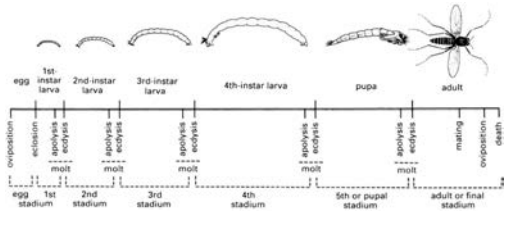
Insect growth

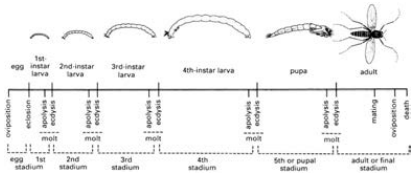
- Kinds of growth
  - Indeterminate
  - Determinate
- Growth through molting
  - Membranes expand *within* instar
  - Growth when exoskeleton is soft just after molting

Insect development

- Instar = Stadium
- Imago = Adult

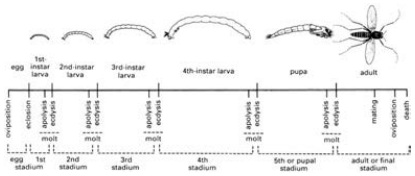


Insect development



- Molt increment: increase in size between instars

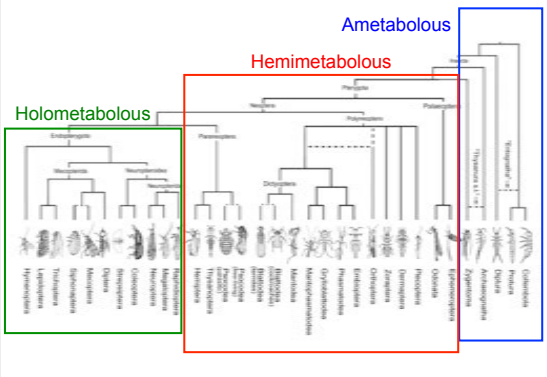
Insect development



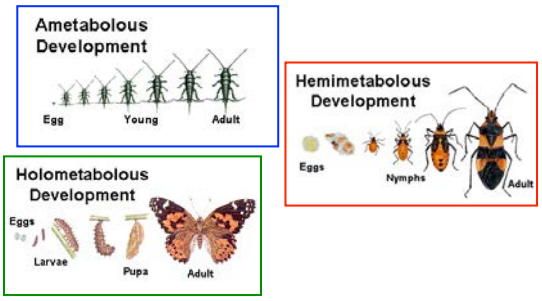
- Factors influencing molt increments, intermolt period, and number of instars
  - Food supply
  - Temperature
  - Sex
  - Interaction between genes and environment

Overall life history patterns

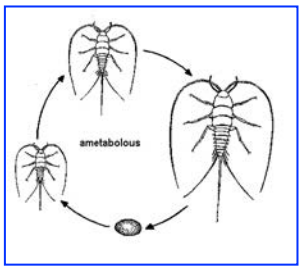
- Ametabolous
  - Primitive wingless groups
  - Indefinite number of molts
- Hemimetabolous
  - Gradual change towards adult form
  - Wings develop externally
- Holometabolous
  - Non-feeding pupal stage present
  - Develop wings and other adult structures internally during immature stages.



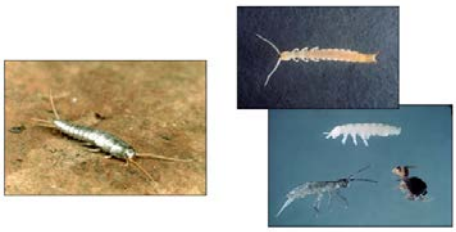
Overall life history patterns



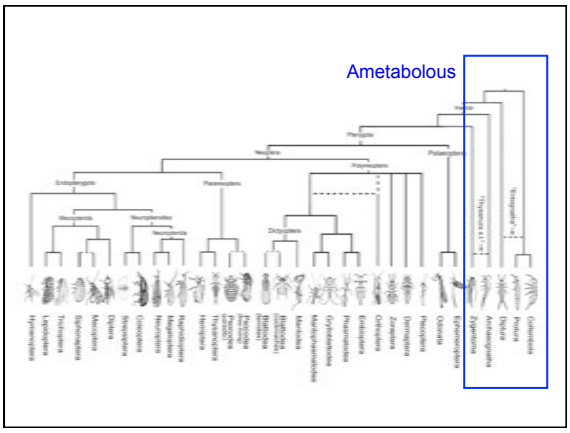
Overall life history patterns



Indeterminate growth

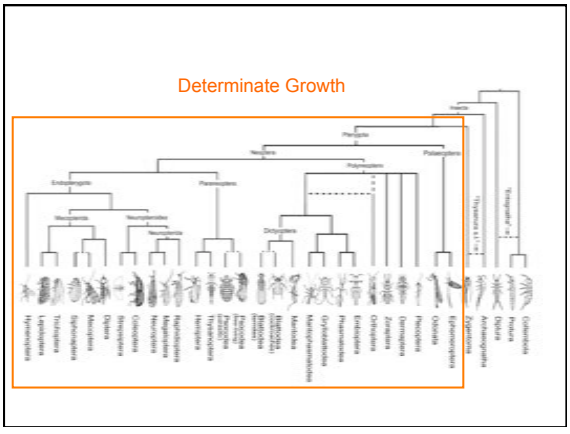


- Continue to molt until death
  - Collembola, Diplura (non-insect Hexapoda)
  - Apterygote insects: Zygentoma (silverfish) & Archaeognatha (bristletails)



Determinate growth

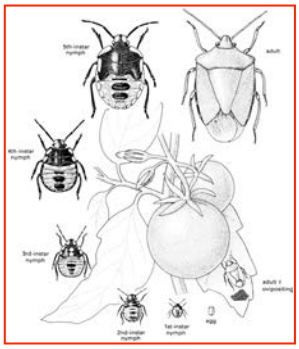
- Most insects (Pterygota)
- Distinctive instar marks end of growth



Hemimetabolous

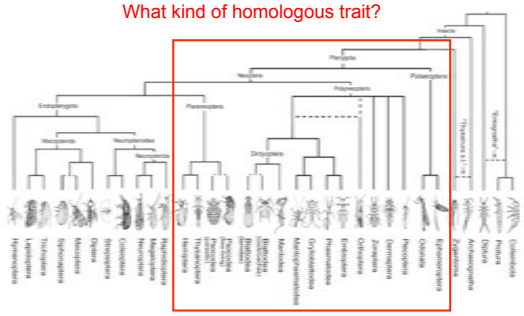
- Stages
  - Egg, nymph, adult (no pupa)
  - In aquatic insects, immature called naiad
  - Nymph resembles adult but without wings
- Exopterygote: wings develop on dorsal surface of thorax
- Terrestrial
  - Adults and immatures often use similar habitats and food
  - Examples are crickets, true bugs, cockroaches
- Aquatic: dragonflies, mayflies, stoneflies

Hemimetabolous



Hemimetabolous

Hemimetabolous
Does this define a monophyletic taxon?
Is this a homologous trait?
What kind of homologous trait?

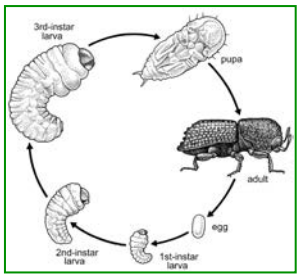


Hemimetabolous nymphs & naiads

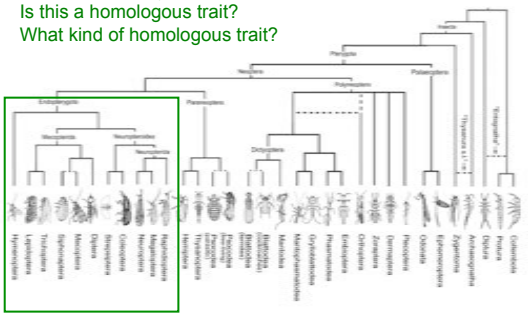
Holometabolous

- Stages
  - Egg, larva, **pupa**, adult
  - Larval stages look very different than adult
  - Larvae often use different habitats and eat different food than adults
- Adult structures found in larvae as 'imaginal disks'
- Endopterygote: wings develop in invaginated pockets of integument
- Bees, wasps, butterflies, beetles, flies, caddisflies.

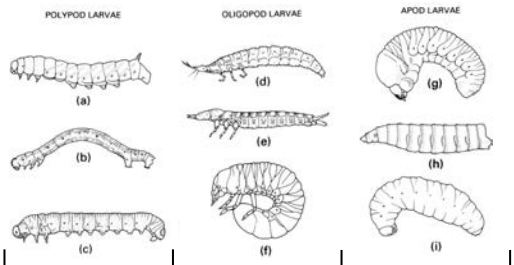
Holometabolous



Holometabolous
Is this a monophyletic trait?
Is this a homologous trait?
What kind of homologous trait?



Larval types

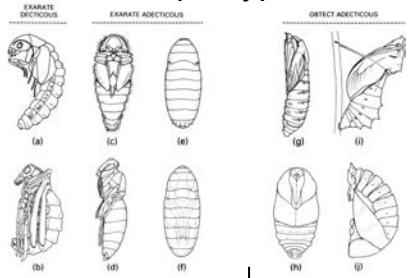


Thoracic legs Abdominal **prolegs** Lepidoptera, sawflies	Thoracic legs No abdominal **prolegs** Prognathous Many orders, predatory beetles	No legs Flies, wasps, some beetles Predators, soil, dung, carrion

Pupa

- Resting stage
- Rearrangement of body into adult form
- Sometimes enclosed in cocoon
- At end, pupa encloses adult

Pupal types



Most pupae	Sclerotized cuticle
Appendages loosely pressed to body	Appendages cemented to body

Ecdysis

Adult

- Wings
- Reproductive organs mature
- May be long lived or may lack mouthparts

Voltinism

- Numbers of generations per year
  - Univoltine
    - One generation per year
    - Tends to occur in colder climates, where season length limits time for completion of life cycle.
  - Bivoltine
    - Two generations per year
  - Multivoltine
    - Multiple generations per year
    - Occurs when enough time exists for completion of multiple reproductive cycles.

Diapause

- Arrested development after physiological change
- Inactive and not feeding
- Can last months or years
- Need 2nd physiological change to break diapause
- Induced or terminated by photoperiod, temperature, food quality, food chemistry
- Types
  - Obligatory: required to complete life cycle regardless of environment, often found in univoltine insects
  - Facultative: Dependent upon environmental conditions.

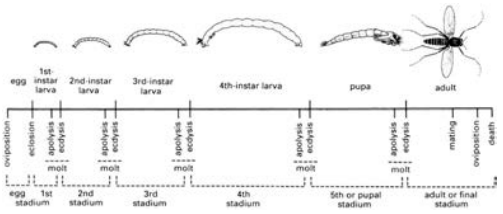
Quiescence

- Halted or slow development during unfavorable conditions
- Activity or slow development during unfavorable conditions.
- Does not involve physiological changes like diapause and is triggered directly by environment (e.g. cool temperature) rather than separate cue
- Difficult sometimes to tell from diapause

Diapause & Quiescence




Diapause can occur in any stage



Evolution of Dispersal

- Principle of allocation
  - Resources are limited
  - Allocation to one trait (e.g. dispersal) reduces other allocation to other traits
  - This generates tradeoffs
- Dispersal has costs and benefits
  - Benefits
    - Ability to leave poor habitats
    - Reduced risk of competition, disease, predation in new habitats
  - Costs
    - Energy required could be invested in egg production
    - Travel time
    - Predation during travel
    - Risk (what kind?)

Salt marsh planthoppers

- Adults polymorphic for wing length
  - Some have reduced hind wings and lay more eggs **(brachypters).**
  - Others have four full wings and can travel long distances **(macropters).**
- Macropter frequency 20-90%
  - Increases under crowded conditions
  - Increases in unpredictable habitats.

Migratory Locusts

- Solitary form
  - Shuns other locusts
  - Large adult with higher fecundity
- Gregarious form
  - Disperses long distances in large groups
  - Induced by crowding and poor habitat

Dispersal: Habitat Differences

- **Crickets & Grasshoppers**
  - Flighted species predominate
    - Pastures, meadows, open areas, trees
  - Flightless species predominate
    - Woodland, beneath stones, caves, in ant and termite nests

Flightlessness

- **Islands**
- Flightlessness often evolves on islands
- Why?
- What kinds of islands?

Flightlessness

- **Large & Cryptic**
- Why be flightless?

Dispersal: Gender Differences

- In which sex would you expect to see flightlessness more often?