

Special Issue on

Origin and Evolution of Life on Earth

Prologue

The chief of existing planet, an organism with highly developed brain, "Human". Where did they actually originate? The place we live "The planet Earth" how did it originate? There are many religious belief and scientific evolutionary theory for the evolution of life on earth. This paper deals with the origin and evolution of planet and life from its root, the mythological story that was widely spread and believed across the globe, the alarming issue of the present, its causes and preventive measures. The evolution is dealt in different geological timescale from the appearance of first living organism on the planet, the various extinction events, tectonic movement of the land mass, various formations of ocean to the appearance of modern human.

I firmly believe that this paper would give a clear picture of the evolution of life on earth and make the readers understand the different stages of evolution effortlessly with the help of the diagrams and point wise presentation of the content. I also trust that the readers will understand the need for preventive measures of climate change and pledge their contribution to make the globe a better place for peaceful living.

Ms.Priya Prabhakar

THE ORIGIN AND EVOLUTION OF LIFE ON EARTH

INTRODUCTION:

The life that we live now is said to have originated long back and there were plenty of evolution that took place intermediately. As Quoted by **Mark Twain** (Samuel Langhorne Clemens) **"Don't go around saying the world owes you a living. The world owes you nothing. It was here first."** The solar system originated well before the origin of life. If the origin of life is glimpsed scientifically, it is said that life originated from the environment that existed primarily. The other way, people believed the mythological story that every religion had for the origin of life. These mythological stories rose first concerning the origin of life and people had a strong belief in these stories. The example which would clearly get us the picture of the strength of belief that people had on these mythology, is Charles Robert Darwin an English naturalist, it took him 20 years to publish his ideas of natural selection as he knew there would be a storm of religious protest and his own wife was not happy as he was going to write something which is incomparable with the bible. She also wrote a letter to him when they were first married saying that his science would not let them eternity into different places. So there were two areas for the origin and evolution of life where the scientific area took a long way to get established as, people had a strong belief in the religious mythologies then. Later due to the vast exposure and the knowledge the scientific discoveries about the origin and evolution of life was established and were accepted by people. Now let us see in detail about both the mythological stories and the scientific discoveries about the origin and evolution of life.

As both are vast areas to deal with, let us observe each separately, that is

- (i) **Mythological stories**
- (ii) **Scientific discoveries**

MYTHOLOGICAL STORIES:

There are numerous mythological stories believed about the origin of life. Each religion has its own mythological stories and the respective people had a strong belief on it. There are several features in all stories of creational myths. They are all stories with a plot and characters who are either deities, human like figures or animals that often speak and transform easily. The different mythology that existed in different parts of different religion were, Creational myths of Maasai and Zulu of Africa; Korea, Mansi and Mongol of Asia; Buddhist, Hindu and Sikhism of India; Sumerian, Babylonian, Egyptian, Hermeticism, Islam, Judaism and Christianity, Mandaism and Zoroastrianism of Middle East; Kiowa apache, Aztec, Cherokee, Choctaw, Creek, Digueno, Hopi, Haida, Inuit, Iroquois, Lakota, Navajo, Seminole, Tlingit and Maya of North America; Incan and Piraha of South America; Australian Aboriginal, Hawaiian, Maori and Tagalog of Pacific.

Even though there were these many mythologies the Christian Mythology was widely spread and believed by majority of world population as Christianity is the world largest religion from the early centuries.

The mythological story that the Christians believed was, God progressively creates the different features of the world over a series of six days. All these creation is by divine command that is God says "Let there be light!" and light is created on the first day. He divided the light from the darkness and he called the light as Day and the darkness as Night. There was morning and evening on that day.

Second day he said "Let there be an expanse in the midst of waters and Let it divide". He made the expanse, and divided the waters which were under the expanse from the waters which were above the expanse. He called the expanse sky.

On the third day he said "Let the water under the sky be gathered together to one place and let the dry land appear". Hence the land and water bodies were formed. He called the land as earth and the gathered water bodies as seas. The same day he created the grass, herbs yielding seeds, fruits, seeds.



On the fourth day he created days, years and seasons dividing the light for day and night. He also made stars on the same day.

On the sixth day he created worms, birds, animals and large sea creatures. Then the man was created from the dust and he breathes life into the man to look after the creatures. God prepares a Garden of Eden and fills it with trees bearing fruit for him to eat. He asked the man to eat fruits from any tree except from the tree of knowledge. As he couldn't use the help of animals god created woman from the rib of man. A serpent from the Eden garden instilled the wish of eating the fruit from the knowledge tree to the woman. She took a fruit from that tree and shared it with the man. The god got angry and cursed the serpent, woman and man.

He said to the serpent "Because you have done this, cursed are you above all cattle, and above every animal of the field. On your belly shall you go, and you shall eat dust all the days of your life. I will put enmity between you and the woman, and between your offspring and her offspring. He will bruise your head, and you will bruise his heel."

To the woman he said "I will greatly multiply your pain in childbirth. In pain you will bring forth children. Your desire will be for your husband, and he will rule over you."

At last to the man he said "Because you have listened to your wife's voice, and have eaten of the tree, of which I commanded you, saying, 'You shall not eat of it,' cursed is the ground for your sake. In toil you will eat of it all the days of your life. Thorns also and thistles will it bring forth to you; and you will eat the herb of the field. By the sweat of your face will you eat bread until you return to the ground, for out of it you were taken. For you are dust, and to dust you shall return."

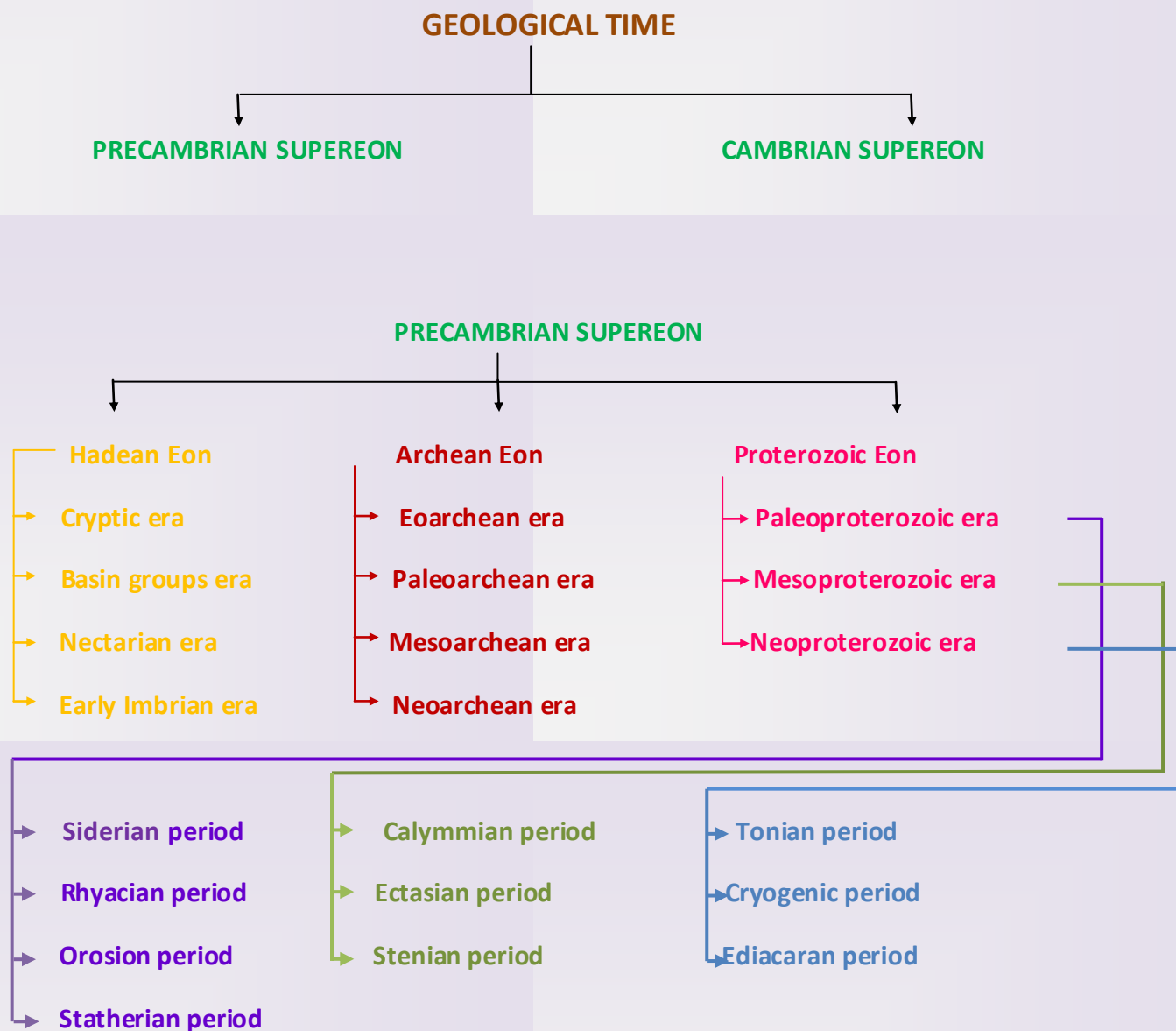
And hence it is believed that the life of man and woman evolved from Adam "The man in the story" and Eve "The woman in the story".

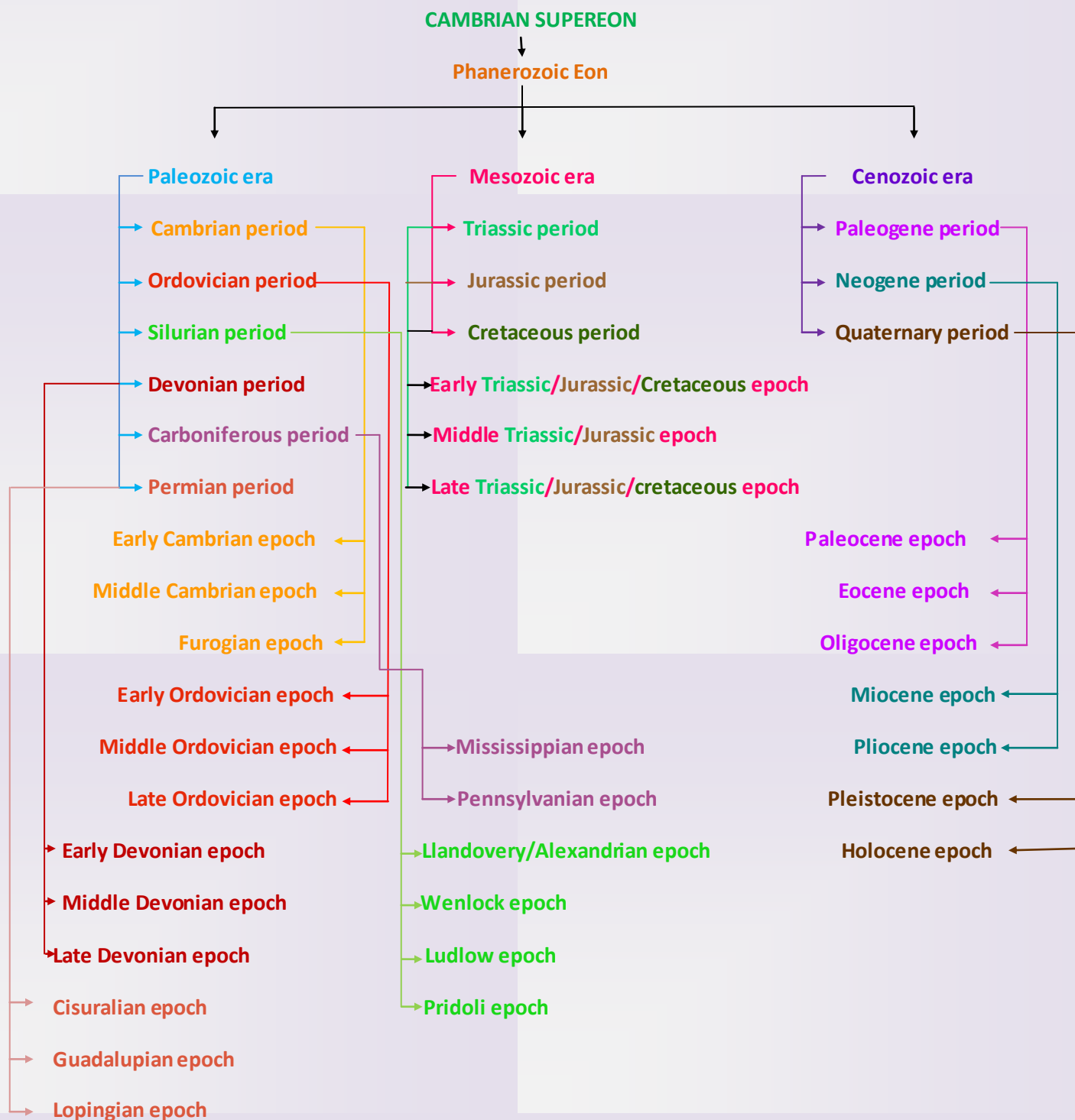


SCIENTIFIC DISCOVERIES:

To glimpse through the scientific discoveries let us take the geologic time scale which provides a system of chronologic measurements that relates stratigraphy to time that is used by geologists, paleontologists and other earth scientists to describe the timing and relationships between events that have occurred during the history of the Earth.

The Geological timing is divided as follows:





Let us now see in detail the origin and the evolution that has take place through various Super eons, Eons, Eras, Epochs and periods. These super eon, eon, era, epoch and period are the term which is used to indicate periods of time in geochronology (Geochronology is the science of determining the absolute age of rocks, fossils and sediments within a certain degree of uncertainty innate to the method used)

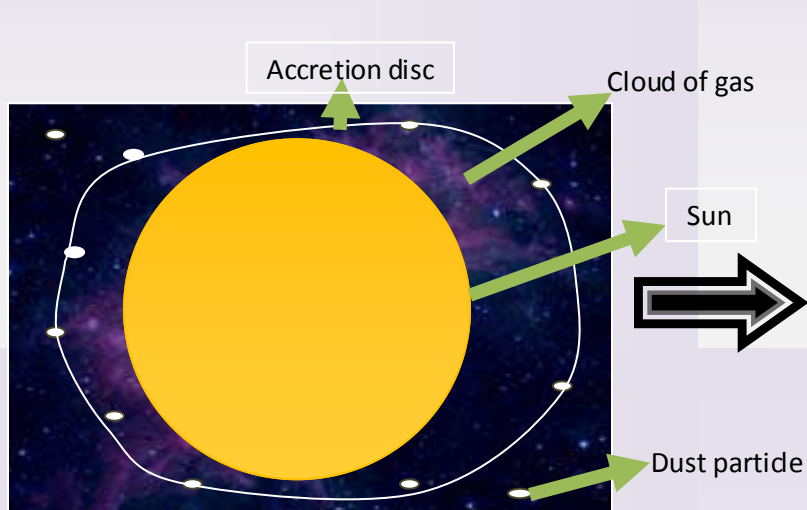
PRECAMBRIAN SUPER EON:

HADEN EON:

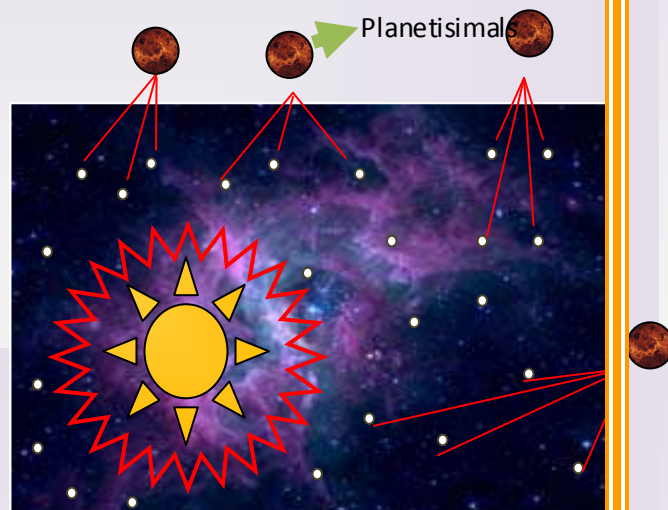
- ✿ **Haden eon** started at the formation of earth about **4.6 billion years ago** and ended roughly about **3.8 billion years ago**. Haden is derived from a Greek work Hades meaning underworld which refers to the **creation of earth** at that time.
- ✿ Hadean eon is subdivided into **Cryptic era, Basin group era, Nectarian era, Lower Imbrian era**.
- ✿ Haden eon and its sub-divisions have little evidence on origin and evolution of solar system and earth and hence they are not officially recognized by the International Commission on stratigraphy.
- ✿ The **solar system formed** during the Haden eon by the **coagulation and gravitational contraction from large cloud of gas and dust** around the sun called an **accretion disc**. The relative abundance of heavier elements in the solar system suggests that **this gas and dust was derived from a supernova or supernovas – the explosion of an old, massive star**.
- ✿ The **sun formed the nucleus** and by gravitational compaction it shrank on itself until it got ignited with nuclear fusion and gave off light and heat.

- ✿ The surrounding particles within this **cloud fused together to form planetisimals**. Later **these planetisimals gathered into a mass to form micro-planets**.
- ✿ Due to the **energy of the collisions between the larger micro-planets, interior radioactive and gravitational heating there was huge amount of heat generated hence earth and other planets was in the molten state initially**.
- ✿ The **moon was also formed** during this eon later; **45 million years after the planet began to form initially**. The present theory is that a **large planetoid**, about the size of mars **collided into the earth**. **Little bit of hot rocks** splashed off during the collision and orbited around the earth. The bodies which were both molten merged fairly smooth **adding about 10% of the earth's surface moon was formed**.
- ✿ The **molten iron** which was heavy **sank down to become the core of the earth** and **lighter atoms** like silica and hydrogen **rose to the surface**. Most of the **gases** – hydrogen, carbon-di-oxide, methane, ammonia and nitrogen **floated away into space**.
- ✿ Due to the **collision of comet, water was brought to the earth** which was converted into **steam** as the earth was very hot and resulted in the **formation of steamy atmosphere around the earth**. When most the planetisimals are gone the **planetary bombardment stopped**, a **stable rocky crust** was formed all over the earth and the moon.
- ✿ About 4.3 billion years ago as the earth cooled, the **steam in the atmosphere condensed into rain** forming the **oceans**. Mostly the **earliest RNA molecules** must have formed at this eon when the first protein was formed by the fusion of amino acids from the space into the oceans.

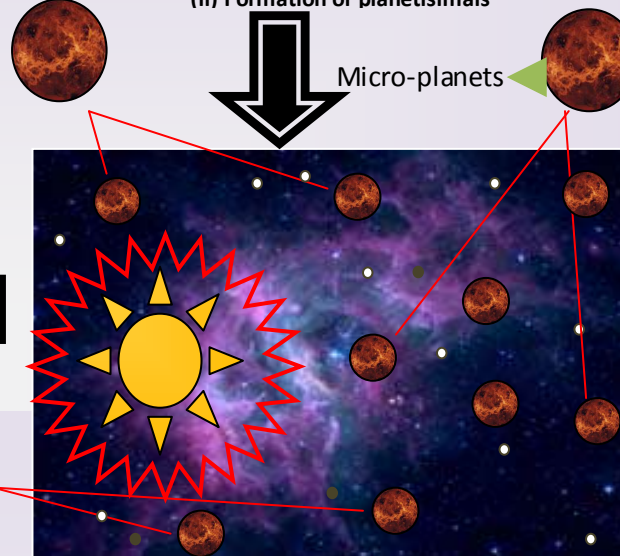
The diagram below illustrates the Haden eon in a diagrammatic way.



(i) Formation of accretion disc around the sun



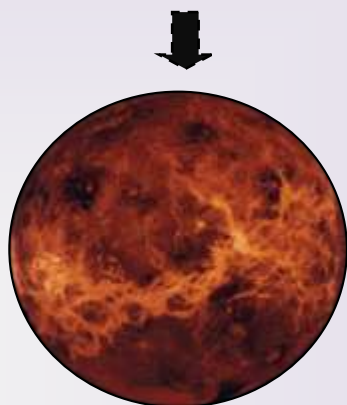
(ii) Formation of planetisimals



(iii) Formation of micro-planets



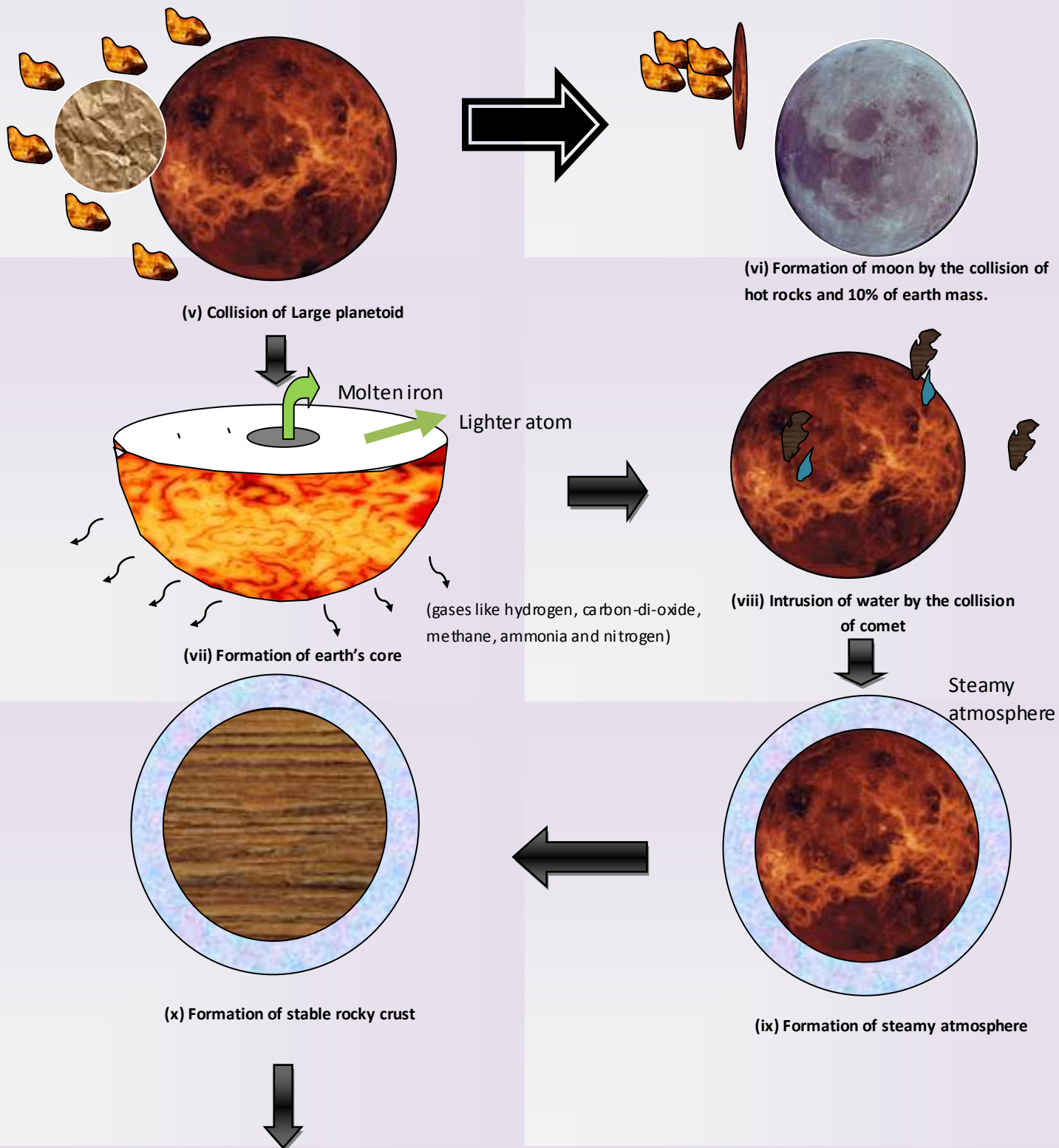
(iv) Collision of larger micro-planets to planet

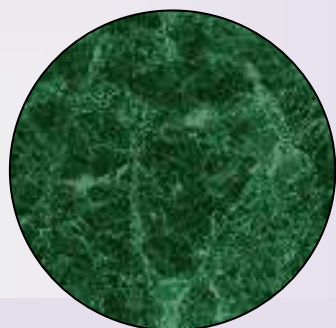


(v) The molten planet

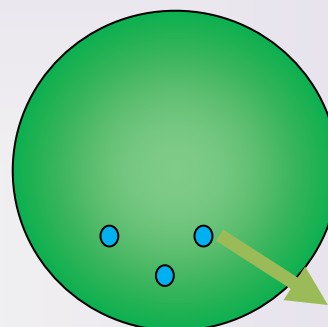


(v) Collision of Large planetoid





(xi) Formation of Ocean



(xii) Formation of First Protein

ARCHEAN EON:

- ✿ **Archean** is a geological eon which comes before the Proterozoic eon dating from **3800 million years ago** to **2500 million years ago**. The name is derived from Greek language meaning **"beginning or origin"**. The Archean eon was divided into **Eoarchean era, Paleoarchean era, Mesoarchean era** and **Neoarchean era**.

EOARCHEAN ERA:

- ✿ The **Eoarchean era** was preceded by the hadean eon and was followed by Paleoarchean eon (**3800-3600 million years ago**). The name was derived from two Greek words [Eos (dawn) and archios (ancient)].
- ✿ About 3.8 billion years ago the **earth was three times hot** than what it is today but not too heat to vaporize water.
- ✿ **Land areas** were forming as **volcanoes began to erupt** out of the water. Volcanic activity was considerably higher than today, with numerous eruptions. Most of the rocks formed were igneous and metamorphic like granite and quartz. At the end of this era around 3600 million years ago, the **first super continent Vaalbara** appeared.

- From the fossil records some interpretations suggests that the **simple prokaryote cells** evolved some 3.8 billion years ago from the earliest living cell in the ocean which was probably much warmer and more acidic than they are now. Around 3.8 billion years ago the oldest rock formation, the **Isua greenstone belt** appeared during this era.

PALEOARCHEAN ERA:

- The **Paleoarchean era** dates from **3600-3200 million years ago**. The oldest ascertained life form (**well- preserved bacteria** older than 3.46 billion years found in Western Australia) is from this era.

MESOARCHEAN ERA:

- The **Mesoarchean era** spans from **3200 million year ago** to **2800 million years ago**.
- Fossils from Australia show that **stromatolites** have lived on earth since Mesoarchean era. Stromatolites are layered accretionary structures formed in shallow water by the trapping, binding and cementation of sedimentary grains by bio-films of micro-organisms, especially Blue green algae (Cyanobacteria). The **first super continent Vaalbara broke up** during this time period around 2.8 billion years ago.

NEOARCHEAN ERA:

- ☀️ **Neoproterozoic era** is the last era in Archean eon. By three million years ago some of the prokaryote cells that evolved were able to make their own food using sunlight, water and carbon-di-oxide, the **photosynthesis process**.
- ☀️ Cells that got their food through photosynthesis **gave out oxygen**. Once there began a lot of photosynthesizing, there began to be more and more oxygen on earth, but during this era none of the oxygen was in the atmosphere rather the iron and sulphur rocks got mixed with these early oxygen atoms to make **rusty red rocks and limestone**. This oxygen producing photoautotroph evolved earlier in this era.

PROTEROZOIC EON:

- ☀️ The **Proterozoic eon** is a geological eon representing a period before the first abundant complex life on earth. The word Proterozoic is from the Greek language meaning "**Early life**". This eon spanned about **2500 to 542 million years ago** and is the most recent part of Pre Cambrian Super Eon.
- ☀️ The Proterozoic Eon is Sub divided into **Paleoproterozoic era, Mesoproterozoic era and Neoproterozoic era**.

PALEOPROTEROZOIC ERA:

- ☀️ The **Paleoproterozoic era** dates from about **2500 million years ago to 1600 million years ago** and it is the first era of Proterozoic eon.
- ☀️ The Paleoproterozoic era is further sub divided into **Siderian period, Rhyacian period, Orosirian period and Statherian period**.

- ✿ The Siderian period is the first era and lasted from **2500 million years ago to 2300 million years ago**.
- ✿ As the oxygen from the photoautotroph is absorbed by the iron and sulphur rocks, the irons in the oceans were cleared, **turning greenish seas clear**.
- ✿ Now the **excess oxygen** produced got deposited in the atmosphere and created an **oxygen rich atmosphere**. This process is known as **Oxygen catastrophe**.
- ✿ This was followed by the **Huronian glaciations**. It started at the end of Siderian period and ended in the Rhyacian period of Paleoproterozoic era.
- ✿ **Rhyacian period** which is derived from the Greek meaning “**Stream of Lava**” is the second geologic period of Paleoproterozoic era lasted from about **2300 million years ago to 2050 million years ago**.
- ✿ The **bushveld complex** and other similar intrusions formed during this period. The **Huronian glaciations ended** late in this period about 2100 million years ago.
- ✿ The organisms with complex structured cells within membranes, **eukaryotes** began to evolve during this period. The eukaryotic cells have the nucleus or nuclear envelope which distinguishes it from the prokaryotic cells. It also includes mitochondria, Chloroplast and the Golgi apparatus.
- ✿ The multi-cellular Francevillian group fossils, 2.1 billion years old are from this period. These fossils are found in the west-African country of Gabon in the Paleoproterozoic **Francevillian B Formation**. This organism was 12 centimeters in size. Their bodies were flattened disks with a characteristic morphology. Their margins were scalloped and had radial slits. They also have an internal radial

fabric. The geochemistry of the fossil site indicates that they lived less than 40 meters of water and breathed oxygen.

- ✿ Following the Rhyacian period was the **Orosirian period**, the third geologic period of the Paleoproterozoic era. Orosirian means “**Mountain Range**”. This period occurred during **2050 to 1800 million years ago**.
- ✿ The forces and events leading to a severe structural **deformation of earth's crust** by **Orogeny** (The engagement of tectonic plates). Due to such engagements the formation the **formation of long tracks** of highly **deformed rock** called **Orogens** or **Orogenic belts** occurred. The word **orogeny** comes from the Greek word Oros meaning “**mountains**” and genesis meaning “**birth or origin**”.
- ✿ It is the **primary mechanism** by which **mountains were built** on the continent. Intensive Orogeny occurred virtually on all continents in the latter half of the period.
- ✿ Mostly during this period **Earth's atmosphere** became **highly Oxygen-rich** due to photosynthesis of Cyan Bacteria.
- ✿ Two of the largest known impact events on earth occurred during the Orosirian period. At the very beginning of this period around 2023 million years ago, a large asteroid collision created the **vedrefort impact structure**. The event that created the major geologic structure in Ontario and Canada, **the Sudbury Basin** was in this period. It is the second largest known impact crater or asterobleme on Earth. It is as well as one of the oldest formed structure too. This was formed at the end of this period around 1850 million years ago.
- ✿ The **Statherian period** is the final geological period in the Paleoproterozoic era that lasted from **1800 million years ago to 1600 million years ago**.

- ✿ The **first complex single celled life appeared** during this period. The period is characterized on most continents by either new platforms or final formation of an old stable part of the continental lithosphere from early rock of fold belts. The **super continent Columbia** was formed during the beginning of this period.

MESOPROTEROZOIC ERA:

- ✿ The **Mesoproterozoic era** is the second era of Proterozoic eon that occurred between **1600 million years** and **1000 million years ago**. The Mesoproterozoic era is further sub divided into **Calymmian period, Ectasian Period** and **Stenian Period**.
- ✿ **Calymmian period** is the first geologic period in the Mesoproterozoic era and lasted from **1600 million years ago** to **1400 million years ago**. The period is characterized by expansion of existing platforms covers or by new platforms on recently cratonized basements.
- ✿ The **Columbia super continent** which was formed at the beginning of Statherian period **broke up** during this period around 1500 Million years ago.
- ✿ The **Ectasian period** lasted from about **1400 million years ago** to **1200 million years ago**. The name is derived from a Greek word ectasis meaning **“Extension”**. This period is named so because of the continued expansion of platform covers.
- ✿ Evidences of eukaryotic red algae, **Bangiomorpha pubescens** (multi-cellular fossils) has been identified from Arctic Canada. This strongly resembles the modern alga Bangia. This is the oldest known sexually reproducing organism and therefore the earliest known Complex multi-cellular organism.

- ✿ **Stenian** is the final geologic period of the Mesoproterozoic era and lasted from **1200 million years** to **1000 million years**. It is derived from Greek word stenos meaning **“Narrow”**.
- ✿ This period is named Stenian because the narrow poly-metamorphic belts are formed over this period. Another **super continent Rodinia** assembled during the Stenian period.

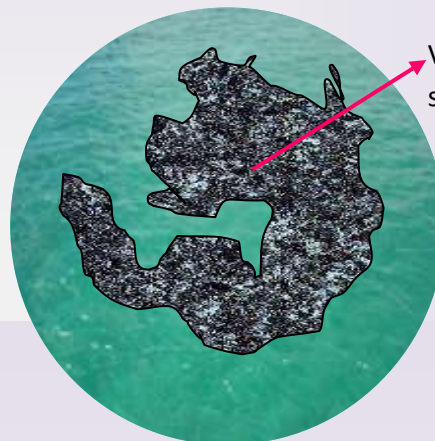
NEOPROTEROZOIC ERA:

- ✿ **Neoproterozoic era** is the last geologic era of the Proterozoic eon and it is further subdivided into **Tonian period**, **Cryogenic period** and **Ediacaran period**. The most severe glaciations known in the geologic record occurred during this era. This period dated from about **1000 million years ago** to **542 million years ago**.
- ✿ The **Tonian period** lasted from **1000 million years ago** to **850 million years ago** and is derived from a Greek word tonas meaning **“Stretch”**.
- ✿ The **events leading** to the **breakup of supercontinent Rodinia** which formed during Stenian period started in this period. The first radiation of **acritarchs** (small organic fossils) occurred during the tonian period.
- ✿ The **cryogenic period** is the second geologic period of Neoproterozoic era which lasted from **850 to 635 million years ago**. The name was derived from the Greek word Cryos meaning **“cold”** and genesis meaning **“birth”**.
- ✿ **The greatest ice ages** known to have occurred on earth and that covered the entire planet, the **Sturtian and Marinoan glaciations** occurred during this period. Glaciers extended and contracted in a series of rhythmic pulses, possibly reaching equator.

- ✿ The earth was much cooler than it is today and a lot of the water in the oceans turned to ice. Possibly for a while about 700 million years ago the whole earth **may have been one big ball of ice**. A phenomenon which led to the hypothesis of deeply frozen planetary oceans called “**snowball Earth**” was found in this period. The **Rodinia supercontinent broke up** and the super continent Pannotia began to form.
- ✿ Fossils of **testate amoeba (Arcellinida)** first appear during the cryogenic period. During this period the oldest known fossils of **sponges** made an appearance.
- ✿ The **Ediacaran period** is the last geologic Period of Neoproterozoic era of the Proterozoic eon of the Pre Cambrian super eon. This period is named after the Ediacara Hills of South Australia. This period was said to exist from **635 million years ago to 542 million years ago**.
- ✿ During this time the global **Marinoan glaciations ended** to the first appearance of somewhat complicated trace fossils.
- ✿ Around 600 million years ago the **first creature developed** which had **more than one cell**, they were something like **hydras**. Around the same time, the **first division between animals, plants and funguses** like **mushroom** happened. Soon there were **sponges and jellyfish** and **flatworms** in addition to hydras and the **first multi-cellular plants** like **seaweed** as well.
- ✿ Around the end of Proterozoic era that is 542 million years ago, is roughly the time when the **first segmented worms** and **arthropods- insects** like **beetles** appear on earth.

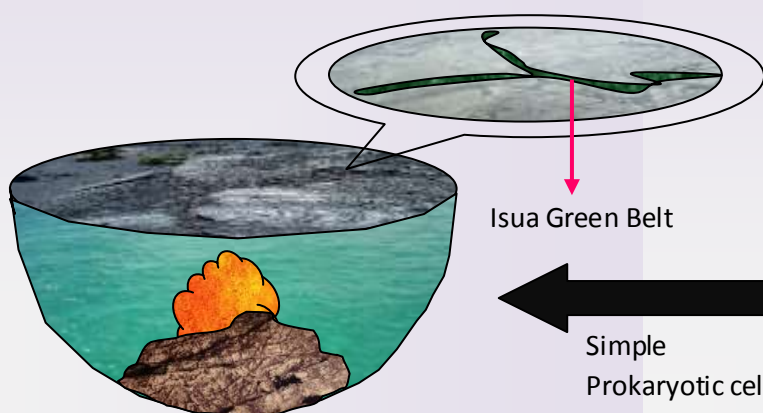


(i) Eruption of volcanoes from water



Vaalbara
supercontinent

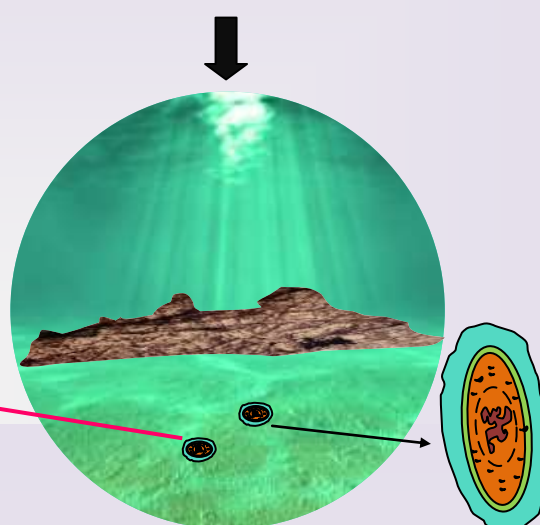
(ii) Formation of Vaalbara supercontinent



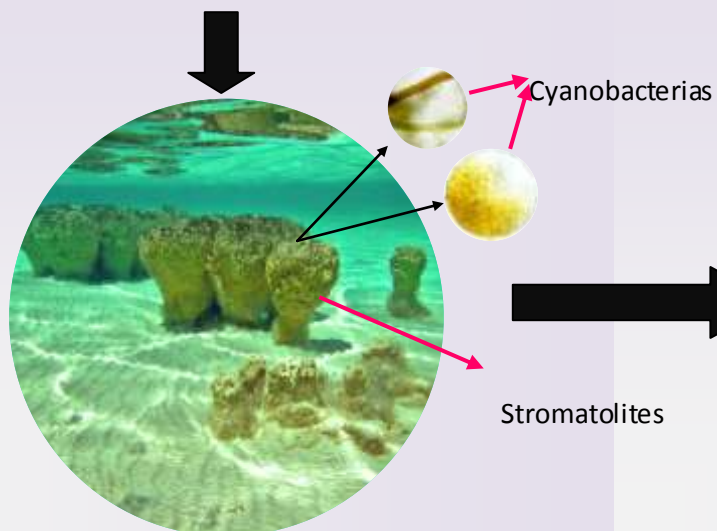
Isua Green Belt

Simple
Prokaryotic cell

(iv) Isua Greenstone belt



(iii) Formation of Simple Prokaryotic cell



Cyanobacterias

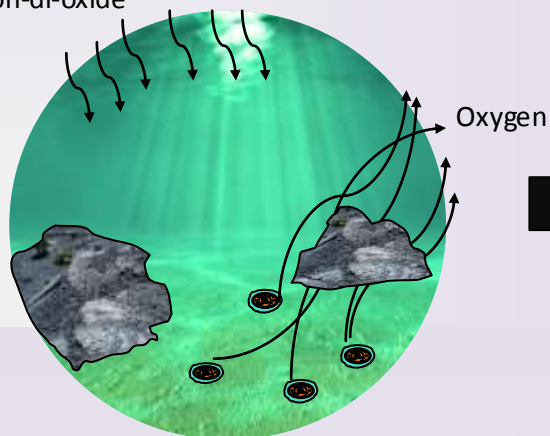
Stromatolites

(v) Formation of stromatolites



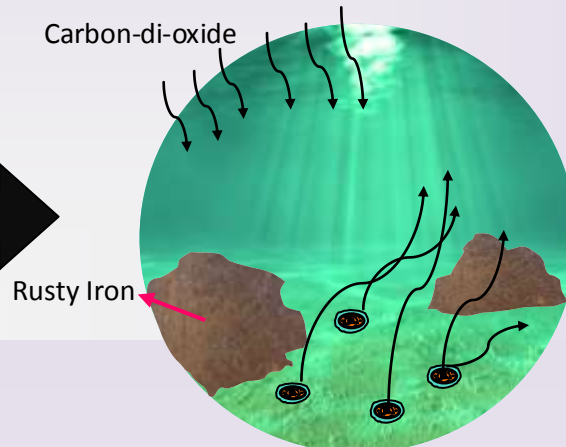
(vi) Breakup of Vaalbara super continent

Carbon-di-oxide



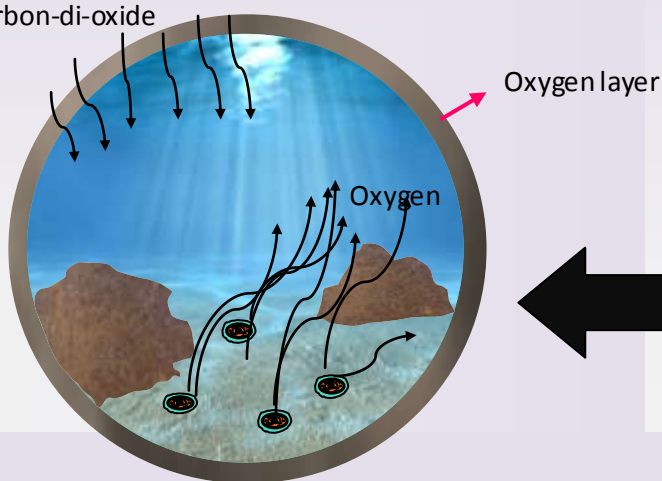
(vii) Photosynthesis by cell

Carbon-di-oxide



(viii) Oxidization of iron and sulphur rocks

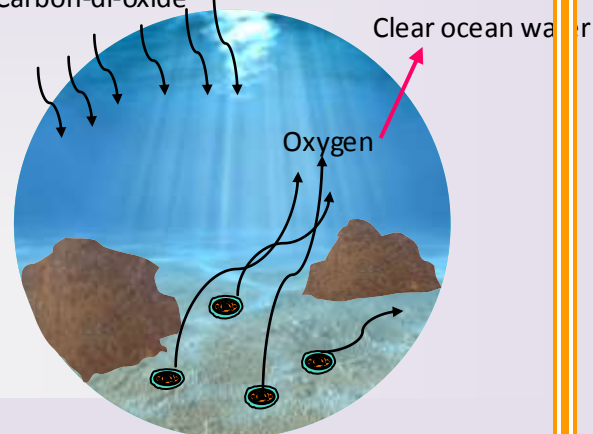
Carbon-di-oxide



(ix) Greenish water turning blue

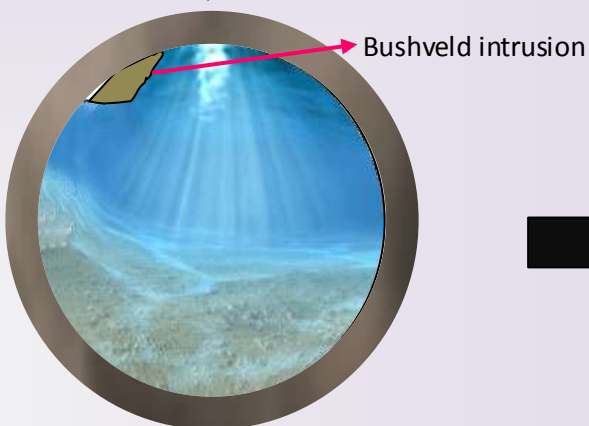
Oxygen layer

Carbon-di-oxide

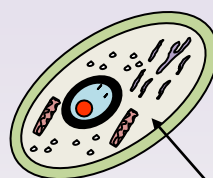


(x) Formation of oxygen atmosphere

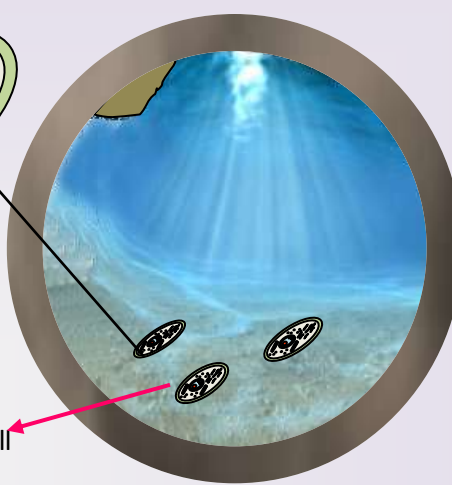
Clear ocean water



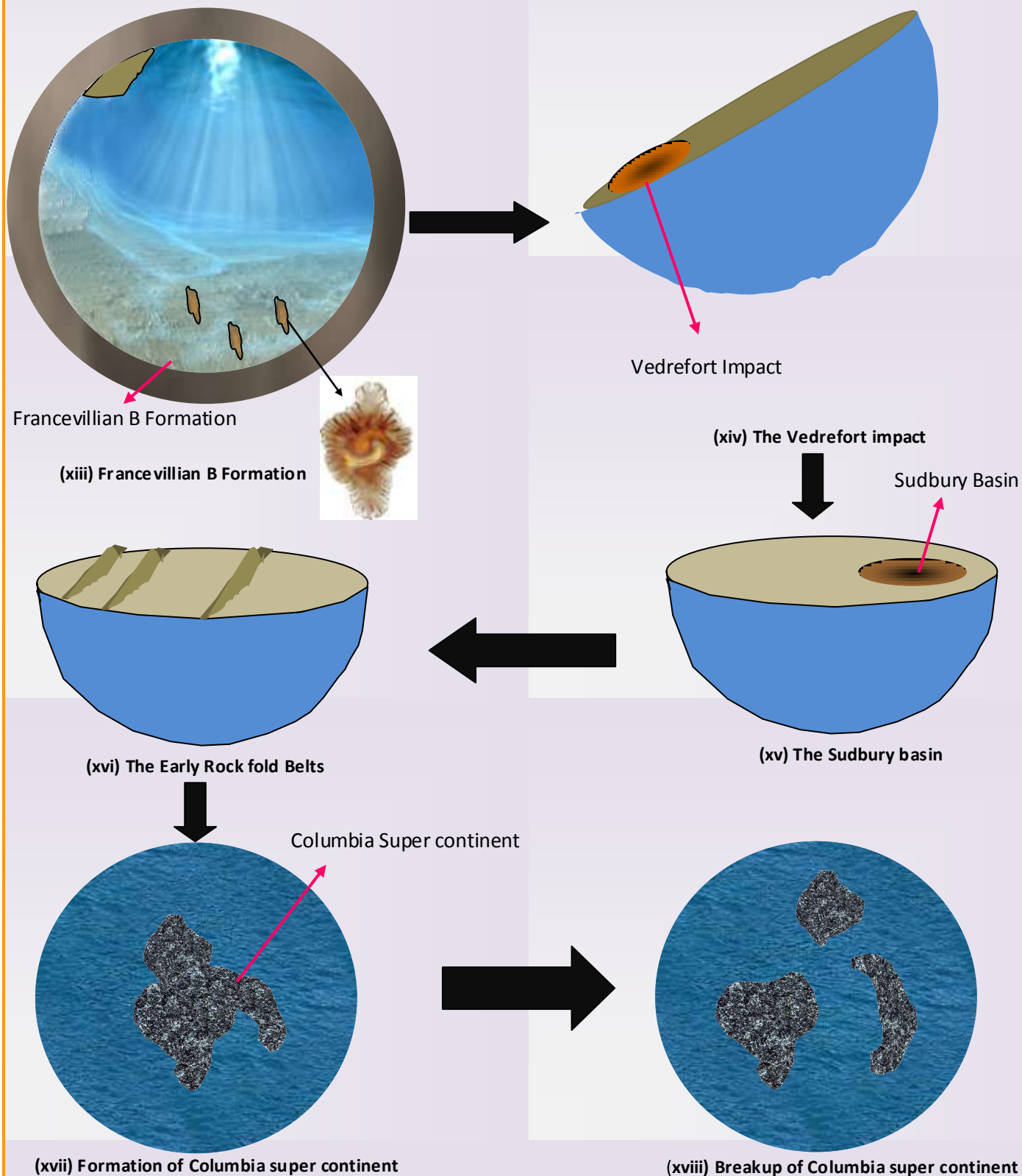
(xi) Formation of Bushveld intrusion

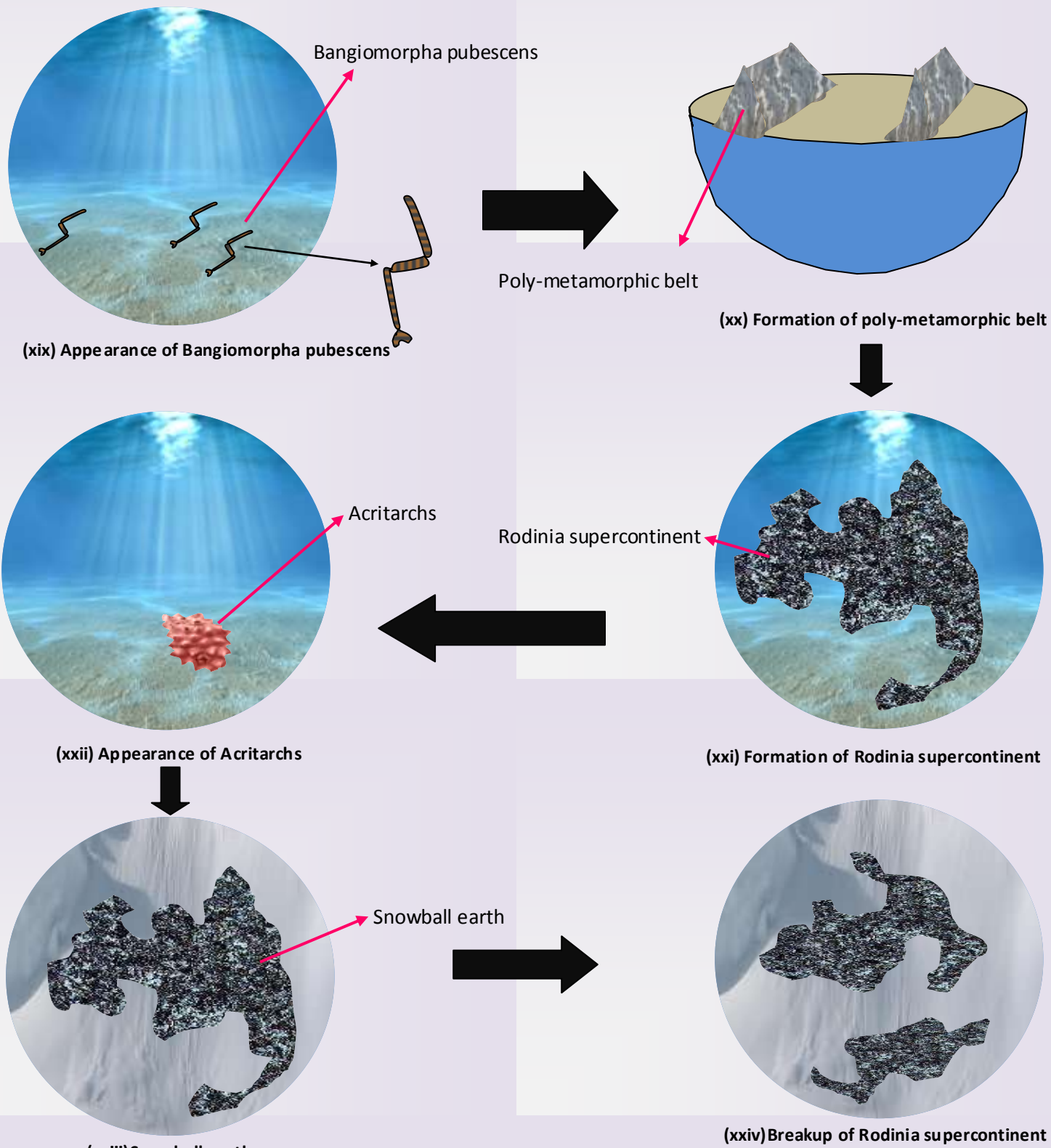


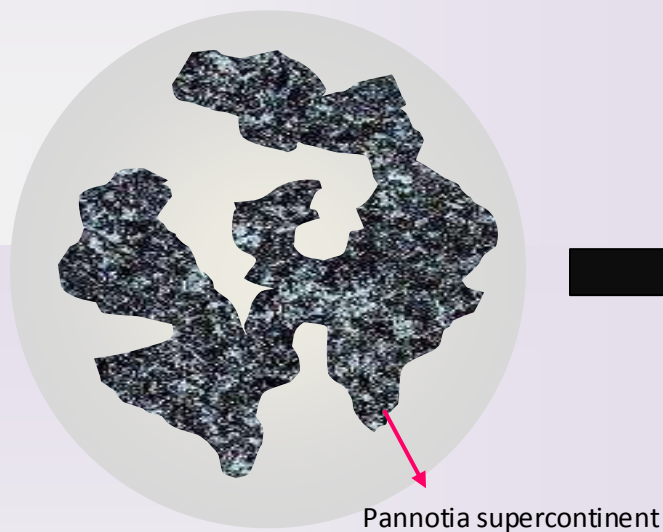
Eukaryotic cell



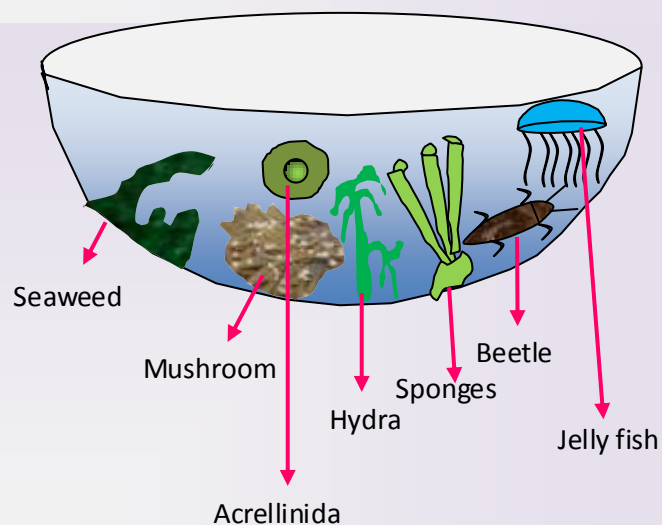
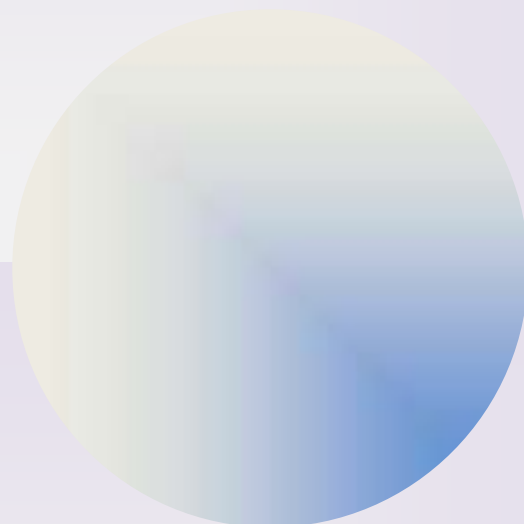
(xii) Formation of Eukaryotic cell







(xxv) Formation of Pannotia supercontinent



(xxvii) Appearance of Seaweed, Mushroom, Acrellinida, Hydra, Sponges, Beetle and jelly

CAMBRIAN SUPEREON:

- ✿ The Cambrian Super eon has only one eon to its division. Phanerozoic eon is the only eon that is currently available in this super eon.

PHANEROZOIC EON:

- ✿ The **Phanerozoic eon** is the geologic eon that dates from **545 million years ago** to **the current year**. The Phanerozoic eon is divided into **Paleozoic Era, Mesozoic Era** and **Cenozoic Era**.

PALEOZOIC ERA:

- ✿ The **Paleozoic era** is the earliest of the three geologic eras of the Phanerozoic eon. The name is derived from the Greek word palaios meaning “Old” and Zoe meaning “life” and hence together it means **“ancient life”**.
- ✿ The Paleozoic era spanned from roughly about **542 million years ago** to **251 million years ago**. This era is further sub-divided into six geologic period; **Cambrian period, Ordovician period, Silurian period, Devonian period, Carboniferous period** and **Permian period**.

CAMBRIAN PERIOD:

- ✿ The **Cambrian** is the first geologic period of the Paleozoic era. Unlike the preceded periods these periods were further sub-divided into epochs. The Paleozoic era lasted from about **542 million years ago** to **488 million years ago**.
- ✿ The Cambrian period is sub-divided into three epochs; **Early Cambrian epoch, Middle Cambrian epoch, Furongian epoch**.

- ✿ By about 540 million years ago the **first land plants** evolved from the land algae, which resembled like **modern moss**.
- ✿ Tracks of some **beetle** were found in sandstone which was got from this period. These could be regarded as the first land animal.
- ✿ The **Pannotia Super continent** was about to **disintegrate**, with Laurentia and Siberia having separated from the main mass of the Gondwana.
- ✿ In the southern hemisphere most of the land masses were clustered. As the great glaciers of the Marinoan Snowball earth were melted long back the sea level was high.
- ✿ Hence there were large areas of continent flooding in warm, shallow seas which was perfect for the life which was flourishing then.
- ✿ Many new kinds of animals and plants appeared on earth which evolved from the earlier once around the same time.
- ✿ This rapid evolution was due to the meiosis. It allows more mutations and diversity in creatures' genetics.
- ✿ **Mollusks like snails and squid** were found during this period. Most of the living creatures were found on the oceans.
- ✿ Rarely **few beetles** were found to have lived in the **sea shore**.
- ✿ The **most surprising discoveries of this period** came from the **530 million year old Chengjiang fossil bed in China**, where scientists found the **remains of two**

different types of tiny, jawless fish. They were representing the oldest known backboneed animals.

- At the end of the Cambrian period, about 488 million years the **burrowing animals** had destroyed the **microbial mats** which covered the sea floor before the Cambrian period through **bio-turbation** and hence many of **those organisms** who were **dependent on those mats went extinct**.
- The **rest adapted to the changed environment**, and this period saw the seemingly rapid appearance of **representatives of all the mineralized phyla**.

ORDOVICIAN PERIOD:

- Ordovician** is the second geologic period in the Paleozoic era and it dates between **488 million years ago** to **443 million years ago**.
- Ordovician period** started at a major extinction event termed the **Cambrian-Ordovician extinction events**. Further this period was divided into **early, Middle and late Ordovician epochs**.
- Sea levels were high during the Ordovician period. The **southern continents collected** together to form the **Gondwana single continent**. It started the period in the equatorial latitude and later drifted towards the South Pole.
- There were **lots of tectonic movements** in the land area, like early in this period the continents **Laurentia (North America), Siberia and Baltica (Northern Europe)** were still **independent** as the **result of disintegration of Pannotia super continent**. But later in the period **Baltica moved towards Laurentia** causing **Lapetus Ocean** to **shrink between them**. The small continent **Avalonia separated**

from Gondwana and began to head north towards Baltica and Laurentia. The Rheic Ocean between Gondwana and Avalonia was formed.

- At the beginning of the period around 480 million years ago, the climate was very hot due to high levels of CO₂ which resulted in strong greenhouse effect. The diversification of complex multi-cellular organisms was restricted as the marine waters were assumed to be around 45 degree Celsius. But later it cooled down, around 460 million years ago, the ocean temperatures cooled down.
- As most of the land was pretty flat near the sea level when the rocks eroded most of the sand drifted into the ocean. When the sand fell to the ocean floor, the weight of the water turned it into sedimentary limestone and hence most of the rocks formed during this period were limestone.
- The trilobite, inarticulate brachiopod, archeocyathis and eocrinoid creatures of the Cambrian were succeeded by those that dominated the rest of the Paleozoic, such as articulate brachiopods, cephalopods, and crinoids.
- As the lime stones were falling into the oceans, the water was full of calcium and animals used this to build bones and shells for themselves.
- The first coral reefs appeared in the early Ordovician, although lonely corals date back to the Cambrian.
- The mollusks became very common and varied like bivalves, gastropods and nautiloids cephalopods. The graptolites which are now extinct thrived in the ocean during this period and also there were some new cystoids and crinoids appearing in this period.

- ✿ It was long believed that the **true vertebrates appeared in the Ordovician** which is recently discovered that they originated in the early Cambrian. The very first **gnathostome (jawed fish) appeared** in the **late Ordovician epoch**.
- ✿ There was a large **increase in the intensity and diversity of bio-eroding organisms** during the middle Ordovician which is known as the **Ordovician Bio-erosion Revolution**.
- ✿ In the early Ordovician, the **trilobite's fossils** were joined by many new types of organisms including **tabulate corals, strophomenid, rhychonellid** and **many new orthid brachiopods, bryozoans, planktonic graptolites and conodonts, many types of mollusks and echinoderms including the ophiuroids (brittle stars) and the first sea stars**.
- ✿ In the middle Ordovician epoch the trilobites which dominated the early Ordovician epoch were replaced by generally more mixed ecosystems in which **brachiopods, bryozoans, mollusks, cornulitids, tetaculitids and echinoderms flourished**. The **tabulate corals diversified** and the **first rugose corals appeared**. **Diplograptina** made their appearance diversifying the **planktonic graptolites**. **Bio-erosion became an important process**, particularly in the **thick calcitic skeletons of corals, bryozoans and brachiopods** and **on extensive carbonate hard grounds** that appear in abundance at this time. One of the earliest known **armoured agnathan (ostracoderm) vertebrate, Arandaspis** dates from the middle Ordovician epoch.
- ✿ **Green algae** were common in this period. **Terrestrial plants** probably **evolved from green algae**, first appearing in **the form of tiny non-vascular mosses** resembling **liverworts**. The first land fungi may have been **arbuscular mycorrhiza fungi** playing crucial role in facilitating the colonization of land plants through mycorrhizal symbiosis, which makes mineral nutrients available to plant cells;

such fossilized fungal hyphae and spores from the Ordovician of Wisconsin have been found with an age of about 460 million years ago, a time when the land flora most likely only consisted of plants similar to non-vascular bryophytes.

- ✿ The **Ordovician period came to an end** in a **series of extinction events**. This event is the **second largest of the five major extinction events** in the earth's history in terms of the percentage of genera. The extinction occurred approximately 447-444 million years ago and marked the boundary between the Ordovician and the following Silurian period.
- ✿ During that time **all complex multi-cellular organisms lived in the sea** and about **49% of genera of fauna disappeared forever, brachiopods and bryozoans were greatly reduced, along with many trilobite, conodont and graptolite families**. The most common accepted theory is that these events were triggered by the **onset of most cold conditions in the late Ordovician epoch followed by an ice age** that ended the long, stable greenhouse conditions typical of the Ordovician.

SILURIAN PERIOD:

- ✿ **Silurian** is the third geologic period of the Paleozoic era and it dates back from **443 million years ago to 416 million years ago**.
- ✿ The Silurian period is further sub-divided into **Llandovery epoch, Wenlock epoch, Ludlow epoch and Pridoli epoch**.
- ✿ During this period, **Gondwana continued a slow southward drift** to high southern latitudes but the **Silurian icecaps were less widespread** than those of the late Ordovician glaciations.

- There was **upsurge in sea level** as the **icecaps and glaciers melted**. The **cartons and fragments of continent** drifted towards the equator forming another super continent known as **Euramerica**.
- The **coastal sediments** that had been **accumulating since the Cambrian period** along the **east coast of North America** and **west coast of Europe** folded due to the **collision of proto-Europe with North America**.
- A **wave of mountain building** that **stretched from New York State through** co-joined **Europe and Greenland to Norway** occurred in the event called **Caledonian orogeny**.
- The **new mountain ranges eroded** as the **sea levels dropped at the end of Silurian period** and there were **evaporates of telltale basin** in a **basin extending from Michigan to West Virginia**.
- The **vast ocean of Panthalassa** covered most of the **northern hemisphere**; other **minor oceans** were the **Proto-Tethys, Paleo- Tethys, the Rheic Ocean, Lapetus Ocean** and the **newly formed Ural Ocean**.
- In this period the **earth entered a long warm greenhouse phase**. There was a **relative stabilization of the earth's general climate** in this period unlike the erratic climatic fluctuations.
- Layers of broken shells** provide a **strong proof that the violent storm generated** dominated the climate. **Later in the Silurian** period the **climate cooled slightly** but in the boundary of Silurian- Devonian the climate became warmer.
- The **Osteichthyes**, the **first bony fish appeared** during this period. There was a **vast diversity in the fishes** and they **developed movable jaws**.

- ❁ **Eurypterids (sea scorpions)**, a diverse fauna of this some of them several meters in length **prowled the shallow Silurian seas of north America** which is evident from the fossils found in New York state.
- ❁ **Leeches appeared** during this period. **Brachiopods, bryozoa, mollusks, hederelloids and trilobites** were **abundant and diverse**.
- ❁ The **first fossil record of vascular plants, land plants with tissues that carry food appeared** in the **second half of the Silurian period**. This period was also **the first period to see macrofossils of extensive terrestrial biota** in the **form of moss forest along the lakes and streams**.
- ❁ The **earliest known representatives of the vascular plants** are the **cooksonia** which was mostly from the northern hemisphere and **Baragwanathia** from Australia.
- ❁ The **Psilophyton, land plants with xylem and phloem** which **lacks differentiation in root, stem or leaf, reproducing through spores, breathing through stomata on every surface** and **photosynthesizing in every tissue exposed to light** was the **first primitive Silurian land plant**.
- ❁ **Rhyniophyta** and **primitive lycopods** were **other primitive land plants that appeared during this period**. Neither mosses nor the vascular plants had deep roots and the **rocks of Silurian period had brownish tints** which were probably **due to the erosion of early soils**.
- ❁ **Predatory invertebrates** would indicate that simple food webs were in place that included non-predatory prey animals.

- There were a **series of minor extinctions events** like Ireviken event, mulde event and lau event in which **lots of plants and animals were killed** due to the **climate change or impact events**.

DEVONIAN PERIOD:

- The **Devonian period** of the Paleozoic era spanned from **416 million years ago** to **359 million years ago**.
- The Devonian period is further sub-divided into early **Devonian epoch**, **middle Devonian epoch** and **late Devonian epoch**.
- As the Devonian dawned the **planet was changing its appearance**. The great **supercontinent of Gondwana** was **headed steadily northward**, away from the South Pole and a **second supercontinent began to form** that **overlapped the equator known as Euramerica or Laurussia**. It was created by the **integration of parts of North America, Northern Europe, Russia and Greenland**.
- Red colored sediments**, generated **when North America collided with Europe**.
- Devonian was a relatively **warmer period**. Around the **mid-devonian** the earth was **completely cool around 5 degree Celsius** as the **CO₂ level dropped steeply** as the **burial of the newly evolved forest drew carbon out of the atmosphere into sediments**.
- Devonian period** was otherwise known as the **age of fishes** as it generated a **remarkable variety of fish**. The most formidable of them were the **armored placoderms**, a group that first appeared during the Silurian with **powerful jaws lined with bladelike plates that acted as teeth**.

- ❁ Early placoderms fed on mollusks and other invertebrates, but later species developed into ferocious, fish slicing monster measuring up to 33 feet (10 meters) long.
- ❁ Devonian ancestors of fishes living today belonged to two main non-armored groups; the cartilaginous fish and the bony fish.
- ❁ The cartilaginous fish is called so because cartilage formed their skeletons, later gave rise to shark and rays. They had small, rough scales, fixed fins and sharp, replaceable teeth.
- ❁ The bony fish were covered in scales and had maneuverable fins and gas-filled swim bladders for controlling their buoyancy. Most modern fishes are bony fish.
- ❁ The bony fish includes lobefins. It is named after the thick, fleshy base to their fins; lobefins are credited with the giant evolutionary stride that led to the amphibians, which made lobefins the ancestor of all four-limbed land vertebrates, including dinosaurs and mammals. Some lobefins are still around today, such as the famous “living fossil” fish, the coelacanth.
- ❁ The fossil creature discovered recently from the Devonian has been hailed as a vital link between fish and the first vertebrates to walk on land. Tiktaalik had a crocodile-like head and strong, bony fins that scientist’s think it used like legs to move in shallow waters or even on land. The fish showed other characteristics of terrestrial animals, including ribs, a neck and nostrils on its snout for breathing air.
- ❁ The first amphibians breathed through simple lungs and their skin. They leave water only to escape themselves from the attention of predatory fish.

- ✿ The **ammonoids** which arose during this period survived until the end of cretaceous period, 65 million years ago.
- ✿ **Plants began spreading beyond wetlands. New plants developed** that could **survive even on dry land** during this period.
- ✿ The first forest evolved during the end of this period as stemmed plants advanced strong, woody structures capable of supporting raised branches and leaves. Some of the trees of Devonian are known to have grown 100 feet (30 meters) tall.
- ✿ By the **end of the period** the **first ferns, horsetails** and **seed plants** had also **appeared**. The new life flourishing on land apparently escaped the worst effects of the **mass extinction** as the **main victims** were **marine creatures with up to 70% of species wiped out**. Reef building communities almost completely disappeared. This mass extinction took place at the end of Devonian period marking the start of carboniferous period.
- ✿ The **theories put forward to explain** this extinction include **global cooling** due to re-glaciation of Gondwana, or **reduced atmospheric levels of the greenhouse gas** carbon dioxide as the continents were forested.

CARBONIFEROUS PERIOD:

- ✿ **Carboniferous period** extends from **359 million years ago** to **299 million years ago**. The name comes from the Latin word coal, carbo. Carboniferous means “**coal bearing**”.
- ✿ Carboniferous period is further subdivided into two parts, **the earlier Mississippian epoch** from **359 million years ago** to **318 million years ago** and **the late Pennsylvanian epoch** from **318 million years ago** to **299 million years ago**.

- ✿ During the Mississippian, Euramerica or Laurussia which included North America, northern Europe and Greenland remained separate from the larger cooler supercontinent Gondwana to the south. To the east, parts of Asia including china were surrounded by warm oceans. While Gondwana became progressively colder as it began another pole ward migration, the tropical land masses remained wet and humid.
- ✿ The early Mississippian epoch was mostly warm; in the later Pennsylvanian epoch the climate cooled due to the glaciations in Gondwana.
- ✿ Carboniferous coal was produced by bark-bearing trees that grew in vast lowland swamp forests. Vegetation included giant club mosses, tree ferns, great horsetails and towering trees with strap-shaped leaves. Over millions of years, the organic deposits of this plant remains formed the world's first extensive coal deposits- coal that humans are still burning today.
- ✿ As all the carbon turned into sediments due to the forestation the oxygen in the atmosphere became surplus. It peaked around 35%. This abundance of oxygen sparked an exponential increase in the size of vascular plants.
- ✿ The size reached by the insects and similar creatures is thought to be limited by the amount of air they are able to breathe explains the giant creepy crawlies that emerged now.
- ✿ Deadly poisonous centipedes some six feet (2 meters) in length crawled in the company of mammoth cockroaches and scorpions as much as three feet (1 meter) long. Most impressive of all were dragonflies that grew to the size of seagulls.

- ✿ An exquisitely detailed fossil of a dragonfly that died 320 million years ago shows that it had wings spanning 2.5 feet (0.75 meters).
- ✿ **Amphibians** were also **growing in size and diversity**. There were **predatory species** that resembled **modern crocodiles**. They were armed with vicious teeth. Some amphibians developed a thicker, scaly skin.
- ✿ They also **reduced their dependence** on **wetland habitats through a crucial evolutionary adaption** known as the **amniote egg**. This protected the embryo inside with a fluid-retaining membrane while still allowing in air. In time, the earliest reptiles appeared. Identified from remains found inside fossilized carboniferous tree stumps, they were small, agile, lizard-like animals.
- ✿ In the **late Pennsylvanian Africa collided with eastern North America**, this event **formed the Appalachian Mountains**. Vast coal swamps stretched across the lowlands to the west of the rising mountains. By the **end of this period** the **earth's landmasses were moving toward a single, global supercontinent called Pangaea**.
- ✿ The **end of carboniferous** period was **marked with an extinction** which is less intense than the extinction event during the middle of this period. This extinction was said to **happen due the global climate change** by the glaciers that covered the South Pole. The marine environments were most affected by this climate change.

PERMIAN PERIOD:

- ✿ The **Permian period** is the last geologic period of the Paleozoic era. It extends from **299 million years ago** to **251 million years ago**.

- ✿ The Permian period is sub-divided into **Cisuralian epoch, Guadalupian epoch** and **Lopingian epoch**.
- ✿ **Almost all the landmasses** on earth grouped together into **one big supercontinent Pangaea** which **ranged from the North Pole to the South Pole**.
- ✿ As the **size of the continent was vast** it had **severe extremes of climate and environment**, the **south was cold** and **arid** with much of the region frozen under ice caps. **Northern areas suffered increasingly from intense heat** and **great seasonal fluctuations between wet and dry conditions**.
- ✿ The **lush swamp forests of the carboniferous** were gradually **replaced by conifers, seed ferns** and other **drought-resistant plants**.
- ✿ **Early reptiles** were placed **to rule the new environment**. They were shielded by their thicker moisture – retaining skins and moved in where the amphibians had manipulated previously. As time passed they became ideal to the desert habitation in which they currently thrive.
- ✿ As there were **big variations in temperature** the **cold blooded reptiles** had to find **ways to protect** them from the below freezing at night and to over 100 degrees Fahrenheit (38 degree Celsius) during the day. Some of the **primitive pelycosarus**, had **sail-like structures** on their backs that are thought to have **acted as heat exchangers** which caught the sun in the day to help the lethargic creature keep them warm at night.
- ✿ Later, **other mammal-like reptiles** known as **therapsids** found an internal solution to shield them from the climatic fluctuations. There has been a suspicion from the scientist that they **eventually became warm-blooded conserving heat generated**

through the **breakdown of food**. As these could survive the harsh interior region of Pangaea, became the dominant land animals of the late Permian.

- ❁ These therapsids flourished during the Permian, rapidly evolving many different forms from dinosaur like fanged flesh-eaters to plodding herbivores. Among them some species reached a huge size, weighing in at over a ton.
- ❁ In the **latter part of the Permian, smaller varieties emerged**, likely **warm blooded and covered in insulating hair** from which mammals would have arisen.
- ❁ The **Permian seas** came to be **dominated by bony fishes** with **fan-shaped fins** and thick, heavy scales. There were **large reef communities** that **harbored squid-like nautiloids**. **Ammonoids, with their tightly coiled, spiral shells, are also widespread in the Permian fossil record.**
- ❁ The **Permian period**, last period of the Paleozoic era **came to an end** with a **massive extinction event recorded in paleontology**; the **Permian-Triassic extinction event**. **90 to 95% of marine species became extinct as well as 70% of all land organisms. There was also mass extinction of insects.**
- ❁ **Various theories seek to explain this mass extinction.** Some scientists think a **series of volcanic eruptions** pumped so much **fragmenting into the atmosphere** that the **sun was blocked out**, causing a **significant drop in temperature** and preventing plant photosynthesis, which **in turn caused food chain to collapse.**
- ❁ Other scientists point to **global climate change**, citing evidence for a period of **sudden warming and cooling**. These **rapid extremes of conditions may have meant species were unable to adjust.** Other theories include a **catastrophic release of methane gas stored under the seabed, triggered by earthquakes or global warming, or a massive asteroid impact.**

MESOZOIC ERA:

- ✿ The **Mesozoic era** is a period from about **250 million years ago** to **about 67 million years ago**. It is called the **Age of dinosaurs** because most dinosaurs developed and went extinct during this time. Mesozoic era is the second geologic era of the Phanerozoic eon.
- ✿ This era lying between the Paleozoic and Cenozoic means **“Middle Animals”**. It is also often called the **“age of the reptiles”**. Mesozoic era is sub-divided into **Triassic period, Jurassic period** and **Cretaceous period**.

TRIASSIC PERIOD:

- ✿ The **Triassic** is a geologic period that extends from about **250 to 200 million years ago**. Triassic is the first geologic period of the Mesozoic era.
- ✿ The Triassic period is further divided into **Early Triassic epoch, Middle Triassic epoch** and **Late Triassic epoch**. The **early Triassic epoch** spanned from **251 million years ago to 245 million years ago**. The **middle Triassic epoch** spanned from **245 million years ago to 228 million years ago**. The **late Triassic epoch** spanned from **228 million years ago to 203 million years ago**.
- ✿ This **period was the time of tremendous change and rejuvenation**. Life that survived the Permian-Triassic extinction repopulated the planet, diversified into freshly exposed ecological places and gave rise to new creatures, including rodent-size mammals and the first dinosaurs.

- ❁ Early in the Triassic, all the earth's landmasses united to form Pangaea, a supercontinent shaped like a giant C that straddled the Equator and extended towards the Poles.
- ❁ Almost as soon as the supercontinent formed, it started to separate. By the end of 199 million years ago, they slowly began to split into two; Laurasia in the north and Gondwana in the south due to the tectonic forces.
- ❁ The giant ocean Panthalassa surrounded Pangaea. Areas near the coast were hit by seasonal monsoons, but ocean circulation patterns kept the isolated and vast interiors warm and dry. Even the poles were ice free.
- ❁ Tethys Ocean filled the C and was the zipper upon Pangaea began to split apart. The earlier attempt of splitting which went unsuccessful formed rift valleys in North America and Africa filled with red sediments that today contains the best preserved fossils of this life.
- ❁ The oceans that thrived with the coiled-shelled ammonites, mollusks and sea urchins that survived the Permian extinction were quickly diversifying. Even though the reef-building organisms were already present the first coral appeared during this period.
- ❁ Giant reptiles such as the dolphin-shaped ichthyosaurs appeared. The long-necked, paddle-finned plesiosaurs which preyed on fish and ancient squid also appeared during this period. The bottom rung of the food chain was filled with microscopic plants called phytoplankton.
- ❁ Frogs, salamanders, crocodiles, turtles, and snakes crept and slithered on and off the Triassic coast, lakes, and rivers. Pterosaurs, a group of flying reptiles also appeared during this period.

- ✿ The **firm ground** of the forests of **conifers, ginkgoes, and palm-like cycads** were carpeted by **moss, liverwort, and ferns**.
- ✿ **Spiders, scorpions, millipedes, Grasshoppers and centipedes** thrived. But perhaps the biggest changes came with the **evolution of dinosaurs and the first mammals** in the **late Triassic**, starting around 230 million years ago.
- ✿ One of the **earliest true mammals** was the three-foot-long (one-meter-long) **Eozostrodon**. These **shrew-like creatures laid eggs** but **fed mother's milk to its young one**. The **first dinosaur** was the **two-footed carnivore Coelophysis**, which **appeared around 225 million years ago** and grew up to 9 feet (2.7 meters) tall, weighed up to a hundred pounds (45 kilograms). It probably **fed on small reptiles and amphibians**. A **few million years later appeared** the **second dinosaur** which is 27.5-foot-long (8-meter-long) **herbivore called Plateosaurus**.
- ✿ The **Triassic closed** in the same way it began. **Volcanic eruptions** or an **asteroid collision caused another mass extinction**. Dinosaurs however survived and went on to dominate the following Jurassic period.

JURASSIC PERIOD:

- ✿ **Jurassic** the second geologic period of the Mesozoic era extends from **199 million years ago** to **145 million years ago**. Jurassic period lies between the Triassic and cretaceous period of the Mesozoic era.
- ✿ **This period** is also known as the **"Age of Reptiles"**. This period is further subdivided into the **early Jurassic epoch** extending from **199 million years ago to 175 million years ago**, the **middle Jurassic epoch** extending from **175 million years ago to 161 million years ago** and the **late Jurassic epoch** extending from **161 million years ago to 145 million years ago**.

- ✿ The **breakup of the supercontinent Pangaea continued** and accelerated at the start of this period. **Laurasia, the northern half broke up into North America and Eurasia. Gondwana, the southern half began to break up by the mid-Jurassic.**
- ✿ The **eastern portion, Antarctica, Madagascar, India, and Australia got split from the western half portion, Africa and South America. New oceans flooded the spaces in between. Mountains rose on the seafloor, pushing sea levels higher and onto the continents.**
- ✿ The **water from the emerging sea gave the previously hot and dry land a humid and drippy subtropical environment. Dry deserts slowly turned green. Palm tree-like cycads and conifers such as araucaria and pines were abundant. Ginkgoes were carpeting from the mid-northern latitudes to the high northern latitudes. Podocarps, a type of conifer were particularly found largely in south of the Equator. Tree ferns were also present.**
- ✿ The **oceans especially the newly formed shallow interior seas multiplied with diverse and abundant life. At the top of the food chain were the long-necked and paddle-finned plesiosaurs, giant marine crocodiles, sharks, and rays. Fishlike ichthyosaurs, squid-like cephalopods, and coil-shelled ammonites were abundant. Coral reefs grew in the warm waters. Sponges, snails, and mollusks flourished. Microscopic, free-floating plankton flourished** which may have turned parts of the ocean red.
- ✿ The **Jurassic was the golden age for the large herbivorous dinosaurs known as the sauropods like Camarasaurus which was 50 feet (15 meters) long, Apatosaurus which was 75 feet (23 meters) long, Diplodocus which was 90 feet (27 meters) long, Brachiosaurus which was 52 feet (16 meters) tall, 85 feet (26 meters) long and weighed more than 80 tons appeared in the later part of this period.**

- ✿ These **sauropods** were **preyed** by the **theropods**, flesh eating dinosaurs like **creatosaurus**, **Megalosaurs**, **Torvosaurus** and **Allosaurus** that **walked on two powerful legs**.
- ✿ The earliest known bird, **Archaeopteryx** appeared in the **late Jurassic epoch**. These **evolved** from the **coelurosaurian dinosaur**. These **birds** had to **struggle for airspace** with **pterosaurs**, the flying reptiles that evolved during the late Triassic. Meanwhile, **insects such as leafhoppers and beetles were abundant**, and many of the **earth's earliest mammals were crushed around dinosaur's feet**.
- ✿ There **was no extinction** that took place to mark the end of this period but this **period gradually changed** into the following cretaceous period about 145 million years ago.

CRETACEOUS PERIOD:

- ✿ **Cretaceous** is the last geologic period of the Mesozoic era extending from **145 million years ago to 65 million years ago**.
- ✿ The cretaceous period is further sub- divided into **early cretaceous epoch** and **late cretaceous epoch**.
- ✿ **Continents were drifting remodeling the shape and tone of life in this period**. At the **start of the period**, dinosaurs ruled the loosening leftovers of the supercontinent Pangaea as **rodents scurried at their feet through forests of ferns, cycads, and conifers**. At the **end of the period**, about **80 million years later**, oceans filled yawning gaps between isolated shaped continents.

- ✿ Flowering plants were spreading across the landscape. And mammals balanced to fill the space that soon would be left by the vanished dinosaurs.
- ✿ The asteroid or comet that carved the Chicxulub crater caused the extinction of more than half the planet's species at the end of the Cretaceous. But the shifted continents, expanded coasts, and widened oceans had cooled and moistened the planet's climate and set motion in dramatic changes to the flora and fauna. An extraterrestrial impact or a short period of volcanism became tough for the earth's species to handle.
- ✿ Long before the massacre began gigantic sauropods led line of dinosaurs through the forests, over the plains, and along the coasts. Long-necked and toothy marine reptiles terrorized fish, ammonites, and mollusks in the seas. Pterosaurs and hairy-feathered birds filled the skies. But as the continents spread, the ocean currents stirred with ever more vigor. After a temperature spike in the mid-Cretaceous, the climate began to cool, and the environment changed.
- ✿ Though dinosaurs ruled throughout the Cretaceous, the dominant groups shifted and many new types evolved. Sauropods dominated the southern continents but became rare in the north. Herd-dwelling ornithischians like Iguanodon spread everywhere apart from Antarctica.
- ✿ Toward the close of the Cretaceous, vast herds of horned beasts such as *Triceratops* ate cycads and other low-lying plants on the northern continents. The *carnivore* Tyrannosaurus rex dominated the late Cretaceous in the north while monstrous meat-eaters like Spinosaurus, which had a huge sail-like fin on its back, thrived in the south. Smaller carnivores likely battled for the scraps.

- ❁ **Other creatures**, such as **frogs, salamanders, turtles, crocodiles, and snakes**, multiplied on the expanded coasts. **Shrew-like mammals ran about the forests.** The **largest pterosaur** known rose overhead though the group as a whole faced ever strengthening competition from **fast diversifying birds, Ancestors to modern grebes; cormorants, pelicans, and sandpipers all show up in the Cretaceous.**
- ❁ **Snake-like mosasaurs appeared from the long-necked plesiosaurs** in the **warm shallow seas that spilled onto the continents.** **Rays and modern sharks became common.** **Sea urchins and sea stars (starfish) thrived.** **Coral reefs** continued to grow. **Diatoms, a type of shelled plankton,** made their first radiation into the ocean.
- ❁ **Flowering plant** had a **rapid spread during this period** with the **help of insects** from bees and wasps to ants and beetles. **Magnolia, ficus, and sassafras quickly outnumbered ferns, conifers, gingkoes, and cycads.**
- ❁ The **cretaceous period came to an end** with an **extinction called KT extinction** where **K is for Kreide, meaning chalk in German,** which describes the chalky sediment layer from that time; **T is for Tertiary, the next geologic period.** It is an **asteroid about 4-9 miles (6-15 Kilometer) in diameter hit the earth** around 65 million years ago. The **impact would have penetrated the earth's crust, scattering dust and debris into the atmosphere** causing **huge fires, tsunamis, severe storms with high winds and highly acidic rain, seismic activity and perhaps even volcanic activity.** The impact could have caused **chemical changes in the earth's atmosphere, increasing concentrations of sulphuric acid, nitric acid and fluoride compounds.** The heat from the impact's blast wave would have destroyed all the life forms in its path. The dust and the debris thrust into the atmosphere would have blocked most of the sunlight for months, and lowered the temperature globally.

❁ Those organisms that could not adapt to the temperature and light changes would die out. Since plants' energy is derived from the sun, they would likely be the first to be affected by changes in climate. Many families of phytoplankton and plants would die out, and the Earth's oxygen levels decreased dramatically, both on land and in the oceans, suffocating those organisms which were unable to cope with the lower oxygen levels.

❁ Major changes in the food chain would result from all of these environmental upheavals. The herbivores (plant eaters) that ate those plants would starve soon after the plants died. Then, at the top of the food chain, the carnivores (meat eaters), having lost their prey, would have to eat each other, and eventually die out. Their large carcasses must have provided smaller animals with food for quite a while. Nearly all the dinosaurs died, snakes and crocodiles were among the few reptiles to survive. Some of the mammals and birds also survived into the next period.

CENOZOIC ERA:

- ❁ The **Cenozoic era** meaning “new life” is the most recent geologic era. The Cenozoic era started **65 million years ago to the present**.
- ❁ The Cenozoic era is further sub-divided into **tertiary period encompassing the Neogene and Paleogene period** and the **Quaternary period**.

PALEOGENE PERIOD:

- ❁ **Paleogene** is the first geologic period of the Cenozoic era. It extended from **65 million years ago to 23 million years ago**.

- ✿ This period is further divided into **Paleocene epoch, Eocene epoch** and **Oligocene epoch**.
- ✿ At the **dawn of the Paleogene**, the beginning of the Cenozoic era **dinosaurs, pterosaurs, and giant marine reptiles** were **conspicuously absent** from the face of the Earth. **Rodent-size** (and perhaps larger) **mammals emerged**.
- ✿ During the **Paleogene the continents drifted farther apart**, heading toward their modern positions. **Oceans widened the gaps, Europe severed its last ties with North America, and Australia and Antarctica finally parted ways.** As the **climate significantly cooled and dried, sea levels continued to drop** from late Cretaceous levels, draining most interior seaways.
- ✿ The **cooling and drying trend began** following a **sudden temperature spike** about **55 million years ago**. **Sea surface temperatures rose** between 9 and 14 degrees Fahrenheit (5 and 8 degrees Celsius) over a period of a few thousand years, **killing off numerous single-celled marine organisms** called **foraminifera**, along with **some other invertebrates**. This event also **profoundly affected northern forests**, previously **full of deciduous hardwoods with sequoias and pines**. The **new, more humid subtropical conditions** nurtured abundant palms and guavas. Land mammals responded in kind, radiating and diversifying into many new forms.
- ✿ Following this warming the climate cooled and dried forests gave way to open woodlands and grasslands in the northern hemisphere which **eventually helped herds of grazing mammals to evolve**.
- ✿ **Fish filled in the oceans**, becoming the **prey for sharks**, which were **fast ruling the waters in the absence of the giant mosasaurs and plesiosaurs of the Cretaceous**.

Squid and **other soft-bodied cephalopods** replaced their **shelled ancestors**, which once filled the middle rung on the food chain. **Sea snails and bivalves** that were similar to modern forms **lurked on the ocean bottom**. **New types of foraminifera and sea urchins** replaced those that had died off in earlier mass extinctions.

- ✿ But the **greatest development in the seas** was the **appearance of whales** in the **mid- to late Paleogene**. The huge animals evolved from land mammals that took to the seas.
- ✿ Meanwhile, **smaller reptiles that survived the Cretaceous**, such as **turtles, snakes, crocodiles, and lizards**, stretched out in the **tropical warmth along the coasts**. **Birds, the holdouts of the dinosaur age, diversified and flourished** in the skies. But the **rapidly evolving mammals** were the highlight of this period. Starting from a fairly humble position **65 million years ago, primates, horses, bats, pigs, cats, and dogs had all evolved** by the close of the period, 23 million years ago.

NEOGENE PERIOD:

- ✿ **Neogene** is the geologic period that extended from **23 million years ago to 2.5 million years ago**. The Neogene period lies between the Paleogene and quaternary period of the Cenozoic period. The Neogene period is further subdivided into **Miocene** and **Pliocene epochs**.
- ✿ From **far away Earth looked much as it does today** when the Neogene period began. **Mountains rose** and **sea levels fell**. The **climate cooled and dried**. Species were forced to adapt or die.

- ✿ Though close to where they are today, the continents began the Neogene by crashing into each other. India continued its slow-moving collision with Asia, which had already started the giant push-up of the Himalaya that continues today. Italy pushed into Europe, giving rise to the Alps. Spain stroke France and the Pyrenees rose. Faulting, stretching, thinning, and lifting created parts of the Rocky, Sierra Nevada, and Cascade Mountains in North America. The high mountains altered air circulation and weather patterns, contributing to the drier and cooler climate.
- ✿ The Arctic ice cap grew and thickened. Snow and ice fell on the high mountains, locking up water far from the oceans. Sea levels dropped, exposing land bridges between Africa and Eurasia and between Eurasia and North America. Eventually, South America moved north and merged with North America, forming the Isthmus of Panama.
- ✿ The continental connections gave animals that had evolved in isolation an access to new lands. Elephants and apes wandered from Africa to Eurasia. Rabbits, pigs, saber-toothed cats, and rhinos went to Africa. Elephants and rhinos continued across the Bering Strait to North America. Horses went the other way. Ground sloths migrated from South America to North America; raccoons scurried south. Even rodents may have hopped Pacific islands route to Australia from Southeast Asia.
- ✿ As the climate changed, many of the great forests that carpeted the continents from shore to shore and from Pole to Pole slowly gave way to grasslands, a habitat more suited to the cooler and drier weather. But that stamina came with less nutrition. Plant-eating animals had to adapt in order to survive. Horses evolved stronger as it has enamel-protected teeth and hence flourished. Also

ruminants such as bison, camels, sheep, and giraffes, whose stomachs were in compartments adapted well to digesting grass. Many of the grazers were evolved quick and roamed in herds. Their predators were also forced to adapt.

- ❁ In the oceans, a new type of large brown algae, called kelp, latched onto rocks and corals in cool shallow waters, establishing a new habitat favored by sea otters and dugongs, a marine mammal related to the elephant. Sharks grew and dominated the seas once again. Megalodon, the biggest shark of all, was nearly 50 feet (15 meters) long.
- ❁ Meanwhile on land, Asian and African apes diverged and then, several million years later, hominins split from their closest African ape ancestors, the chimpanzees. Adapted to two-footed walking, early hominins dropped out of the trees and started to carry food and tools in their hands.
- ❁ The tertiary period ended with the planet getting cool enough to cause the last big Ice Age, about 1.8 million years ago.

QUATERNARY PERIOD:

- ❁ The quaternary period is the most recent of the three periods of the Cenozoic era. It spans from 2.5 million years ago to the present. The quaternary period is further sub-divided into Pleistocene and the Holocene epochs.
- ❁ At the start of the Quaternary, the continents were just about where they are today, slowing inching here and there as the forces of plate tectonics push and tug them about. But throughout the period, the planet has wobbled on its path

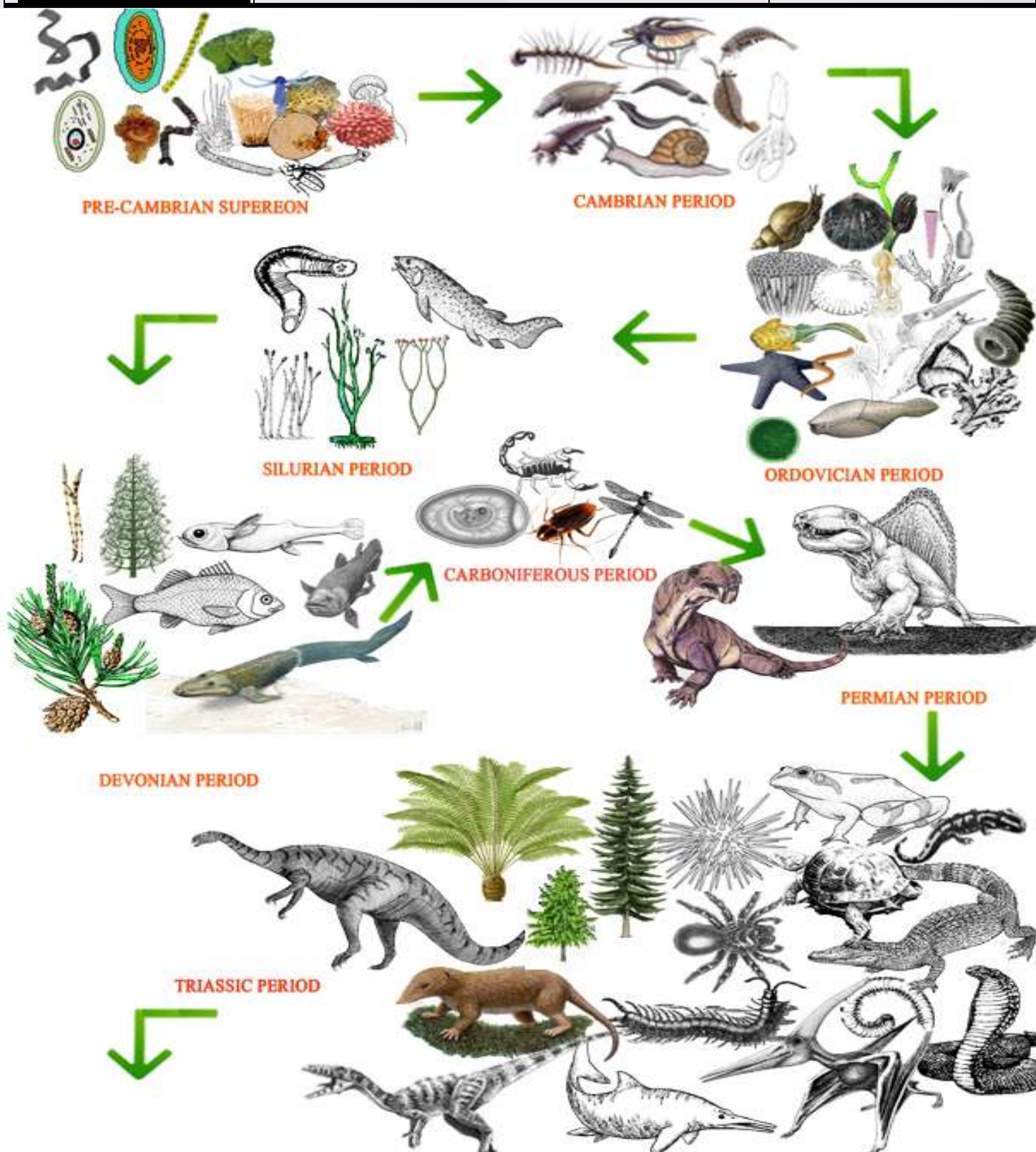
around the sun. The slight shifts cause ice ages to come and go. **By 800,000 years ago, a cyclical pattern had emerged: Ice ages last about 100,000 years followed by warmer interglacial of 10,000 to 15,000 years each. The last ice age ended about 10,000 years ago. Sea levels rose rapidly, and the continents achieved their present-day outline.**

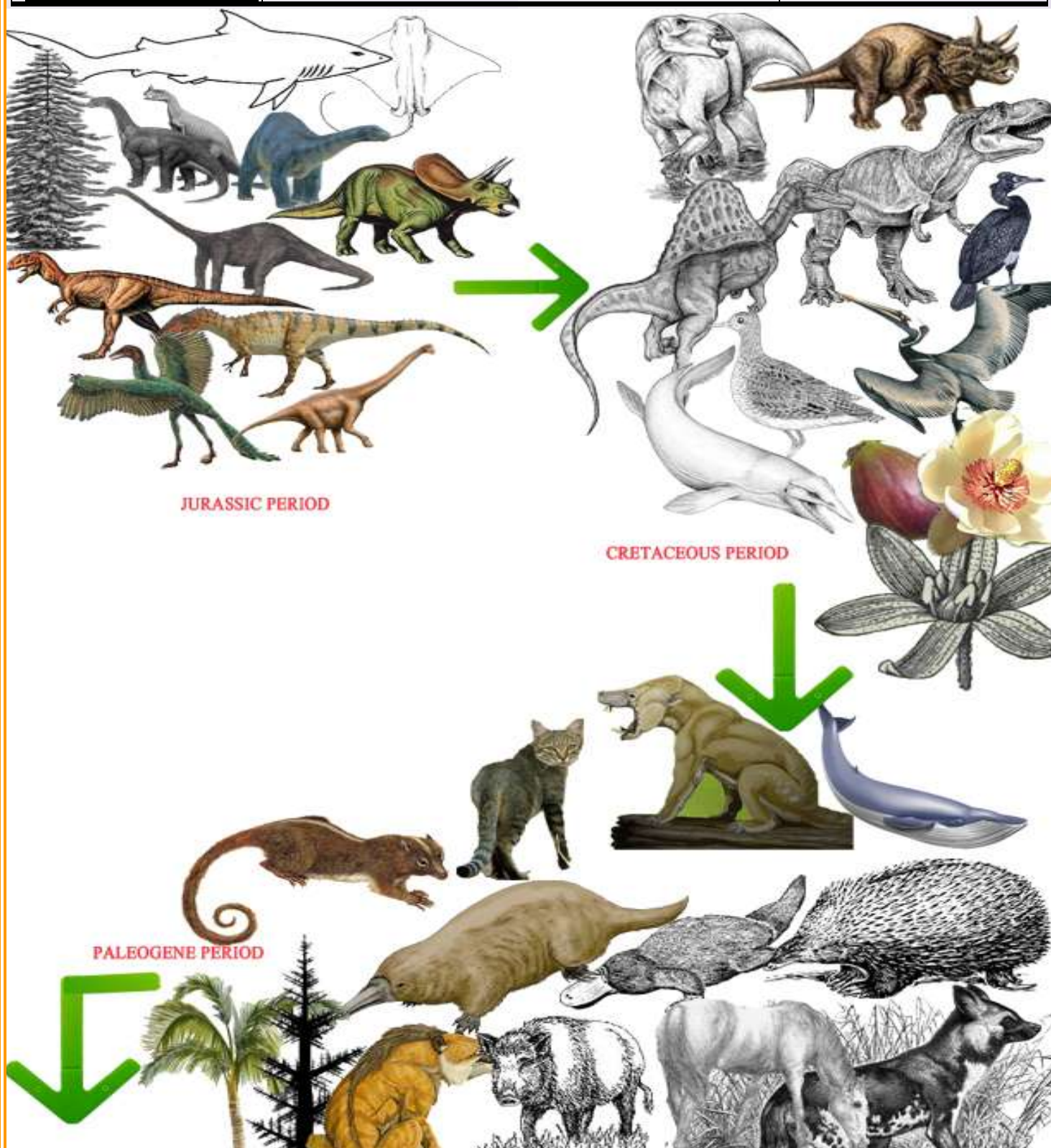
- ❁ When the **temperatures drop**, ice sheets spread from the Poles and cover much of North America and Europe, parts of Asia and South America, and all of Antarctica. As much of the **water are being locked up as ice**, there comes a **fall in sea level. Land bridges form between the continents. The land bridges allow animals and humans to migrate from one landmass to another.**
- ❁ During warm spells, the ice retreats and **exposes reshaped mountains striped with new rivers draining to giant** basins like today's Great Lakes. **Plants and animals that required warmth and comfort toward the Equator return to the higher latitudes.** In fact, each shift alters global winds and ocean currents that in turn alter patterns of precipitation and aridity around the world.
- ❁ Since the **start of the Quaternary, whales and sharks have ruled the seas, topping a food chain with otters, seals, dugongs, fish, squid, crustaceans, urchins, and microscopic plankton filling in the descending rungs.**
- ❁ On land, the **chilliest stretches** of the **Quaternary saw mammals** like **mammoths, rhinos, bison, and oxen grow massive and don shaggy coats of hair. They fed on small shrubs and grasses that grew at the ever moving edges of the ice sheets. About 10,000 years ago, the climate began to warm, and most of these so-called mega fauna went extinct. Only a handful of smaller, however still impressively large, representatives remain, such as Africa's elephants, rhinoceroses, and hippopotamuses.** Scientists are uncertain whether the warming climate is to

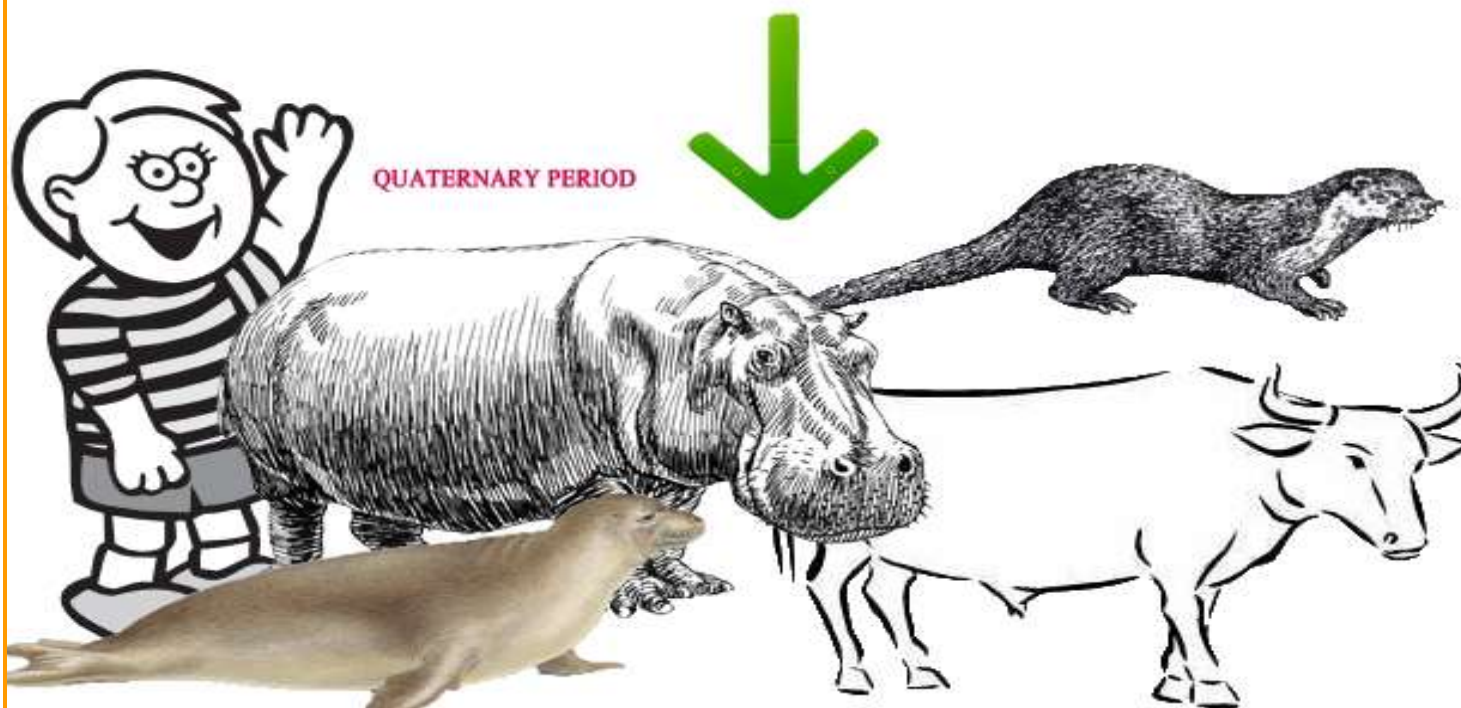
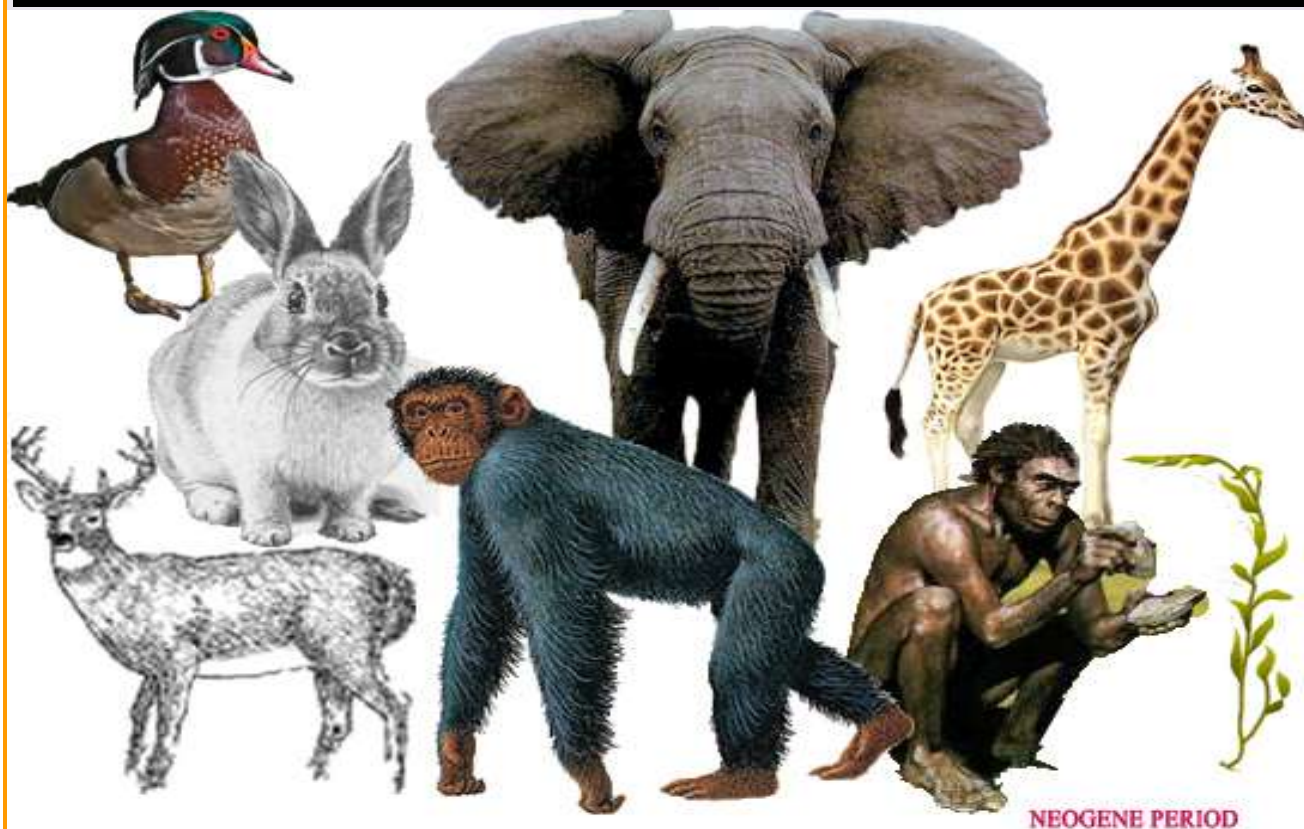
blame for the extinction at the end of the last ice age. **At the time, modern humans were rapidly spreading around the globe** and some studies link the **disappearance of the big mammals with the arrival of humans** and **their hunting ways**.

- ❁ In fact, the **Quaternary** is often considered the "**Age of Humans**." **Homo erectus appeared in Africa** at the start of the period, and **as time marched on the hominid line evolved bigger brains and higher intelligence**. **The first modern humans evolved in Africa about 190,000 years ago** and **dispersed to Europe and Asia and then on to Australia and the Americas**. Along the way the **species has altered the composition of life in the seas, on land, and in the air**.

For a better understanding of evolution of life, a diagrammatic flow chart has been illustrated below







THE CONTINUING TREND OF THE GLOBE:

There are many issues that arose after the appearance of modern human as they tend to over-power the nature. As days evolved there were many issues concerning the environment. But the alarming issue of the present is the Climate change due to global warming. As the economy raised people became more luxurious disregarding the environmental factor and ethical factor. They just give even their life to get money without even thinking what the money will be used for when they are no more. It was found that around 440 Giga tones of carbon are emitted by vegetation and 332 Giga tones by oceans wherein they in turn absorb 778 Giga tons of carbon hence balancing the carbon content. Here the problem arises from human. 29 Giga tons of carbon is emitted per year due to fossils burning ultimately upsetting the natural balance. At present a family is said to be royal if each person in the family own a car individually. To get this status people run behind money and mindlessly own 5 to 6 cars, spoiling their peace of mind and contributing more carbon foot print. The big shots owing the oil industry bribe the automobile manufacturers not to invent a solar driven car as they would be largely affected. Therefore the climate changes play a main role in the current scenario and now let us now take a deep look into the factors affecting the climate change and the prevention techniques.

CLIMATE CHANGE:

- ✿ After the origin and evolution of modern human in the current scenario the earth globe is subjected to climate change due to the emission of green house gases.
- ✿ During the 20th Century the earth's surface warmed by about 0.74° Celsius, according to IPCC.
- ✿ The IPCC's Fourth Assessment reports in 2007 stated that warming of the climate system is clear and that most of the observed increase in global average

temperatures since the mid-twentieth century is very likely due to the rise in greenhouse gases generated by human activity.

- IPCC's Fourth Assessment Report observed that between 1970 to 2004, greenhouse gas emissions increased by 70 percent, and carbon-dioxide (CO_2) being the far largest source with 77 percent of total emissions. IPCC found the atmospheric concentration of CO_2 , methane (CH_4) and nitrous oxide (N_2O) had risen markedly since 1750 due to human activity and today far exceed pre-industrial values.

CAUSES OF CLIMATE CHANGE:

- The causes of climate change can be divided into two categories, natural and human causes.
- In the current scenario the climatic changes have been speeded up because of man's activities. Now let us see in details these two categories of causes.

NATURAL CAUSES:

- The earth's climate is influenced and changed through natural causes like volcanic eruptions, ocean current, the earth's orbital change and solar variations.

VOLCANIC ERUPTIONS

- When a volcano erupts it throws out large volume of sulphur dioxide (SO_2), water vapour, dust, and ash into the atmosphere.

- ✿ Large volumes of gases and ash can influence climatic patterns for years by increasing planetary reflectivity causing atmospheric cooling. Tiny particles called aerosols are produced by volcanoes.
- ✿ As they reflect solar energy back into space they have a cooling effect on the globe. The greenhouse gas, carbon-dioxide is also produced however the CO₂ produced is insignificant when compared to emissions created by humans.
- ✿ There is a real time evidence for volcanoes affecting the climate change, the 1991 eruption of Mount Pinatubo in the Philippines lowered global temperatures by about 0.4-0.5° C.

OCEAN CURRENTS:

- ✿ The oceans are a major component of the climate system. Ocean currents move vast amounts of heat across the planet. Wind push horizontally against the sea surface and drive ocean current patterns.
- ✿ Interactions between the ocean and atmosphere can also produce phenomena such as El Nino which occur every 2 to 6 years. Deep ocean circulation of cold water from the poles towards the equator and movement of warm water from the equator back towards the poles. Without this the poles would be colder and the equator warmer.

- ✿ The oceans play an important role in determining the atmospheric concentration of CO₂. Changes in this circulation may affect the climate through the movement of CO₂ into or out of the atmosphere.

EARTH ORBITAL CHANGES:

- ✿ The earth makes one full orbit around the sun each year. It is tilted at an angle of 23.5° to the perpendicular plane of its orbital path. Changes in the tilt of the earth can lead to small but climatically important changes in the strength of the seasons, more tilt means warmer summers and colder winters; less tilt means cooler summers and milder winters.
- ✿ Slow changes in the earth's orbit lead to small but climatically important changes in the strength of the seasons over tens of thousands of years. Climate reactions amplify these small changes, thereby producing ice ages.

SOLAR VARIATIONS:

- ✿ The Sun is the source of energy for the Earth's climate system. Although the Sun's energy output appears constant from an everyday point of view, small changes over an extended period of time can lead to climate changes.
- ✿ Some scientists suspect that a portion of the warming in the first half of the 20th century was due to an increase in the output of solar energy. As the sun is the fundamental source of energy that is instrumental in our climate system it would be reasonable to assume that changes in the sun's energy output would cause the climate to change.

- Scientific studies demonstrate that solar variations have performed a role in past climate changes. For instance a decrease in solar activity was thought to have triggered the Little Ice Age between approximately 1650 and 1850, when Greenland was largely cut off by ice from 1410 to the 1720s and glaciers advanced in the Alps.

MAN-MADE CAUSES:

- On the other hand the climate change is fairly influenced by the human activity. The Industrial Revolution in the 19th century saw the large-scale use of fossil fuels for industrial activities. Fossil fuels such as oil, coal and natural gas supply most of the energy needed to run vehicles generate electricity for industries and households. The energy sector is responsible for about $\frac{3}{4}$ of the carbon dioxide emissions, $\frac{1}{5}$ of the methane emissions and a large quantity of nitrous oxide.
- Carbon emitted due to deforestation, transportation, etc. The various activity of the human has contributed a large amount of carbon to the atmosphere which has drastically increased the climate.

PREVENTIVE MEASURES:

- The natural cause for climate change is inevitable and have always been a part of earth's history
- The energy produced by burning of fossil fuel such as coal can be got by the solar heat found abundant in the atmosphere. Early in the stage the amount of sun's heat was less and vast amount of land was needed in order to generate solar energy. But now the heat of the sun is incomparably high and we have reached

high energy phenomena hence solar energy can be generated in a limited amount of space using pair production process. When the enormous amount of heat is absorbed for power generation the atmospheric heat gets reduced. Hydro-power is another renewable resource of energy which can be used as supplementary power production process.

- ✿ The daily transportation of the human can be shrunk to absolute necessity and maximum part of the work can be shifted online. When the online activity rules the society there won't be much demand for transportation. The Copenhagen summit that was conducted to discuss the preventive measures of climate change had numerous leader of different countries gathered there in Bella. The travel and work for this summit has created around 42,600 tons of carbon-dioxide most of which was contributed from their flight. When all these governmental activities, Professional activities and educational activities turn online completely, tons and tons of carbon footprints can be eliminated. Most of the developed countries have automated governance but the governance of the developing country entails a personal visit for each and every issue under the name of authority.
- ✿ During the photosynthesis process the plants take in carbon-dioxide and gives out oxygen and hence growing trees would let us hand in the absorption of carbon-dioxide. It is also important to have care on the varieties of tree that we grow. The fast growing trees like honey locust, weeping willow, American linden, spring groove, Quaking, Autumn purple ash, Black cottonwood, black willow, Cimarron ash, Eucalyptus, Bamboo, Crape myrtle takes in large amount of carbon-dioxide to grow faster. Grass is another variety of plant that grows fast and has some unique qualities. It holds the soil firmly hence fixing the carbon in soil. It is the food for the herbivores which forms the primary ring of food web. When consumed it quickly replaces with new grass. As the carbon absorbed by these plants are converted in carbohydrates during photosynthesis, the herbivore in the lower ring of the food web when munch these the carbohydrates gets transformed into

them and again when the carnivore in the higher ring eat these lower ring herbivores they are transferred with the nutrient.

- ✿ It is found that the carbon-dioxide emitted by vegetation and oceans are again absorbed by the same balancing the carbon content in the atmosphere. And therefore it is our duty to retrieve the carbon that is emitted into the atmosphere by our activity for our own better living and a green healthy environment for our future generation.

CONCLUSION:

- ✿ The emergence of underwater organisms early in the evolution is due to the hydrothermal vent. It is evident from the discovery of Bob Ballard and his crew; they found new life-forms living completely independent of the sun's energy around deep sea, hydrothermal vents. These undersea geysers form along volcanic mid-ocean ridges, where cold seawater penetrates deep into the cracks in the earth's crust. Heated water rises back out and the hot vent water mixes with cold ocean-bottom seawater, creating a rising plume of warm, black fluid filled with mineral particles. The chemicals support a thriving ecosystem on the ocean.
- ✿ The variety of evolution that took part in the formation of life can be proved by the theory of natural selection by Charles Darwin. And it also solidly proves the possibility of emergence of huge mammals from the evolution of simple celled organism.
- ✿ Life may also evolve on other planet eventually when the condition favors origin of life there. This is clearly established by the experiment of Stanley miller, a chamber containing only hydrogen, water, methane and ammonia. He boiled the

water and exposes the elements to an electric discharge like lightning, simulating earth's early processes. After a week, he found organic compounds have formed, including amino acids, the "building blocks of life". Artificially creating an ecosystem in other planet will end up disastrous in a long run. However intelligent human becomes nature has its own power and cannot be competed.

- ✿ The evolution of hominids from ape can be proved by the discoveries of Donald Johanson in 1974. He discovered the partial skeleton of a 3.2 million year old female hominid resembling apes in Ethiopia. Also a team led by Mary Leaky discovered fossilized Australopithecus footprints in Laetoli, Tanzania. The footprints were formed when two individuals walked over wet volcanic ash that had hardened like cement. These human ancestors had perfect, two-footed strides, indicating that hominids walked upright.
- ✿ Extinctions are common and have been a part of earth's history in its evolution. The extinction caused by nature is inevitable but the extinction caused by human activity can be avoided as when the man caused extinction and nature caused extinction merges the result will be disastrous.