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

First insect fossils
Land becomes habitable
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 number of individuals, increased range of variation
• = more variation for natural selection
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
## Insect Life Spans

<table>
<thead>
<tr>
<th>Days</th>
<th>Weeks</th>
<th>Months</th>
<th>Years</th>
<th>Decades</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Apterygota</strong></td>
<td></td>
<td><em>protura/silverfish/springtails</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Odonata</strong></td>
<td></td>
<td><em>damselflies/dragonflies</em></td>
<td></td>
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</tr>
<tr>
<td><strong>Ephemeroptera</strong></td>
<td><em>mayflies</em></td>
<td><em>grasshoppers/katydid/focustis</em></td>
<td></td>
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</tr>
<tr>
<td><strong>Orthoptera</strong></td>
<td><em>worker termites</em></td>
<td></td>
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<tr>
<td><strong>Isoptera</strong></td>
<td><em>plant bugs</em></td>
<td><em>stink bugs</em></td>
<td><em>assassin bugs</em></td>
<td><em>queen termites</em></td>
</tr>
<tr>
<td><strong>Hemiptera</strong></td>
<td><em>aphids</em></td>
<td><em>cicadas</em></td>
<td><em>leafhoppers</em></td>
<td></td>
</tr>
<tr>
<td><strong>Homoptera</strong></td>
<td><em>ladybird beetles</em></td>
<td><em>weevils</em></td>
<td><em>Tribolium/scarabs</em></td>
<td></td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td><em>midges/gnats</em></td>
<td><em>mosquitoes</em></td>
<td><em>fruit flies</em></td>
<td><em>tsetse flies</em></td>
</tr>
<tr>
<td><strong>Diptera</strong></td>
<td><em>stored grain moths</em></td>
<td><em>Colias butterflies</em></td>
<td><em>Heliconius butterflies</em></td>
<td></td>
</tr>
<tr>
<td><strong>Lepidoptera</strong></td>
<td><em>parasitoid wasps</em></td>
<td><em>worker bees/ants</em></td>
<td><em>stingless bees</em></td>
<td><em>queen bees/vasps</em></td>
</tr>
<tr>
<td><strong>Hymenoptera</strong></td>
<td><em>jumping spiders</em></td>
<td><em>wolf spiders</em></td>
<td><em>tarantulas</em></td>
<td><em>queen ants</em></td>
</tr>
<tr>
<td><strong>Araneida</strong></td>
<td><em>spider mites</em></td>
<td><em>predaceous mites</em></td>
<td><em>hard ticks</em></td>
<td><em>soft ticks</em></td>
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<tr>
<td><strong>Acari</strong></td>
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</tr>
</tbody>
</table>
Life Span

• Wide variation **but** most are relatively short
insect cuticle

• 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.
Flight
• 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
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...
serial modularity
Life History words to know...

**Metamorphosis** – a distinct change in form and or 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.
Ametabolous
Hemi-metabolous

- 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

**Fig. 11.**—Three larval stages of a meloid beetle, *Mylabris variabilis* Pall. (from Paoli, 1938).

A, first instar, planidium. B, same, more enlarged. C, second instar. D, fourth instar, similar to third and fifth instars.
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>Blattodea</td>
<td>Cockroaches</td>
<td>6-10</td>
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<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.

![Graph showing growth stages of terrestrial insects.](image)
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.

Over all, holometabolous insects grow more each instar than hemimetabolous insects.
A march through the orders...

Diversity organized
Phylogenetic Organization
Archaeognatha, Thysanura
(The Primitively Wingless APTERYGOTA)
Archaeognatha = Bristletails

(arkhios=ancient; gnathos=jaw)

Alternate: Microcoryphia=small head

- Metamorphosis = ametabolous
- Key features:
  - Mandible with 1 pivot point
  - Primitively wingless
  - Indirect fertilization
condyle
acetabulum
(naiad)
Orthoptera
ARCHAEOGNATHA
ZYGOMYTA
EPHEMEROPTERA
winged insects
METAPTERYGOTA
Thysanura = Silverfish
\( (thysanos = \text{fringe}; \ ura = \text{tail}) \)

- Metamorphosis = ametabolous
- Key features:
  - Mandible with 2 pivot points
  - Primitively wingless
  - Scales
  - Indirect fertilization
PTERYGOTA

"Paleoptera" = old wings

Ephemeroptera and Odonata

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