Geological time scale, Fossil, Carbon dating, Evolution of horse

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Geological time scale

Definition : Geological time scale is a record of earth's history based on the organisms that lived at different times.

The Geological time scale was recognized on the basis of characteristic fossil faunas. Although earlier divisions are recognized too, but the past 550 million years are paleontologically most important because fossils are much less common before this time.The times of transition between two eras are times of transition between different characteristic fossil faunas: the fossils of the Permian, for instance, characteristically differ from those of the Triassic and at the Permo-Triassic boundary there is a relatively sudden transition between the fossil faunas. In the nineteenth century it was not known whether the transition times corresponded to mass extinctions and sudden replacements, or to long gaps in the fossil record while a slower replacement was proceeding. It is now known they were mass extinctions in short periods.

The first geological time scale was proposed in 1913 by the British geologist Arthur Holmes (1890-1965). This was soon after the discovery of the radioactivity.

Divisions :

The geological time scale has been divided into four **eons.** These are-

Hadean – rocks from meteorites and the moon.
Archean – earliest rocks on earth form.
Proterozoic – organisms with well developed cells.
Phanerozoic – means "visible life" well represented in the fossil record.

The eons have been divided into several **eras**. The most important eons in terms of evolution i.e. phanerozoic have been divided into Cenozoic, Mesozoic, Paleozoic, Proterozoic and Archezoic. Each era is again divided into **periods** and each period is subdivided into **epochs.**

Precambrian : Three eons- Hadean, Archean and Proterozoic together are known as precambrian and comprises about 88% of the geological time (4500 million years).

Most research on the origin of life is not on fossils, but consists of laboratory research on the kinds of chemical reactions that may also have taken place on Earth 4 billion years ago.The oldest known rocks are at a site at Isua, Greenland, and are 3.8 billion years old. These rocks contain chemical traces that may or may not be chemical fossils of life forms (van Zuilen et al. 2002).The earliest fossil cells were until recently thought to come from 3.5 billion-year-old rocks from the Apex Chert in Western Australia (Schopf 1993).Cells had therefore likely evolved by 3.5 billion years ago, or soon afterwards.Fossils of cellular prokaryotic life have been found at several sites, aged between 3.5 and 2 billion years ago.Thus, cellular life was flourishing by 2–3 billion years ago.The earliest fossil cells that have been proposed to be eukaryotic were found in an abandoned mine in Michigan and are described by Han & Runnegar (1992). The fossils are corkscrew shaped and closely resemble later algae (algae are eukaryotes).Molecular clock studies suggest the eukaryotes originated in the 2.2–1.8 billion years ago range. Thus the body fossil and molecular evidence agree, but chemical fossil evidence hints at an earlier date.The molecular clock suggests that multicellular life originated about 1.5 billion years ago. This is somewhat, but not much, before the oldest multicellular fossils. Currently the earliest such fossils are algae from about 1.2 billion years ago (Butterfield 2000). The earliest definite fossils of multicellular animals (Metazoa) come from the Ediacaran deposits in Australia. These, and similar deposits elsewhere in the world, date to the period from 670 to 550 million years ago.The Ediacaran fossils decline in abundance about 550 million years ago due to a mass extinction but continue to exist in the Cambrian (Jensen et al. 1998).

Phanerozoic eon

Paleozoic era :

Cambrian : Explosion of life. All existing phyla come into being at this time- this is known as cambrian explosion. The main time periods of the fossils record begin with the Cambrian. Dominant animals were marine invertebrates.

Ordovician: The Fish group proliferated in the ordovician period, though dominant animals are still trilobites, brachiopods and corals. Invertebrates diversify into many new types. Land was colonized by plants and fungi. Little is known about early terrestrial fungi, but for plants, widely accepted evidence of fossil spores have been found from 475 million years ago.Land plants were most closely related to a group of green algae called charophyceans and bryophytes. The main events in the early evolution of land plants were the evolution of a resistant spore stage.

Silurian : First vascular plants evolved. The earliest fossils of whole plants, as distinct from spores, date back to around 430 million years ago. Clarksonia is one of the commonest fossils of this time. These early land plants lacked roots and leaves, and simply had branching stems.They photosynthesized through their stems, because stomata are visible in the fossil stems. First jawed fishes, as well as many armoured jawless fish, populate the seas.

Devonian : First leafy plants (clubmosses, horsetails and ferns) appear. The evolution of leaves coincides with a dramatic fall of about 90% in atmospheric carbon dioxide concentration. Terrestrial plants at the water's edge with their roots growing down into the water and the arthropod life associated with them, combined to create a new habitat at the water's edge. Fish would have evolved to exploit the resources there which promoted evolutionary transition from fish to terrestrial amphibians, the first of the tetrapod groups to evolve. Tetrapods have descended from lobe-finned fish ancestors like lungfish. Between the lungfish and amphibians, a series of fossil forms range from the com-pletely fish-like Eusthenopteron, through aquatic (Acanthostega), and partly terrestrial(Ichthyostega) tetrapods, to amphibians. Trilobites and armoured agnaths decline, while jawed fishes (placoderms,lobe-finned and ray-finned fish, and early sharks) rule the seas.

Carboniferous : Carboniferous period subdivided into Mississippian and Pennsylvanian epoch. Fossil seeds exist in the Carboniferous, which indicates seed plants evolution , however, seed plants were a minor group at that time. The coal deposits formed during the carboniferous, mainly formed from fossil pteridophytes. Winged insects radiate suddenly; some (esp.Protodonata and Palaeodictyoptera) are quite large. Amphibians are common and diverse. First reptiles evolved. . The small lizard-like creature called Hylonomus, is an early reptile. Highest-ever atmospheric oxygen levels.

Permian : Landmasses unite into supercontinent Pangaea. The next big step in terrestrial vertebrate evolution was the origin of the amniotic egg. Synapsids reptiles including (pelycosaurs and therapsids) become plentiful, The coal-age flora are replaced by cone-bearing gymnosperms (the first true seed plants).

Mesozoic era :

Triassic: Dinosaurs, like Archosaurs dominant on land, pterosaurs in the air andIchthyosaurs dominate large marine fauna. Cynodonts become smaller and more mammal-like, while first mammals appear. *Dicroidium* flora is common on land.Modern corals and teleost fish appear, as do many modern insect clades.

Jurassic : Gymnosperms and ferns are common. First birds appear. Many types of dinosaurs, such as sauropods, carnosaurs, and stegosaurus. Mammals are common but small.

Cretaceous : Flowering plants (angiosperms) evolved, along with new types of insects. More modern teleost fish begin to appear. Many new types of dinosaurs (e.g. Tyrannosaurs, Titanosaurs, Hadrosaurs, and Ceratopsids) evolve on land and mosasaurs and modern sharks appear in the sea. Birds toothed and toothless coexist with pterosaurs. Monotremes, marsupials and placental mammals appear.

Cenozoic era:

Tertiary : Tertiary period is subdivided into paleocene, eocene, oligocene,miocene and pliocene epochs. During this period Mammals diversify into a number of lineages following the extinction of the non-avian dinosaurs. First large mammals (up to bear or small hippo size).Major evolution and dispersal of modern types of flowering plants. Ancestors of apes, including humans evolved.

Quaternary : Quaternary period is sub-divided in pleistocene and holocene epochs. Start of Quaternary glaciations or ice age. Rise of the Pleistocene megafauna and Homo habilis, Homo erectus and Homo sapiens.

EON	ERA	PERIOD	EPOCH	DURATION (Millions)	MAJOR EVENTS
Hadean				4500-543	
Archean					
Proterozoic					First cell.
Phanerozoic	Paleozoic	Cambrian		543-490	Explosion of life. All animal phyla come into existance
		Ordovician		490-443	Proliferation of fish group group. Resistant spore helped in land colonization by algae and fungi.
		Silurian		443-417	First jawed fish evolved. First vascular plants evoled.
		Devonian		417-354	First leafy plants appear. First tetrapods evolved from lung fish. Ocean dominated by jawed fish.
		Carboniferous	Mississippian	354-290	First reptiles evolved.Winged insects radiate suddenly First seed plants appear.
			Pennsylvanian		
		Permian		290-251	Synapsids reptiles including (pelycosaurs and therapsids) become plentiful. True seed plants dominate the earth.
	Mesozoic	Triassic		251-206	Dicroidium flora is common on land. Dinosaurs evoled. First mammals appear.
		Jurassic		206-144	First birds appear. Many types of dinosaurs Gymnosperms and ferns are common
		Cretaceous		144-65	Marsupials and placental mammals appear. Dinosaur domiante the world.Toothed and toothless bird coexist. Flowring plants appear.
	Cenozoic	Tertiary	Paleocene	65-1.8	Mammals diversify into a number of lineages(from small mammals to ancestor of human) following the extinction of the non-avian dinosaurs. Major evolution and dispersal of modern types of flowering plants
			Eocene		
			Oligocene		
			Miocene		
			Pliocene		
		Quaternary	Pleistocene	1.8-0.01	Start of ice age. Human evolutuion.
			Holocene	0.01 to recent	

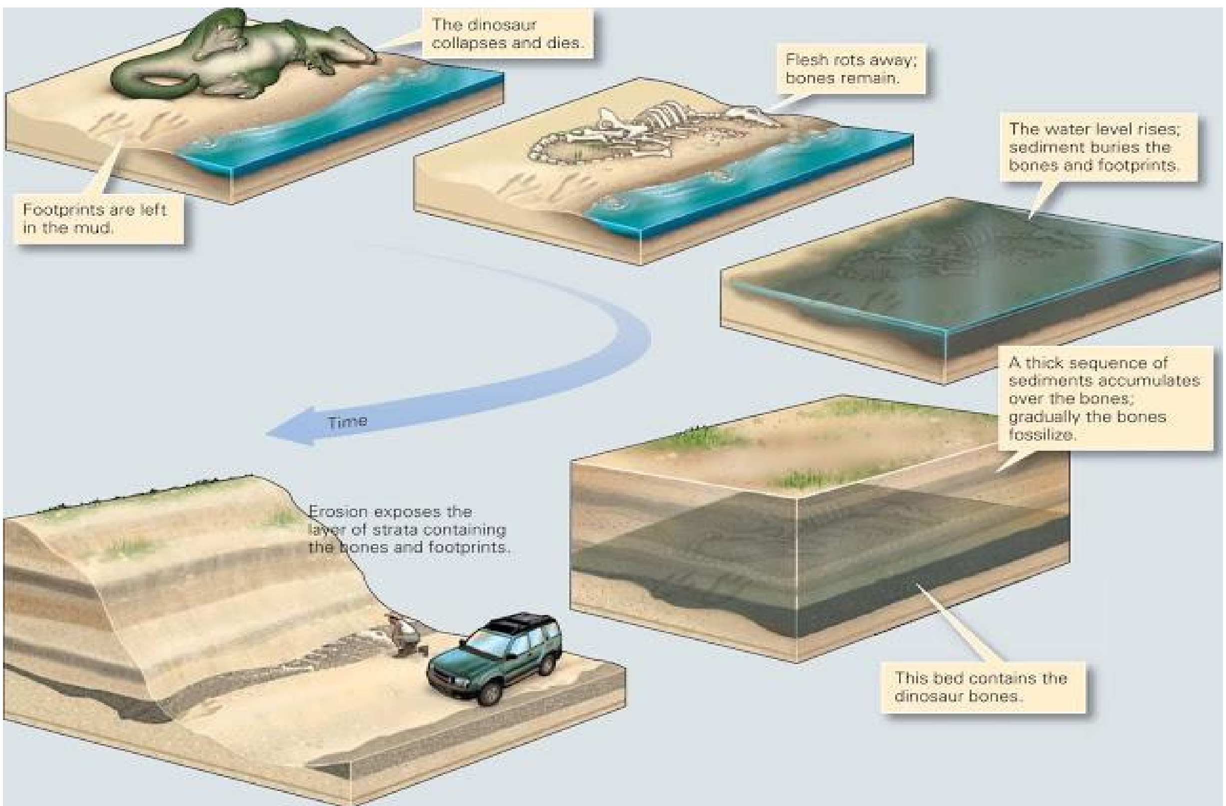
Camels Often Sit Down Carefully, Perhaps Their Joints Creak.
Put Eggs On My Plate, Please Hurry.

Fossils: Fossils are remains or remnants of organisms (such as shells, bones, and teeth) or their activities(such as burrows or footprints) from the past and are usually preserved in sedimentary rocks, ambers or in other things.

Mechanism of fossilization :

When an organism dies, its soft parts are usually either eaten by scavengers or decay by microbial action. For this reason, organisms that consist mainly of soft parts (such as worms and plants) are less likely to leave fossils than are organisms that have hard parts. Some fossils of soft parts do exist, but they were either deposited in exceptional circumstances or preserve exceptionally abundant life forms.Although an organism’s hard parts stand the best chance of fossilization, even they are usually destroyed rather than fossilized. Hard parts may be crushed by rocks, stones, or wave action, or broken up by scavengers. If the hard parts survive, the next stage in fossilization is for them to be buried in sediment at the bottom of a water column. Animals that normally live within sediments are more likely to be buried in sediment before being destroyed. These animals are therefore more likely to leave fossils than are species that live elsewhere. Likewise, species that live on the surface of the sediment (i.e., on the sea bottom) are more likely to be fossilized than are species that swim in the water column. Terrestrial species are least likely of all to be fossilized.

Once an organism’s remains have been buried in the sediment, they can potentially remain there for an indefinitely long period of time. As new sediment piles on top of older sediment, the lower sediments are compacted a the water is squeezed out and the sedimentary particles are forced closer together. As the sediments compact, they are gradually turned into sedimentary rock. They may subsequently be moved up, down, or around the globe by tectonic movement, and can be re-exposed in a terrestrial area. Any fossils they contain can then be picked up, or dug up, on land.



Types of Fossils: On the basis of casting materials.

(i) Sedimentary Rocks (e.g. Coal):
Majority of plant materials are preserved as fossils in sedimentary rocks. Coal is the best known example of sedimentary rock. Present coal belt in the world, therefore, represents dense forests of the world of earlier times. Least metamorphosed coal shows maximum details of fossilized or preserved plant material.Therefore, lignite's (early stage of coal formation) carry less crushed plant parts and their details can be studied more easily than bituminous coal and anthracite coal.

(ii) Amber:
The fossilized plant resin secreted by coniferous trees that grew in very early times is called amber. This "very early time" in the geological past ranged from Carboniferous (i.e. about 345 million years ago) to Pleistocene (i.e. about 2.5 million years ago). Fungal spores, pollen grains, etc. were trapped in this resin before fossilization.




iii) Diatomite :
Diatoms are unicellular algae belonging to class Bacillariophyceae. Their walls have silicon deposits. The sedimentary rock formed by the remains of diatoms is called diatomite. In due course of time, diatoms keep on depositing at the base of sea, oceans or lakes and form sedimentary rock.

(iv) Mummification:
The process of the formation of fossils in ice-frozen environments in the polar regions is termed as mummification. The moisture of the tissue of the organism gets converted to very small or microcrystals of ice. It is almost a process similar to deep freezing.

(vi) Biochemical Fossils:
These are fossils which consist of chemical substances like chlorophyll, amino acids, aromatic acids, flavonoids, branched hydrocarbons and steroids. These have been reported to be present either in the fossilized remains of organisms or in the rocks.

(iv)Pseudo-Fossils or Dendrites:
Pseudo-fossils or dendrites are completely inorganic structures of various types. They often resemble plant organs. Their formation takes place by the deposition of

minerals due to seepage or percolation of water in rock crevices. They superficially resemble leaves of ferns.

Types of fossils : On the basis of types of fossilization

Mold fossils : A fossilized impression made in the substrate; a negative image of the organism.External features of the organisms in three-dimensional view are best seen and studied in molds.

Cast fossils : Formed when a mold is filled with mineral matter i.e. sediments, it results in the formation of a cast. An exact replica of the original plant material is thus obtained.

Trace fossils : Fossilized nests, gastroliths, burrows, footprints, etc.

True form fossils : Fossils of the actual animal or animal part.

Carbon dating

Carbon dating is used for determination of age of fossils.

Radioisotopes of chemical elements decay over time. For example, the isotope of carbon ^{14}C decays into an isotope of nitrogen, ^{14}N. The decay is very slow and Half-life of about 48.6 billion years.

Half-life: The time required to decay half of an initial sample of radioactive element.

If there is 10 gm of radioactive element with half life 1000 year, then after 1000 year 5 gm of radioactive element will remain.

So the rate should be = 10/1000 = 0.01 gm/year. But…..
Decay constant (λ): Radioactive decay proceeds at an exponentially constant rate. Exponential decay means that a constant proportion of the initial material decays in each time unit.
Suppose $1/10^{th}$ of initial amount decay in each year……
Initial amount of radioactive element (N_0): here ^{14}C isotope of Carbon. The ratio of $^{12}C/^{14}C$ carbon is constant in atmosphere, so also in plants and animal bodies when they live. But after their death the ratio continues to increase. Or amount to ^{14}C continues to decrease. So, the present atmospheric ^{14}C level is considered as initial amount of radioactivity.

Current amount of radioactive element (N): Determined by radio techniques.
Age of fossils (t) : ?

Ex: if 3% of the original 14C in a fossil has decayed into nitrogen, then the age of the fossil is calculated as

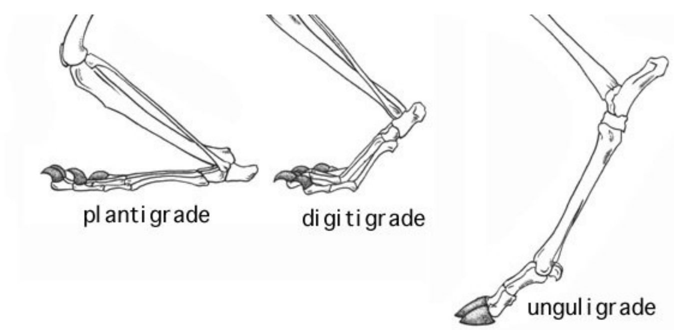
$t = (1/\lambda) \log N_0/N$ where: $\lambda = 1.2 \times 10^{-4}$ per year
$N_0 = 100$
$N = 97$

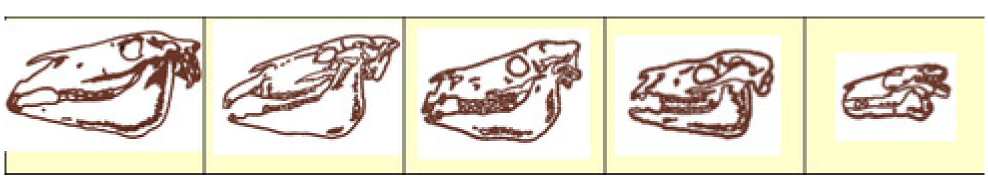
$T = 1/1.2 \times 10^{-4} \log 100/97 = 1/1.2 \times 10^{-4} x\ 0.02 = 167$ year.

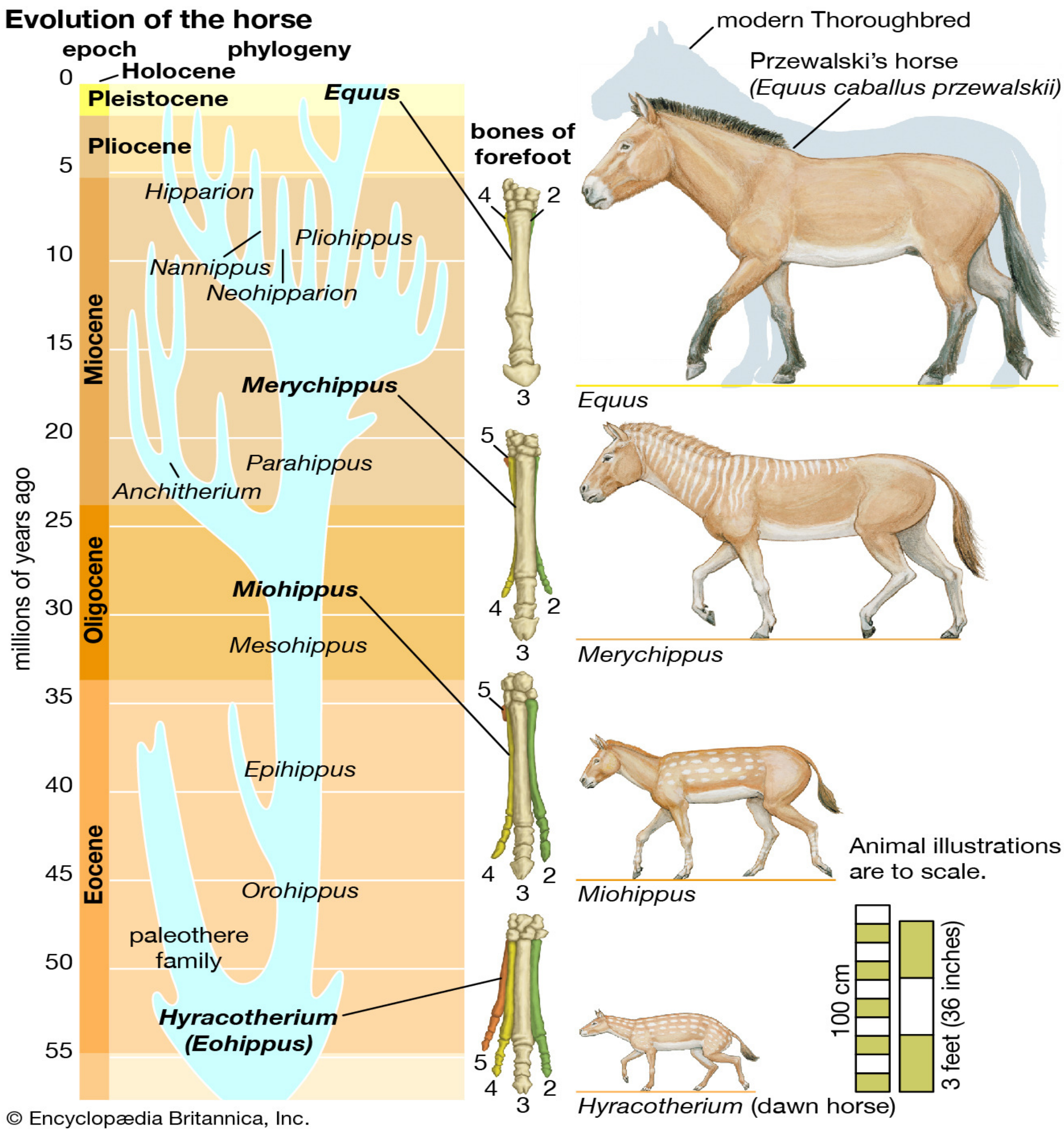
Evolution of horse : Evolution of horse dates back to Eocene epoch, about 60 million years ago. Primary center of evolution were Great Plains of North America, from where species migrated to Europe and Asia from time to time. For some reasons horses became extinct in North America by the end of Pleistocene epoch but their offshoots in Europe and Asia flourished.

Evolution of horse was triggered by a change in the climate and vegetation during lower cenozoic period, when grasslands in most parts of the world replaced forests. The main modifications in the body of horses from small forest-dwelling animals to large, grazing and fast-running animals can be outlined as follows:

- Increase in the size and height of the body from a small, dear-like animal to 6 feet tall grassland animal.
- Gradual enlargement and better development of the third digit (median digit) and reduction of the other lateral digits.
- Lengthening of the limbs and perfection of the hoof for fast running in open grasslands.
- Reduction of ulna bone in the fore leg and fibula in the hind leg and strengthening of radius and tibia.
- Change from digitigrades to unguligrade locomotion for fast running.
- Elongation of the preorbital or facial region of the skull and migration of eyes to the top of head.
- Modification of teeth from brachydont (low-crowned) to hypsodont (high crowned) to withstand tougher food (grass).
- Increase in the size and complexity of the brain for superior intelligence.
- Reduction in pectoral girdle and disappearance of the weak clavicle.
- Body became streamlined, muscles tight, without loose fat, for long and sustained running.
- Nostrils became wide to allow more air into strong lungs and stamina increased.







Phylogeny

Eocene horses

Eohippus (Hyracotherium): Fossils of *Hyracotherium* were found in Europe and those of *Eohippus* in North America. Height was about 2 feet. Facial region was short and eye-orbits located about in the middle of the length of the skull. Dentition was brachydont (low-crowned) and bunodont (low cusps) to feed on soft vegetation. Ulna in the foreleg and fibula in the hind leg were complete. Fore foot had 4 digits and hind foot had 3 digits, all touching the ground.

Orohippus and ***Epihippus:*** Both are related genera and do not differ much from the preceding species. There were four digits in front foot and three in the hind foot. Median digit became larger and lateral ones shorter but all touched ground and carried the body weight.

Oligocene horses

Mesohippus and ***Miohippus:*** There is enlargement in size to about 24 inches. Three functional digits in fore as well as hind foot, all touching the ground but the median toe was much stronger than the others. Ulna and fibula became thin and slender. All premolars became molariform, as a pre-adaptation to harsh diet.

Miocene horses

Parahippus and ***Merychippus:*** There were three digits in each foot but the middle one was larger and stronger and the lateral digits did not reach the ground. Preorbital region of the face became elongated. All premolars became molariform and dentition became hypsodont but the milk teeth were still low-crowned. Central toe ended in a large convex hoof.

Anchitherium: It was found in Europe and Asia where it came from North America. It was larger than *Miohippus*. It had 3 toes and digitigrade locomotion. Teeth were low-crowned and molars were simple.

Pliocene horses

Pliohippus: Lateral digits reduced to vestiges. Skull had elongated. Crown of teeth was similar to modern horses but they were curved and pattern of ridges was not so advanced. Facial fossae were deep. It had acquired unguligrade gait of swift locomotion.

Hipparion: Size about 40 inches. There were three toes in each foot but lateral digits were small. They migrated from North America to Old World through Alaska and Siberia.

Protohippus: It was a 3-toed grazing horse that had low crowned teeth.

Hippidion: It had short and stout feet having only one toe. Head was large with long and slender nasal bones.

Pleistocene horses:

Because of the harsh climate of the Pliocene and glaciations of Pleistocene epoch, horses became extinct in North America. Only one genus, ***Equus,*** survived in northern Africa, Asia and Europe. It soon spread to different parts of Asia, Africa and Europe and diversified into 5 distinct species, namely, *Equus caballus, E. zebra, E. hemionus, E. assinus* and *E. przevalskii.*

Related questions:

1. What are different periods under Palaeozoic era? Describe the major events of Palaeozoic era.

2. What is carbon dating? How is it performed?

3. Describe briefly about the different types of fossils.

4. Describes the gradual changes in horse anatomy in different epochs.

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