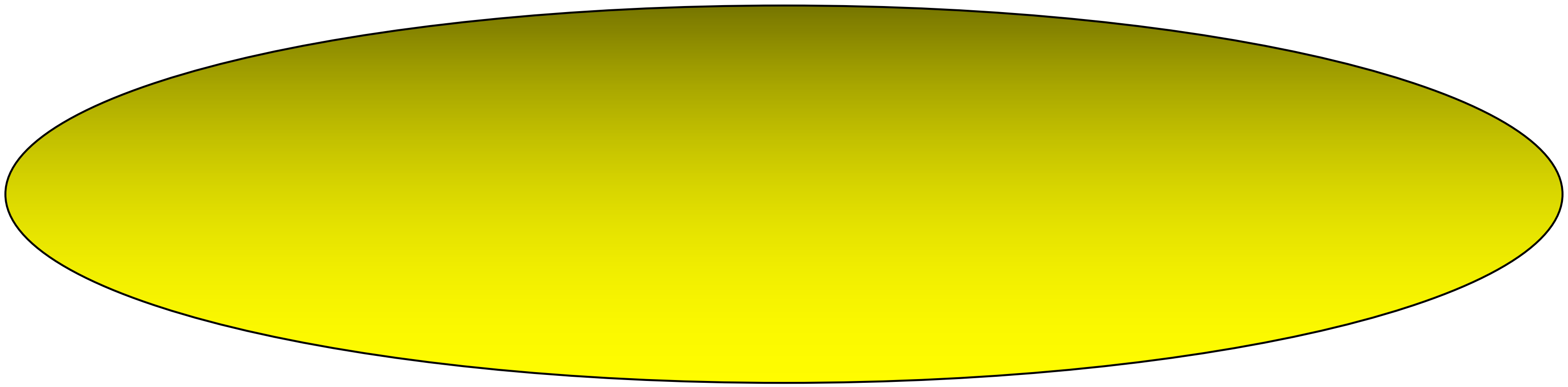
The insect egg



From outside
Chorion peeled off

Germ Band-side view

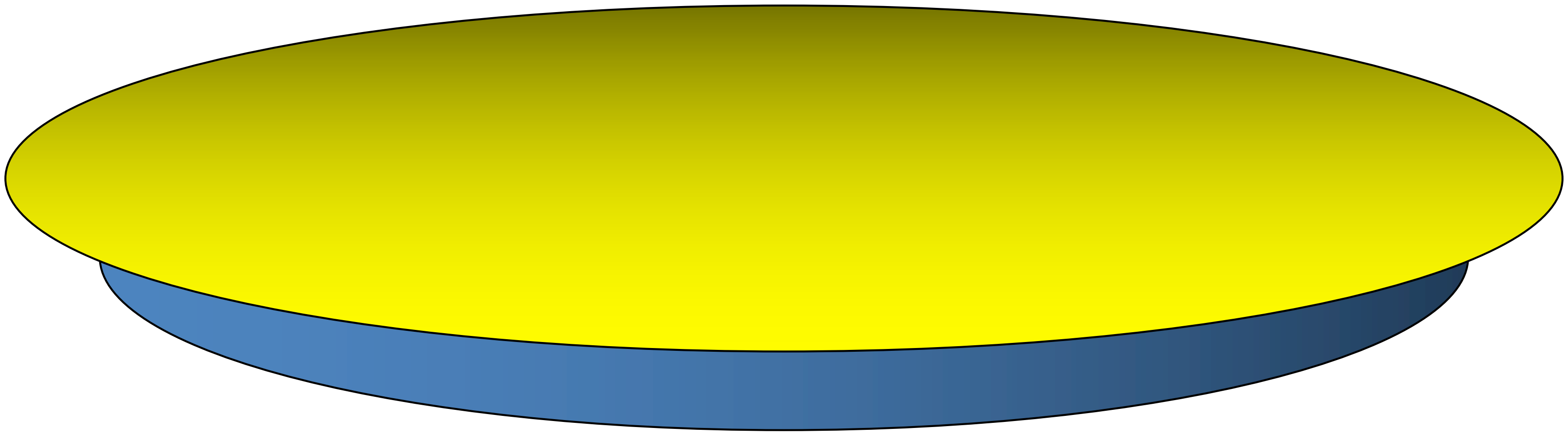
Yolk with blastoderm
Membrane covering



Tail end

Head end

Germ Band side view

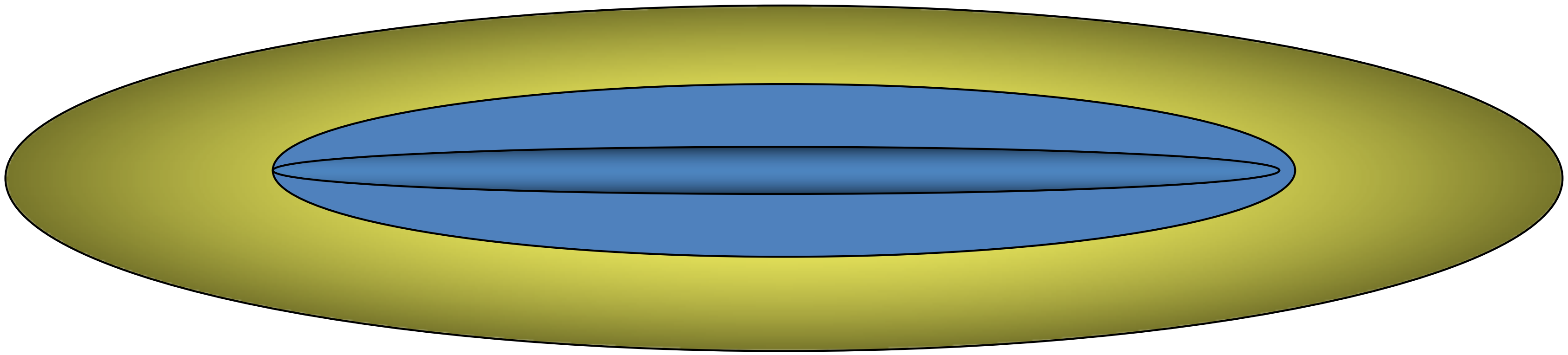


Ventrally, cells thicken, form germ anlage
(undeveloped cell layers)

Tail end

Head end

Germ Band ventral view

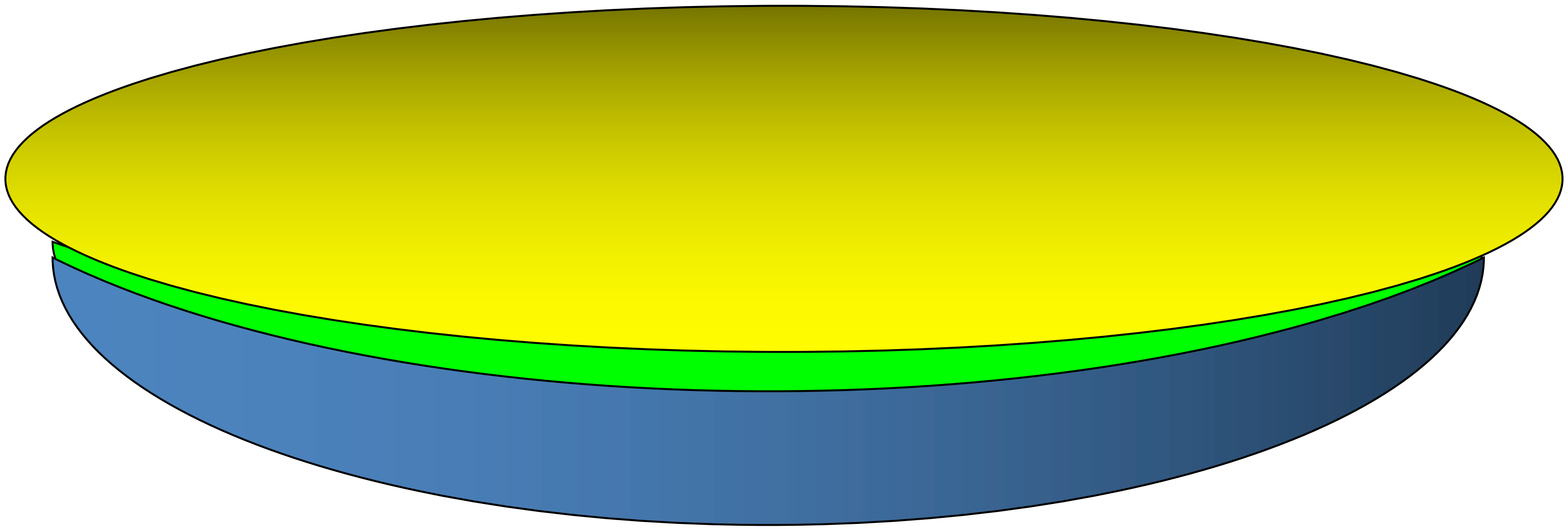


Groove forms—
now blue structure is the germ band;
Will form 2 layers of tissues

Tail end

Head end

Germ Band side view again



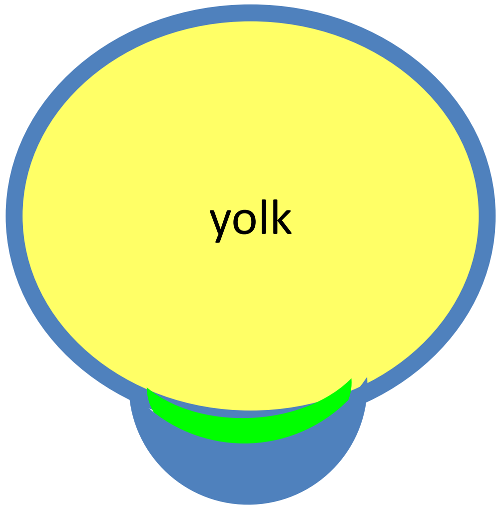
Inner mesoderm layer, outer ectoderm layer

Tail end

Head end

Now, cross section

Edges of ectoderm grow to enclose yolk

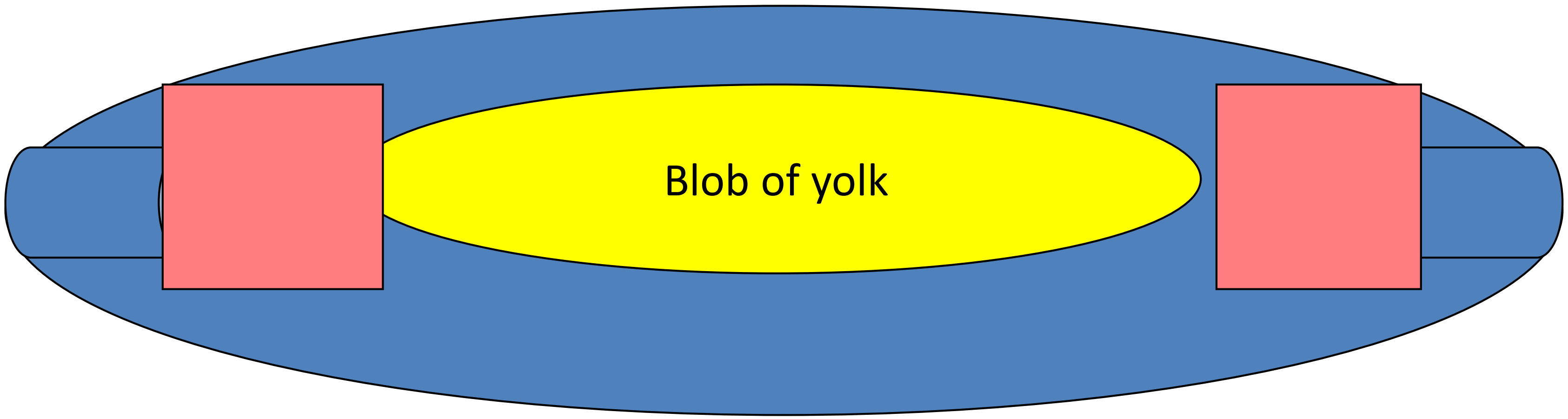


Tail end

Embryo side view

Foregut

Hindgut

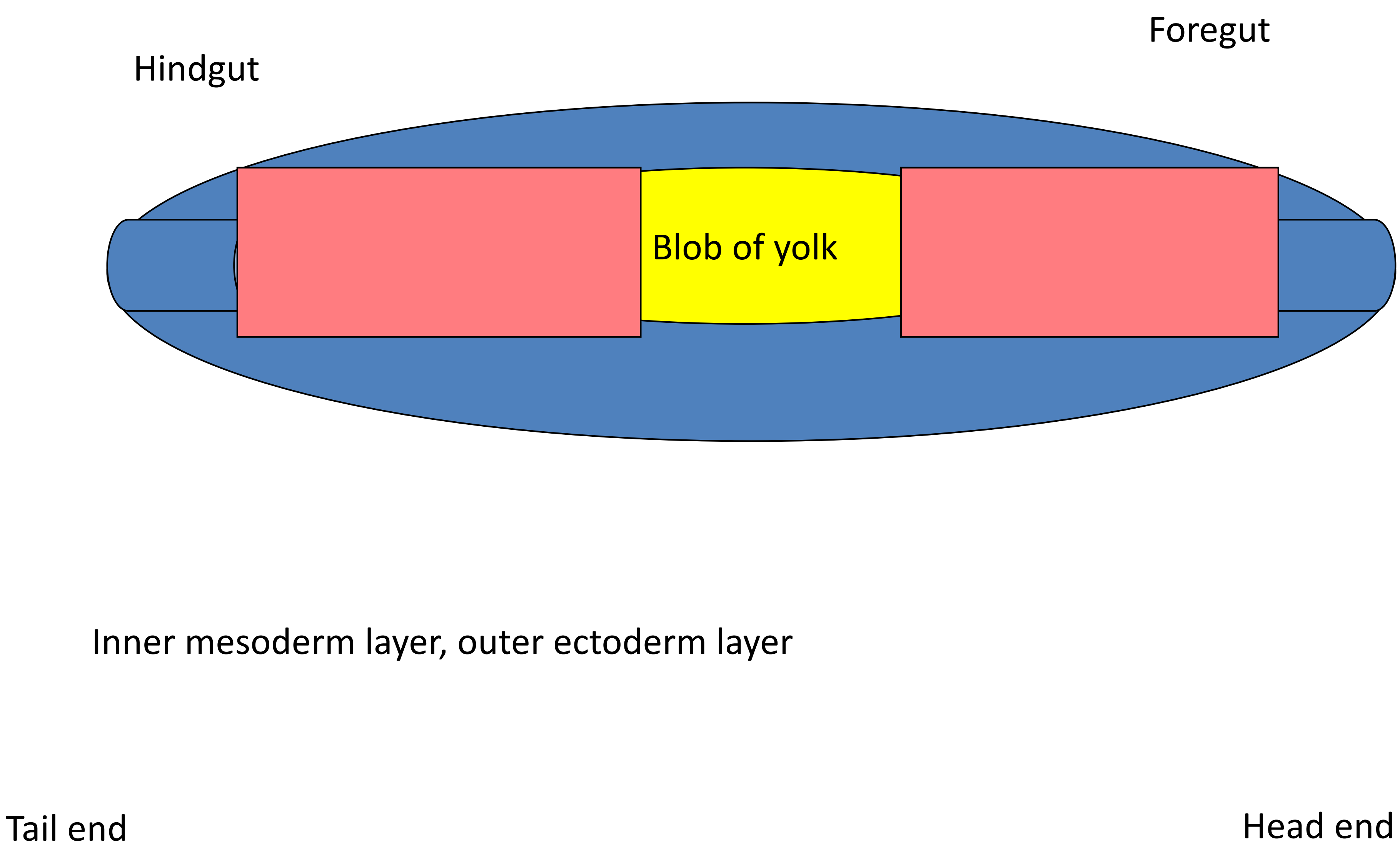


Inner mesoderm layer, outer ectoderm layer

Tail end

Head end

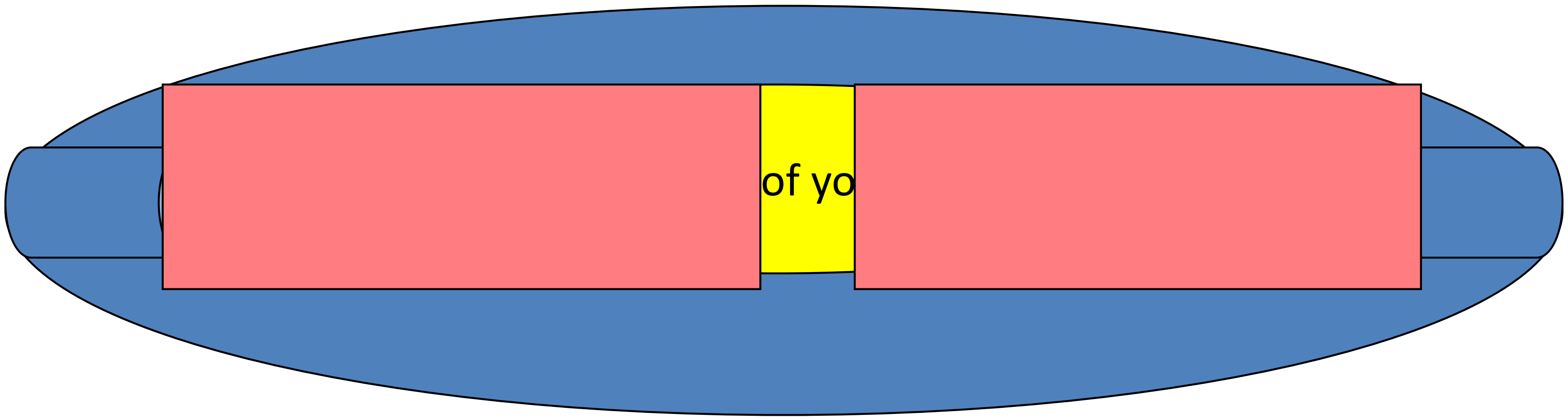
Embryo side view



Embryo side view

Foregut

Hindgut

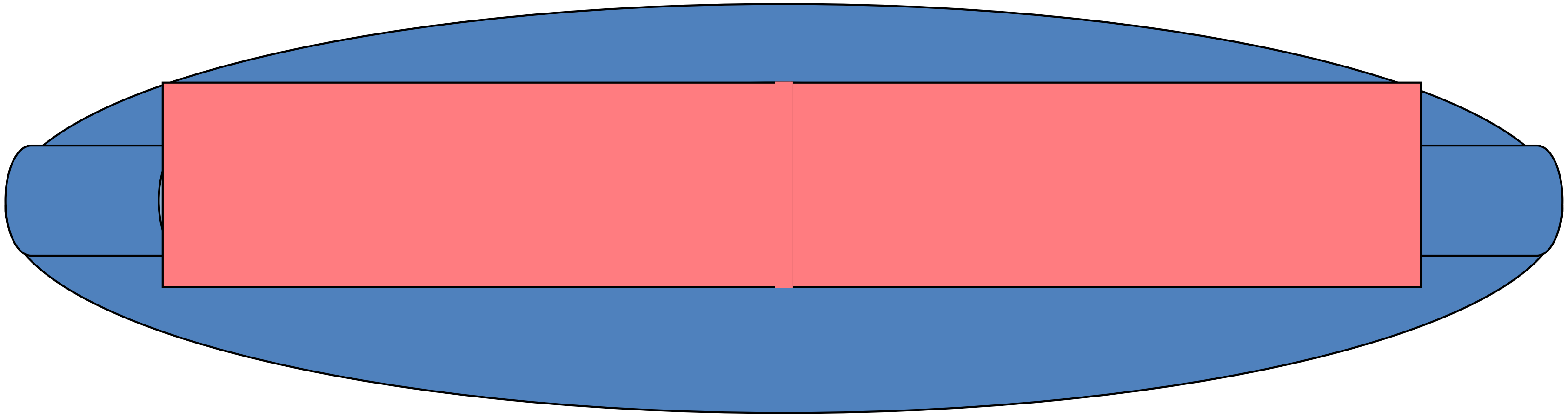


Inner mesoderm layer, outer ectoderm layer

Tail end

Head end

Embryo side view

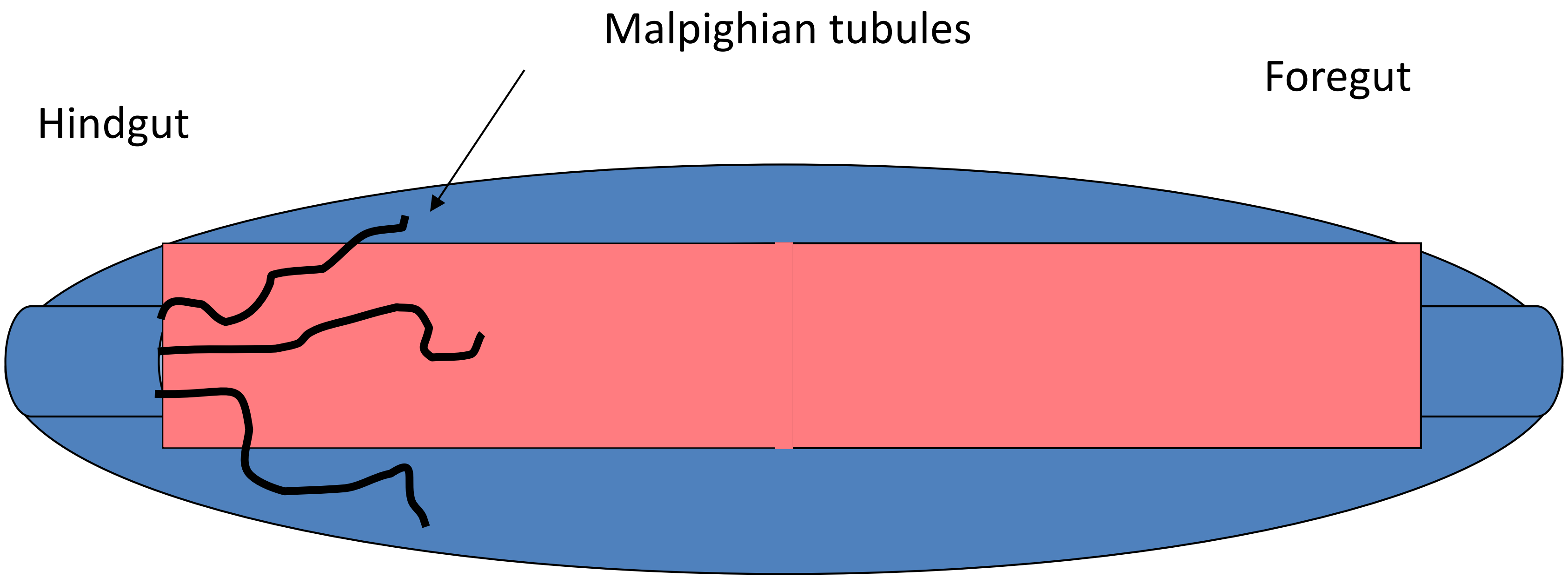


Endoderm layer forms midgut

Tail end

Head end

Embryo side view



Endoderm layer forms midgut

Tail end

Head end

As the embryo grows..

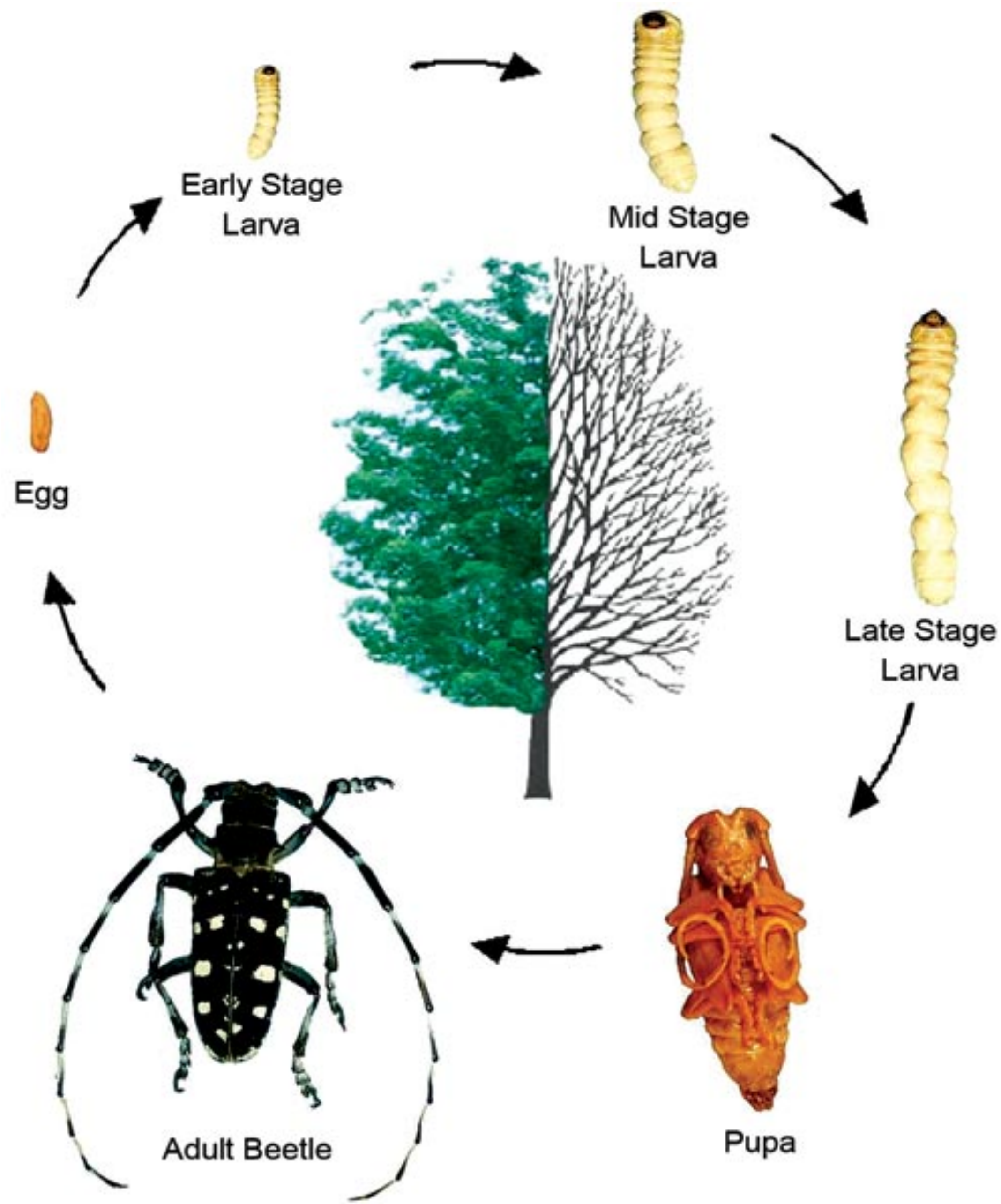
- Limb buds develop into limb-derived structures.
- Gut is completed
- The little insect hatches...

The young insect

- Hemimetabolous
- “half” transformation
- Immatures called nymphs
- Nymphs resemble adults except for wings, genitalia

- Holometabolous
- “whole” transformation
- Immatures called larvae
- Larvae completely different from adults

Box Elder bugs

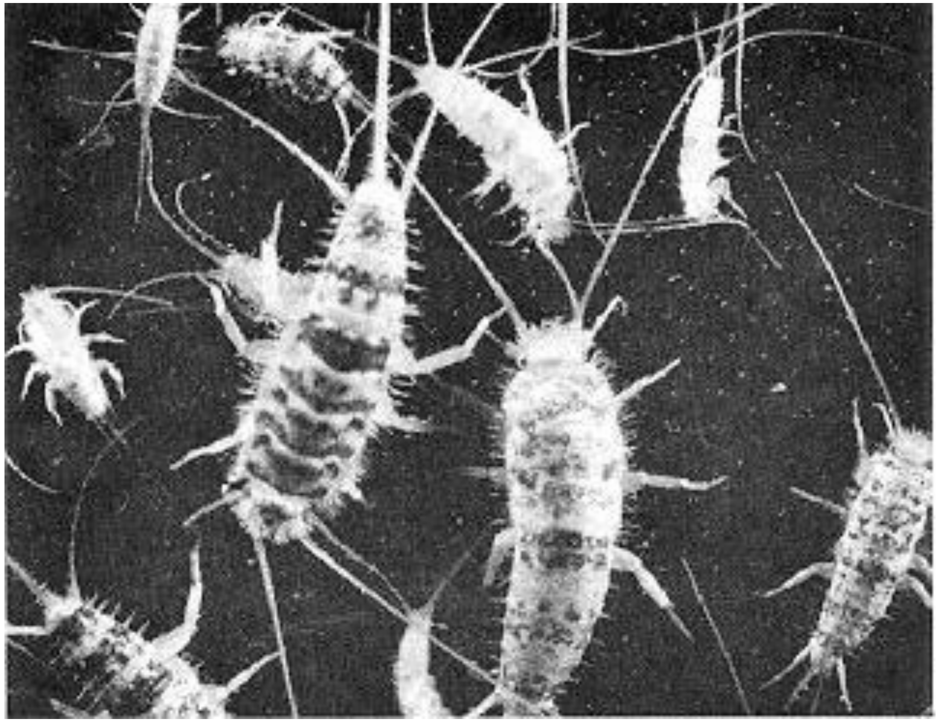


Asian long-horned beetle

Photo Credit: *Michael Bohne, University of Vermont*

Ametabolous insects

- Essentially no external changes from immature to adult
- Apterygotes, such as silverfish (Thysanura)

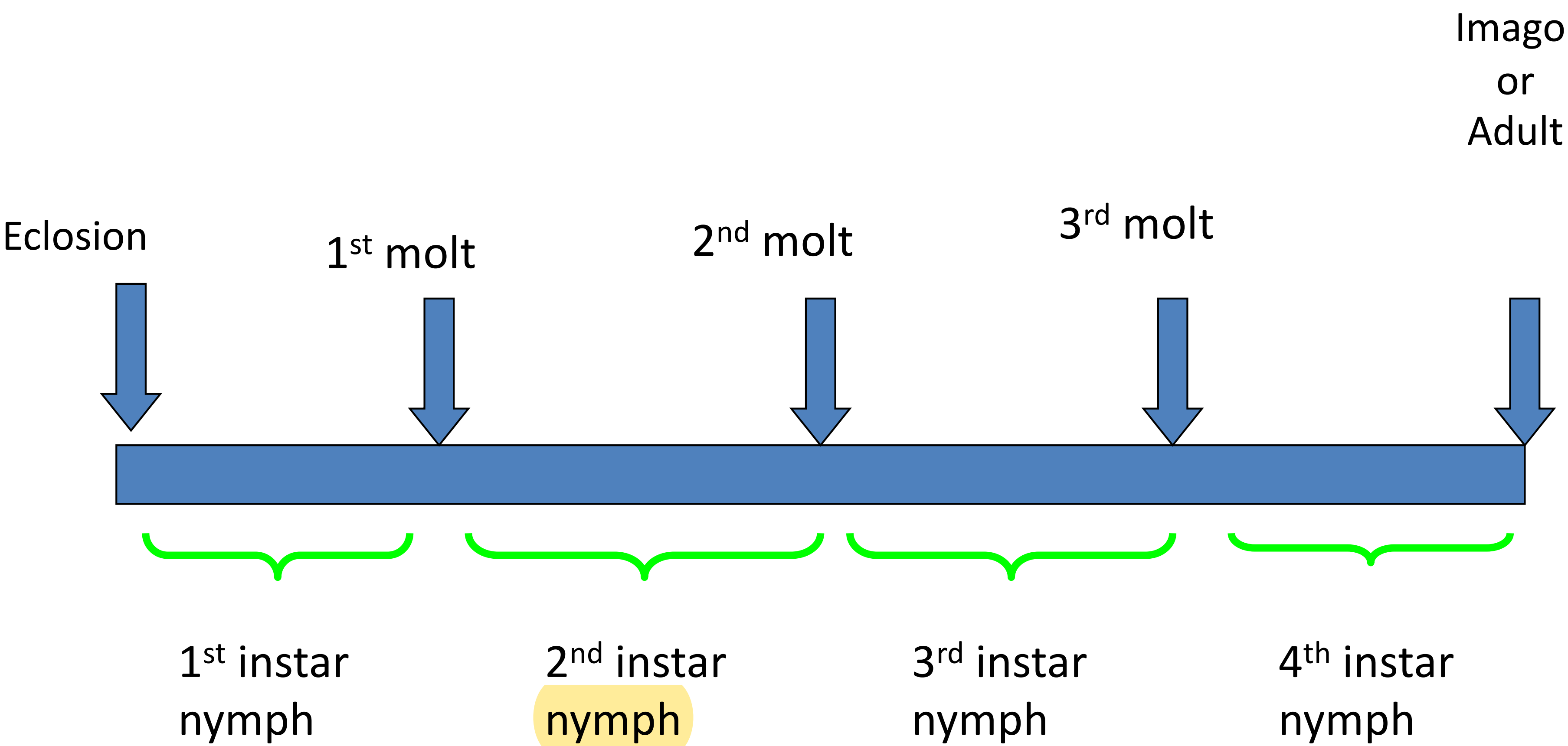


Growing means molting

- New, larger cuticle forms under theold cuticle
- Cuticle is shed
- New larger cuticle expands, is sclerotized
- (There’s MUCH MORE to this!)
- Number of molts to adult varies.
- MOST insects do not as adults

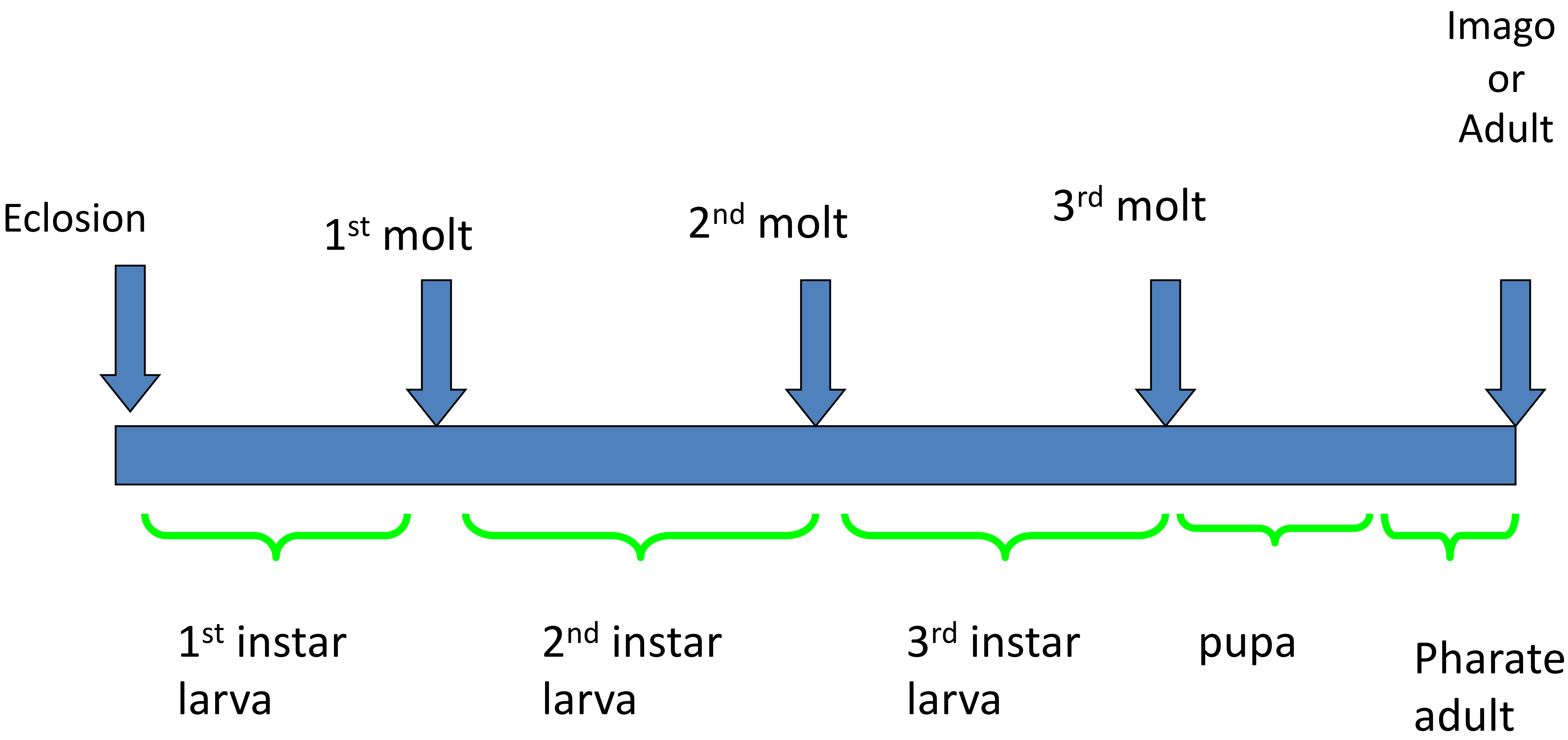
Growing means molting

- Instars and molts: hemimetabolous



Growing means molting

- Instars and molts: holometabolous

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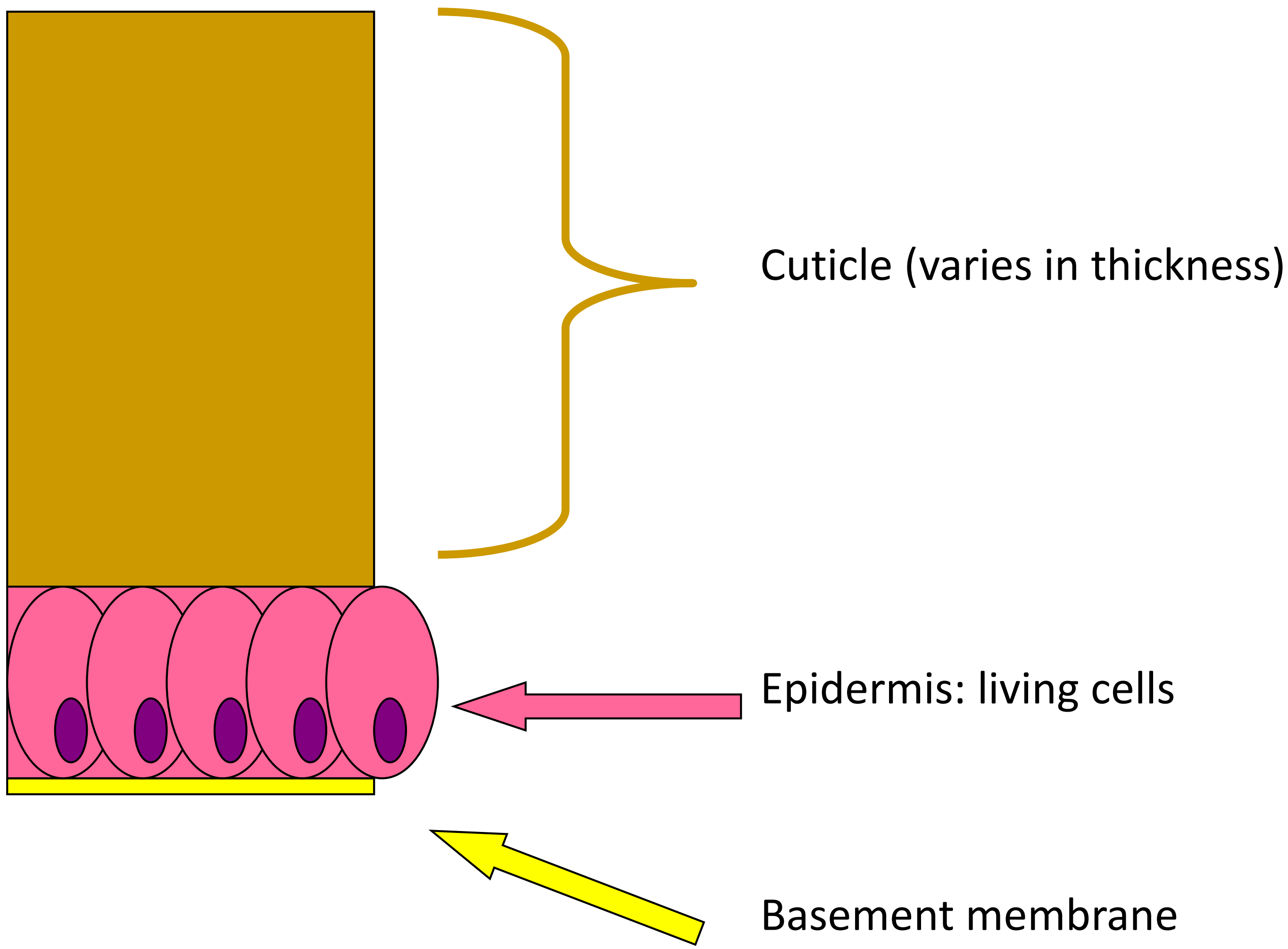
Development

- Types of metamorphosis:
- Ametaboly – no change
- Himemetaboly – some changes
- Holometaoly – changed all

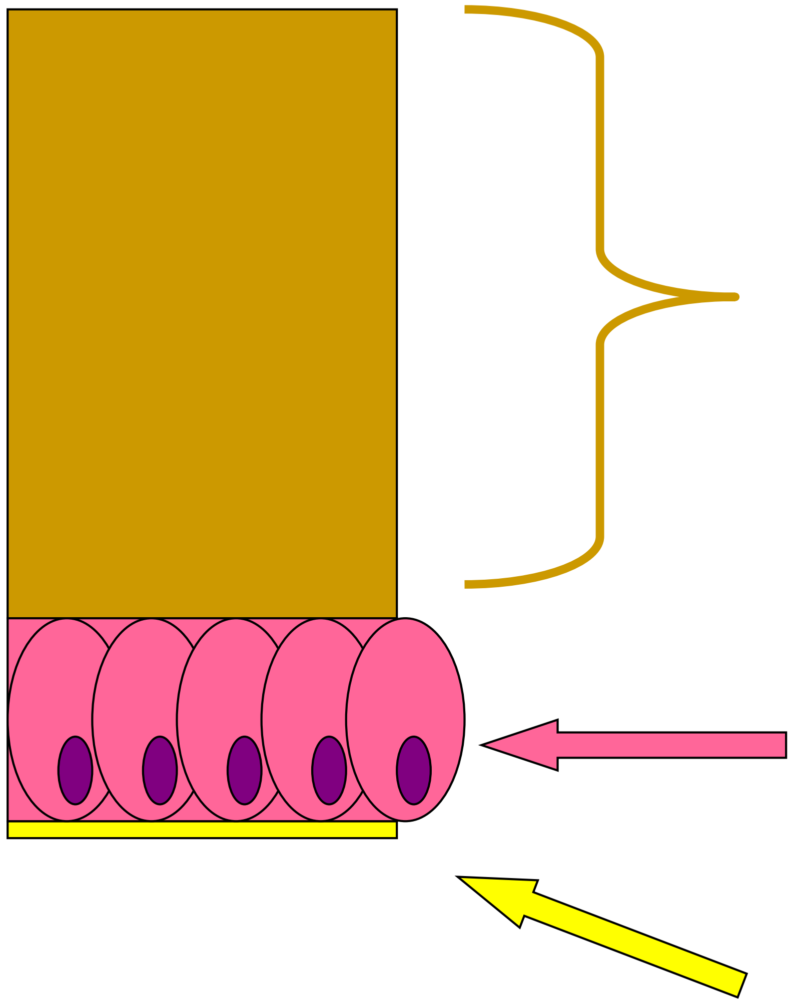
Integument is *complex*

- Composed of many layers
  - Living cells
  - Secreted layers
- Perforated by pores
- Sites for muscle attachments

Three basic components



Three basic components

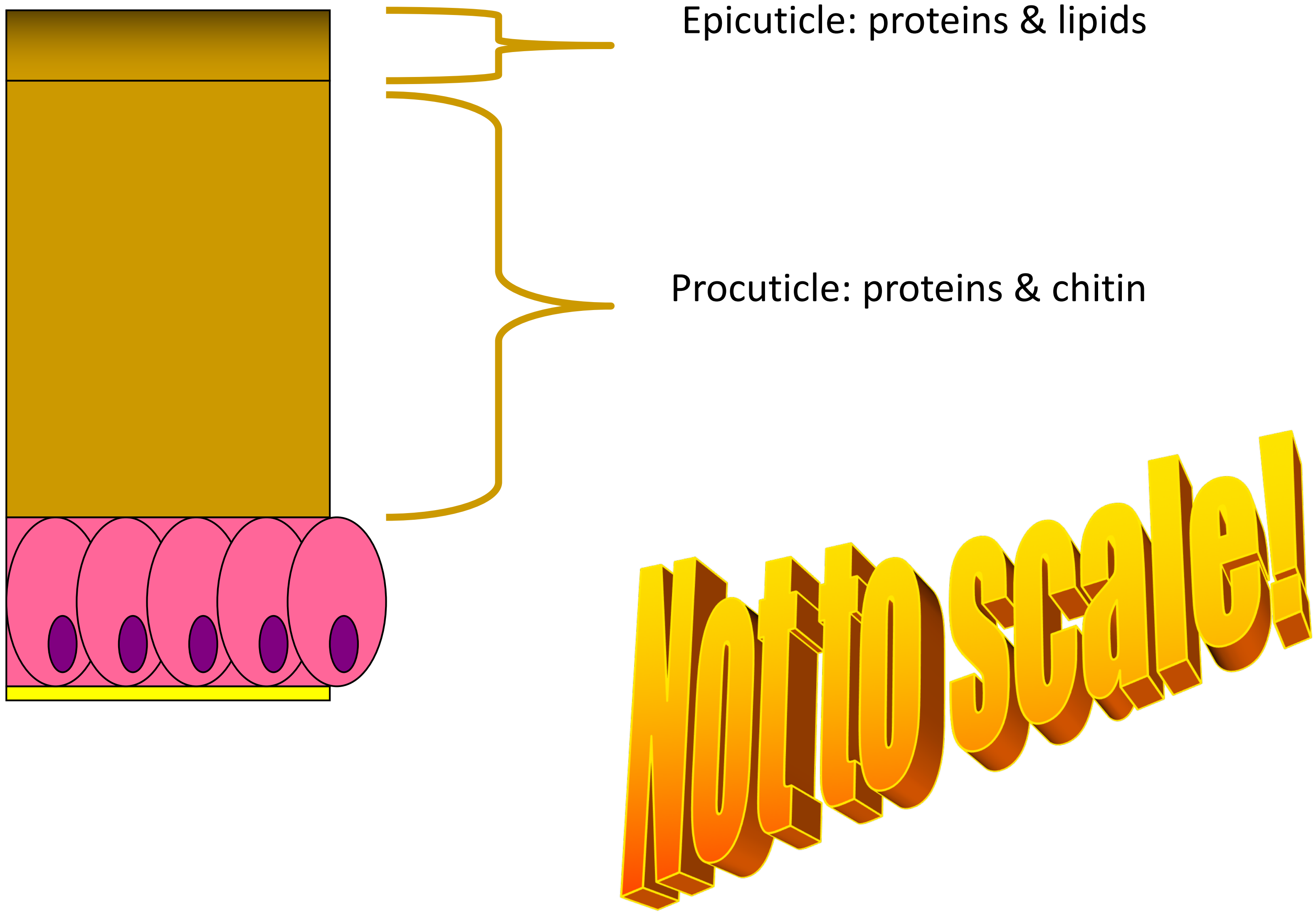


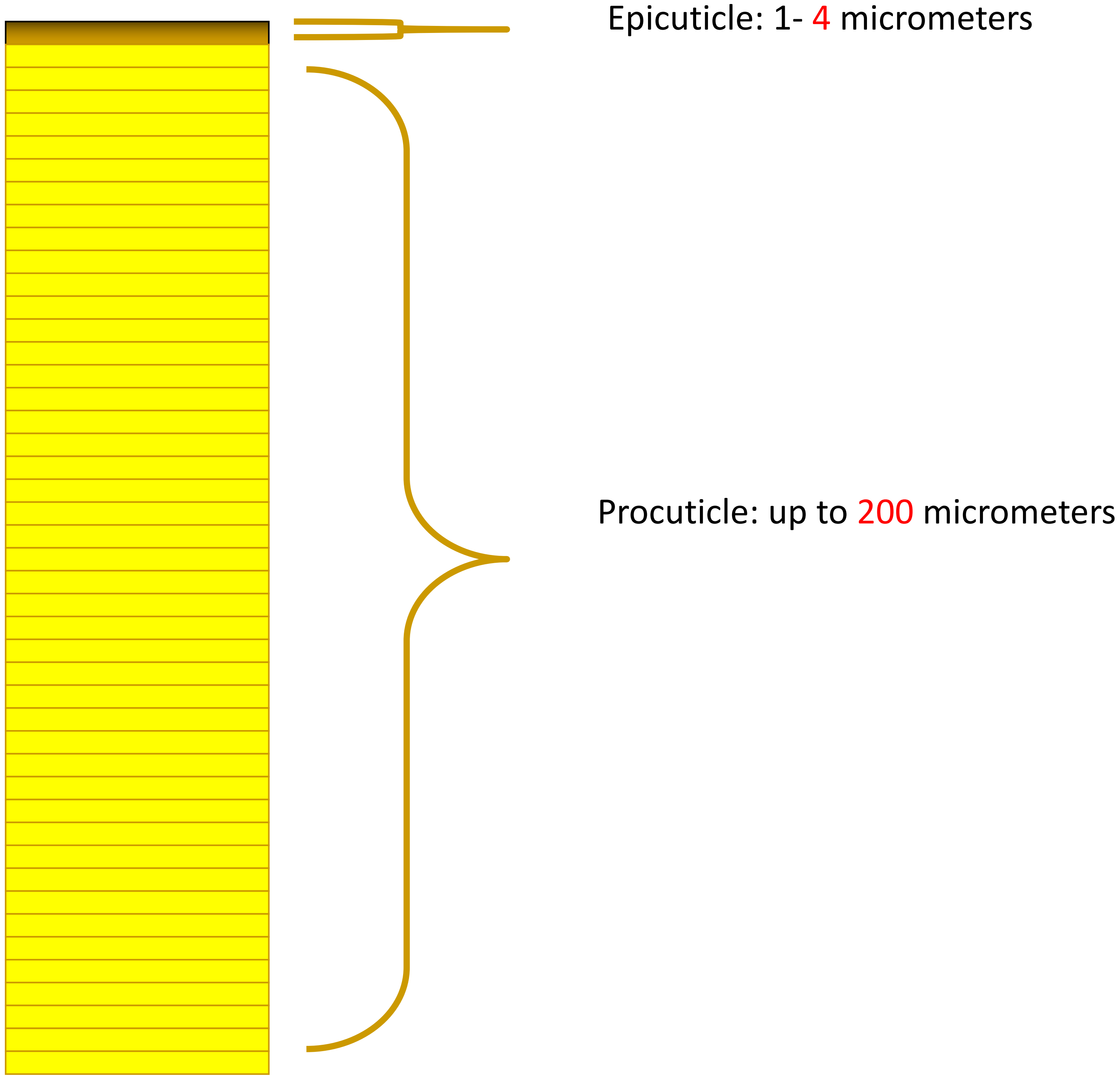
Secreted mainly
by epidermis; contains
CHITIN

Epidermis (living cells)

Secreted by blood cells and others..

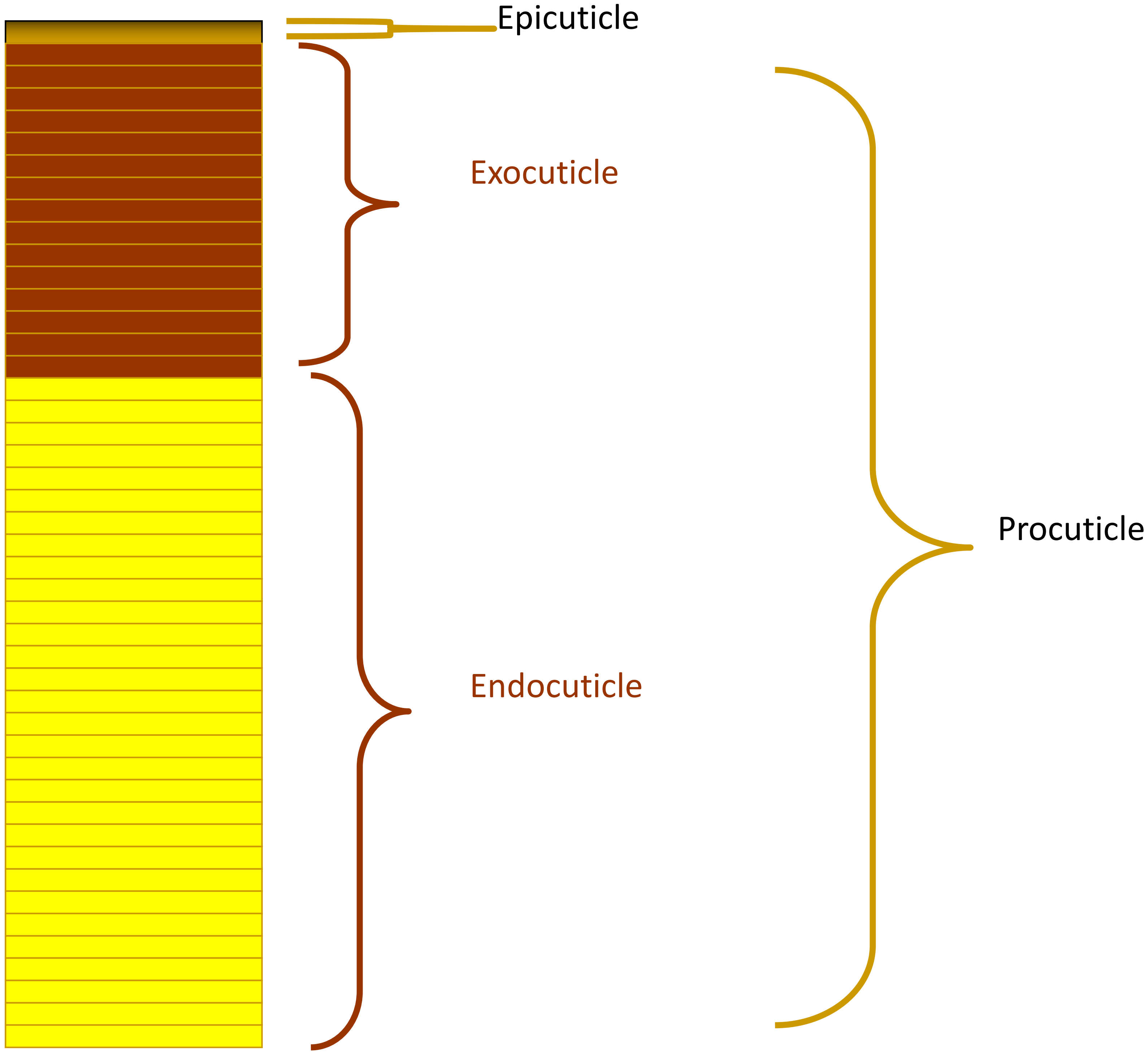
Fine structure of cuticle




Epicuticle: 1- 4 micrometers
Procuticle: up to 200 micrometers

Chitin fibers secreted in layers

- Chitin fibers embedded in protein matrix
- Orientation of chitin fibers changes
- Like plywood: layers oriented in different directions increases strength

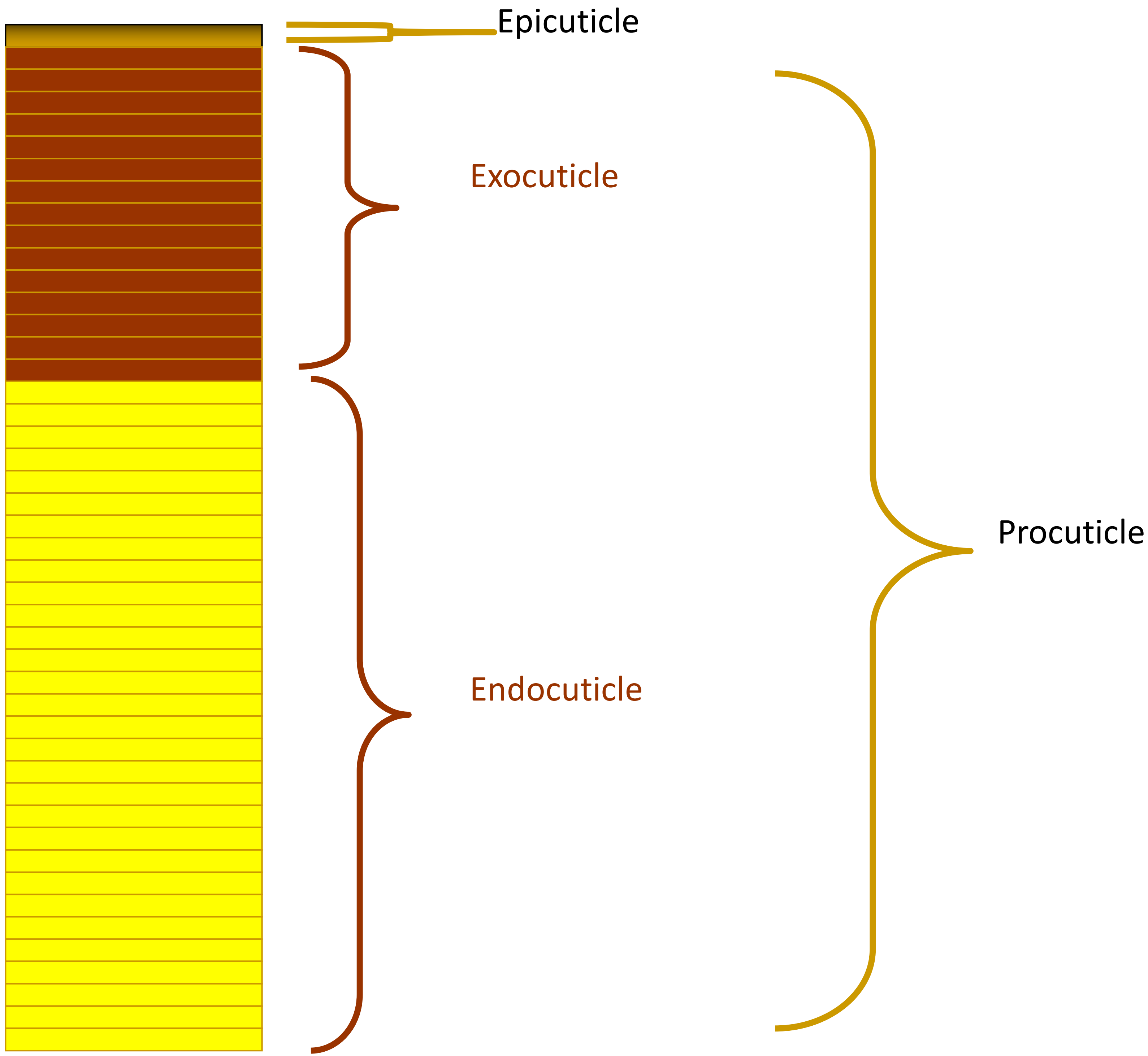

Epicuticle
Exocuticle
Procuticle
Endocuticle

Tanning or sclerotization

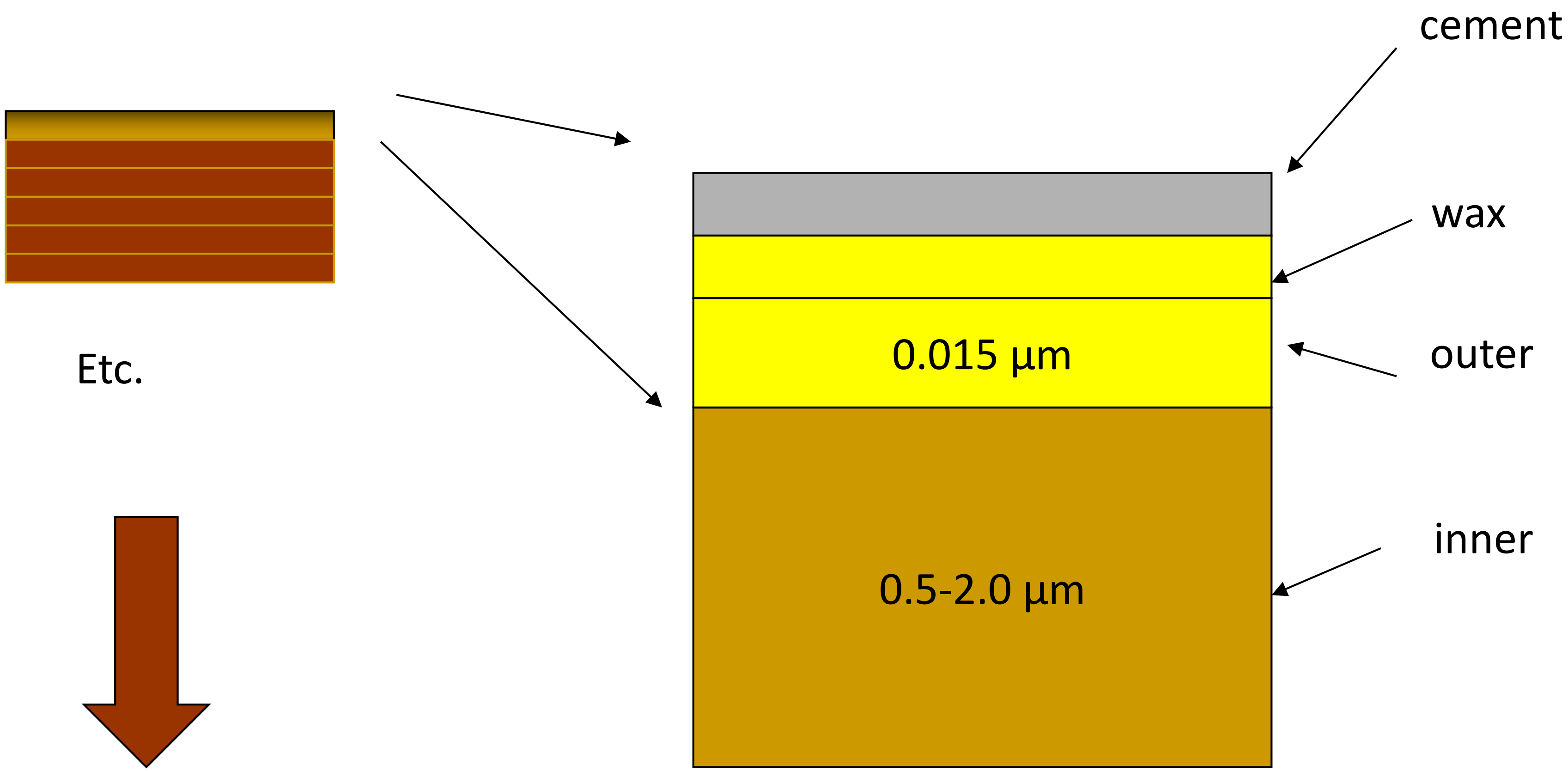
- In exocuticle
- Protein-protein cross linkages
- More cross-linkage, exocuticle is stiffer, more rigid
- Thin flexible membrane at joints not sclerotized

Epicuticle: thin, but crucial

- 1-4 micrometers
- contains many layers


Epicuticle
Exocuticle
Procuticle
Endocuticle

Layers of epicuticle



Layers of epicuticle

- Secreted by epidermis
  - Remember the epidermis?
  - Living cells
- Cement layer: mucopolysaccharide
  - Protects
- Wax: hydrocarbons
  - Waterproofs
  - Distinctive odors
  - Blooms, fluffs
- Outer layer: polymerized lipids
- Inner: tanned lipoproteins

Molting

- https://www.youtube.com/watch?v=QfeEZl0VGs0

Summary of Molting

Step 1: Apolysis -- separation of old exoskeleton from epidermis

Step 2: Secretion of inactive molting fluid by epidermis

Step 3: Production of cuticulin layer for new exoskeleton

Step 4: Activation of molting fluid

Step 5: Digestion and absorption of old endocuticle

Step 6: Epidermis secretes new procuticle

Step 7: Ecdysis -- shedding the old exo- and epicuticle

Step 8: Expansion of new integument

Step 9: Tanning -- sclerotization of new exocuticle