The Lead-up to *On the Origin of Species*

Epigenesis vs. Preformationism

- Close historical and conceptual relation between formation of species and development of individual organisms
- Two competing perspectives:
  - Epigenesis: mechanical causal processes putting together life forms
    - Challenge—inconceivability of making complex forms in this way
  - Preformationism: All organisms preformed in the initial creation
    - Development consisted of the growth of the *seed* into the organism
    - Theorists differed over where the seed existed—female egg, male sperm, in the soil

Species and classification

- History of classification systems, usually focused on practical objectives (plants as medicines)
- The 17th and 18th centuries were a period of exploration, with explorers bringing back to Europe many specimens of life found elsewhere
- Need to organize these
- The Swede Karl von Linné (Linnaeus: 1707-1778) was himself an explorer and sought to develop a *natural* system of classification

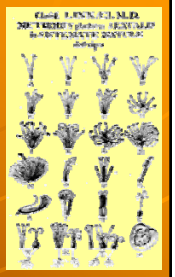
Linnaeus' task

- How to define what a species is (*i.e. a* theoretical "species concept")
- How to show the relationships between species
- How to develop a *method* of classifying any given specimen

- Essentialism—each species has an essence, set down in the type specimen
- Species are separately created
- Each species has a place in the *economy of nature*

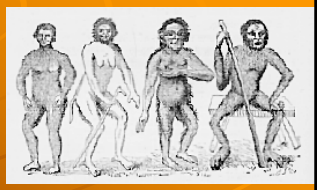
Hierarchical Classification

- Extended the species-genera relationship to higher levels: genus, order, family, kingdom
- Tried to create a rational basis for identifying similarities
  - in plants, used sex organs (number & arrangements of pistils, stamens) as the major basis for grouping
  - Not always perfect:
    - grouped conifers such as pines, firs, and cypresses as well as a few true flowering plants, such as the castor bean, in the Class Monoecia (separate male and female "flowers" on the same plant), Order Monadelphia (multiple male organs joined onto one common base)
    - grouped algae, lichens, fungi, mosses and other bryophytes, and ferns together as plants that lacked obvious sex organs in the Class Cryptogamia, or "plants with a hidden marriage."



Classifying humans

- Anthropomorpha:
  - Races as varieties or sub-species



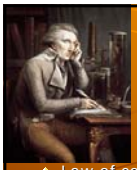
- Species could undergo trans*formations* (but not trans*mutations*) by:
  - Hybridization
  - selection
  - (these could act separately or together)
- Could generate *varieties*, "*races*" or subspecies, *but not new species (essences)*

William Paley (1743-1805)

- "In order to pass the B.A. examination, it was, also, necessary to get up Paley's *Evidences of Christianity*, and his *Moral Philosophy*. . . The logic of this book and as I may add of his *Natural Theology* gave me as much delight as did Euclid. The careful study of these works, without attempting to learn any part by rote, was the only part of the Academical Course which, as I then felt and as I still believe, was of the least use to me in the education of my mind. I did not at that time trouble myself about Paley's premises; and taking these on trust I was charmed and convinced of the long line of argumentation." Charles Darwin. *Autobiography*

Watchmaker Argument

- "when we come to inspect the watch, we perceive. . . that its several parts are framed and put together for a purpose, e.g. that they are so formed and adjusted as to produce motion, and that motion so regulated as to point out the hour of the day; that if the different parts had been differently shaped from what they are, or placed after any other manner or in any other order than that in which they are placed, either no motion at all would have been carried on in the machine, or none which would have answered the use that is now served by it. . . . the inference we think is inevitable, that the watch must have had a maker -- that there must have existed, at some time and at some place or other, an artificer or artificers who formed it for the purpose which we find it actually to answer, who comprehended its construction and designed its use.
- "Every observation which was made in our first chapter concerning the watch may be repeated with strict propriety concerning the eye, concerning animals, concerning plants, concerning, indeed, all the organized parts of the works of nature."



George Cuvier (1769-1832)

- Focus on the similarities between species
- Divided the animal kingdom into vertebrates, mollusks, articulates, and radiates
- Law of coordination
  - an animal with sharp talons for catching living prey (cats) also has
    - sharp teeth, adapted for tearing up the flesh of its victim
    - a particular type of stomach, quite different from that of herbivorous creatures
- Observed succession of fossil forms, which he attributed to repeated catastrophes, followed by new divine creation
- The creator established a few basic bauplans, which were then modified for specific functions: radiata (starfish, jellyfish), articulata (worms, insects), mollusca (snails, octopus), and vertebrata

"Give me one bone, and I can reconstruct the entire organism"

- "Every organized individual forms an entire system of its own, all the parts of which naturally correspond, and concur to produce a certain definite purpose, by reciprocal reaction, or by combining towards the same end. Hence none of these separate parts can change their forms without a corresponding change in the other parts of the same animal, and consequently each of these parts, taken separately, indicates all the other parts to which it has belonged."
- Corollary: forms intermediate between species would not be viable—and hence transmutation not possible

Proponents of Transmutation

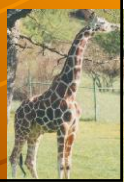
- George Louis Leclerc, Comte de Buffon (1707-1789) proposed species transmutation could occur via degeneration
  - Migration & climate
  - Hybridization
  - All animal and plant life, including human degenerated in America!
  - Age of the Earth at least 75,000 years (based on cooling of iron)
- Geoffroy St. Hilaire (1772-1844)
  - All vertebrates from a common origin
  - Different organs might be variants of a common structure
  - Debated Cuvier (whom he had brought to Paris!) at the French Academy 8 times in 1830 as to which is primary—function (Cuvier) or form (Geoffroy)

Erasmus Darwin

- A respected physician, a well known poet, philosopher, botanist, and naturalist as well as grandfather of Charles Darwin
- *Zoonomia, or, The Laws of Organic Life* (1794-1796).
- Although did not develop natural selection, did seem to have a version of sexual selection: "The final course of this contest among males seems to be, that the strongest and most active animal should propagate the species which should thus be improved".
- Process of transmutation: wants and desires ("lust, hunger, and danger") result in habits, which are then inherited

Jean Baptiste Monet, Chevalier de Lamarck (1744-1829)

- While working at the Paris Museum of Natural History, found it difficult to differentiate species from mere varieties
- In *Philosophie Zoologique* (1809) proposed a mechanism for improvement of species
  - Animal seeks to improve some characteristic
  - Changes it makes in its lifetime passed to offspring
  - Inheritance of effects of use and disuse
  - Giraffe: brought to France from Africa during Napoleonic campaigns of 1798-1799
    - Striving to eat from branches stretched neck
    - Physiological fluids from neck change germ plasm
    - Changed germ plasm passed to offspring



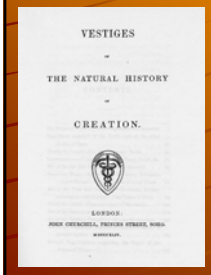
Species progression

- Species gradually change into improved species
- They why are there still "lower" species?
  - Spontaneous generation
- Although a foremost naturalist, he quickly fell from creditability:
  - The Church condemned his writings as "atheistic", as God had no explicitly stated role
  - Opposed by naturalists for proposing a mechanism of transformation with no empirical support
  - Idea of organisms "striving for perfection" rejected as ludicrous
  - Became associated with "inheritance of acquired characters" and ridiculed for giraffe example

Richard Owen

- Situated at the Hunterian Museum of Comparative Anatomy in London
- Set out to resolve the controversy between Cuvier and Geoffroy
- Posited archetypal vertebrate to explain both the resemblance between different species and their differences
- Introduced the distinction between homology and analogy
  - Homology: same parts due to common archetype
  - Analogy: similarity due to conditions of existence

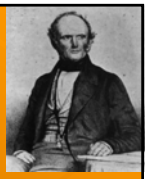
Vestiges of the Natural History of Creation (1844)


VESTIGES
OF
THE NATURAL HISTORY
OF
CREATION.

LONDON:

- Published anonymously by Robert Chambers, whose family owned *Chambers Encyclopedia*
- Proposed sequence of geological epochs punctuated by catastrophes
- A few species survived and radiated out to form many new groups in the next epoch
- Roundly condemned, including by Darwin

Charles Lyell



- In geology, advocated uniformitarian principle—there were no causes in the past that are different from those operative today
- Darwin took the first volume of Lyell's *Principles of Geology* with him on the Beagle.
- Not just rocks—records of introduction and extinction of species, which also must be explained in terms of causes still operating

Charles Darwin

- Darwin born into upper middle class
- Left medical school since he couldn't stand blood
- Became interested in biology and went on field trips in Scotland, where he became impressed with the power of geological forces to shape terrain
- Went to Cambridge to become a country parson, but instead became interested in botany and natural history
- Graduated in 1831 with "Poor Degree"

The Beagle

- Set sail on December 26, 1831 as companion to Captain Fitzroy
- Purpose: to obtain information on
  - Weather, ocean currents, ocean depths, especially around east and west coasts of South America
  - Gather military and commercial information as to who is trading where, especially the French, who were making moves into South America

Variation and adaptation

- Two forms of iguana
  - Land
  - Marine—the only sea-going lizard in the world
- Obvious related but occupy different niches

On the other hand, Darwin noted that similar niches in different locations occupied by different species: the rhea of South America, the African ostrich, the emu of Australia, and the cassowary of New Guinea and Australia

Galapagos: Finches

- All the island species were similar to the ***one*** species found on the mainland
- Major specializations were observed in beak shape and size: Large, medium and small seed and insect-eaters, cactus eaters, Tree-dwelling and ground-dwelling finches
- Pattern true not just of finches: giant tortoises, lizards, mockingbirds
- Some species lacking altogether: only one species of mammals and no frogs

Transmutation of species

- The closer an island was to the nearest mainland, the more the island fauna and flora resembled the mainland forms
- The closer two islands were in an archipelago, the more similar the fauna and flora
- Darwin wondered:
  - Could island forms have established themselves as offshoots of mainland forms?
  - Could their *similarities* and *differences* be the result of divergence from a common ancestor?
- Beagle returned to Britain in October 1836
- In early 1837 Darwin began his *Notebook on the transmutation of species* (second edition in 1845 entitled *Voyage of the Beagle*)

Transmutation Notebooks

- Descent with modification
- Notion of divergence from a common ancestor
- Variation within domestic varieties
- Variation within natural species
- Patterns of geographic distribution

Transmutation: Puzzles and Answers

- Why homology?
  - Adaptations that modify the same inherited body plan
- Why vestigial organs?
  - Parts once common to a whole group not used in current organisms
- Why distinct patterns of geographic distribution?
  - Result of migration and adaptation to new localities
- Why do similar types of animals have similar behaviors? (Humans, dogs, horses "yawn", but lizards and birds do not)
  - Common ancestry
- Why do older fossils differ more from modern forms than younger fossils?
  - diverged from common ancestor much longer ago than newer fossils
- Similarity of early embryos, divergence of older
  - share common ancestral developmental pathways

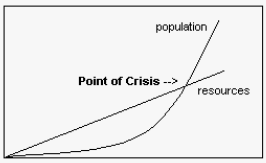
In search of a mechanism

- What is Darwin lacking?
  - A mechanism—no understanding of how these patterns arose
- September 1838: *for amusement* Darwin read the *Essay on Population* (1798) by Rev. Thomas Robert Malthus (1766-1834)

- Malthus, along with Adam Smith and others interested in political economy, sought to discover the *laws of society*

Malthus' laws of population

- Law 1: Food Supply grows *arithmetically*: 2, 4, 6, 8, 10, 12 . . .
- Law 2: Population tends to grow *geometrically*: 2, 4, 8, 16, 32, 64, 128 . . .
- 1st consequence: Populations always tend to outrun food supplies
- 2nd consequence: More offspring born than can survive
- 3rd consequent: There will always be competition for food (and other) resources



Malthus' Basic Theory

The Futility of Fighting the Laws of Population

"I can see no way by which man can escape from the weight of this law which pervades all animated nature. No fancied equality, no agrarian regulations, in their utmost extent, could remove the pressure of it [population] for a single century. To remove the wants of the lower classes of society . . . No human ingenuity can reach it. Were I to propose a palliative . . . It should be the total abolition of all the present [forms of charity]. To prevent the recurrence of misery is, alas! beyond the power of man."

From competition to selection

- Overproduction means only some will survive
- That doesn't yet imply selection
  - Survival might only depend on luck, chance, etc.
  - Must add that survival depends upon the organism's *abilities to deal with the demands of competition*
  - Also, that there is *variability* among the competitors
  - And that this variability is *heritable*—offspring will possess those very traits that improved the parents' ability to deal with environment demands
- Evolution by natural selection requires heritable variation in fitness