Virtual Entomology for Master Naturalists

2. Evolutionary innovations of insects

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8 April 2020
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WHY are insects so diverse and so successful?

Lots of reasons. Let’s think of some.
Some of the reasons for insect success

- Small size
- Rapid evolution
  - Short generation times
  - Large numbers of offspring
- They moved onto land early
- They evolved along with the flowering plants
- They evolved flight
Let's pay attention to three evolutionary innovations:

1. Wings & flight

2. Folding wings

3. Complete metamorphosis
The earliest insects were wingless. Two modern orders lack any evidence of wings.

“APTERYGOTES”

Archaeognatha: bristletails

Thysanura: silverfish
Evolutionary innovation 1: Wings and flight

MOST INSECT GROUPS HAVE WINGS

What's so great about having wings?
Advantages of insect flight

Controlled movement
(vs, for example, Collembola)

Directionality
Distance

Dispersal
Escape
Foraging
Mate location

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How many other times has flight evolved?

Reptiles: Pterosaurs

Birds

Mammals: Bats
Flight requires

- **wings**
  - on the second and third thoracic segments

- **power (flight muscles)**
  - in thorax

- **articulated joints**
  - wings operate as levers on a fulcrum
Early flying insects

These insects could fly, but **they could not fold up their wings**. Trait still found in two modern groups: mayflies (Ephemeroptera) and dragonflies and damselflies (Odonata).

What is a **disadvantage** of this?
Folding wings allows an insect to both fly and hide, burrow, seek shelter.
MOST FLYING INSECTS FOLD THEIR WINGS

Evolutionary innovation 2: Folding wings
Three developmental cycles

1. Ametabolous
   (the wingless insects)
Three developmental cycles

2. Hemimetabolous (external wing devel)

Ametabolous (the wingless insects)
Flying insects may have external wing development

Example: *Leptoglossus*

Wings develop in external pockets and are visible in late-instar nymphs
Flying insects may have external wing development

Example: *Leptoglossus*

This is called: Hemimetabolous or Exopterygote development, “Incomplete” or “gradual” metamorphosis
Hemimetabolous insects

Adults and **nymphs** live in the same habitat, have the same lifestyle.
Example of a hemimetabolous insect: Squash bug, *Anasta tristis*
Order: Hemiptera, Family: Coreidae
Three developmental cycles

1. Ametabolous (the wingless insects)

2. Hemimetabolous (external wing develop)
   - Egg → Nymph → Adult

3. Holometabolous (internal wing develop)
   - Egg → Larva (caterpillar) → Pupa → Adult
   - New developmental stage: PUPA
Evolutionary innovation 3: Internal wing development

WHY IS THIS SO GREAT?

Synonyms:

• Holometabolous
• Endopterygote
• Complete metamorphosis
Example of a holometabolous insect: Japanese beetle, *Popillia japonica*
Order: Coleoptera, Family: Scarabaeidae

- Adults feed on foliage of >300 plants
- Adults produce pheromones, causing aggregations
Example of a holometabolous insect: Japanese beetle, *Popillia japonica*
Order: Coleoptera, Family: Scarabaeidae

- Females burrow into soil to lay eggs on turf
- Larvae (grubs) feed on turf roots, overwinter in soil
- Pupate in soil in spring
Japanese beetle, *Popillia japonica*
Order: Coleoptera, Family: Scarabaeidae
Holometabolous insects (Endopterygote)

- a “complete metamorphosis”
- Larvae and adults are **dramatically** different
Holometabolous development (Endopterygote)

- Why is there an additional life stage, the **pupa**?
Rearranging a butterfly's gut for a diet change

Caterpillar: consumes vegetation (usually)

Butterfly: consumes nectar (usually)
Rearranging a fly's thorax for flight

*Calliphora*, blow fly
Rearranging a moth’s nervous system

*Manduca*

how does a caterpillar move?

how does a moth move?
Rearranging a moth’s nervous system

Brain and ventral nerve cord of larva and adult *Manduca*. Note fusion of ganglia.
Imaginal discs: undifferentiated embryonic tissue
Each life stage has adaptive features (adaptations)
Each life stage has adaptive features... including the pupa
Each life stage has adaptive features ... including the pupa
Each life stage has adaptive features... including the eggs.
The seven largest orders

<table>
<thead>
<tr>
<th>ORDER</th>
<th># families worldwide</th>
<th># species in North America</th>
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<tbody>
<tr>
<td>ODONATA (dragonflies and damselflies)</td>
<td>29</td>
<td>400</td>
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PALEOPTERA

EXTERNAL WING DEVELOPMENT

INTERNAL WING DEVELOPMENT
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The four largest orders are endopterygotes

INTERNAL WING DEVELOPMENT
Let’s take a break