Insect Life Histories and Diversity

Outline

1. There are many kinds of insects
2. Why, how?
3. The Orders

How many species of insects are there?

Insect Diversity

- Distribution spread primarily between 5 orders
  1. Coleoptera (beetles) = 350,000
  2. Lepidoptera (butterflies and moths) = 150,000
  3. Hymenoptera (wasps, ants and bees) = 125,000
  4. Diptera (flies) = 120,000
  5. Hemiptera (bugs etc) = 90,000
There has never been more insect diversity than now

WHY DO INSECTS DOMINATE THE NUMBER OF SPECIES?

Why?

• Insects have been around over 400 million years

Why?

• Their geologic age

**High speciation rates**

• One estimate: Lepidoptera in the last 100 million years added 2-3 species every thousand years

Why is the basis of high rates of speciation?

• High fecundity (many offspring)

• Short generation time (more chances for mutation)

• These combine to produce huge # of individuals, increased range of variation

• = more variation for natural selection

Insects were the first animals to adapt to and diversify on land

First insect fossils

Land becomes habitable

Geologic Time

<table>
<thead>
<tr>
<th>Period</th>
<th>Age</th>
</tr>
</thead>
</table>
| Paleozoic Era | Carboniferous | 350 M.Y.
|               | Devonian   | 420 M.Y.
|               | Silurian   | 440 M.Y.
|               | Ordovician | 485 M.Y.
|               | Cambrian   | 510 M.Y.
|               | Triassic   | 245 M.Y.
|               | Jurassic Period | 210 M.Y.
|               | Cretaceous Period | 150 M.Y.
|               | Tertiary   | 65 M.Y.
| Mesozoic Era  | Cenozoic Era | 540 M.Y.
Combined with low rates of natural extinction

- Fossil evidence that insects were not affected (much) by previous mass extinction events
- Why?

Why?

- Geologic age
- Capacity for high speciation rates
- Low rates of extinction
- Design

DESIGN

- size and life span
- diversity of characteristics of insect cuticle
- flight
- modularity at many levels
- holometabolous larvae

Insect Size

Wide range of insect sizes....

But most are small
Small size

1. Shorter generation time
2. More ecological niches available than to larger animals

Life Span

• Wide variation

Life Span

• Wide variation but most are relatively short

Insect Life Spans

• Takes on diversity of shapes, colors, textures
• A composite material: variations are tough enough to cut hardwood, have high plasticity, delicate enough gases will diffuse through it.
• Different properties found in variations for burrowing, flying, crawling, jumping, climbing, etc.
• Insects were the first animals to fly

Flight
• Faster access to 3d world
• Access to more resources and microhabitats
• New types of specializations (such as aerial predators)

Modularity
• Units that are connected but have a lot of independence in change
  1. Modularity within the body
  2. Modularity within their lives

Modularity is a design strategy. It can offer [software] system simplicity, flexibility, scalability, durability, reusability, and more.

Integrated Modularity
• Multiple units
• A degree of independence (low linkage) between them
• Can be high degree of integration of the units
During the evolution of arthropods, segments have become reduced in number and specialized with some independence from each other.

Note head, abdominal appendages. Modules containing modules.

**Life Histories**

- EGG, LARVA, LARVA..., PUPA, ADULT, EGG, LARVA.....

**MODULES IN A SERIES**

**Life History words to know...**

*Metamorphosis* – a distinct change in form and function between immature stage and the adult

*Ametabolous* – no metamorphosis

*Hemimetabolous* – wings, reproductive organs

*Holometabolous* – virtually all body parts change

*Instar* – Growth stage between two molts.

*Larva (larvae)* – immature holometabolous insect.

*Nymph* – immature hemimetabolous insect.

*Pupa (pupae)* – inactive stage between larva and adult in holometabolous insects.

*Stadium (stadia)* – period between molts.
Hemimetabolous
- larvae have same general body plan as adults
- feed on the same foods
- final molt adds gonads and wings

Holometabolous
- adults and larvae veryyyyy different
- generally live in different environments and eat different diets
- last two molts replace many of larval parts with different adult ones

Each module can evolve independently of others

More differences between modules: larval stages

Different functions

advantages of holometabolous development
- immatures and adults are specialized for different functions: feeding vs. dispersal and reproduction
- immatures and adults don’t compete for resources
- even more specialization of modules (instars) possible
Why?

- Geologic age
- Capacity for high speciation rates
- Low rates of extinction
- Design
  - size and life span
  - diversity of characteristics of insect cuticle
  - flight
  - modularity at many levels
  - holometabolous larvae

Insect Growth and Diversity

- # of instars
- rules of growth

# of immature stages of a few insect orders

<table>
<thead>
<tr>
<th>Metamorphosis</th>
<th>Order</th>
<th>Common name</th>
<th># of stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ametabolous</td>
<td>Thysanura</td>
<td>Silverfish</td>
<td>9-14</td>
</tr>
<tr>
<td>Hemimetabolous</td>
<td>Phthiraptera</td>
<td>Lice</td>
<td>3-4</td>
</tr>
<tr>
<td></td>
<td>Ephemeroptera</td>
<td>Mayflies</td>
<td>20-40</td>
</tr>
<tr>
<td></td>
<td>Blattoidea</td>
<td>Cockroaches</td>
<td>6-10</td>
</tr>
<tr>
<td></td>
<td>Orthoptera</td>
<td>Grasshoppers</td>
<td>5-11</td>
</tr>
<tr>
<td></td>
<td>Hemiptera</td>
<td>True bugs</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>Isoptera</td>
<td>Termites</td>
<td>5-11</td>
</tr>
<tr>
<td>Holometabolous</td>
<td>Diptera</td>
<td>Flies</td>
<td>3-6</td>
</tr>
<tr>
<td></td>
<td>Lepidoptera</td>
<td>Butterflies</td>
<td>5-6</td>
</tr>
<tr>
<td></td>
<td>Coleoptera</td>
<td>Beetles</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>Hymenoptera</td>
<td>Bees, ants</td>
<td>3-6</td>
</tr>
</tbody>
</table>

Growth in stages

- Is growth continuous or in steps? Both
- Plotting leg length gives a stepped increase
- Molt to make a bigger box

Growth in stages

- Regions with soft cuticle have a more continuous growth curve because of cuticular pleating or folding
- Larvae with all soft cuticle increase in size continuously

Growth in stages

- Even in insects with hard cuticle, growth by weight is continuous
- At first the bigger box has extra space
- Tissue growth fills it
Proportional growth: Is there a formula?

Commonly used estimate: **Dyar’s rule**: postmolt/premolt dimension = constant of 1.2-1.4
- This yields a curved line in a size-time graph.
- Interesting history of use, misuse and oversimplification

Dyar

- Looked only at Lepidoptera
- Goal was to determine number of instars
- And resolve conflicting data about instar 
- Listed species and measurements of their larvae
- Concluded instar dimensions increased geometrically (by a certain proportion) at each molt

Dyar’s Law

**Reality**: more complicated, growth depends on many variables, differs widely between species.

A march through the orders...

Diversity organized

Phylogenetic Organization

Archaeognatha, Thysanura
(The Primarily Wingless APERYGOTA)

Insecta includes 3 divisions: Archaeognatha, Thysanura, Pterygota
Archaeognatha = Bristletails
(arkhios=ancient; gnathos=jaw)
Alternate: Microcoryphia=small head
- Metamorphosis = ametabolous
- Key features:
  - Mandible with 1 pivot point
  - Primitively wingless
  - Indirect fertilization

Thysanura = Silverfish
(thysanos=fringe; ura = tail)
- Metamorphosis = ametabolous
- Key features:
  - Mandible with 2 pivot points
  - Primitively wingless
  - Scales
  - Indirect fertilization

Ephemeroptera = Mayflies
(ephemeros = lasting a day, pteron = a wing)
- Metamorphosis = hemimetabolous
- Key features:
  - Aquatic larvae
  - Wings cannot be folded down on back
  - 2! Winged stages
  - Non-functional mouthparts in adults
  - Direct fertilization

Odonata = Dragonflies
(odontos = toothed [of the mandibles])
- Metamorphosis = hemimetabolous
- Key features:
  - Aquatic larvae
  - Wings stick out or up
  - Direct fertilization (males have secondary sexual organs)

PTERYGOTA
"Paleoptera" = old wings
Ephemeroptera, Odonata, and Neoptera

Pterygota comprised of 3 divisions:
Ephemeroptera, Odonata, and Neoptera