

# Definition of Life

**Organization or Order** Cell structures formed from specific molecular patterns.

Necessary but not sufficient

**Homeostasis** Regulates its internal environment to maintain a stable, constant condition.

Necessary but not sufficient

**Growth and Development** Directed by heredity. Organism increases in size of its parts, doesn't just accumulate mass.

Necessary but not sufficient

**Reproduction** Cells divide both to make new organisms and new cells for growth.

Some living organisms can't reproduce – mules. Necessary but not sufficient

Other entities, like viruses and prions, don't reproduce by themselves.

**Metabolism or Energy Utilization** To create and maintain patterns of order, to reproduce, and to grow. Energy used to counter the increasing disorder mandated by the second law of thermodynamics.

Necessary but not sufficient

**Response to Environment or Stimuli** Capable of responding to environmental changes or stimuli (touch, light, sound), involving active responses such as motion.

Necessary but not sufficient

**Evolutionary Adaptation** Permanent changes carried by heredity to evolutionary pressures, resulting in positive adaptations and entirely new species.

Sufficient

# *Evolution of Evolution*

- Anaximander (Greek, 610-547 BC) – simple life originally arose in water and gradually evolved to more complex forms.
- Empedocles (492-432 BC) – suggested creatures poorly adapted to their environment would perish, foreshadowing adaptation.
- Aristotle – maintained that species are fixed and non-evolving. Eventually became view adopted by the Church and fundamentalists.
- Jean Lamarck (1809) – fossils represent extinct ancestors of living species.
  - Organisms possess a built-in drive for perfection
  - Organisms can adapt to circumstances
  - Simple organisms spontaneously created, evolve to greater complexity
  - Organisms inherit characteristics acquired by ancestors
- Charles Darwin and Alfred Wallace (1850) – Supplied evidence for evolutionary changes and put forth a model of how evolution occurs (natural selection).
  - Any population has the potential to overproduce itself, leading to scarcity of resources, and competition for survival.
  - Individuals within a population vary in many heritable traits, some of which make them more competitive.
  - These lead inescapably to unequal reproductive success among individuals, the population ultimately becoming progressively populated by the more competitive individuals.

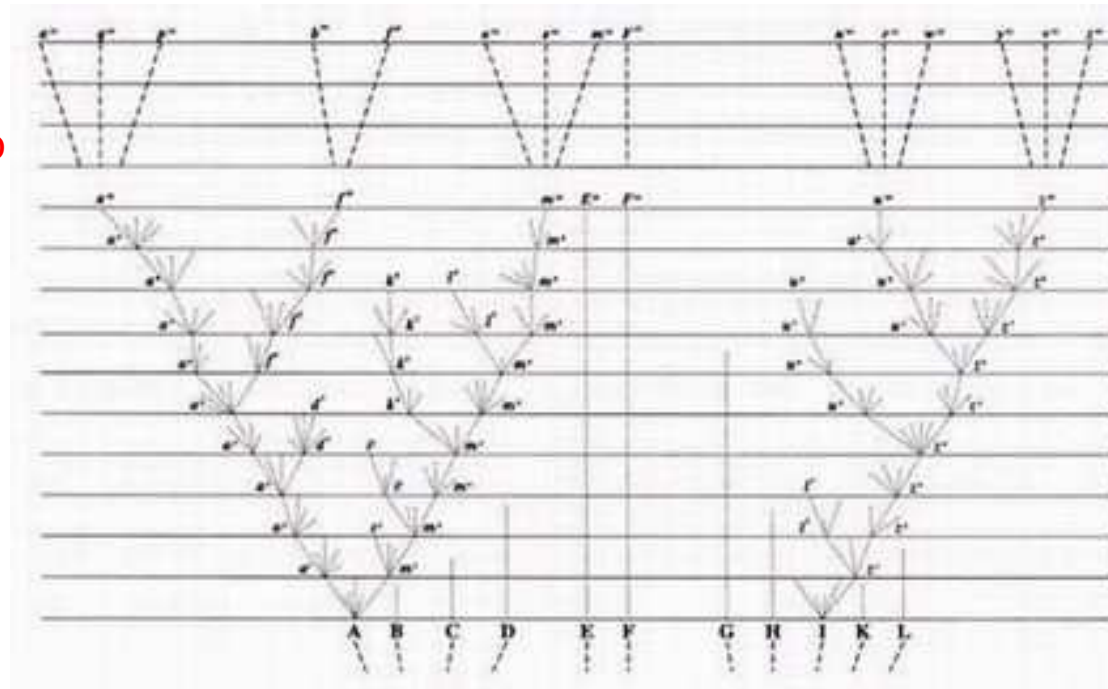
# Darwinian Theory of Evolution

- The biological environment is not static but evolving.
- Similar organisms are related, descend from a common ancestor; all life forms are descendent from a single common ancestor. Darwin tree
- Evolutionary change is the result of natural selection.
- Evolution is gradual and continuous. Here Darwin was heavily influenced by Charles Lyell's *Principles of Geology*.

## Evidence for Darwinian evolution

- Galapagos Island finches
- giant armadillo fossils in Brazil
- selective breeding: mustard into broccoli, cauliflower, cabbage, brussels sprouts, kale and kohlrabi; dogs

Darwin Tree



*On the Origin of Species* – Darwin

# *Modern Synthesis with Genetics*

- Evolution is the cornerstone of modern biology, and is a fact – defined as “confirmed to such a degree that it would be perverse to withhold provisional consent” – not a theory.
- In evolution, the whole population, not individuals, is what counts. Evolution is a change in the gene pool of individuals over time.
- Variations in individuals are caused by genetic differences.
- Populations are collections of individuals which evolve.
- A single organism is never typical of an entire population; individuals do not evolve – populations evolve.
- Genes can change between generations because of sexual reproduction and mutations.
- When mutations first occur, they are not adaptive because most mutations are detrimental. The short-term effect of mutations is minimal or nil.
- Longer-term, the accumulation of mutations and random shuffling of genes through reproduction or migration from another population provides the source of variation in a population.
- Natural selection controls the direction, rate and intensity of evolution.
- Sudden, catastrophic environmental changes can force a speed-up of evolution.
- The only scientific controversy surrounding evolution is exactly how it occurs, not if it occurs.

# *Evidence for Evolution*

**Fossil Record – Paleontology** Fossil record provides consistent evidence of systematic change through time—of descent with modification. It can be predicted that no reversals will be found in future paleontological studies.

**Common Structures – Comparative Anatomy** Scientists call strikingly similar structures in varied species homologies and have concluded that they are best explained by common descent

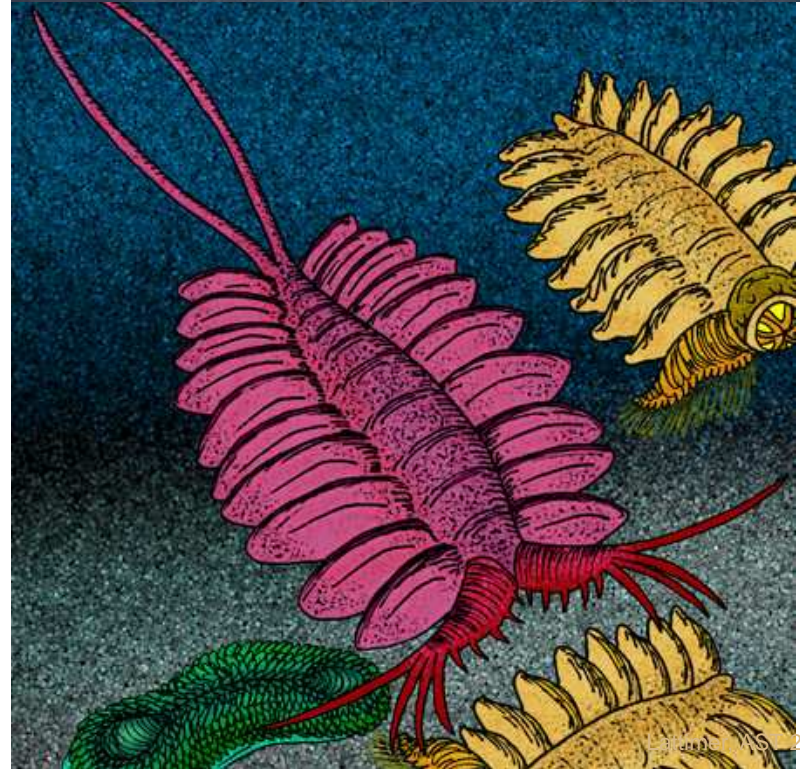
**Distribution of Species – Biogeography** Simultaneous wide diversity and specialization. Geographical isolation (Hawaii, Australia, Galapagos)

**Similarities During Development – Embryology** Ontogeny recapitulates phylogeny: Although discredited in detail, if a structure pre-dates another structure in evolutionary terms, then it also appears earlier in the embryo. Related species typically share the early stages of embryonal development and differ in later stages. A wide variety of organisms from fruit flies to worms to mice to humans have very similar sequences of genes that are active early in development. The cerebrum in humans, the most sophisticated part of the brain, develops last.

**Molecular Evidence – Unity of Life** The code used to translate nucleotide sequences into amino acid sequences is essentially the same in all organisms. Hemoglobin and myoglobin, among others, sequencing shows family trees identical to those derived from paleontology and anatomy. Genetic sequencing and molecular clocks reinforce this. Also pseudogenes, which are remnants of genes that no longer function but continue to be carried along in DNA as excess baggage (junk DNA). Pseudogenes change through time, as they are passed on from ancestors to descendants, reconfirming other observations.

# Cambrian Explosion

Wikipedia



# *Catastrophism vs. Uniformitarianism*

- Georges Cuvier argued for catastrophism on the basis of geological evidence (canyons in southern France).
- Charles Lyell debated in favor of gradualism, partly because of the negative religious fundamentalist connotations of catastrophism (e.g., biblical flood). Lyell was trained as a lawyer, and won debate.
- Darwin was heavily influenced by Lyell and his own observations of gradual changes in finches, etc.
- Fossil record in early 19th century was very limited; the missing pieces were thought to be due to incomplete sampling rather than being evidence for rapid changes connected with extinctions. Now that the fossil record is much more complete, evidence for catastrophies is more obvious.
- Abundant evidence has accumulated to indicate that evolution proceeds in spurts and starts rather than gradually – the Punctuated Equilibrium Theory of Eldridge and Gould posits that the dominant evolutionary changes, involving both extinctions and originations, occurred during very short violent catastrophic events.
  - Mass extinctions at boundaries between geologic eras: Permian 250 Myr BC, Cretaceous/Tertiary 65 Myr BC.
  - Sudden originations of several families of animal types during the Cambrian explosion 540 Myr BC
  - Thought to be caused by impacts, supernovae, plate tectonics, development of Earth's magnetic field, oxygenation of Earth's atmosphere.

# Principal Creationist Objections

**Evolution is just a theory.** Scientist's use of theory is different than general public. Gravity is a theory, but is essentially a fact from observations.

**There are no fossil intermediates – missing links.** Darwin worried about gaps in the fossil record. Since then most fossil intermediates in vertebrate evolution have been found. Invertebrate fossils are much rarer; gaps are expected.

**Intelligent design – life is too complex.** The intermediates in the evolution of the ear and eye are observed. Complex structures evolved as a progression of slight improvements.

**Evolution violates 2<sup>nd</sup> law of thermodynamics.** The 2<sup>nd</sup> law really says: disorder increases in a closed system; the Earth is not. Solar energy is received and the Earth reradiates it.

**Proteins are too improbable.** Hemoglobin has 140 amino acids. Probability that first one would be leucine is 1/20, and that all 140 would be the ones they are by chance is  $(1/20)^{140} = 7.2 \times 10^{-183}$ , an impossibly rare event. Statistical foolishness: You cannot use probability to argue backwards. The probability that everyone in a class of 50 would have the birthdays they do is  $(1/365)^{50} = 7.6 \times 10^{-129}$ .

**Natural selection does not imply evolution.** Microevolution (evolution within a species) seems to be the mechanism that has produced macroevolution (evolution among species). Man-made selections alone are remarkably distinctive: dachshunds, chihuahuas and greyhounds; mustard and cauliflowers.

**Irreducible complexity.** If each part of a complex process like blood clotting is essential, how can natural selection fashion any one part?

What's wrong with this argument is that each part of a complex molecular machine evolves in tandem as part of the system. Blood clotting evolved from a much simpler system which originated 600 Myrs ago in lampreys, the most primitive fish. Proteins were incorporated 100 Myrs later in the first vertebrates. 50 Myrs later clotting triggered by contact with jagged surfaces evolved. Mammalian clotting now relies on all three components and can't act independently of any of them.