Evolution and Classification

What were Darwin and the other thinkers of his day trying to explain?
- How did the great diversity of plants and animals arise?
- Where does the obvious design in nature come from?
- What process explains the patterns in the way life appears to be organized?
- How do we classify biological systems?

**Aristotle's Scala Naturae: "Great Chain of Being"**
Believed in linear arrangement of animate and inanimate objects, based on their relative "perfection". The lowest life forms were most similar to earth, whereas the most perfect were humans, of course. Coming from the ideas of Plato, each object was a reflection of some immutable "ideal" or "essence".
This was a **static hierarchy**: did not change or develop through time.

**Lamarck: 1790's**: First widely recognized evolutionary theory
- **Spontaneous generation** of organisms through history
- **Organic Flux**: use/disuse of parts caused transformation, beings moved up ladder
- **Inheritance of acquired characteristics**
- **No extinction** - would create gaps in the "ladder"

**Cuvier: 1790's**: Also at National Museum of Natural History, Paris
- **No organic flux**: Species were real, stable, exquisitely functioning machines
- **Catastrophism**: Species became extinct due to dramatic environmental change
- **Life is bushy, not linear**: Comparative anatomy revealed nested sets of designs

**Big dichotomies between extinction/evolution and bushy/linear organization**

**Charles Darwin (1809-1882)**
- Sailed on Beagle from 1831 to 1836 as male companion of the captain. Primary training was in geology. Figured out his theories by 1838, but didn’t publish until 1859.
Darwin's theory of evolution included extinction, excluded the chain, and offered a mechanism completely based on the material world - no role for a deity.

Darwin's argument had two parts
PART ONE - EVOLUTION/COMMON DESCENT
  1) The only observable process connecting organisms through time is parent-offspring or, over longer time, ancestor-descendent.
  2) Darwin proposed that all organisms are connected through time by parent-to-offspring or ancestor-to-descendent ties.
  3) If so, and if there are different types of organisms at different times (as shown by the fossil record, then they must transform into one another. They must evolve.

What are the alternatives:
  Scientific alternative: spontaneous generation of new forms throughout earth history
  Disproved by Pasteur in the early 19th century.
  Mystical alternative: creation by deity.

What evolution explains that creation does not.
Homology: Owen (1848) noted that body parts in different organisms that have a similar structure, similar relationships to other organs, and similar development. Need not serve the same function. Owen thought this reflected creation following created following a common plan or archetype. Darwin's explanation was descent from a common ancestor with independent modification in different descendants.

Vestigial Structures: Structures that are functionless in a species but homologous to a functioning structure in other species.

Embryology
Organisms start similar as embryos but diverge as they mature. Adults adapt to environment; embryos do not. Embryonic similarity is evidence of shared ancestry.

Geographic Distribution
Different types of organisms filling the same ecological roles on different continents. Evidence that fauna were derived from different common ancestors.
The Fossil Record
Predicted intermediates between modern forms do exist in fossil record.

Classification/Nested Hierarchy
Why do organisms seem to form nested sets of increasing similarity. A reflection of the tree of life.

PART TWO - NATURAL SELECTION
Natural selection is the mechanism Darwin proposed to explain why evolution occurs. It is logically independent from the evidence presented above for the occurrence of evolution.

Theory of Natural Selection
If a population has
a) variation among individuals for some attribute or trait: VARIATION
b) a consistent relationship between variation in this trait and mating ability, fertility, fecundity and/or survivorship: FITNESS DIFFERENCES
c) a consistent relationship, for that trait, between parents and offspring: INHERITANCE

then
1) different age groups in the population may have different mean values for the trait
2) if not in equilibrium, the frequency of the trait will change and even transcend the original variation in population: EVOLUTION

Problems and Modifications since 1859
Greatest weakness of Natural Selection in 19th century related to Inheritance
Darwin and contemporaries believed in blending inheritance. Natural selection doesn't work with blending inheritance. Too much dilution of favorable variants.
Basis of Inheritance and Variation

Inheritance
Gregor Mendel showed through experiments inheritance was **particulate, not blending.**
**Genes** - hereditary particles passed from parent to offspring, one set from each parent.

It was later discovered that genetic material occurs on **Chromosomes**, packets of **DNA** and **protein**, located within the nuclei of cells. One set of chromosomes from each parent. Genes correspond to segments of DNA.

Variation
Produced by **Mutation**, random changes in DNA or chromosomal order. Must occur in sex cells to be inherited.

The mathematics and logic of particulate inheritance and natural selection were worked out by the 1930s. Yet many paleontologists and scientists studying the relationships of animals and plants ignored this genetic work. Many accepted internally driven models of evolution or Lamarckian models.

**Modern Synthesis**: In early 1940s, a series of seminal books and papers fused genetics into paleontology, population biology, and the study of relationships. Broad agreement was reached within biologic community that evolution was caused by **natural selection on individuals within populations**, which sorts genetic information to produce change between generations. Major gap in synthesis was the failure to integrate developmental biology.
"Design" in Nature
Adaptation: the precise matching between an organism, its functions, and its environment.

William Paley (1743-1805) - *Natural Theology, or Evidences of the Existence and Attributes of the Deity collected from the Appearances of Nature* (1802)

“In crossing a heath, suppose I pitched my foot against a stone, and were asked how the stone came to be there; I might possibly answer, that, for anything I knew to the contrary, it had lain there forever: nor would it perhaps be very easy to show the absurdity of this answer. But suppose I had found a watch upon the ground, and it should be inquired how the watch happened to be in that place; I should hardly think of the answer I had before given, that for anything I knew, the watch might have always been there. (...) There must have existed, at some time, and at some place or other, an artificer or artificers, who formed [the watch] for the purpose which we find it actually to answer; who comprehended its construction, and designed its use. (...) Every indication of contrivance, every manifestation of design, which existed in the watch, exists in the works of nature; with the difference, on the side of nature, of being greater or more, and that in a degree which exceeds all computation.”

William Buckland (1836) Bridgewater Treatise

Buckland argued that the superb design of ancient organisms proved the constant superintendence of a loving deity rather than a natural process of increasing excellence, from initial crudity to current complexity. According to Buckland, superb design of giant Mesozoic reptiles "shows that even in those distant eras, the same care of the common Creator, which we witness in the mechanism of our own bodies . . . was extended to the structure of creatures, that at first sight seem made up only of monstrosities." He then inferred God's direct benevolence from the excellent adaptation of the teeth of Iguanodon to a herbivorous lifestyle: we cannot "view such examples of mechanical contrivance, united with so much economy of expenditure . . . without feeling a profound conviction that all this adjustment has resulted from design and high intelligence." (Gould 1998)
How are adaptations explained by evolution by natural selection?
Not through design by creator.
Not through single mutation. This is infinitely improbable. Most big mutations are bad.
Through series of small, intermediate steps. Emphasis on gradual transformation.

If individuals with small morphological or biochemical differences have subtle differences in ability to reproduce or survive, these differences will be preserved through time and build up into ever more complex structures. Just need a large amount of time. Chief evidence for this argument is not perfection of design, but the fact that organisms are designed poorly. Natural selection doesn't make perfect structures. It makes the cheapest possible structures using available designs and materials that fulfill the minimum requirements for functioning. Can lead to highly designed structures if the function is difficult and there is some advantage to having an improved structure.

Classification

Naming conventions (which we will not follow!!):

Linnean System
Kingdom
Phylum
Class
Order
Family
Genus
species

Phylogenetic or Evolutionary Trees
These diagrams show the branching relationships that connect a group of organisms plotted against time. They show the sequence of ancestors turning into descendents. In essence, they are pictures of chunks of the tree of life.

Cladograms
These are simple branching diagrams that show the relative closeness of relationship among a set of organisms. A cladogram presents a hypothesis about how groups of organisms are related to one another. They make no claims about one animal being ancestral to another.
How do you read a cladogram?
First, note that the Y-axis is not absolute time.
At the end of each line (branch) is an organism (living or extinct).
Branch points (or nodes) represent “hypothetical” ancestors of all organisms higher on the cladogram.
If you have an animal, and who want to know which of two other animals is more closely related to it, just see which animal shares a closer node (i.e., a closer common ancestor).
Cladograms can rotate around nodes (don't need to be read left to right).

**Polytomy** - many branches coming from a node. Don't understand relationships.

A **Clade** is a group of organisms including an ancestor and all of its descendents. Sometimes, I will indicate the name of the clade at the top of the cladogram. Sometimes, I will indicate the appearance of a trait clade by putting a tick on a branch. Sometimes, I will put the name of the group at the top of the cladogram, sometimes at the node.

**Clades are diagnosed by:**

**Shared Novelties**: characters that are "new" or derived in an evolutionary sense and are shared by all members of the group.

**Clades are not diagnosed by:**

**Distinctive or Unique Features**: traits that arise on a branch leading to an organism after the split with a last common ancestor. They are new characters, but they aren't shared, so they don't provide information about relationships.

**Shared Primitive Features**: old traits that are shared by all members of a group. They are shared but not new, and therefore are not useful in mapping relationships within the group.
Types of Groups:
**Monophyletic** group - an ancestor and all its descendents
**Paraphyletic** group - an ancestor and some, but not all descendents
**Polyphyletic** group - a group that does not share a common ancestor

How are cladograms constructed?
- Huge question - huge field: How do we reconstruct relationships?
- Identify taxa to be studied
- Record characters
- Construct cladogram with the greatest amount of **Parsimony**
  (fewest evolutionary events)