Fossil Variability

Living things and their fossil remains vary due to:

- Variation within individual’s lifetime (Ontogeny)
- Population Variation (Biology)
- Fossil Assemblage Variation (Geology)
Ontogenetic Variability

- **Examples:**
  - Humans
  - Insects
  - Protista

- **Ontogenetic variability** in fossil assemblages

- **Ontogenetic bias** in fossil assemblages - one stage preserved?

Butterfly Life Cycle
Ontogeny in Fossils

Need to accommodate soft part growth

➤ Skeletal Growth (Endo- and Exoskeletons)
  - Accretion
    - Tree Rings
    - Growth bands in mollusks (note Wells, 1960 p.23)
    - Growth bands in dinoflagellates
  - Addition of Parts
  - Molting
  - Modification
Tree rings

Accretion

Shell Growth Bands

Growth Bands In Dinoflagellates

Before growth

After Growth
Ontogeny in Fossils

- **Skeletal Growth**
  - Addition of parts
    - Forams and Cephalopods
    - Echinoderms
    - Trilobites
  - Disadvantage of Accretion and Addition:
    need to incorporate juvenile skeleton in adult

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Chambered Nautilus - Cephalopod
Foraminifera

Echinoderms

Origin of Plates

See also Fig. 2.5 p. 24 text
Ontogeny in Fossils

- **Skeletal Growth**
  - Molting
    - Snakes
    - Trilobites and other arthropods
  - Rapid Growth between skeletons
  - Detection in the fossil record
    - "hash"
    - See p. 25 text - quantification
  - Advantage of abandoning juvenile form
  - Disadvantage of perilous period between molts

Trilobites – Molting with Additions

*Figure 5:3*
Four stages in ontogeny of the trilobite Paradoxides. Ontogeny is accompanied by radical changes in the forms of existing parts and by the addition of new parts.
(From Whittington, 1971)
Ontogeny in Fossils

- **Skeletal Growth**
  - Modification
    - Humans and other mammals
    - Convolutions – corals, lungs
    - Add chambers and/or individuals – sponges, bryozoans
    - Complex ontogeny of colonial animals generally
  - Principle of Similitude - Quantification
  - Advantage of independence from juvenile forms without perilous period in growth

Modification with Growth

Modification using convolutions
Growth by addition of chambers and individuals

Principle of Similitude

“In short, it often happens that of the forces in action in a system some vary as one power and some as another, of the masses, distances or other magnitudes involved; the 'dimensions' remain the same in our equations of equilibrium, but the relative values alter with the scale. This is known as the 'Principle of Similitude', or of dynamical similarity, and it and its consequences are of great importance. “ D’Arcy Wentworth Thompson (1917) (see p. 27 text)
Quantification of Growth

- Isometric growth, \( y = mx + b \), salamanders

- Allometric growth, \( y = mx^n \)
  - Volume increase vs. cross-sectional area (allows for large limbs for support of large individual)
  - Volume vs. surface area (for dissipation of heat)

- Multivariate analysis

The Problem of Similitude in Terrestrial Vertebrates

- Doubling of linear dimensions produces an eight-fold increase in volume or weight. \( V = L^3 \)
- Doubling length of leg bones increases cross-sectional area by only 4 times. \( X = L^2 \)
- Leg cannot support weight unless it changes shape.
Example of Results of Similitude

Pelycosaurian Reptile femurs
Femur on the left is actually 4 times longer than one on the right

Does Ontogeny Recapitulate Phylogeny?

See Figure 2.2, p. 22
Ontogeny: Changes in form during the embryonic stages and lifetime of an individual.

Phylogeny: Evolutionary development of any plant or animal species.

Ontogeny Recapitulates Phylogeny

**Pro**
- Similarities in embryos of certain vertebrates
- Beginnings as a single cell
- Features of more primitive ancestors in embryos
- Sequence often same as phylogenetic history (worm before arthropod)

**Con**
- “The lie”
- Juvenile stages only
- Cellular specializations
- Fetal specializations
- Sequencing sometimes wrong

Support for Evolution?
Heterochrony and Evolution

- Heterochrony: “different time” changes in the timing and rate of development within a species or evolutionary line.
- Paedomorphosis: sexual maturity at a juvenile stage.
- Peramorphosis: sexual maturity at a late adult stage.
- How does this relate to a means for evolution?

Aspects of Heterochrony

<table>
<thead>
<tr>
<th>Paedomorphosis</th>
<th>Onset of growth</th>
<th>Sexual maturation</th>
<th>Rate of morphological development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progenesis</td>
<td>—</td>
<td>early</td>
<td>—</td>
</tr>
<tr>
<td>Neoteny</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Post-displacement</td>
<td>delayed</td>
<td>—</td>
<td>reduced</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Peramorphosis</th>
<th>Onset of growth</th>
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<th>Rate of morphological development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypermorphosis</td>
<td>—</td>
<td>delayed</td>
<td>—</td>
</tr>
<tr>
<td>Acceleration</td>
<td>—</td>
<td>—</td>
<td>increased</td>
</tr>
<tr>
<td>Pre-displacement</td>
<td>early</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
Examples of Heterochrony in Fossil Evolution

- Mesozoic ammonites
- Graptolite lineages
- Origin of the Hexacorals from the Tetracorals
- Cenozoic brachiopods
- Triassic rynchosaurs
Population Variability

- Population = species or other related group (sub-species, variety, race), “local breeding population” or deme
- Ontogenetic variability
- Typology
- Genetic differences in populations
- Sexual dimorphism
- Ecophenotypic variation
Ontogenetic Differences in Populations

- Young and old forms found together making description complicated.
- Season of year may influence population.
- Different life stages (sexual or asexual, metamorphosis) occur in populations.

Typology

- Ideal version of a species is God’s original and all individuals are imperfect copies, hence variable.
- Legacy – The “type specimen” and “type species” of modern taxonomy
Populations as Species - Genetics

- Darwin – natural variations in species, pre-genetics.

- In any interbreeding population there are genetic variations that give rise to differences in morphology of individuals.

- Population seen as species.

Genetic Variations

- Sexual Dimorphism (text p. 33-34)

- Some characters are more variable than others – survival?

- Discontinuous or Continuous variations
  - Coiling direction in forams and gastropods
  - Size at the same stage of growth
Sexual Dimorphism

Genetic Variation in Humans
Ecophenotypic Variations

- Ecophenotypic change: change in the phenotype during an organism's lifetime, induced by local environmental changes, but not coded in the genotype.
- Population varies according to factors in paleoenvironment
- Examples
  - Corals (p. 32, text) and other reef builders
  - Dinoflagellates

Genetic? Variation in Forams
### Growth Forms of Reef Building Organisms

<table>
<thead>
<tr>
<th>Growth Form</th>
<th>ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delicate branching</td>
<td>Wave energy: Low, Sedimentation: High</td>
</tr>
<tr>
<td>Thin, delicate, plate-like</td>
<td>Wave energy: Low, Sedimentation: Low</td>
</tr>
<tr>
<td>Globose, bulbose, columnar</td>
<td>Wave energy: Moderate, Sedimentation: High</td>
</tr>
<tr>
<td>Robust, dendroid branching</td>
<td>Wave energy: Moderate/high, Sedimentation: Moderate</td>
</tr>
<tr>
<td>Hemispherical, domal, massive</td>
<td>Wave energy: Moderate/high, Sedimentation: Low</td>
</tr>
<tr>
<td>Encrusting</td>
<td>Wave energy: Intense, Sedimentation: Low</td>
</tr>
<tr>
<td>Tabular, laminar</td>
<td>Wave energy: Moderate, Sedimentation: Low</td>
</tr>
</tbody>
</table>

**Dinoflagellate Cysts – Ecophenotypic variation?**

- **Deep Water Environment**
- **Shallow Water**
Fossil Assemblage Variability

- Taphonomic effect – post-mortem distortion
- Selective sorting by transport
- Transport to unnatural environments
- Selection by delicate vs. robust shells or bones – juvenile bones v. adults
- Selective dissolution by rock fluids, groundwater – aragonite v. calcite
- Resedimentation – Paleocene dinosaurs

Distorted Ammonites
Distorted Oreodont

Right and left valves

<table>
<thead>
<tr>
<th>Locality</th>
<th>Total Number</th>
<th>Percent right valves</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
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</tr>
<tr>
<td>2</td>
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</tr>
<tr>
<td>8</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>
Pollen, wood and marine algae and dinoflagellates