Evolution and Palaeontology

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4.1 Speciation and theories of organic evolution

Species

The Species Concept

1. Typological or morphological species concept (essentialism)

- by Plato and Aristotle in 350 BC.

Species are groups of individuals that resemble each other in most **essential visible morphological characters**
OR
morphologically distinct organisms constitute a species.

2. Nominalistic species concept

- by Buffon and Lamarck in mid 18th century in France.

According to this concept, only individuals exist and species are man-made aberrations or abstractions.

Followers_ treat species as individuals on higher plane.

Numerical taxonomists of today essentially follow this concept by taking all characters of individuals and feeding them into a computer to get a classification.

- Such classifications are likely to be erroneous as they give equal importance to all characters.

3. Genetic species concept

- M. Florkin (1964)

"Species are groups of individuals with more or less similar combinations of sequences of purine and pyramidine bases in their macromolecules of DNA and with a system of operators and repressors leading to the biosynthesis of similar amino acid sequences."

4. Evolutionary species concept

- Meglitsch (1954)

"Natural population evolving as a unit in actuality and retaining this capacity in case artificial barriers are removed."

- Simpson (1961)

"Species is a lineage evolving separately from others and with its own unitary evolutionary role and tendencies."

- Wiley (1978)

"Species is a single lineage of ancestral descendant populations of organisms which maintain its own evolutionary tendencies and historical fate."

5. Biological species concept

- Ernst Mayr (1969)

"Species are groups of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups."

species richness + species evenness = Biodiversity

Species richness- number of species found in a community

Alpha diversity

- the diversity within a particular area or ecosystem, and is usually expressed by the number of species in that ecosystem.

Beta diversity

- a comparison of diversity between ecosystems.

Gamma diversity

- a measure of the overall diversity for the different ecosystems within a region.

Species evenness- It measures the proportion of species at a given site

e.g. low evenness indicates that a few species dominate the site.

Speciation

Prezygotic and Postzygotic barriers

Prezygotic

- prevent members of different species from mating

Postzygotic

- hybrid zygotes


Adaptive radiation in Galapagos finches
medium tree finch
(Camarhynchus pauper)
large tree finch
(Camarhynchus psittacula)
small tree finch
(Camarhynchus parvulus)
mangrove finch
(Camarhynchus heliobates)
vegetarian finch
(Camarhynchus crassirostris)
mainly insects
woodpecker finch
(Camarhynchus pallidus)
buds and fruits
ancestral seed-eating ground finch
warbler finch
(Certhidea olivacea)
large cactus finch
(Geospiza conirostris)
cactus seeds and parts
Cocos Island finch
(Pinaroloxias inornata)
cactus finch
(Geospiza scandens)
mainly seeds
sharp-beaked ground finch
(Geospiza difficilis)
small ground finch
(Geospiza fuliginosa)
large ground finch
(Geospiza magnirostris)
medium ground finch
(Geospiza fortis)
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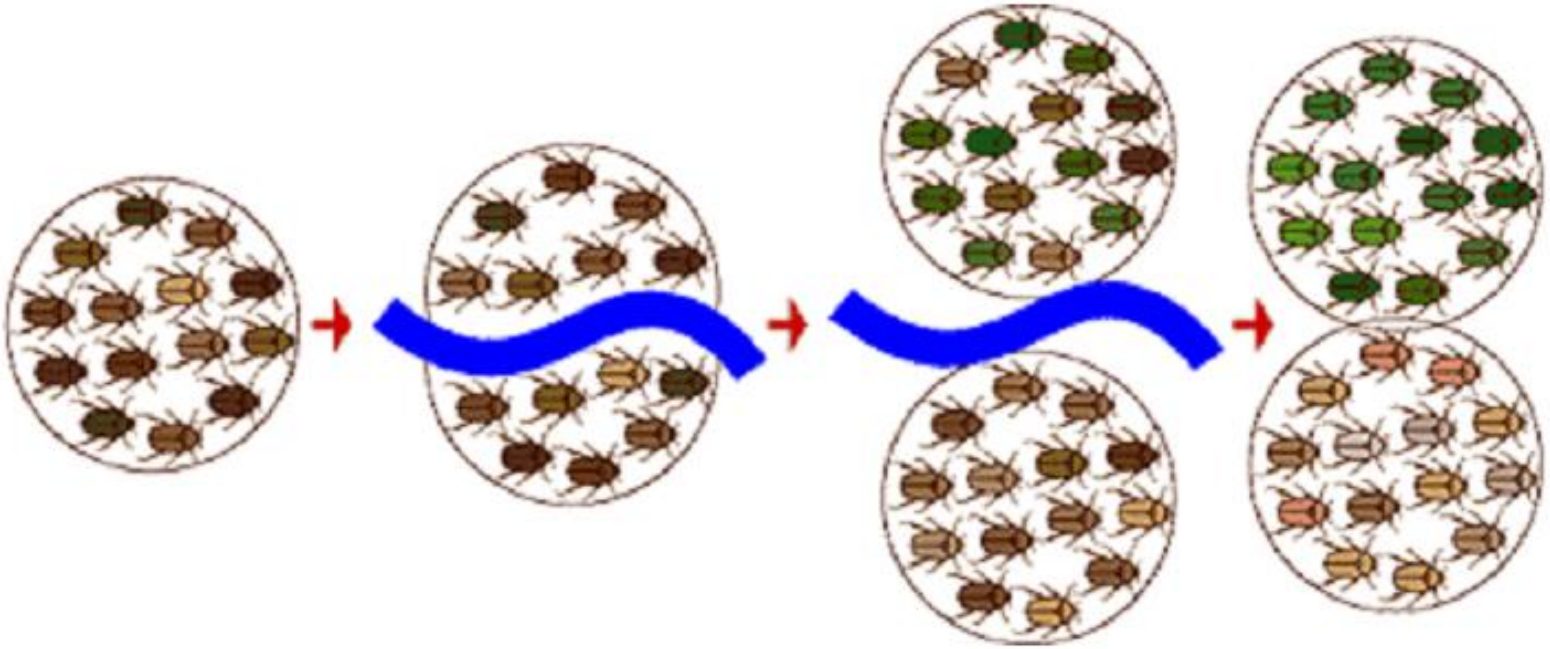
Allopatric Speciation: The Great Divide

- allo meaning other and patric meaning homeland

- involves geographic separation of populations from a parent species and subsequent evolution.



Squirrels and the Grand Canyon

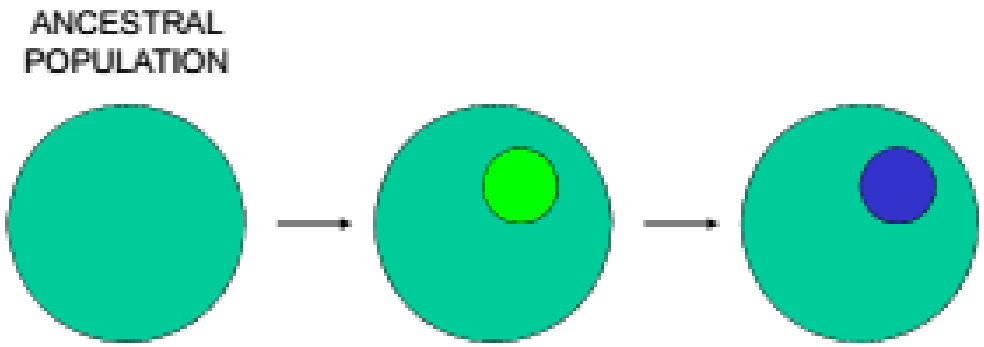
Image credit: *Toroweap sunrise* by John Fowler, CC BY 2.0

Image credit: left, image modified from *Ammospermophilus harrisii* by Ryan Johnston, CC BY 2.0; right, image modified from *Ammospermophilus leucurus* by Jarek Tuszynski, CC BY-SA 3.0

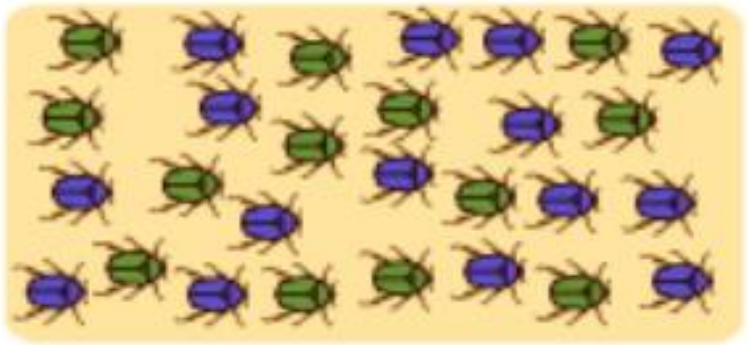
Sympatric Speciation

-sym meaning same and patric meaning homeland

- speciation occurring within a parent species remaining in one location.



Reproductively isolated, geographically sympatric populations

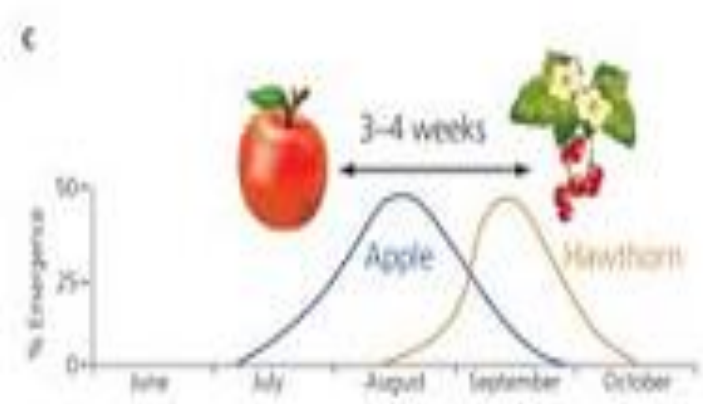


North American apple maggot fly

subgroups in a population use different habitats or resources, in the same geographical area

original host plant - hawthorn tree.

introduced apple trees



Ecological speciation: adaptation to different host plants drives reproductive isolation – temporal isolation driven by host plant phenology

Brought to you by the Feder Lab at ND!!!

North American apple maggot fly

Studies of African cichlid fishes in Lake Nyasa and other lakes in the East African Rift System

- from a combination of sexual selection and ecological factors.
- result in groups of females within a population developing a strong affinity for males with different extreme phenotypic traits.

Lamarckism

or

Theory of Inheritance of Acquired characters.

French naturalist,
Jean Baptiste de Lamarck

- in 1809 A.D. famous book “Philosphic Zoologique”

- based on the comparison between the contemporary species of his time to fossil records

- His theory is based on the inheritance of acquired characters

- defined as the **changes (variations) developed in the body of an organism from normal characters**,

➢ in response to

the **changes in environment/** in the **functioning** (**use and disuse**) of organs

- in their own life time to fulfill their new needs

- Thus Lamarck stressed on **adaptation** as means of evolutionary modification.

Postulates of Lamarckism:

Lamarckism is based on four postulates

1. New needs:

Every living organism is found in some kind of environment.

The changes in the environmental factors like light, temperature, medium, food, air… etc.

or

migration of animal

lead to the origin of new needs in the living organisms, especially animals.

To fulfill these new needs, the living organisms have to exert special efforts like the changes in habits or behavior.

2. Use and disuse of organs:

The new habits - the greater use of certain organs - disuse or lesser use of certain other organs.

- greatly affect the form, structure and functioning of the organs.

Continuous and extra use of organs - **more efficient**
Continued disuse of other organs
- degeneration and disappearance

Lamarckism is also called "Theory of use and disuse of organs."

So the organism acquires certain new characters due to direct or indirect environmental effects during its own life span and are called Acquired or adaptive characters.

3. Inheritance of acquired characters:

Lamarck believed that acquired characters are inheritable and are transmitted to the offsprings

- born fit to face the changed environmental conditions

- Increase the chances of their survival.

4. Speciation:

Lamarck believed that

in every generation, new characters are acquired and transmitted to next generation,

so that **new characters accumulate** generation after generation.

After a number of generations, a new species is formed.

So according to Lamarck,

an existing individual is the sum total of the characters acquired by a number of previous generations and the speciation is a gradual process.

Evidences in favour of Lamarckism:

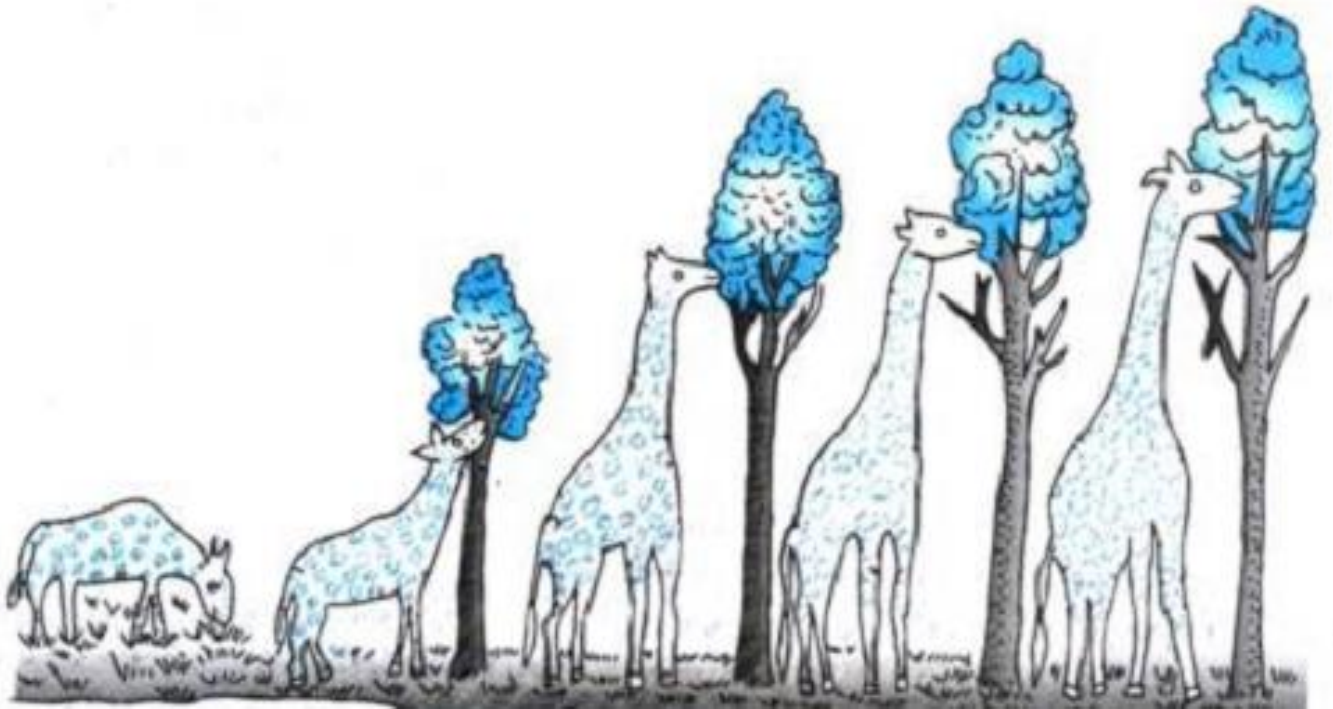
1. Phylogenetic studies of horse, elephant and other animals show that all these increase in their evolution from simple to complex forms.

2. Giraffe :

Deer-like ancestor - present day long-necked and long forenecked giraffe of Africa

- in response to deficiency of food.

This is an example of **effect of extra use and elongation of certain organs.**



3. Snakes:

limbed ancestors- limbless snakes with long slender body

due to

- continued disuse of limbs and stretching of their body - creeping mode of locomotion
- fossorial mode of living out of fear of larger and more powerful mammals

- example of **disuse and degeneration of certain organs.**

4. Aquatic birds:

terrestrial ancestors - aquatic birds like ducks, geese etc. by the acquired characters

- reduction of wings due to their continued disuse
- development of webs between their toes for wading purposes

➢ changes were induced due to
- deficiency of food on land
- severe competition.

example - **extra use** (skin between the toes) **and disuse** (wings) **of organs**.

5. Flightless birds:

flying ancestors - flightless birds like ostrich

due to

- continued disuse of wings

    birds were found in well protected areas with plenty of food

6. Horse:

Ancestors (Dawn horse - Eohippus)

- **live in the areas with soft ground**
- short legged with more number of functional digits (4 functional fingers and 3 functional toes)

Modern horse (*Equus caballus*)

- **gradually took to live in areas with dry ground**
- change in habit - accompanied by increase in length of legs and decrease in functional digits for fast running over hard ground.

Criticism of Lamarckism:

August Weismann, German biologist, in 1892 A.D.

"**Theory of continuity of germplasm**"

- environmental factors **do affect only somatic cells and not the germ cells**

- the germ cells link between the generations
- the somatic cells are not transmitted to the next generation
- so the acquired characters must be lost with the death of an organism so these should have no role in evolution.

Weismann mutilated the tails of mice for about 22 generations and allowed them to breed

- but tailless mice were never born

Pavlov trained mice to come for food on hearing a bell.

- not inherited and training was necessary in every generation.

Similarly,

- boring of pinna of external ear and nose in Indian women
- tight waist of European ladies
- circumcising (removal of prepuce) in certain people

- Eyes which are being used continuously and constantly develop defects instead of being improved.

- Heart size does not increase generation after generation though it is used continuously.

- Presence of weak muscles in the son of a wrestler

.....etc

So, Lamarckism was rejected.

Significance:

1. It was first comprehensive theory of biological evolution.

2. It stressed on adaptation to the environment as a primary product of evolution.

Darwinism

or

Theory of Natural Selection.

Darwin-Wallace theory?

Charles Darwin (1809- 1882 A.D.),

- Naturalist
- Voyage on ship “H.M.S. Beagle”
- explored South America,
  the Galapagos Islands and other islands.

observations

- on animal distribution
- the relationship between living and extinct animals

statemnt –

- existing living forms share similarities to varying degrees not only among themselves but also with the ancestors, some of which have become extinct.

- every population has built in variations in their characters.

- analysis of his data and Malthus' s Essay on Population

got an idea of

struggle for existence within all the populations

due to

continued reproductive pressure and limited resources

all organisms, including humans are modified descendents of previously existing forms of life.

Alfred Russel Wallace (1812-1913)

- studied biodiversity of Malayan archipelago
- Written essay (1858 A.D),

"On the Tendency of Varieties to Depart Indefinitely from the Original Type"

-similar conclusions like Darwin

Work of Darwin's and Wallace's was jointly published (1859) in "Proceedings of Linnean Society of London"

.....So it is called Darwin-Wallace theory

Darwin explained his theory of evolution in a book (1859) entitled

“On the Origin of Species by means of Natural Selection”.

proposed the concept of natural selection as the mechanism of evolution.

Postulates of Darwinism:

Main postulates of Darwinism are:

1. Geometric increase.
2. Limited food and space.
3. Struggle for existence.
4. Variations.
5. Natural selection or Survival of the fittest.
6. Inheritance of useful variations.
7. Speciation.

1. Geometric increase:

➢ the populations tend to multiply geometrically and the reproductive powers of living organisms (biotic potential) are much more than required to maintain their number.

e.g., Paramecium divides three times by binary fission in 24 hours during favourable conditions.

At this rate, a Paramecium can produce a clone of about 280 million/ one month and in five years, 10,000 times than the size of the earth.

Cod (one million eggs per year)

Oyster (114 million eggs in one spawning)

Ascaris (70, 00,000 eggs in 24 hours)

Housefly (120 eggs in one laying and laying eggs six times in a summer season)

Rabbit (6 young ones/litter and 4 litters/year and young ones start breeding at the age of six months).

Even slow breeding organisms reproduce at a rate which is much higher than required

e.g., an elephant becomes sexually mature at 30 years of age and during its life span of 90 years, produces only six offsprings.
At this rate, if all elephants survive then a single pair of elephants can produce about 19 million elephants in 750 years.

➢ every species can increase manifold within a few generations and occupy all the available space on the earth, **provided all survive and repeat the process.**

So the number of a species will be much more than can be supported on the earth.

2. Limited food and space. two main limiting factors

- though a population tends to increase geometrically, the food increases only arithmetically .

- food and space- together form the major part of carrying capacity of environment.

- These do not allow a population to grow indefinitely which are nearly stable in size except for seasonal fluctuation.

3. Struggle for existence.

Due to rapid multiplication of populations but limited food and space,

there starts an everlasting **competition between individuals having similar requirements**.

In this competition, **every living organism desires to have an upper hand over others**.

This competition between living organisms for the basic needs of life like food, space, mate etc., is called struggle for existence.

which is of **three types**:

(a) Intraspecific:

Between the members of same species

e.g. two dogs struggling for a piece of meat.

(b) Interspecific:

Between the members of different species

e.g. between predator and prey .

(c) Environmental or Extra specific:

Between living organisms and adverse environmental factors like heat, cold, drought, flood, earthquakes, light....etc.

4. Variations. It is the law of nature.

- no two individuals are identical
  except identical (monozygotic) twins .
- competition among the organisms
  forced to change according to the conditions to utilize the natural resources and can survive successfully

According to Darwin –two types of variations
- **continuous variations or fluctuations** and
- discontinuous variations.

On the basis of their effect on the survival chances of living organisms, the variations may be
- neutral, harmful and useful

5. Natural selection or Survival of the fittest.

Darwin stated that **as many selects the individuals with desired characters in artificial selection**; nature selects only those individuals out of the population which are with useful **continuous variations** and are best adapted to the environment while the less fit or unfit individuals are rejected by it.

Darwin stated that discontinuous variations appear suddenly and will mostly be harmful, so are not selected by nature- he called them "sports"

So **the natural selection is an automatic and self going process and keeps a check on the animal population**.

Sorting out of the individuals with useful variations from a heterogeneous population by the nature was called Natural selection by Darwin and Survival of the fittest by Wallace.

So natural selection acts as a restrictive force and not a creative force.

6. Inheritance of useful variations.

Darwin believed that

the selected **individuals pass their useful continuous variations to their offsprings** so that they are born fit to the changed environment.

7. Speciation.

According to Darwinism, **useful variations appear in every generation and are inherited from one generation to another**.

So the useful variations go on accumulating and after a number of generations, the variations become so prominent that the individual turns into a new species.

So according to Darwinism, evolution is a gradual process and **speciation occurs by gradual changes in the existing species**.

Evidences in favour of Darwinism:

1. There is a **close parallelism** between natural selection and artificial selection.

2. The remarkable cases of resemblance
e.g. mimicry and protective colouration can be achieved only by gradual changes occurring simultaneously both in the model and the mimic.

3. Correlation between position of nectaries in the flowers and length of the proboscis of the pollinating insect.

Evidences against Darwinism:

1. The inheritance of small variations in those organs which can be of use only when fully formed

e.g. wing of a bird - no use in incipient or underdeveloped stage.

2. Inheritance of vestigial organs.
3. Inheritance of over-specialised organs

e.g. antlers in deer and tusks in elephants.

4. Presence of sterile flowers and sterility of hybrids.
5. Did not differentiate between somatic and germinal variations.
6. He did not explain the causes of variations and the mode of transmission of variations.

So this theory explains **only the survival of the fittest** but does not explain the arrival of the fittest so Darwin himself confessed, "**natural selection has been main but not the exclusive means of modification**."

Principle of Natural Selection:
proposed by Ernst Mayer in 1982
This principle demonstrates that **natural selection is the differential success in reproduction and enables the organisms to adapt them to their environment by development of small and useful variations**.

These favourable Variations accumulate over generation after generation and lead to speciation.

So natural selection operates through interactions between the environment and inherent variability in the population.

Table 7.7. Principle of Natural Selection.

Observations	Inferences
1. All species have such great potential of fertility that their population size would increase exponentially if all individuals that were born reproduced successfully. 2. Most populations are normally stable in size, except for seasonal fluctuations. 3. Natural resources are limited. 4. Individuals of a population vary extensively in their characteristics; no two individuals are exactly alike. 5. Much of this variation is heritable.	(a) Production of more individuals than the environment can support leads to a struggle for existence among individuals of a population, with only a fraction of offspring surviving each generation. (b) Survival in the struggle for existence is not random, but depends in part on the hereditary constitution of the surviving individuals. Those individuals whose inherited characteristics fit them best in their environment are likely to leave more offsprings than less fit individuals. (c) The unequal ability of individuals to survive and reproduce will lead to a gradual change in a population with favourable characteristics accumulating over the generations.

Neo-Darwinism

or

Modern concept

or

Synthetic theory of evolution.

Modern or synthetic theory of evolution was designated by Huxley (1942).

The scientists who contributed to the outcome of Neo-Darwinism were: J.S. Huxley, R.A. Fischer and J.B.S. Haldane of England; and S. Wright, Ford, H.J. Muller and T. Dobzhansky of America.

The detailed studies of Lamarckism, Darwinism and Mutation theory of evolution showed that no single theory is fully satisfactory .

Neo-Darwinism is a modified version of theory of Natural Selection and is a sort of reconciliation between Darwin’ s and de Vries theories.

It emphasizes **the importance of populations** as the units of evolution and the central role of natural selection as the most important mechanism of evolution.

Postulates of NeoDarwinism:

1. **Genetic Variability:**
   - (i) Mutations:
     - (a) Chromosomal aberrations:
     - (b) Numerical chromosomal mutations:
     - (c) Gene mutations (Point mutations):
   - (ii) Recombination of genes:
   - (iii) Hybridization:
   - (iv) Physical mutagens and chemical mutagens
   - (v) Genetic drift:
2. **Natural Selection:**
3. **Reproductive isolation:**

1. Genetic Variability:

Variability is an opposing force to heredity and is essential for evolution as the variations form the raw material for evolution.

The studies showed that the units of both heredity and mutations are genes which are located in a linear manner on the chromosomes.

Various sources of genetic variability in a gene pool are:

(i) Mutations:

These are sudden, large and inheritable changes in the genetic material.

On the basis of amount of genetic material involved, mutations are of three types:

a) Chromosomal aberrations:

These include the **morphological changes in the chromosomes** without affecting the number of chromosomes.

These result changes either in the **number of genes** (deletion and duplication) or in the **position of genes** (inversion).

These are of four types:

1. **Deletion (Deficiency) -** the **loss of a gene block** from the chromosome and may be terminal or intercalary .
2. **Duplication** - the **presence of some genes more than once (**repeat). It may be tandem or reverse duplication.
3. **Translocation - transfer of a gene block** from one chromosome to a non-homologous chromosome and may be simple or reciprocal type.
4. **Inversion** - the **rotation of an intercalary gene block** through 180° and may be paracentric or pericentric.

b) Numerical chromosomal mutations:

include **changes in the number** of chromosomes.

These may be

- euploidy (gain or loss of one or more genomes)

Polyploidy provides greater genetic material for mutations and variability.

- aneuploidy (gain or loss of one or two chromosomes).

Aneuploidy may be hypoploidy or hyperploidyl

Hypoploidy may be **monosomy** (loss of one chromosome) or **nullisomy** (loss of two chromosomes).

Hyperploidy may be **trisomy** (gain of one chromosome) or **tetrasomy** (gain of two chromosomes).

c) Gene mutations (Point mutations):

invisible changes in chemical nature (DNA) of a gene.

three types:

1. Deletion involves **loss of one or more** nucleotide pairs.
2. Addition involves **gain** of one or more nucleotide pairs.
3. Substitution involves **replacement** of one or more nucleotide pairs **by other base pairs**. These may be transition or transversion type.

(ii) Recombination of genes:

Thousands of **new combinations of genes** are produced due to **crossing over, chance arrangement of bivalents at the equator during metaphase – I** and **chance fusion of gametes during fertilization.**

(iii) Hybridization:

It involves the interbreeding of two genetically different individuals to produce ‘hybrids’.

(iv) Physical mutagens and chemical mutagens

Physical mutagens

(e.g. radiations, temperature etc.)

and

chemical mutagens

(e.g. nitrous acid, colchicine, nitrogen mustard etc.).

(v) Genetic drift:

It is the **elimination of the genes** of some original characteristics of a species by extreme reduction in a population **due to epidemics or migration**.

The chances of variations are also increased by nonrandom mating.

2. **Natural Selection:**

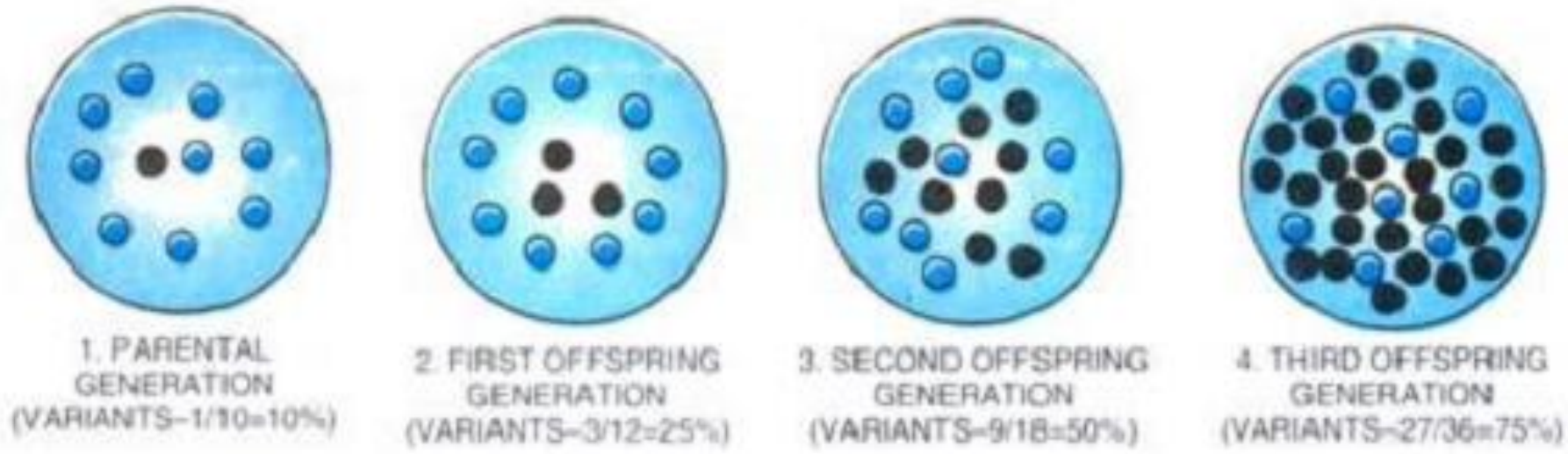


Fig. 7.40. Spread of genetic variability by differential reproduction.

3. **Reproductive isolation:**

Any factor which reduces the chances of interbreeding between the related groups of living organisms is called an isolating mechanism.

Reproductive isolation is must so as to allow the accumulation of variations leading to speciation by preventing hybridization.

In the **absence of reproductive isolation**, these variants freely interbreed which lead to intermixing of their genotypes, dilution of their peculiarities and disappearance of differences between them.

So, reproductive isolation helps in evolutionary divergence.

Hardy–Weinberg equilibrium, principle, model, theorem, or **law**,

states that **allele** and **genotype frequencies** in a population will remain constant from generation to generation in the absence of other evolutionary influences.

Mutation
Gene Flow
Genetic Drift
Natural Selection
Isolation

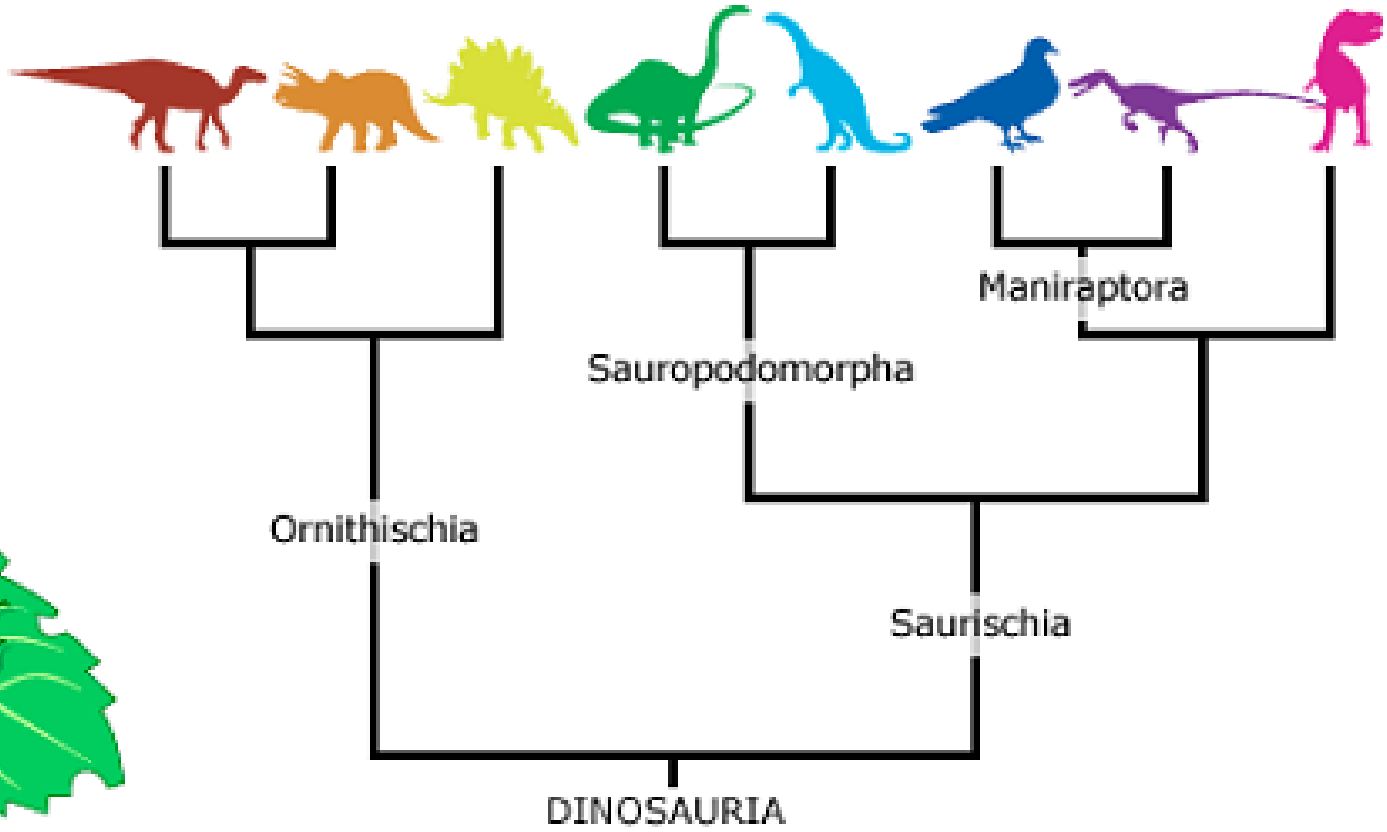
In the simplest case of a single locus with two alleles denoted A and a

- with frequencies $f(\mathrm{A}) = p$ and $f(\mathrm{a}) = q$,
- the expected genotype frequencies are
  $f(\mathrm{AA}) = p^2$ for the AA homozygotes,
  $f(\mathrm{aa}) = q^2$ for the aa homozygotes, and
  $f(\mathrm{Aa}) = 2pq$ for the heterozygotes.

- The genotype proportions p^2, $2pq$, and q^2 are called the Hardy–Weinberg proportions.

- the sum must be equal to 1.

- Therefore, $(p + q)^2 = p^2 + 2pq + q^2 = 1$.



micro vs. MACRO

Types of macroevolution

Molecular evolution - small changes in the molecular or cellular level. Over a long period of time, this can cause **big effects on the genetics of organisms**.

Taxonomic evolution - small changes between populations and then species. Over a long period of time, this can cause **big effects on the taxonomy of organisms**, with the growth of **whole new clades above the species level**.

Morphological evolution - small changes in the morphology of an organism. Over a long period of time, this can cause big effects on the morphology of major clades.

Ecological evolution - small changes in the ecological roles organisms occupy. Over a long period of time, this can cause big effects on the ecological landscape.

Molecular phylogeny

Molecular phylogeny is the use of a gene's molecular characteristics to classify an organism and to place it on a map of evolutionary relationships known as the phylogenetic tree.

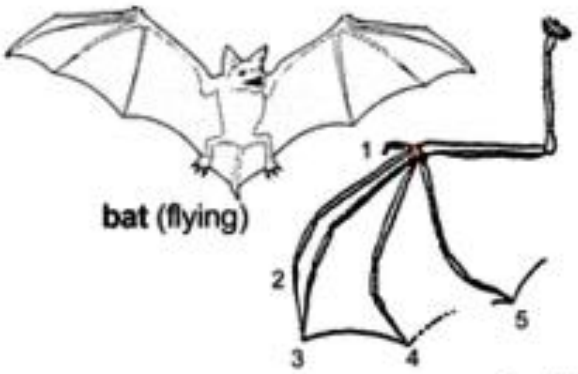
4.2 Evidences of Organic Evolution

Comparative morphology/Anatomy

Evidence from homologous organs

Evidence from analogous organs

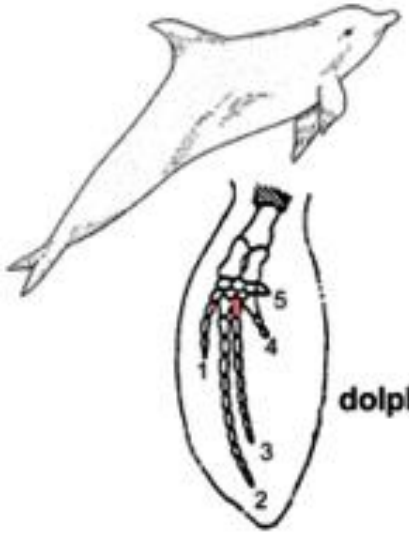
Evidences from vestigial organs

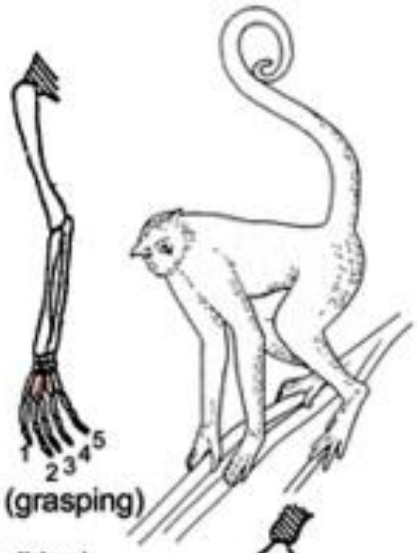


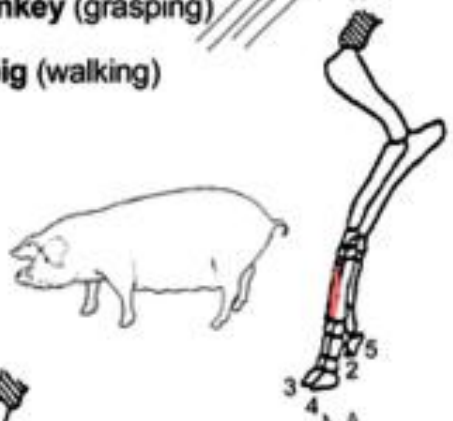
The **pentadactyl limb** as the 'ancestral' terrestrial vertebrates limb plan, subsequently adapted by modification for different uses/habitats.

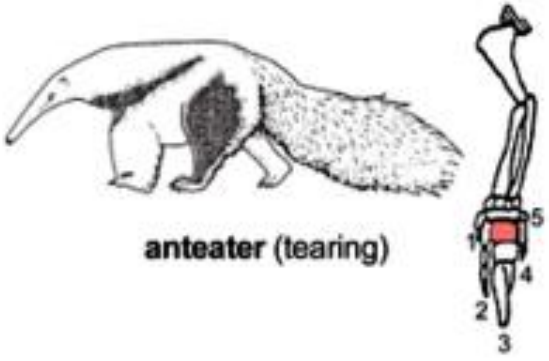
lay-out of a 'five-fingered' (pentadactyl) limb

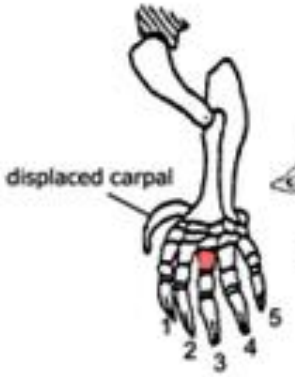
forelimb		hindlimb
upper arm →	humerus	femur ← thigh
forearm →	radius + ulna	tibia + fibula ← lower leg
wrist →	carpals	tarsals ← ankle
hand/foot →	metacarpals + phalanges	metatarsals ← foot + phalanges

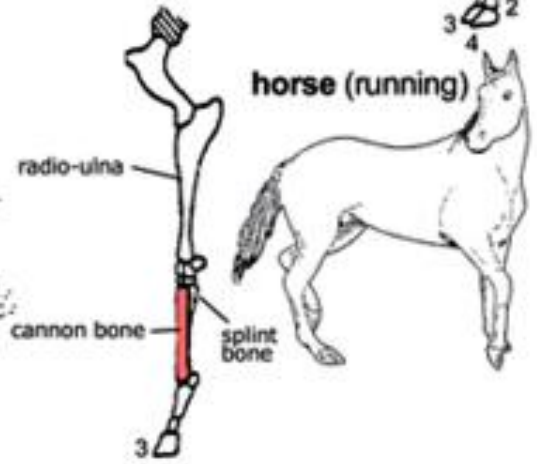


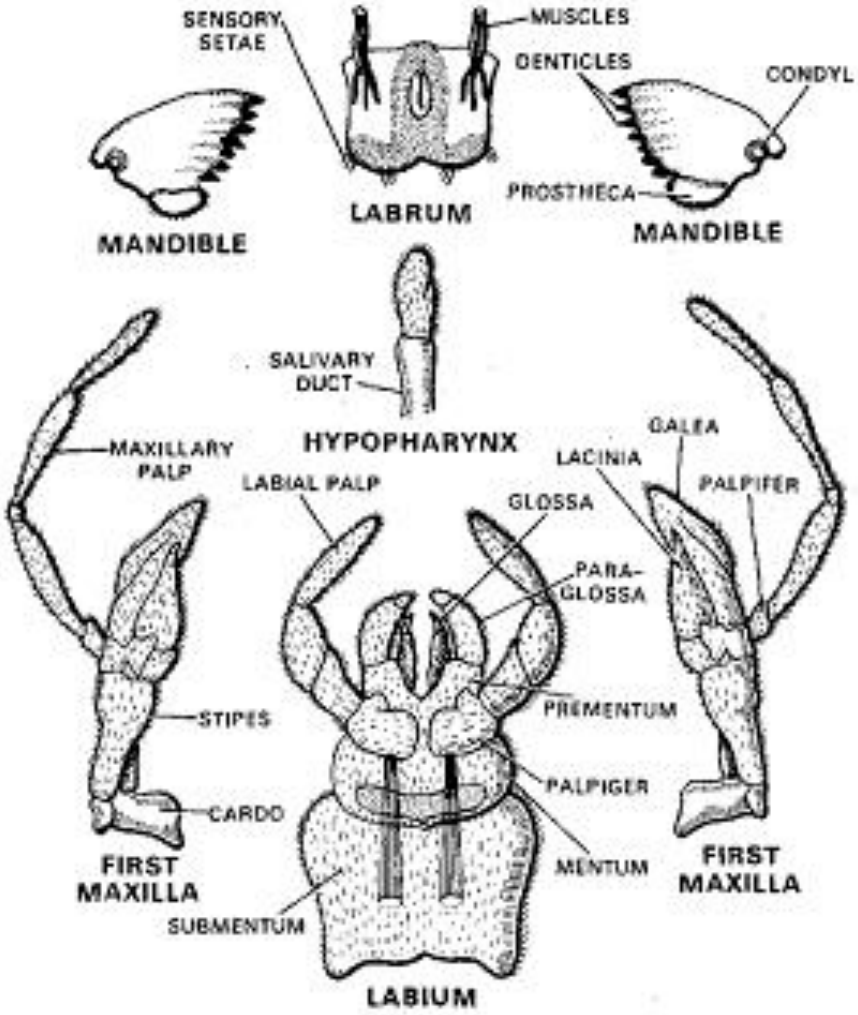


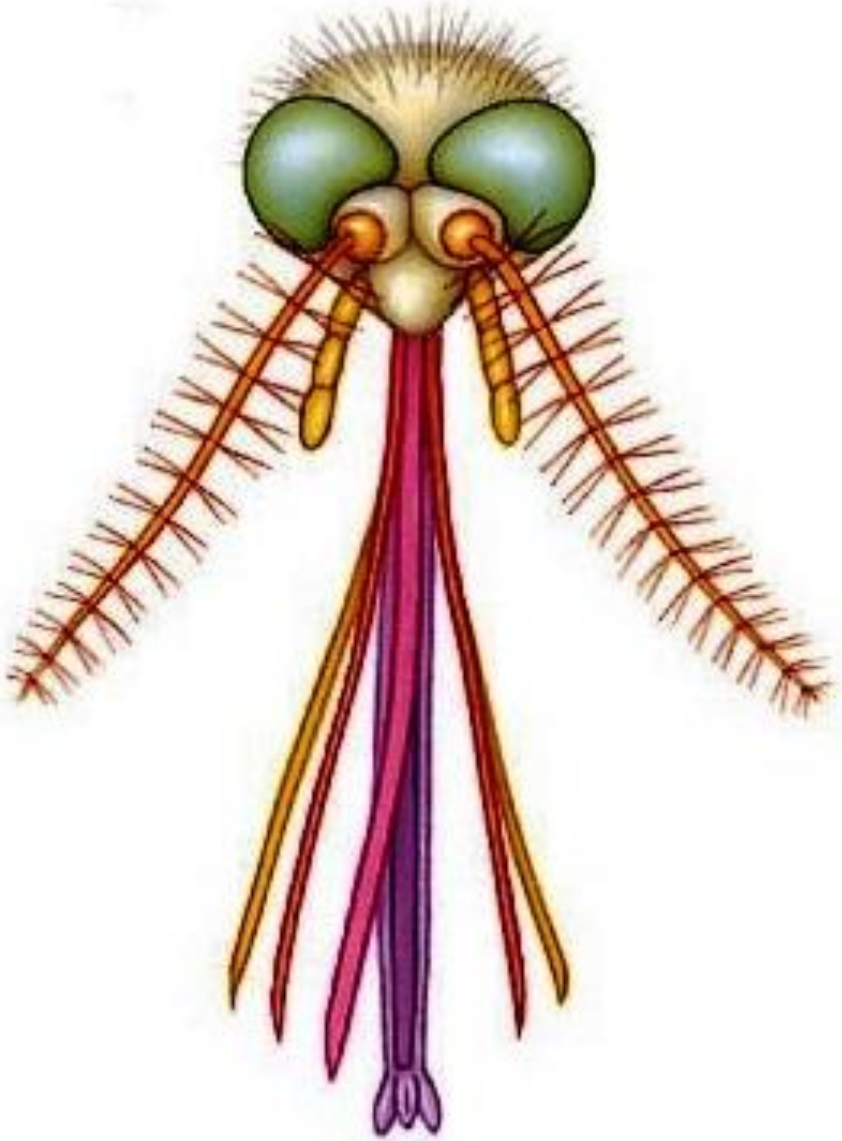






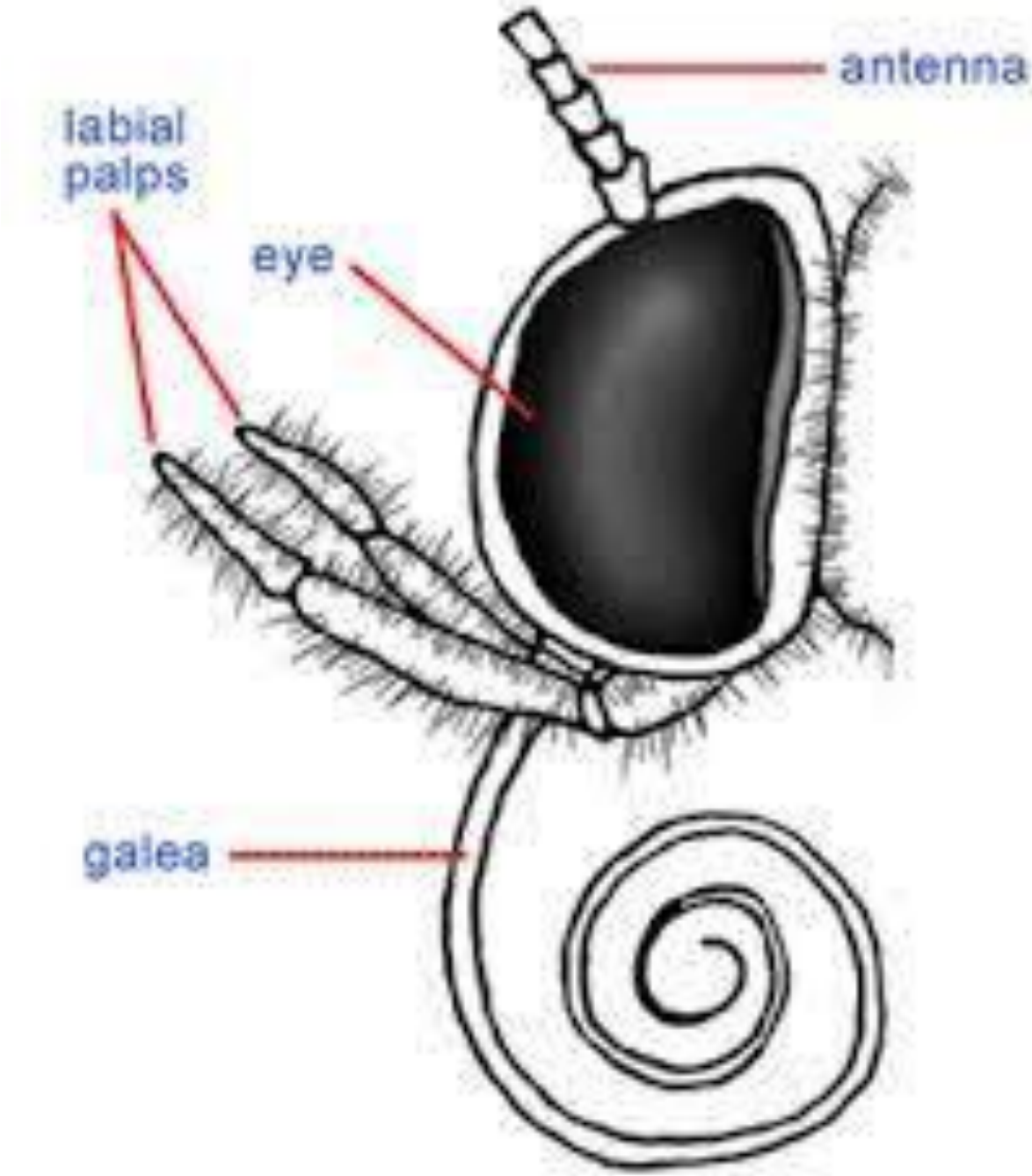


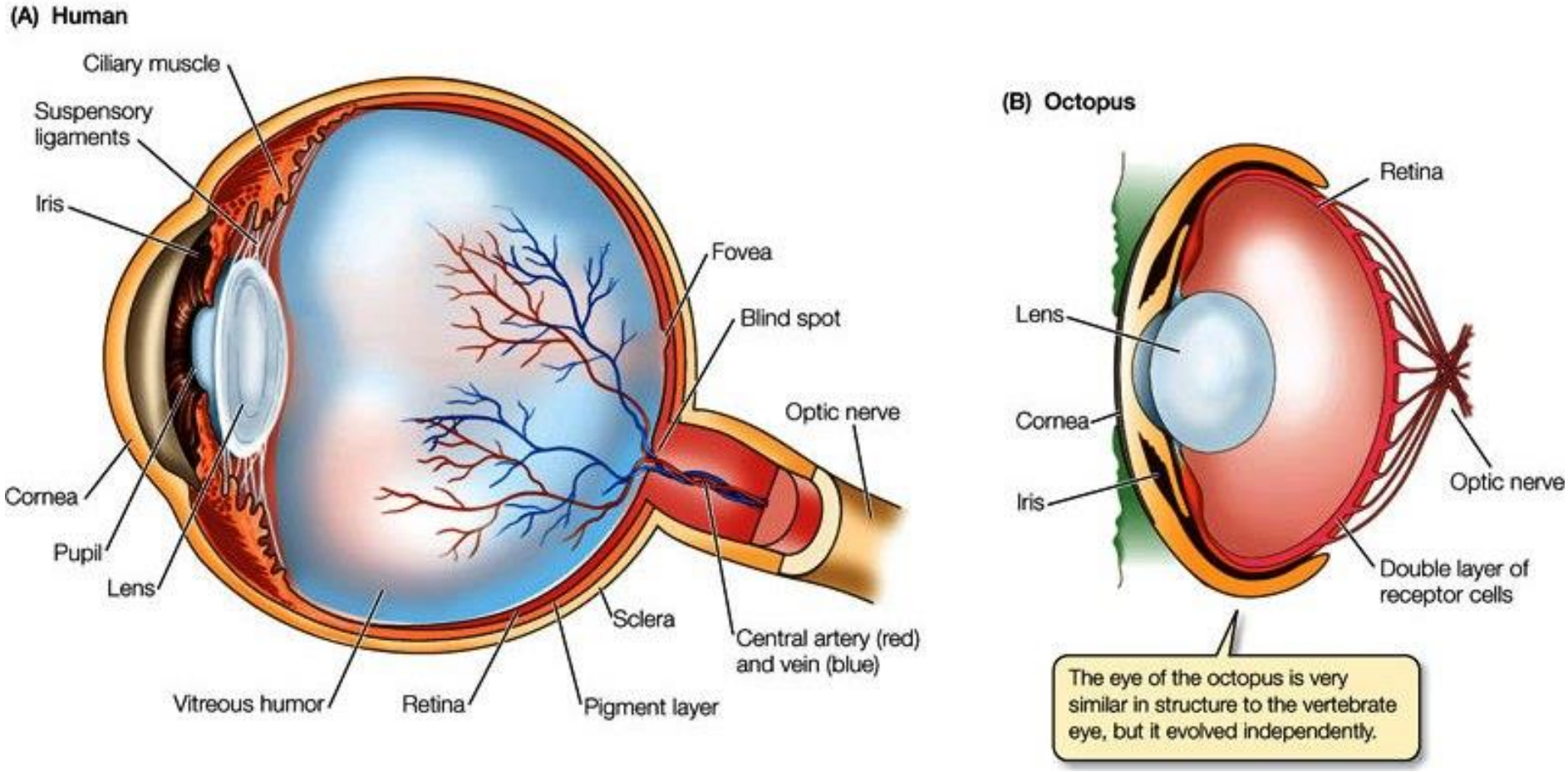




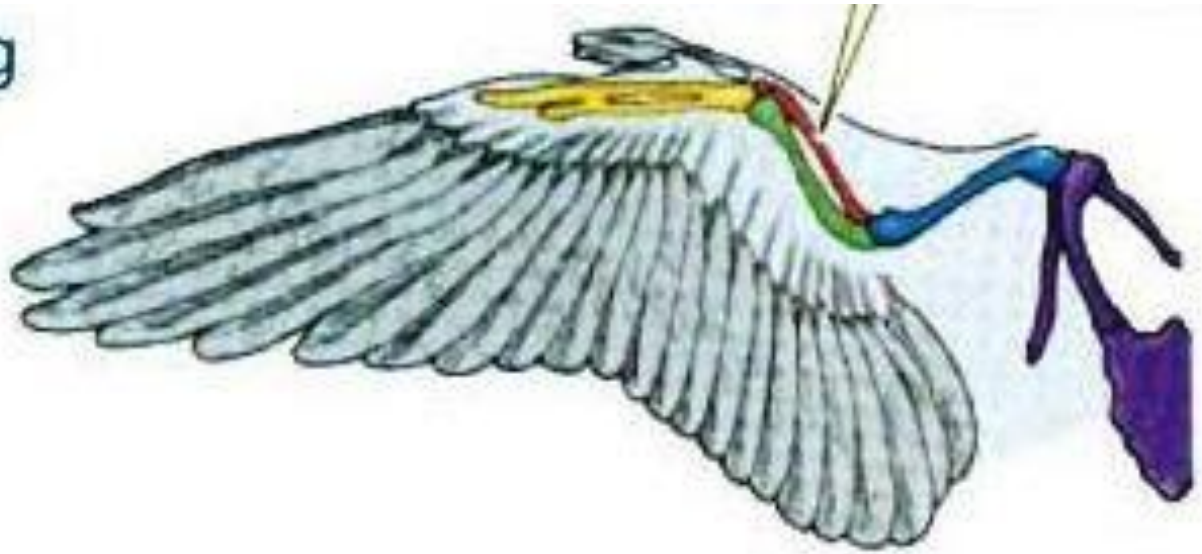
COCKROACH **MOSQUITO**

MOUTH PARTS

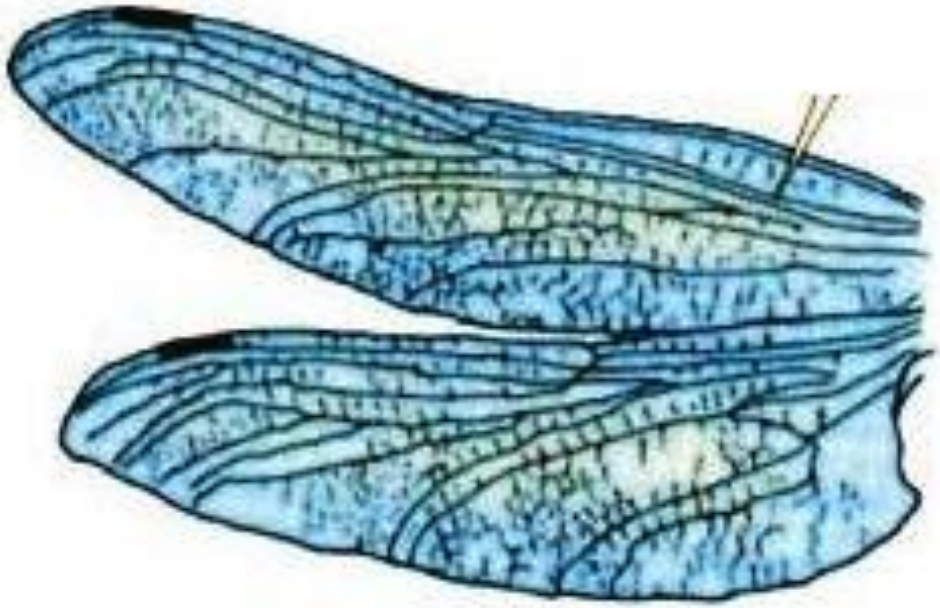

antenna
labial palps
eye
galea

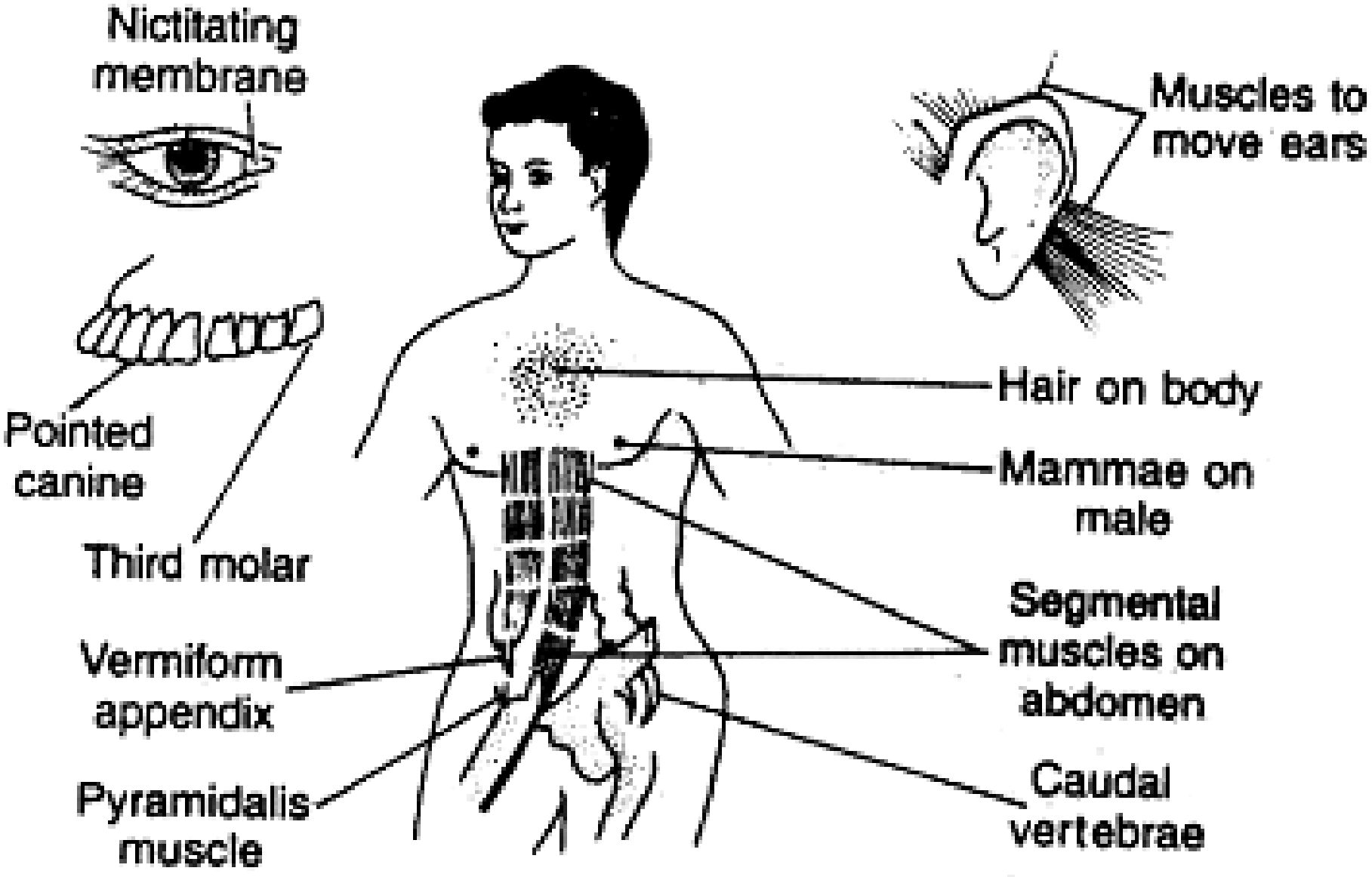

(A) Human
Ciliary muscle
Suspensory ligaments
Iris
Fovea
Blind spot
Optic nerve
Cornea
Pupil
Lens
Sclera
Central artery (red) and vein (blue)
Vitreous humor
Retina
Pigment layer
(B) Octopus
Retina
Lens
Cornea
Iris
Optic nerve
Double layer of receptor cells
The eye of the octopus is very similar in structure to the vertebrate eye, but it evolved independently.

Bird wing



Insect wing





Vestigial organs of man

Biochemistry and Physiology

1. Protoplasm Chemistry:

2. Chromosome Chemistry:

3. Enzyme Similarities: Trypsin/amylase

4. Hormonal Similarities: thyroid hormone

5. Comparative Serology: serum/ABO blood groups

6. Phosphagens: Phosphoarginine = invertebrates
Phosphocreatine = vertebrates

7. Visual pigments: Porphyropsin=freshwater fishes
Rhodopsin= marine fish/vertebrates

All organisms have certain biochemicals in common.

All use DNA, ATP, and many identical or nearly identical enzymes.

Organisms use the same triplet code and the same 20 amino acids in proteins.

This similarity is not necessary, but can be explained by common descent.

Example: the protein hemoglobin (for gas exchange). This chart compares short amino acid chains of different animals.

Species	Sequence of Amino Acids in the Same Part of the Hemoglobin Molecules
Human	Lys–Glu–His–Iso
Horse	Arg–Lys–His–Lys
Gorilla	Lys–Glu–His–Lys
Chimpanzee	Lys–Glu–His–Iso
Zebra	Arg–Lys–His–Arg

Embryology


Gill slits
Tail
Gills
Gill-slits
Tail
Fore-limb bud
Hind-limb bud
Fish
Sala mander
Tortoise
Chick
Rabbit
Man

Palaeontology

Paleontology deals with study of past life as revealed by fossils.

It has 2 branches normally
1. Paleozoology (study of animal fossils)
2. Paleobotany (study of plant fossils)

Paleontology is more reliable source of organic evolution because

1. Fossils are the remains of actual organisms which lived in past years.

2. The various body parts of organisms found preserved under sea-beds, rocks, soils etc. provide the information regarding development and variation of organisms from simple to complex and developed forms.

3. We can know the types of organisms found in earth at various eras by studying the age of rocks in which fossils are found in different strata.

Thus, paleontology provides a reliable source of information regarding organic evolution.

4.3 Palaeontology

- **Geological time scale**
- **Fossils and fossilization**
- **Dinosaurs and Archaeopteryx**
- **Origin and Evolution of Horse and Man**

Geological time table

- a calendar of the earth's past history.
- The largest divisions ERAS.

  It is recognized on the basis of presence of major groups of plants and animals in their rocks.
- Eras are divided into PERIODS.
- Periods are divided into EPOCHS.

Eras and year of their duration	*Major divisions of era*	*Periods and their beginning*	*Epochs or Notes*	*Plants*	*Animals*	*Outstanding features*
Paleozoic (36,80,00,000 years)	Later Paleozoic	Permian 22,30,000,00 years ago		First cycads & conifers. Reduction of pteridophytes.	Rise invertebrate Reptiles.	Uplift of Continents. Elimination of Inland seas. Cold & dry.
		Pennsylvanian (upper carboniferous) (27,10,00,000 years ago)		Dominance of fossil lycopods, Equisetales, ferns, Pteridosperms & cordiatales.		Formation of coal in Swamps, shallow Inland seas. Warm humid climates.
		Mississippian. (Lower carboniferous) (30,90,00,000 years ago)		Dominant lycopods, Horse-tails, ferns & seed, ferns. Early coal deposit.	Rise of Reptiles & insects. dominance of fishes.	Mountain Building Extensive Inland Warm climates.
	Middle Paleozoic	Devonian. (35,40,00,000 years ago)		Early land plants-Psilophytales Equisetales, ferns, seed ferns, lycopodiales. First Forests.	Rise of amphibians dominance of fishes.	Mountain Building Extensive Inland Seas, heavy rainfall.
		Silurian 38,10,00,000 years ago		First known land plant. (Algae dominant)	Lung fishes and air breathing animals and corals.	Continents low with greatest extention of Inland seas.
	Early Paleozoic	Ordovian 44,80,00,000 years ago		Marine algae	Many groups of invertebrates	Warm mild climates.
		Cambeian 555 million years ago		Marine algae	Invetebrates. Molluscs, Echinoderms, Brachypods	Spreading of Inland seas. Climates mild.
Proterozoic 90,00,00,000 years		15,00,000,000 years ago		Bacteria, Algae and Fungi.	Worms, crustaceans and brachiopods.	
Archeozoic (55,00,00,000 + years)		20,00,000,000 years ago		Organisms very simple.	No fossils.	

Eras and year of their duration	*Major divisions of era*	*Periods and their beginning*	*Epochs or Notes*	*Plants*	*Animals*	*Outstanding features*
Cenozoic from 60,00,000 years ago-up to date	Quaternary	20,00,000 years ago	Recent	Dominance of herbs	Civilized Man	
			Pleistocene	Extinction of many trees and increase of herbs.	Extinction of mammals.	Ice Age glacial cold
	Tertiary	Late Tertiary	Pliocene	Evolution of herb, reduction of forest.	Man appeared	Development of plains and grasslands, Mid climates becoming cooler and drier.
			Miocene	Forest reduction.	Culmination of mammals.	
		Early Tertiary 60,00,000 years ago	Oligocene	World wide distribution of tropical forests.	Disappearance of primitive mammals, and evolution of higher mammals and birds.	
			Eocene	Evolution of modern Flowering plants	Modern birds and marine mammals appear.	
Mesozoic (12,50,00,000 years)	Late mesozoic	Upper creataceous		Angiosperms dominate. Dwindling Gymnosperms	Rise of primitive mammals.	Last great spread of Inland seas
		Middle cretaceous		Rapid developent of Angiosperms	Extinction of great reptiles.	Mountain Building at close of period.
		Lower cretaceous (12,50,00,000 years ago)		Rise of angiosperms Cycads & conifers dominants.		Mild do cool climates.
	Early Mesozoic	Jurassic 15,70,00,000 years ago		Rise of angiosperms. Caytoniales, conifers and cycads dominant. Cordiatales disappeared	Primitive birds and flying reptiles (Pterodactyles) Dinosaurs & higher insects dominant.	Continents low Inland seas restricted, Mild climates.
		Triassic 18,50,00,000 years ago		Dominance of higher gymnosperms. Disappearance of seed ferns.	First mammals. Rise of giants reptiles (Dinosaurs)	Elevated continents, Extensive deserts.

The geological timetable shows that

1. None of the organisms of the past were exactly similar to those found today.
2. All fossils did not appear at the same time but in different periods.
3. The older forms are relatively simpler and comparable, at least, with unspecialized member of the living phyla.
4. There has been a gradual progress from the simpler to complex forms in time.
5. A new type appearing in one period became predominant in the latter period and that finally disappeared. Though there have been extinctions of many large groups, once a major phylum was established that has persisted with more or less number of species living today.
6. The mammals among the animals and angiosperms in plants are the latest products of evolution.

Fossils and fossilization

- **Petrified fossils**

  - Original protoplasmic substance of each cell of fossilized materials is replaced by mineral particles (converted into stones- iron oxide, iron pyrites, sulphur, silica, malachite, etc).

- **Natural moulds of plants and animals**

  - These are formed in mud and sand which become hardened into slates or stones.

- **Compression and impression**

  - These are found in sedimentary deposits.

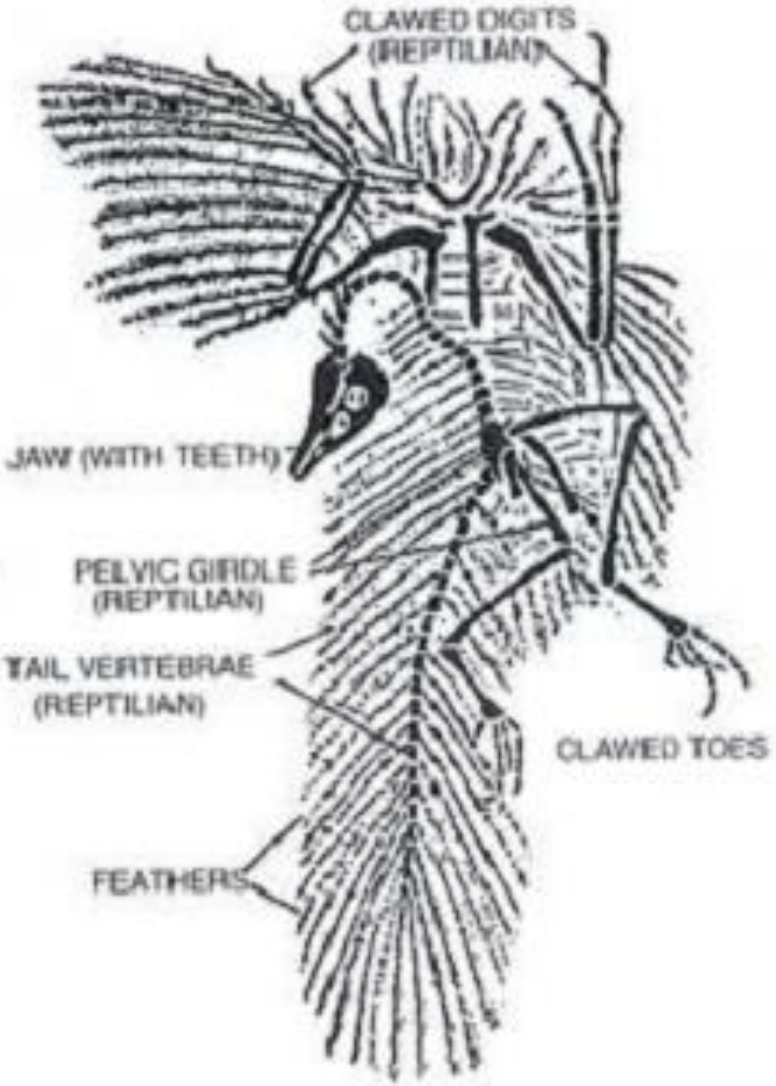
Archaeopteryx

(Archae - primitive, old, pteryx = wing)

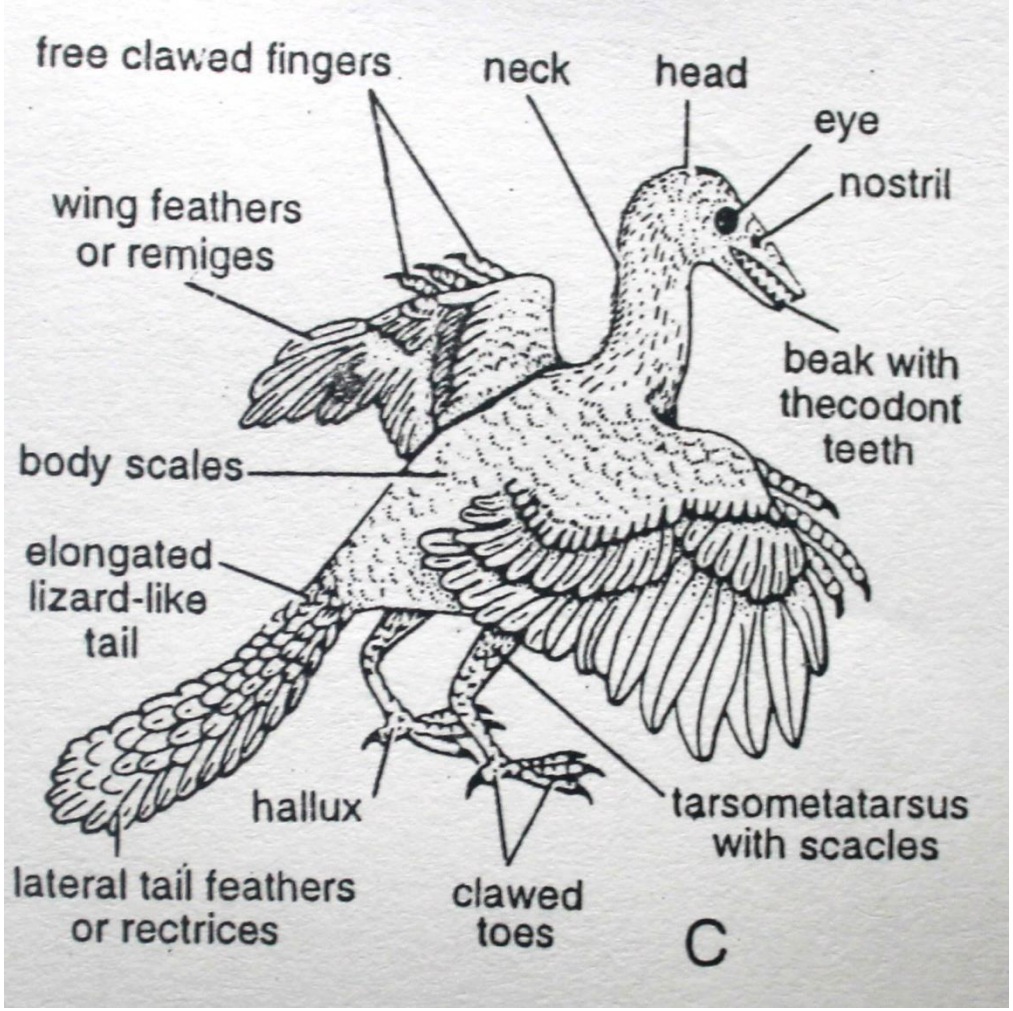
- It was found in the rocks of the Jurassic period.

- *Archaeopteryx lithographica* was discovered in 1861 by Andreas Wagner from the lithographic quarry at Solenhofen, Bavaria, in Germany.

- It displays the characters of both the reptiles and birds.



Archaeopteryx fossil after restoration.



Reptilian Characters of Archaeopteryx:

(a) The body axis is more or less lizard-like

(b) A long tail is present

(c) The bones are not pneumatic

(d) The jaws are provided with similar teeth

(e) The hand bears a typical reptilian plan and each finger terminates in a claw

(f) Presence of a weak sternum

(g) Presence of free caudal vertebrae as found in lizards

Avian Characters of Archaeopteryx:

(a) Presence of feathers on the body

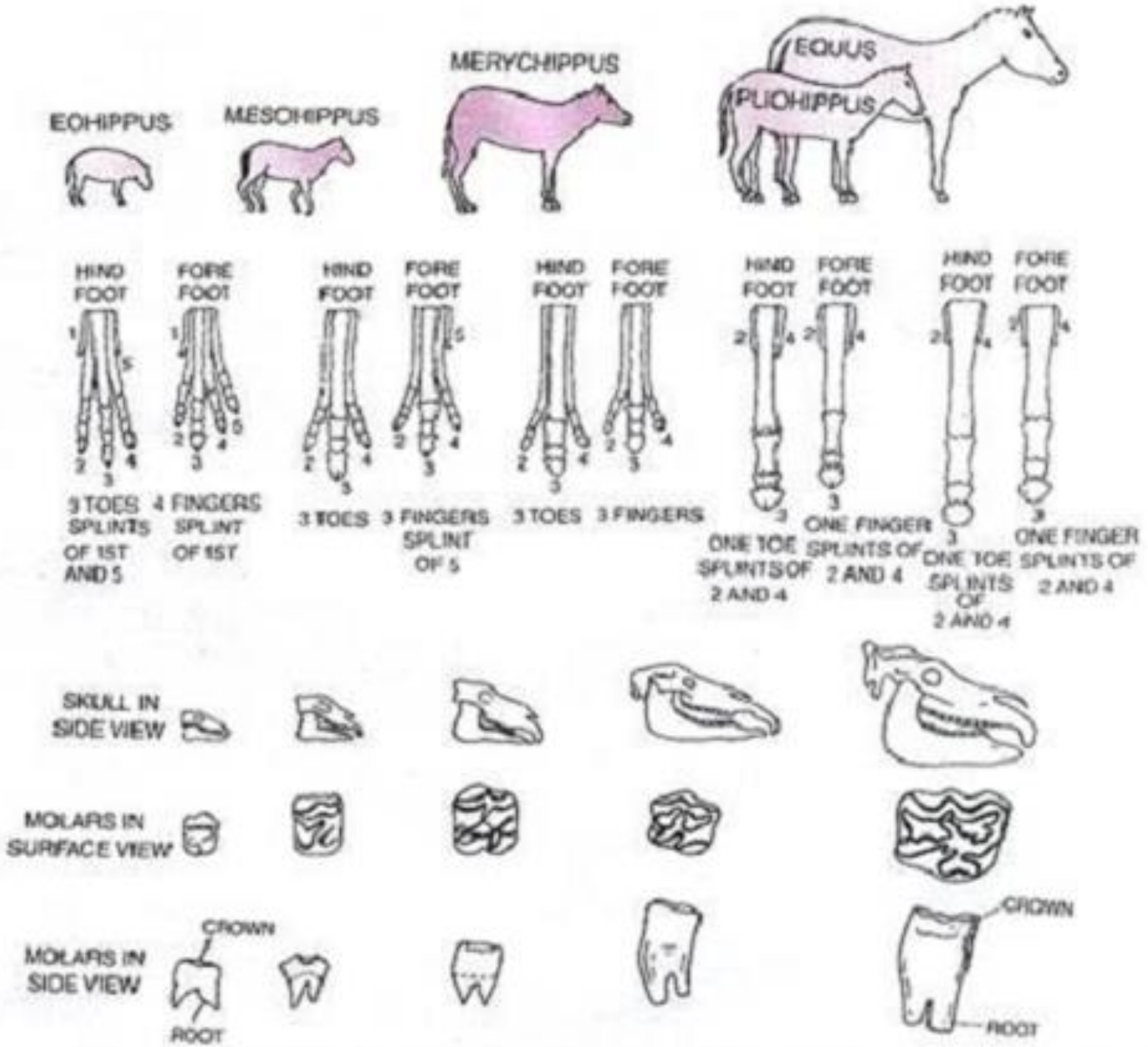
(b) The two jaws are modified into a beak

(c) The forelimbs are modified into wings

(d) The hind-limbs are built on the typical avian plan

(e) An intimate fusion of the skull bones as seen in the birds.

Evolution of Horse


EOHIPPUS
MESOHIPPUS
MERYCHIPPUS
EQUUS
PLIOHIPPUS
HIND FOOT
FORE FOOT
3 TOES SPLINTS OF 1ST AND 5
4 FINGERS SPLINT OF 1ST
3 TOES
3 FINGERS SPLINT OF 5
3 TOES
3 FINGERS
ONE TOE SPLINTS OF 2 AND 4
ONE FINGER SPLINTS OF 2 AND 4
ONE TOE SPLINTS OF 2 AND 4
ONE FINGER SPLINTS OF 2 AND 4
SKULL IN SIDE VIEW
MOLARS IN SURFACE VIEW
MOLARS IN SIDE VIEW
CROWN
ROOT
CROWN
ROOT

Evolutionary Trend:

- continuous change of a character within an evolving Lineage
- trend may be progressive (a general increase in size of organs) or
- retrogressive (a general degeneration and loss of organs)
- the major evolutionary trend of horses

(a) Increase in size

(b) Elongation of neck and head

(c) Lengthening of fore and hind limbs

(d) Reduction of lateral digits

(e) Increase in length and thickness of the third digit

(f) Straightening and stiffening of the back

(g) Increase in size and complexity of the brain

(h) Better developed sense organs

(i) Increase in tooth length

(j) Increase in width of incisors

(k) Replacement of premolars by molars

(l) Increase in crown height of molars

(m) Increased lateral support of teeth by cement

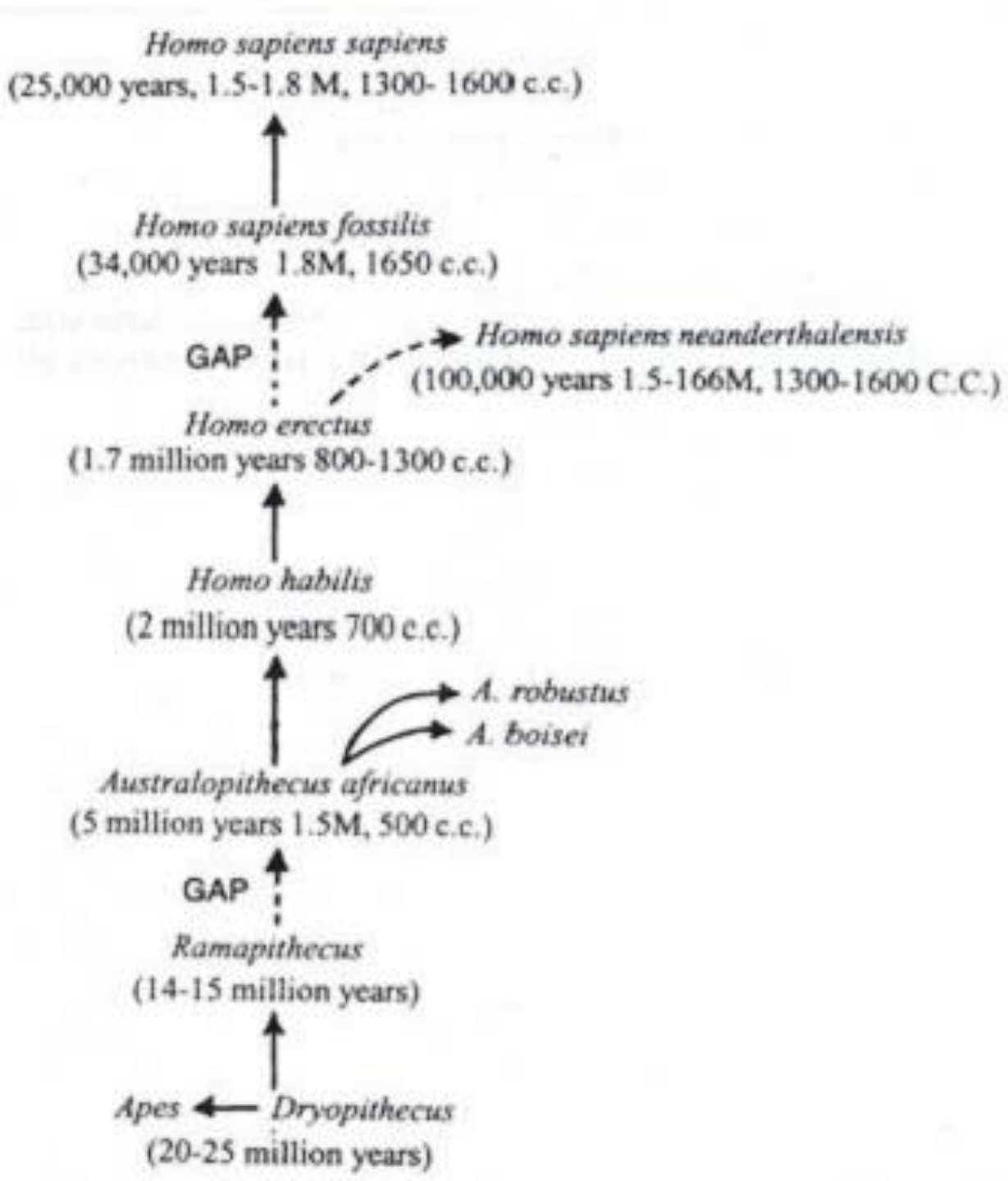
(n) Increased surface area of cusps by the development of enamel ridges (change in premolars and molars teeth from browsing type to grazing type).

Evolution of man

fossil evidence **- origin of man occurred in Central Asia, China, Java and India.**

Dryopithecus is one of the oldest fossil which **in turn evolved into apes and men**.

1. Prior to ape men
2. Ape men including prehistoric man
3. True men including the living modern man.



Morphological Changes involved in Evolution of Man:

(1) Narrowing and elevation of nose.
(2) Formation of chin.
(3) Reduction of brow ridges.
(4) Flattening of face.
(5) Reduction in body hairs.
(6) Development of curves in the vertebral column for erect posture.
(7) Formation of bowl like pelvic girdle with broad ilia in support of viscera.
(8) Increase in height.
(9) Attainment of erect posture and bipedal locomotion.
(10) Enlargement and rounding of cranium.
(11) Increase in brain size and intelligence.
(12) Broadening of forehead and with vertical elevation.

1. Prior to ape men

Dryopithecus

- more ape-like but had arms and legs of the same length.
- Heels in its feet indicate its semierect posture.
- had large brain, a large muzzle and large canines.
- without browridges.
- arboreal, knuckle-walker and ate soft fruits and leaves.
- *Dryopithecus africanus* is regarded a common ancestor of man and apes (gibbons, orangutan, chimpanzee and gorilla).

Ramapithecus

- Perhaps it walked erect on its hind feet.
- More man-like and lived on the tree tops but also walked on the ground.
- Its jaws and teeth were like those of humans.
- Its small canines and large molars suggest that Ramapithecus ate hard nuts and seeds like modem man.

There is a gap of about 9 to 10 million years.

2. Ape men including prehistoric man

Australopithecus (First ape man)

Australopithecus africanus was about 1.5 metres high and had human as well as ape characters.

- with bipedal locomotion, omnivorous diet and had erect posture.
- had human like teeth
- had more of an ape brain than a human brain (brain capacity was about 500 c.c.)
- He lived in caves.
- Brow ridges projected over the eyes.
- It did not have chin.
- There was lumbar curve in the vertebral column.
- The pelvis was broad.

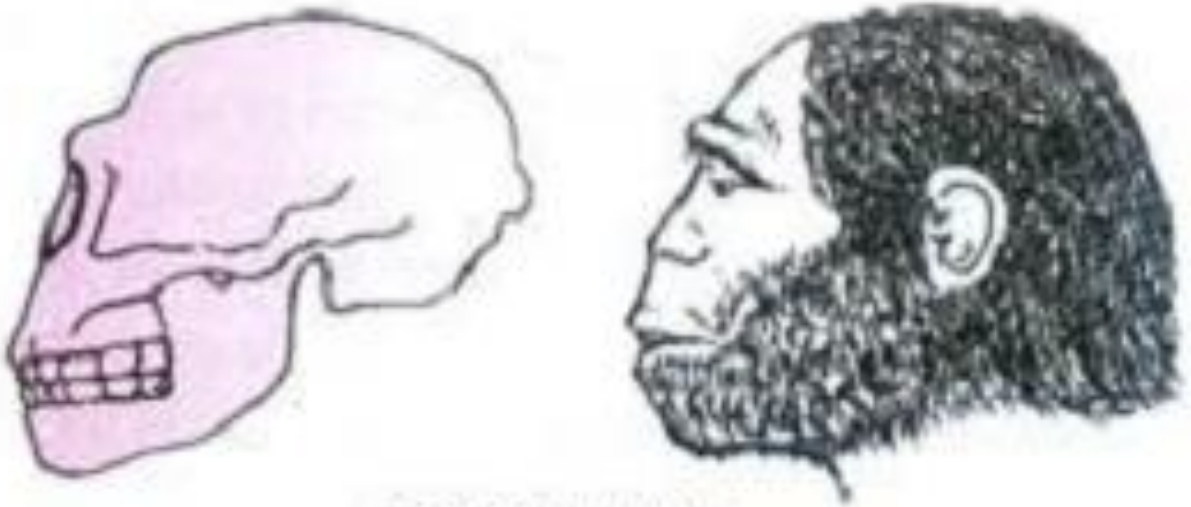
Australopithecus africanus gave rise to *Homo habilis* about two million years ago.

AUSTRALOPITHECUS

Skull and reconstructed head.

Homo habilis (Able or Skillful man, the tool maker, or 'Handy man')

- about 1.2 to 1.5 metres tall.
- had bipedal locomotion, moved erect and omnivorous.
- about 700 c.c. cranial capacity .
- The teeth were like that of modern man.
- Homo habilis (habilis – mentally able or skillful) was the **first tool maker** and used tools of chipped stones extensively.
- He also led community life in caves and greatly cared for the young ones.

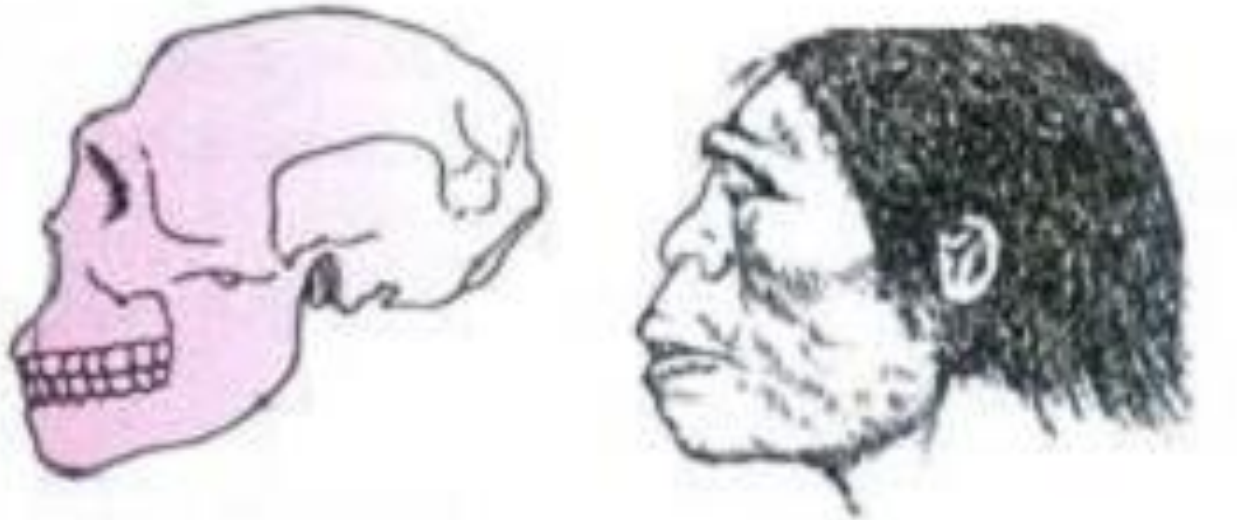


HOMO HABILIS

Skull and reconstructed head.

***Homo erectus* (Erect man):**

- evolved from Homo habilis.
- about 1.5-1.8 metres tall.
- males were probably larger than females.
- erect posture.
- skull was flatter than that of modem man.
- had protruding jaws, projecting brow ridges and small canines and large molar teeth.
- The cranial capacity was 800 to 1300 cc.
- Cranium was domed to accommodate the large brain.
- He was omnivorous.
- He made more elaborate tools of stones and bones, hunted big game and perhaps knew use of fire.
- Homo erectus includes three fossils: **Java Ape-man, Peking man** and Heidelberg man.



HOMO ERECTUS

Skull and reconstructed head.

Java Ape man

- Body 1.65 to 1.75 mtrs tall and weight about 70 kg.
- Legs long and erect, but body slightly bent when moving.
- Inconspicuous chin and somewhat broader nose.
- Forehead low and receding, but brow ridges high like those of apes.
- Skull cap thick and heavy, flattened in front.
- Cranial capacity 800 to 1000 cc. (average 950 cc).
- Lower jaw large and heavy .
- Teeth large, but quite like those of modem man, except larger canines of the lower jaw.
- Lips thick and protruding.
- He was omnivorous and cannibal.
- **Perhaps he was the first prehistoric man to make use of fire for hunting, defence and cooking.**

Peking Man

- Java ape man and Peking man as **subspecies** of Homo erectus because of close similarities between these.
- The body structure was quite similar in both.
- Being about 1.55 to 1.60 metres tall, Peking man was slightly shorter and a little lighter and weaker.
- The only noticeable difference of Peking man from Java ape man was its large cranial capacity which ranged from 850 to 1100 c.c.
- Like Jave ape man, the Peking man was omnivorous and cannibal.
- There is a clear evidence of use of fire by it.
- It has been confirmed that both Java and Peking men used to live in caves in small groups or tribes.
- The tools of Peking man were relatively more sophisticated.

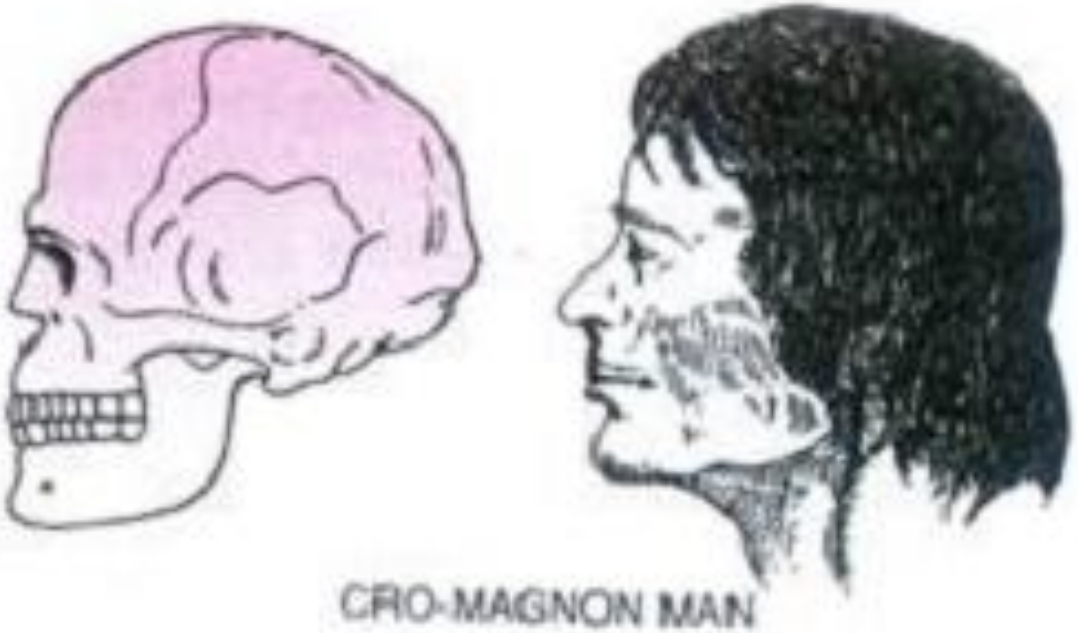
3. True men including the living modern man

Neanderthal Man (Homo sapiens neanderthalensis)

- had slightly prognathous face (having a forward projecting face and jaws).
- Neanderthals walked upright, as we do, and had low brows, receding jaws, and high domed heads and were much stockier than we are.
- Their cranial capacity was 1,300 to 1,600 cc.
- Neanderthals were the legendary cave dwellers.

- Neanderthals were adapted to a cold environment.
- They were not only skilled hunters but true predators, a specialization that did not occur among hominids before or after them.
- The neanderthals were cannibals.
- They fashioned the skin into clothing to protect themselves against the harsh climate.
- Natural caves became camp sites that were illuminated and heated by fire.
- It is usually considered that Homo sapiens neanderthalensis did not evolve into Homo sapiens.

Cro-Magnon man



CRO-MAGNON MAN

Skull and reconstructed head.

- had about 1.8 metres tall, well-built body.
- Its face was perfectly **orthognathous** (Jaws do not project forward) with an arrow, elevated nose, broad and arched forehead, moderate brow ridges, strong jaws with man-like dentition, and a well developed chin.
- Its cranial capacity was 1650 cc, somewhat more than our. It is, therefore, believed that Cro Magnon man was somewhat more intelligent and cultured than the man of today.
- could walk and run faster and lived in families in caves.
- made excellent tools and even ornaments, not only of stones and bones, but also of elephant tusks- included spears, bows and arrows = omnivorous.
- Use of the skin clothes.
- cave paintings done.
- It became extinct about 10,000- 11, 000 years ago.
- The Cro-Magnon man was the direct ancestor of the living modern man.

The Living Modern Man (Homo sapiens sapiens)

Morphologically, the transition is marked merely by

- a slight raising of skull cap,
- thinning of skull bones,
- a slight reduction in cranial capacity (1300-1600 c.c.
- average about 1450 c.c.), and
- formation of four curves in the vertebral column.

It is believed that the man of today **first appeared** about 11,000 or 10,000 years ago in the **region around Caspean and Mediterranean Seas**. From there, its members migrated westwards, east wards and southwards, respectively changing into the present day white or Caucasoid, Mongoloid and black or Negroid races.