Evolution - Origin of Life

Universe 13.7 billion yrs ago - BIG BANG.
Earth formed 4.5 b yrs ago.
Life appeared 3.5 b yrs ago.

Theories

1. Special Creation - religious / Genesis view.
2. Spontaneous Generation - abiogenesis (disproved by Pasteur)
3. Panspermia - life from outer space (meteorites)
4. Cosmozoic - life arrived as spores
5. Chemical Evolution - Oparin (1924) + Haldane

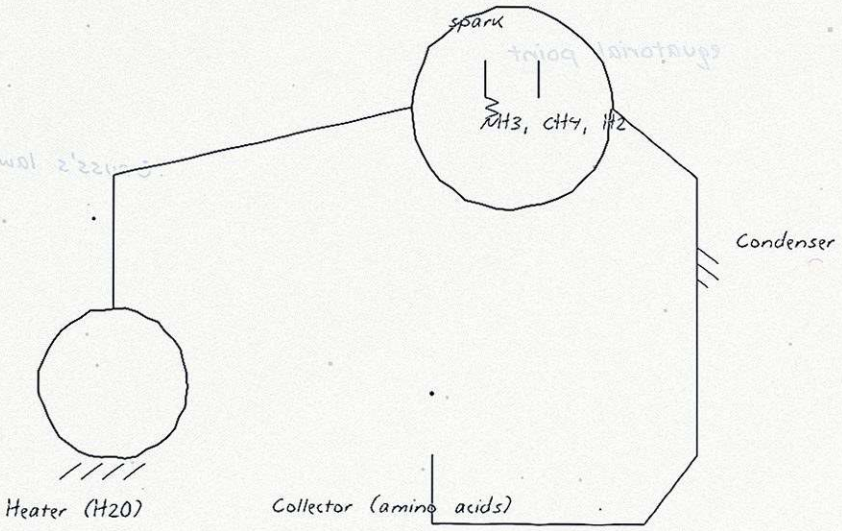
Chemical theory - simple molecules in primordial atmosphere (CH_4, NH_3, H_2, water vapour) -> amino acids -> proteins -> nucleic acids -> protocells.
Energy sources : UV, lightning, volcanic heat.

Stanley Miller (1953)

Recreated primitive earth in glass apparatus.
Used - CH_4 + NH_3 + H_2 + H_2O + electric sparks (80
Result - amino acids (Gly, Ala) + other organic compounds

Confirmed - organic molecules form abiotically.
First life - non-cellular (3.5 bya) -> single-celled (prokaryotes) 2 bya -> eukaryotes 1.5 bya.

Miller-Urey Apparatus



Result : amino acids found in 1 week.

Sidney Fox (1958) - showed proteinoids form from heating amino acids.

Critique - primitive atmosphere may not have been strongly reducing -> reduced importance of Miller.

Alternative - RNA WORLD hypothesis (1980s)
- self-replicating ribozymes preceded DNA.

Theories of Evolution

Lamarck (1809) - Use & Disuse

Acquired characters are inherited.

Eg. Giraffe neck got longer due to stretching.

Now disproved by ~~Darwin~~ Weismann (germ plasm theory).

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Darwin (1859) - Natural Selection

Voyage of HMS Beagle (1831-36) -> Galapagos Is.

Book - Origin of Species (1859).

Key ideas :

1. Variation exists in every population
2. Overproduction of offspring (Malthusian)
3. Struggle for existence (limited resources)
4. Survival of the fittest (natural selection)
5. Inheritance of fit traits -> evolution

Wallace - Co-Discoverer

Alfred Wallace independently proposed same theory.

Joint Linnean Society paper, 1858.

Modern Synthesis (Neo-Darwinism)

Darwin's selection + Mendel's genetics + population genetics (Dobzhansky, Mayr, Huxley, Simpson, 1942). *

Variation = mutation + recombination + drift + NS.

Evidences of Evolution

(i) Palaeontological - Fossils

Preserved remains in sedimentary rocks. Show :

(a) Change in form over geological time

(b) Connecting links (Archaeopteryx - reptile-bird)

(c) Dating by radiometric methods (C14, K40)

(ii) Comparative Anatomy

(a) Homologous - same origin, different function

Forelimbs of whale, bat, cheetah, human

-> DIVERGENT evolution

(b) Analogous - different origin, same function

Wings of insect vs bird vs bat

-> CONVERGENT evolution

(c) Vestigial organs - reduced organs (appendix, wisdom teeth, tail bone in humans).

(iii) Embryological

Embryos of vertebrates show similar features in early stages (gill slits, tail) - Karl Ernst von Baer.

Haeckel's law (ontogeny recapitulates ~~ecology~~ phylogeny) - large

(iv) Biogeographical

Darwin's Galapagos finches - 14 species from 1 ancestor.

Marsupials of Australia - isolated radiation.

Homologous Forelimbs (BIG)

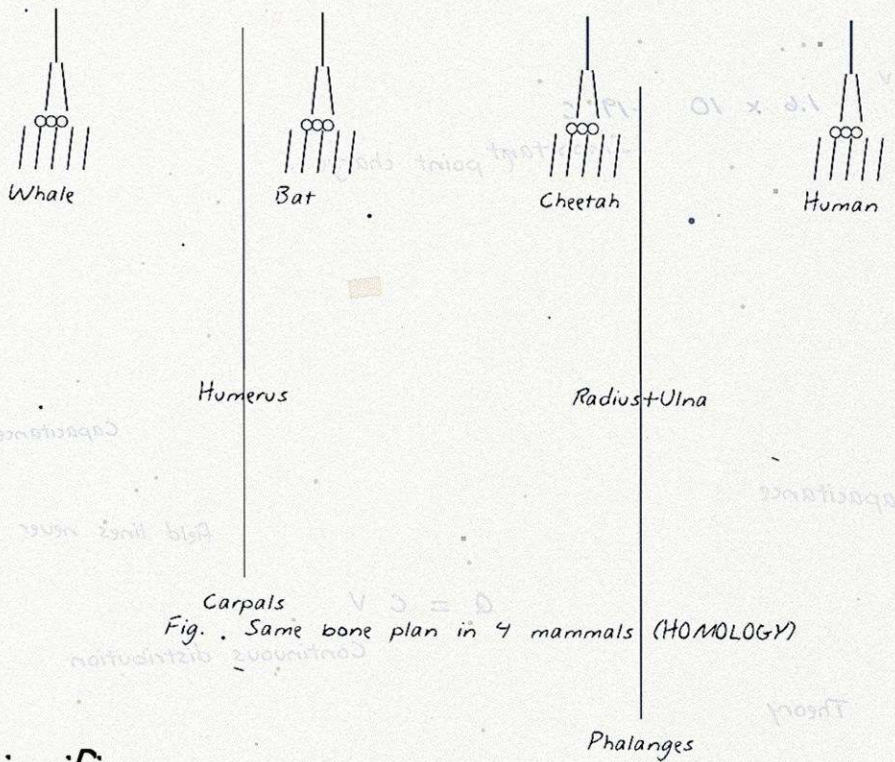


Fig. . Same bone plan in 4 mammals (HOMOLOGY)

Significance

Same bone plan inherited from common ancestor but modified for swimming, flying, running, grasping. PROOF of divergent evolution from common origin.

Analogous Examples

Insect / bird / bat wings (different bones).

Darwin's Finches - Adaptive Radiation

13-14 finch species in Galapagos islands - all evolved from a single ancestral species.
Different BEAK shapes for different food sources.

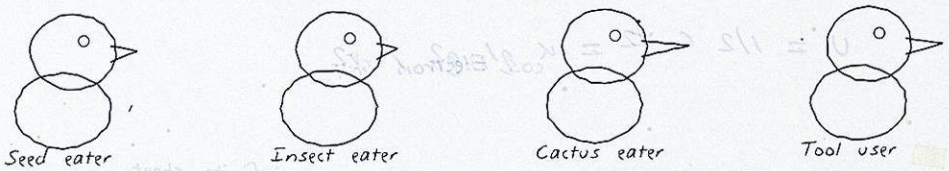


Fig. Adaptive radiation in beak shape

Convergent Evolution

When 71 adaptive radiations occur in isolated areas.
Marsupials of Australia placentals of N. America.
(Tasmanian wolf placental wolf ; Anteater aardvar

Punctuated Equilibrium

Eldredge + Gould (1972) - long stasis followed by bursts of ~~slow~~ rapid change.

Co-evolution

Hardy-Weinberg Principle (1908)

Allele + genotype frequencies in a population remain CONSTANT across generations - GENETIC EQUILIBRIU

Equation

Let p = frequency of dominant allele (A)

Let q = frequency of recessive allele (a)

Then : $p + q = 1$; $(p + q)^2 = 1$

$$p^2 + 2pq + q^2 = 1$$

p^2 = homozygous dominant (AA)

$2pq$ = heterozygous (Aa)

q^2 = homozygous recessive (aa)

Conditions

1. Large population (no genetic drift)
2. Random mating (no selection)
3. No mutations
4. No gene flow (no migration)
5. No natural selection

Violation = Evolution

Any change in allele frequency over generations = EVOLUTION.

5 forces alter equilibrium -> evolution occurs.

Forces of Evolution

(1) Mutation

Sudden, random heritable change in DNA.

Source of NEW alleles - raw material of evolution.

Hugo de Vries proposed mutation theory (1901-03).

Eg. Oenothera lamarckiana - sudden mutants.

(2) Recombination

Crossing over + independent assortment in meiosis create new gene combinations.

(3) Genetic Drift

Random change in allele frequency in small populations:

Two special cases :

(a) Bottleneck effect - drastic population reduction

(b) Founder effect - small group starts new population

(4) Gene Flow / Migration

Movement of alleles between populations via interbreeding migrants.

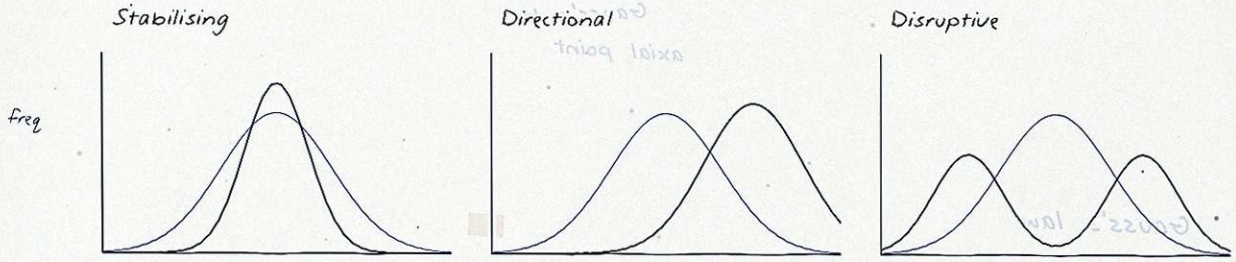
(5) Natural Selection

Non-random survival + reproduction of fittest.

Result - adaptation over generations.

3 sub-types - stabilising, directional, ~~constant~~ disruptive.

Types of Natural Selection



Examples

STABILISING - avg phenotype favoured (human birth weigh

DIRECTIONAL - shift to one extreme

(industrial melanism - dark moth in polluted Manchester)

DISRUPTIVE - both extremes favoured

(small + large beak finches; medium beaks die out)

Industrial Melanism

Biston betularia - peppered moth.

Pre-industrial : light moths common, dark rare.

Post-industry : dark moths increased on sooty trees.

Speciation

Speciation = formation of new species.

Species = group capable of interbreeding to produce fertile offspring (BIOLOGICAL species concept, Mayr).

Modes of Speciation

(1) Allopatric - geographic isolation -> divergence
(Darwin's finches - separated by islands)

(2) Sympatric - split within same area (rare)
(eg. cichlid fish in African lakes)

(3) Parapatric - partial overlap of populations

Isolation Mechanisms

Pre-zygotic :

(a) Geographic (mountains, rivers)
(b) Temporal (different breeding seasons)
(c) Behavioural (different mating rituals)
(d) Mechanical (incompatible reproductive organs)

Post-zygotic :

(e) Zygote mortality
(f) Hybrid sterility (mule)
(g) Hybrid breakdown

Adaptive Radiation

Geological Time Scale

Cenozoic 65 mya - present	Age of mammals + birds
Mesozoic 245 - 65 mya	Age of dinosaurs / reptiles
Palaeozoic 570 - 245 mya	Age of fishes -> amphibians -> reptiles
Proterozoic 2500 - 570 mya	First multi-cellular life
Archean 3800 - 2500 mya	Origin of life / bacteria

Key Events

Cambrian explosion (540 mya) - sudden diversity of phy

First fishes - Ordovician

First amphibians - Devonian (370 mya)

First reptiles - Carboniferous (320 mya)

First mammals - Triassic (200 mya)

Dinosaurs extinct - end of Cretaceous (65 mya)

First primates - early Cenozoic

Modern Homo sapiens - 50,000 yrs ago

Origin of Different Groups

Plants

First plants - *green algae (1.5 bya)
Bryophytes - Silurian (430 mya)
Pteridophytes - Devonian
Gymnosperms - Permian + Triassic
Angiosperms - Cretaceous (130 mya)

Vertebrates

Jawless fish (Agnatha) - Cambrian
Cartilaginous fish - Devonian
Lobe-finned fish -> Amphibians (Devonian)
Amphibians -> Reptiles (Carboniferous)
Reptiles -> Birds + Mammals (Triassic-Jurassic)
Birds from ~~amphibians~~ theropod dinosaurs (Archaeopteryx)

Mass Extinctions

5 major extinctions in Earth history :
Ordovician end (444 mya) - 85% loss
Devonian late (372 mya)
Permian (252 mya) - 96% loss (worst)
Triassic-Jurassic (201 mya)
Cretaceous-Paleogene (66 mya, killed dinos)

6th extinction may be happening (anthropogenic)..

Human Evolution

Order Primates - Hominoidea - Hominidae - Homo

Common ancestor with apes 25 mya.

Dryopithecus	15 mya	ape-like; Africa
Ramapithecus	10 mya	more man-like (later reclassified)
Australopithecus	4 mya	E. Africa, bipedal, 4 ft, 450 cc brain
Homo habilis	2 mya	1st tool-maker, 650-800 cc
Homo erectus	1.5 mya	Java + Peking man, 900 cc, fire
H. neanderthalensis	0.1 mya	buried dead, fire, 1400 cc
Homo sapiens	0.05 mya	MODERN, Africa origin, 1350 cc

Cro-Magnon Man

Lived in caves; cave art (Lascaux), tools, agriculture.

18,000 yrs ago.

Key Trends

1. Bipedal posture ; 2. Cranial capacity (450 -
3. Reduced face / jaws ; 4. Tool use ; 5. Language

Out-of-Africa Hypothesis

Modern humans (H. sapiens) evolved in AFRICA 200,000 yrs ago, then migrated worldwide.

Evidence - oldest fossils + mtDNA studies.

Migration Timeline

200,000 yrs ago - origin in East Africa

120,000 yrs ago - reached Middle East

60,000 yrs ago - reached Asia, Australia

40,000 yrs ago - reached Europe (met Neanderthals)

15,000 yrs ago - reached Americas

Mitochondrial Eve

Most-recent common matrilineal ancestor of all humans.

Lived in Africa 150,000 - 200,000 yrs ago.

~~Y chromosome~~ mtDNA traces maternal lineage.

Indian Origin Studies

Lalji Singh + Thangaraj - ANI (Ancestral North Indians) + ASI (Ancestral South Indians) mixed long ago.

Indians = mix of multiple ancestral populations.

Race vs Species

All humans (Caucasoid, Mongoloid, Negroid, etc.) belong to ONE species - H. sapiens. 'Races' = social.

Modern Evolutionary Concepts

Microevolution

Small changes within species (allele frequencies).

Eg. industrial melanism, drug resistance.

Macroevolution

Large-scale changes -> new species + higher taxa.

Operates over millions of years.

Saltation

Sudden major mutation -> instantaneous evolution.

Proposed by Hugo de Vries. Mostly disproven now.

Molecular Clock

DNA / protein sequence changes accumulate at fairly constant rate - used to date divergence.

Eg. Humans and chimps differ by 1.2 % -> diverged 6 - 7 mya.

Sympatric vs Allopatric - Recap

Allopatric = geographically isolated populations

Sympatric = in same area, ecological / behavioural isolation -> new species.

Polyploidy speciation - common in plants.

Variations - Sources

Mutations

Sudden, heritable, random changes in DNA.

Types :

1. Point mutation (single bp change)
2. Frame-shift (insertion / deletion)
3. Chromosomal (big rearrangement)
4. Genome (polyploidy) (extra full sets)

Causes

Physical - UV, X-ray, gamma

Chemical - base analogs, alkylating agents

*Biological - transposons, viruses, errors of repair

Recombination

Independent assortment + crossing over in meiosis.

Creates new combinations - source of variation.

*Gene Flow

Movement of alleles between populations.

Genetic Drift

Random fluctuation in small populations.

Founder effect - small group settles new area.

Bottleneck - drastic reduction (cheetahs!).

Population Genetics - Sample Problems

Q1

Sickle cell anaemia - $q^2 = 0.04$, find heterozygotes.

$q = 0.2$ -> $p = 0.8$ -> $2pq = 0.32$

So 32 % are carriers (Hb A Hb S).

Q2

PKU homozygotes = 1 / 10,000 -> $q^2 = 0.0001$

$q = 0.01$, $p = 0.99$, carriers = $2pq$ 0.0198 (

Q3 - ABO blood group

Frequencies (Indian) : $I^A = 0.21$, $I^B = 0.26$, $i =$

Expected % O = $i^2 = 0.53^2 = 28$ %.

Q4 - Drug resistance

Initial frequency of resistant allele = 0.001 (rare).

After drug treatment - sensitive individuals die ->
resistant allele frequency RISES rapidly ->
selection in action.

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Antibiotic Resistance

Beta-lactam, MRSA, ~~amoxicillin~~ vancomycin resistance now seen.

Overuse of antibiotics -> rapid evolution of
resistant strains -> superbugs.

Demonstrates evolution in real time.

Brain Evolution & Tools

Cranial capacity (CC) increased 3x in 4 my :

Australopithecus	450 cc
Homo habilis	700 cc
Homo erectus	900-1000 cc
Neanderthal	1400 cc
Modern man	1350-1450 cc

Tools - Cultural Evolution

Stone tools - H. habilis (Olduvai chopper)

Hand axes - H. erectus

Composite tools - Neanderthal, Cro-Magnon

Use of fire - H. erectus

Agriculture - 12,000 yrs ago (Neolithic)

Language Evolution

FOXP2 gene - important for speech.

Language gave us cooperation + culture.

Bipedalism

Frees hands, sees farther, less heat from sun -> savanna.

Evolution Glossary

Allopatric	- geographically separated speciation
Sympatric	- speciation within same area
Phylogeny	- evolutionary history
Homology	- common ancestry
Analogy	- convergent function
Vestigial	- reduced ancestral organs
Adaptive radiation	- 1 species -> many niches
Hardy-Weinberg	- $p^2 + 2pq + q^2 = 1$
Genetic drift	- random allele change in small popn
Founder effect	- small group starts new popn
Bottleneck	- drastic popn reduction
Punctuated eq.	- long stasis + sudden bursts
Cladistics	- groups by shared ancestry
Hominid	- human + ape lineage
Hominin	- humans + extinct relatives only
Bipedal	- walks on 2 legs
Quadrupedal	- walks on 4 legs
Prosimian	- primitive primates (lemurs)

Evolution - Recap Numbers

Timeline Recap

Universe Big Bang - 13.7 b yrs ago
Earth formed - 4.5 b yrs ago
First life - 3.5 b
Eukaryotes - 1.5 b yrs ag
Multicellular - 600 mya
Fish -
Amphibians - 370 mya
Dinosaurs - 230 - 6
Mammals - 200 m
Primates - 65
Genus Homo - 2.5 mya
Modern man (sapiens) - 200,000 yrs ago
Out of Africa - 70,000
Agriculture - 12,000

Major Names

Lamarck - use & disuse, inheritance of acquired
Darwin - natural selection
Wallace - co-discoverer of NS
de Vries - mutation theory
Hardy + Weinberg - population genetics
Mayr - biological species concept
Miller + Urey - abiogenesis experiment (1953)