SUBJECT- ENVIRONMENTAL SCIENCE

SEMESTER –M.Sc 2nd SEMESTER (C22)

TEACHER- SHRAMANA ROY BARMAN

TOPIC- ENVIRONMENTAL GEOSCIENCE

Origin, composition and structure of lithosphere.

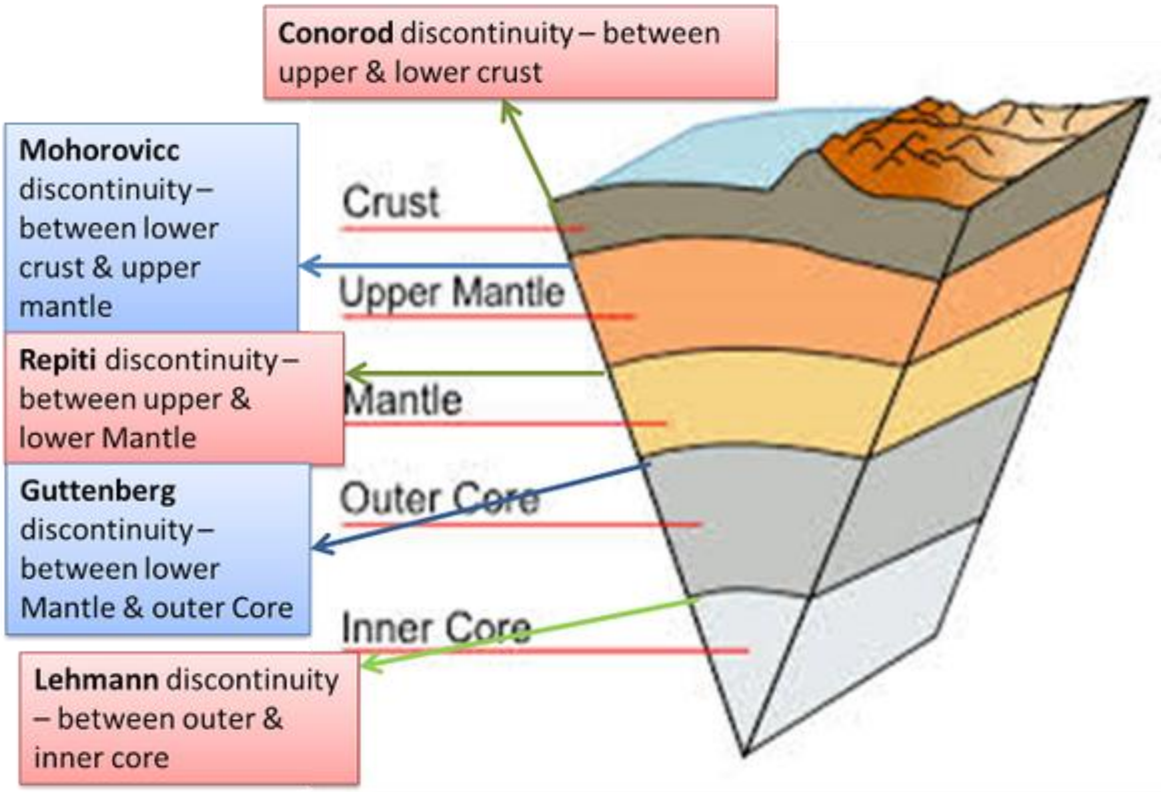
The name '**lithosphere**' comes from the Greek words *lithos*, meaning 'rocky,' and *sphaeros*, meaning 'sphere.'

As the earth cooled, there was no atmosphere to trap the heat. The surface cooled off fast due to the cold temperature of space (like how the top of coffee cools off when exposed to the air). This created a layer of cooled rock that solidified into the crust. Differences in magma created two types of the lithosphere, oceanic and continental, characterized by the **basalt** in oceans and **granite** in the continents.

The lithosphere is the solid, outer part of the Earth. The lithosphere includes the brittle upper portion of the mantle and the crust, the outermost layers of Earth's structure. It is bounded by the atmosphere above and the asthenosphere (another part of the upper mantle) below.

Although the rocks of the lithosphere are still considered elastic, they are not viscous. The asthenosphere *is* viscous, and the lithosphere-asthenosphere boundary (LAB) is the point where geologists and rheologists—scientists who study the flow of matter—mark the difference in ductility between the two layers of the upper mantle. Ductility measures a solid material's ability to deform or stretch under stress. The lithosphere is far less ductile than the asthenosphere.

The Mohorovičić discontinuity (Moho) represents the border between the crust and mantle parts of the lithosphere.



There are two types of lithosphere: oceanic lithosphere and continental lithosphere. Oceanic lithosphere is associated with oceanic crust, and is slightly denser than continental lithosphere.

Plate Tectonics

The most well-known feature associated with Earth's lithosphere is tectonic activity. Tectonic activity describes the interaction of the huge slabs of lithosphere called tectonic plates.

The earth's crust consists of several large dynamic tectonic plates. These tectonic plates moves slowly but continuously at an average rate of around 10 cm. Considering this, there was no Atlantic Ocean, and North America and Europe together were one continent 180 million years ago. The Atlantic Ocean came into being because of the drafting apart of the Eurasian and North America plates.

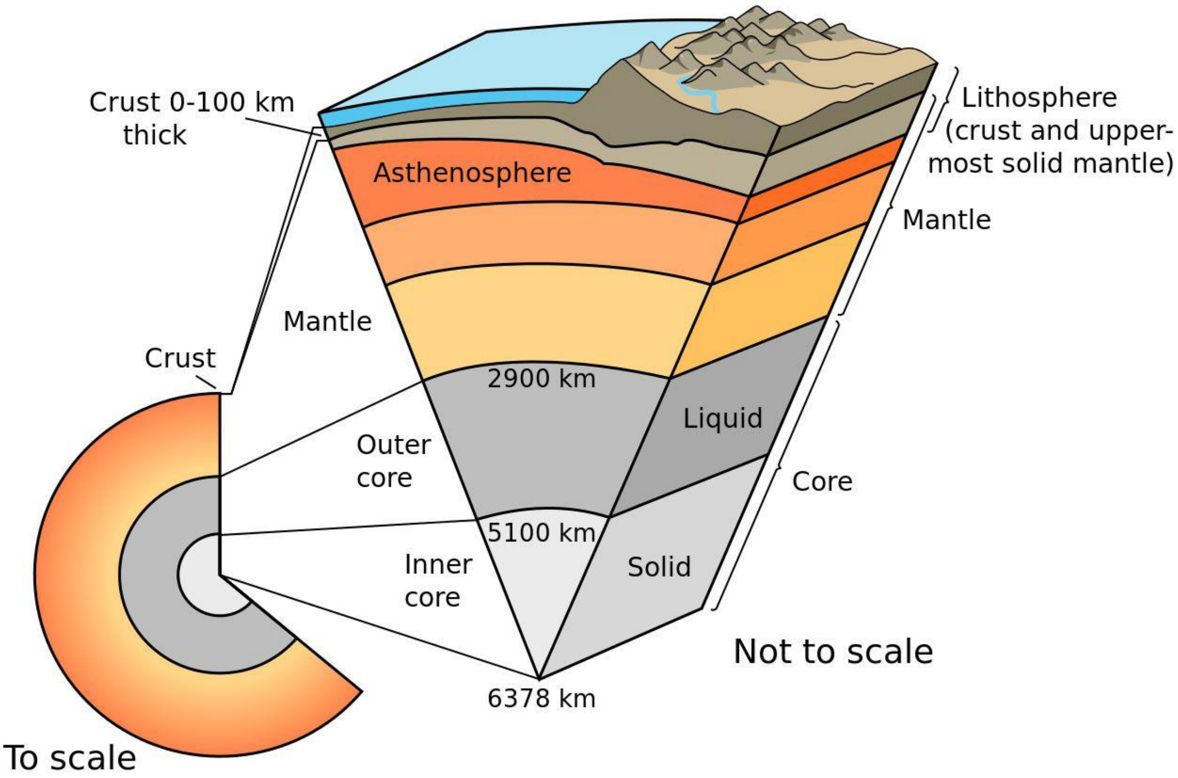
Most tectonic activity takes place at the boundaries of these plates, where they may collide, tear apart, or slide against each other. The movement of tectonic plates is made possible by thermal energy (heat) from the mantle part of the lithosphere. Thermal energy makes the rocks of the lithosphere more elastic.

Tectonic activity is responsible for some of Earth's most dramatic geologic events: earthquakes, volcanoes, orogeny (mountain-building), and deep ocean trenches can all be formed by tectonic activity in the lithosphere. Tectonic activity can shape the lithosphere itself.

Mantel convection (leading to tectonic activity)

Heat flows in two different ways within the Earth: conduction and convection. Conduction is defined as the heat transfer that occurs through rapid collisions of atoms, which can only happen if the material is solid. Heat flows from warmer to cooler places until all are the same temperature. The mantle is hot mostly because of heat conducted from the core. Convection is the process of a material that can move and flow may develop convection currents. Convection in the mantle is the same as convection in a pot of water on a stove. Convection currents within Earth's mantle form as material near the core heats up. As the core heats the bottom layer of mantle material, particles move more rapidly, decreasing its density and causing it to rise. The rising material begins the convection current. When the warm material reaches the surface, it spreads horizontally. The material cools because it is no longer near the core. It eventually becomes cool and dense enough to sink back down into the mantle. At the bottom of the mantle, the material travels horizontally and is heated by the core. It reaches the location where warm mantle material rises, and the mantle convection cell is complete.

Convection in the mantle is the same as convection in a pot of water on a stove. Convection currents within Earth's mantle form as material near the core heats up. As the core heats the bottom layer of mantle material, particles move more rapidly, decreasing its density and causing it to rise. The rising material begins the convection current. When the warm material reaches the surface, it spreads horizontally. The material cools because it is no longer near the core. It eventually becomes cool and dense enough to sink back down into the mantle. At the bottom of the mantle, the material travels horizontally and is heated by the core. It reaches the location where warm mantle material rises, and the mantle convection cell is complete.



Lithosphere composition

The earth's crust is not a homogeneous substance; it has different layers of rocks including **sedimentary rocks** on top, **granitic** and **metamorphic** rocks in the middle and **basaltic** rocks on the bottom.

Composition of Crust:

Major Elements	Percent by Weight	Percent by Volume	Percent by Atoms
Oxygen	46.6	93.8	62.6
Silicon	27.7	0.9	21.2
Aluminium	8.1	0.5	6.5
Iron	5	0.4	1.9
Calcium	3.6	1	1.9
Sodium	2.8	1.3	2.6
Potassium	2.6	1.8	1.4
Magnesium	2.1	0.3	1.8

.

It is evident from the above table that oxygen composition exceeds 60 percent in terms of the number of atoms. If the volume of different atoms (or ions) is calculated, oxygen makes up more than 90 percent of the volume.

Composition of Mantle:

The mantle represents about **68 percent** of the mass of the earth. It is subdivided into the **upper, transition and the lower zones**.

- The upper mantle extends to about 400 kms.
- This region contains predominantly three silicate material olivine, pyroxene and garnet.
- The transition zone extends from a depth of about 400 kms to about 1000 kms.
- The above mentioned three components of the upper mantle are also present in this region but in chemically modified forms.
- The lower mantle, which extends from a depth of about 1000 kms to about 2900 kms. The main components are magnesium oxide, iron oxide and silica.

Element	Present by Weight	Oxide	Percent by Weight
Oxygen	44	SiO2	48
Silicon	23	M2O	31
Magnesium	19	FeO	13
Iron	9.9	Al2,O3	3
Calcium	1.7	CaO	2.3
Aluminium	1.6	Na2,O3	1.1
Sodium	0.84	Cr2,O3	0.55

Like in crust, oxygen is the most predominant element in the mantle too. Most of the oxygen in the upper mantle and transition zone is present in the form of silicates, and therefore, silicon is the second most abundant element in the mantle. But in the lower mantle, oxygen is present as oxides.

Composition of Core:

The outer core extends from the depth of about 2900 kms to about 5080 kms while the inner core extends from about 5080 kms to about 6370 kms. The inner core, which is in a solid state, contains nearly **pure iron** while the outer core which is in liquid state also contains predominantly **iron**. The composition of outer core is believed to be **nickel and iron**. In fact, the outer core is predominately an iron nickel alloy.

Minerals and Rocks:

- Minerals are naturally occurring inorganic crystalline substances with physical and chemical properties within prescribed limits.

- Rocks are aggregates of a mineral or minerals.

There are over 2000 minerals, however, only a few are necessary to identify most of the rocks. Minerals and rocks are the foundation materials for the solids. Their composition, texture and structure determine the type of the soil.

Soil:

It is a shallow body of material formed on the surface of the land. It is the habitat of micro-organisms and burrowing animals. Moreover it supplies materials to indwelling members of biota.

Weathering of Rocks:

There are three kinds of soil forming rocks viz. igneous, sedimentary and metamorphic rocks. Soil formation results from its disintegration or weathering of parent rock by physical, chemical or biological agents. As a result, small particles called regoliths are formed. Regoliths under the influence of other pedogenic processes finally develop into mature soil.

(a) Physical Weathering:

When climatic agents such as temperature, water, ice and gravity change the rocks in regoliths but do not cause any chemical transformation of rocks, the process is called as physical weathering. It occurs in deserts, at high altitudes and latitudes specially at places where sparse vegetation grow over the rocks.

(b) Chemical Weathering:

Chemical transformation of parent mineral occurs to form new mineral complexes. Water is the most potent weathering agent. Soluble rocks like gypsum, lime stone and those with a calcareous content gets weathered by the solvent action of water.

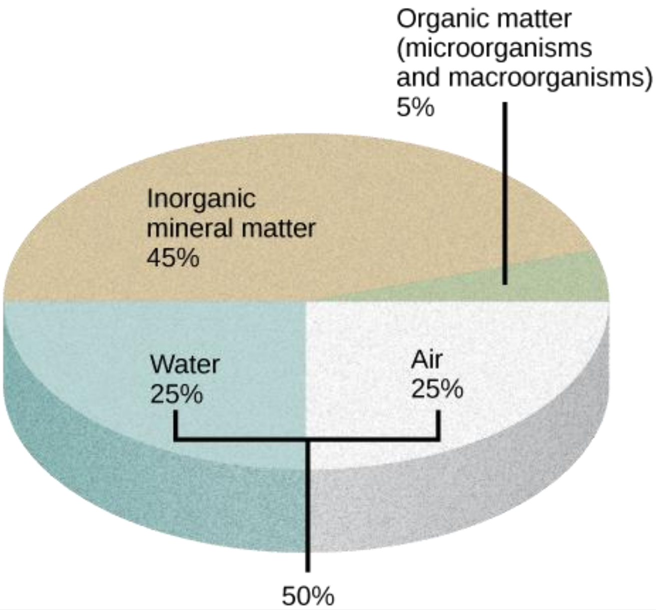
(c) Biological Weathering:

Certain organisms like bacteria, protozoans, fungi and nemetodes as well as lichens and mosses colonize the rocks and transfer it into a dynamic system storing energy and synthesizing organic material. Their activities change the physical structure of the rock.

Weathered rocks are changed into regoliths that are again changed into soil. Thus weathered material undergoes a number of complex processes collectively known as pedogenesis. Pedogenesis is by and large a biological phenomenon. During this process living organisms such as bacteria, algae, fungi and lichens, insects and molluses contribute to different geochemical, biochemical and biophysical reactions.

These activities convert the weathered earth crust into true soil consisting of mineral matrix in association with a variety of organic compounds supporting rich population of micro organisms. The processes, being continuous, keep on adding to the developing soil, organic matter and materials in the form of layers. Therefore, the soil when fully developed can be observed having a number of horizons, starting from surface to downwards. These horizons make a soil profile.

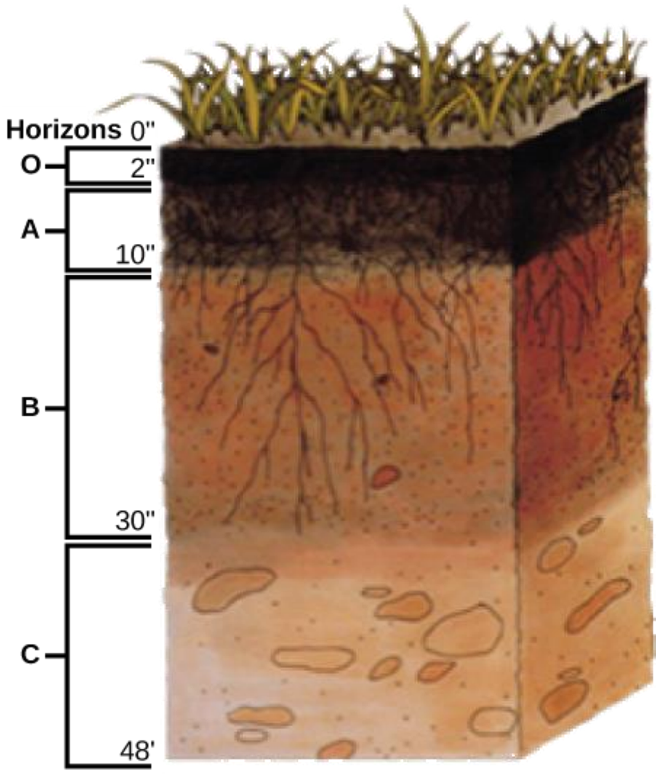
Soil consists of these major components:



Components of soil: The four major components of soil are shown: inorganic minerals, organic matter, water, and air.

- inorganic mineral matter, about 40 to 45 percent of the soil volume
- organic matter, about 5 percent of the soil volume
- water, about 25 percent of the soil volume
- air, about 25 percent of the soil volume

Soils are named and classified based on their horizons. The soil profile has four distinct layers:



Soil profile: This soil profile shows the different soil layers (O horizon, A horizon, B horizon, and C horizon) found in typical soils.

1. The O horizon has freshly-decomposing organic matter, humus, at its surface, with decomposed vegetation at its base. Humus enriches the soil with nutrients, enhancing soil moisture retention. Topsoil, the top layer of soil, is usually two to three inches deep, but this depth can vary considerably. For instance, river deltas, such as the Mississippi River delta, have deep layers of topsoil. Topsoil is rich in organic material. Microbial processes occur there; it is responsible for plant production.
2. The A horizon consists of a mixture of organic material with inorganic products of weathering; it is the beginning of true mineral soil. This horizon is typically darkly colored because of the presence of organic matter. In this area, rainwater percolates through the soil and carries materials from the surface.
3. The B horizon, or subsoil, is an accumulation of mostly fine material that has moved downward, resulting in a dense layer in the soil. In some soils, the B horizon contains nodules or a layer of calcium carbonate.
4. The C horizon, or soil base, includes the parent material, plus the organic and inorganic material that is broken down to form soil. The parent material may be either created in its natural place or transported from elsewhere to its present location. Beneath the C horizon lies bedrock.

Biota of the Soil:

The organic matter of the soil supports a complex micro flora and fauna and often a complex biota of higher communities.

These can be classified as follows:

1. Microflora:

It includes bacteria, soil fungi and algae. Soil bacteria grows fairly well in neutral soil whereas soil fungi and fauna in acidic soils. Symbiotic fungi live on the roots of plants whereas fungi depend on the dead organic matter of the soil.

2. Microfauna:

Protozoa, rotifers, mites, nematodes, copepods collectively constitute the micro-fauna. The size of these animals varies from 20μ to 200μ. Protozoans like amoeba, ciliates and flagellates occur near the surface soil.

3. Mesofauna:

The animals ranging in size from 200 μ to 1 cm. constitute mesofauna. Among insects, collembola is the main soil insect. Among the Hymenoptera, ants are the most important soil dwelling animals. Mites flourish in moist organic soil.

4. Macroflora:

Soil supports a wide variety of plants like herbs, shrubs and trees. Plants growing on acidic soils are called as oxylophytes. Those growing on saline soils are called Halophytes. The plants growing on sand are called as Psammophytes. Plants that grow on rock surfaces are called lithophytes whereas those which grow on rock cervices are called as charmophytes.

Origin, composition and structure of atmosphere.

One of the four components of the Earth's ecosystem (the other three are biosphere, hydrosphere, and lithosphere), it is a band of gases enveloping the Earth's surface. Ninety-nine percent of its mass is concentrated within 20 miles of the earth's surface. Atmosphere has no outer boundary, just fades into space.

Early Earth would have been very different and inhospitable compared to the Earth today.It was very hot due to- Primordial heat, decay of short-lived radioactive elements

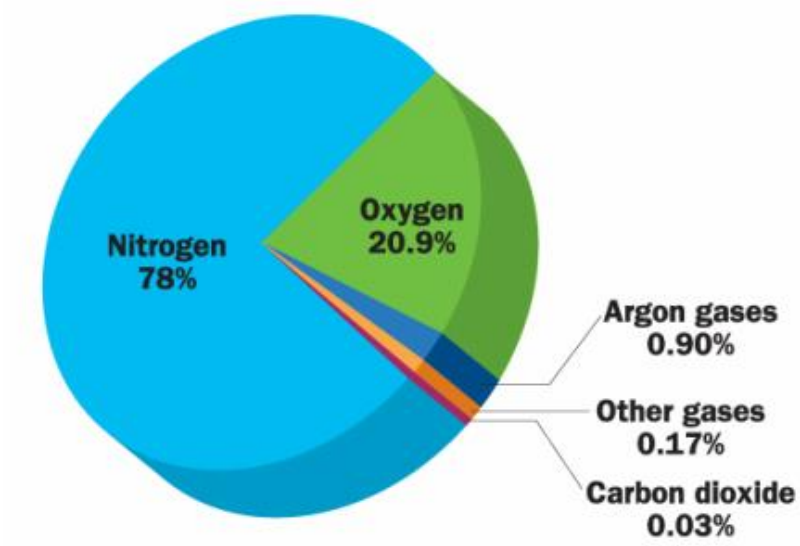
Consequences - Constant volcanism, surface temperature too high for liquid water or life as we know it, molten surface or thin, unstable basaltic crust. Early atmosphere was probably completely different in composition (H_2, He)

Then cooling took place

- Primordial heat dissipated to space
- Condensation of water (rain), accumulation of surface water.
- Accumulation of new atmosphere due to volcanic out gassing
- Conditions appropriate for evolution of life

Evolution of the Atmosphere

- Chemical Composition Today - Nitrogen (N_2)- 78%, Oxygen (O_2)- 21%, Carbon Dioxide (CO_2) - 0.03 %, plus other miscellaneous gases (H_2O for one).



Constituent	Percent by Volume	Concentration in Parts Per Million (PPM)
Nitrogen (N_2)	78.084	780,840.0
Oxygen (O_2)	20.946	209,460.0
Argon (Ar)	0.934	9,340.0
Carbon dioxide (CO_2)	0.036	360.0
Neon (Ne)	0.00182	18.2
Helium (He)	0.000524	5.24
Methane (CH_4)	0.00015	1.5
Krypton (Kr)	0.000114	1.14
Hydrogen (H_2)	0.00005	0.5

First Atmosphere

- Composition - Probably H_2, He

- These gases are relatively rare on Earth compared to other places in the universe and were probably lost to space early in Earth's history because
  - Earth's gravity is not strong enough to hold lighter gases
  - Earth still did not have a differentiated core (solid inner/liquid outer core) which creates Earth's magnetic field (magnetosphere = Van Allen Belt) which deflects solar winds.
- Once the core differentiated the heavier gases could be retained

Second Atmosphere

Produced by *volcanic out gassing.*

- Gases produced were probably similar to those created by modern volcanoes (H_2O, CO_2, SO_2, CO, S_2, Cl_2, N_2, H_2) and NH_3 (ammonia) and CH_4 (methane)
- No free O_2 at this time (not found in volcanic gases).

- *Ocean Formation* - As the Earth cooled, H_2O produced by out gassing could exist as liquid in the Early Archean, allowing oceans to form.

Addition of O_2 to the Atmosphere

Today, the atmosphere is ~21% free oxygen. How did oxygen reach these levels in the atmosphere?

Oxygen Production

  - **Photochemical dissociation** - breakup of water molecules by ultraviolet
    - Produced O_2 levels approx. 1-2% current levels
    - At these levels O_3 (Ozone) can form to shield Earth surface from UV
- **Photosynthesis** - $CO_2 + H_2O$ + sunlight = organic compounds + O_2 - produced by cyanobacteria, and eventually higher plants - supplied the rest of O_2 to atmosphere.
- **Oxygen Consumers**
  - **Chemical Weathering** - through oxidation of surface materials (early consumer)
  - **Animal Respiration** (much later)
  - **Burning of Fossil Fuels** (much, much later)

Throughout the Archean eon there was little to no free oxygen in the atmosphere (<1% of presence levels). What little was produced by cyanobacteria, was probably consumed by the weathering process. Once rocks at the surface were sufficiently oxidized, more oxygen could remain free in the atmosphere.

During the Proterozoic eon the amount of free O_2 in the atmosphere rose from 1 - 10 %. Most of this was released by cyanobacteria, which increase in abundance in the fossil record

2.3 Ga (giga annum). Present levels of O_2 were probably not achieved until ~400 Ma(mega annum)

Composition

About 99 percent of the atmosphere is composed of nitrogen and oxygen. The remaining 1 percent consists of argon, carbon dioxide , water vapour and other trace gases.

The amounts of nitrogen and oxygen in the atmosphere are fairly constant over recent time and are known as **permanent gases of the atmosphere.**

The concentrations of some atmospheric gases are not as constant over time as the concentrations of nitrogen and oxygen. They are known as **variable gases.** Gases such as water vapour and ozone can vary significantly from place to place. The concentrations of some of these gases, such as water vapour and carbon dioxide, play an important role in regulating the amount of energy the atmosphere absorbs and emits back to Earth's surface

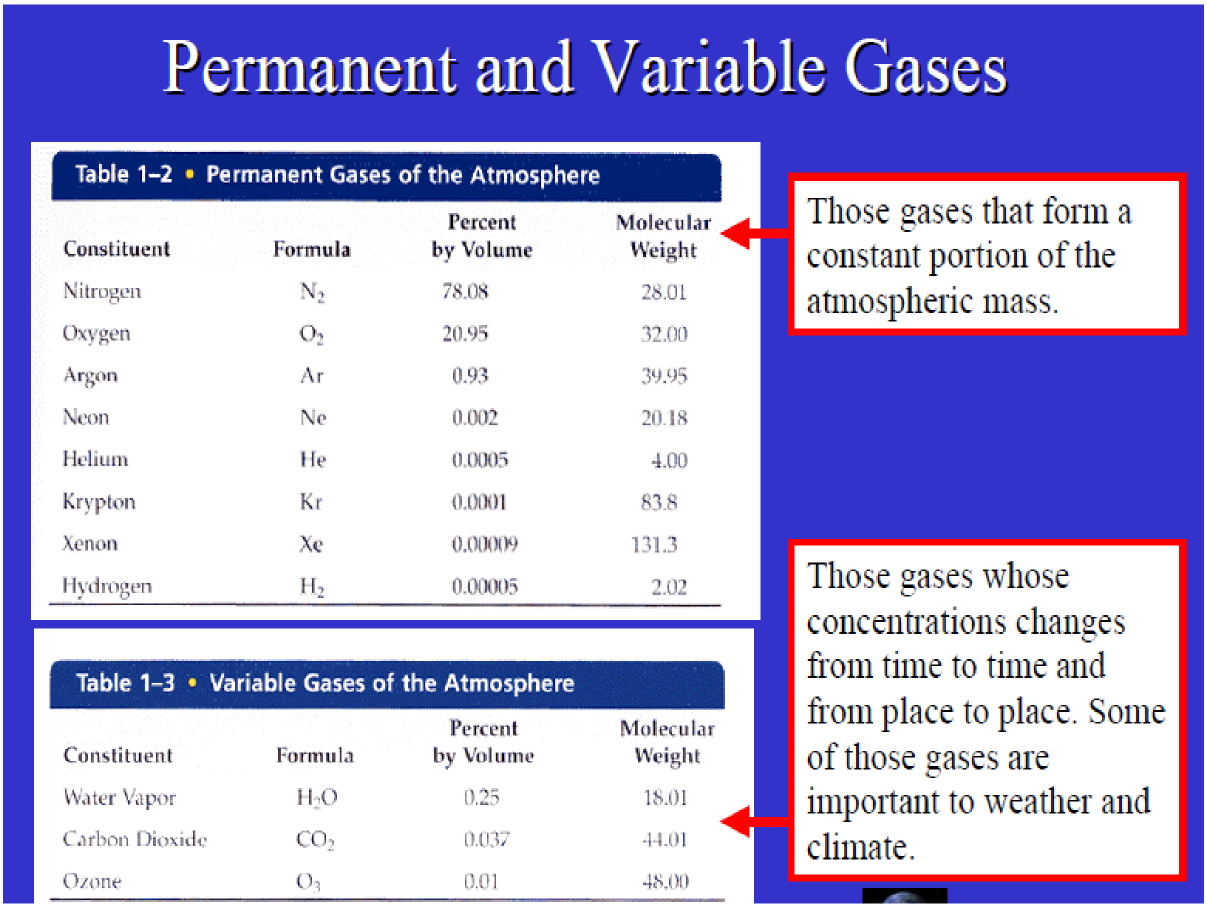


Table 1–2 • Permanent Gases of the Atmosphere

Constituent	Formula	Percent by Volume	Molecular Weight
Nitrogen	N_2	78.08	28.01
Oxygen	O_2	20.95	32.00
Argon	Ar	0.93	39.95
Neon	Ne	0.002	20.18
Helium	He	0.0005	4.00
Krypton	Kr	0.0001	83.8
Xenon	Xe	0.00009	131.3
Hydrogen	H_2	0.00005	2.02

Table 1–3 • Variable Gases of the Atmosphere

Constituent	Formula	Percent by Volume	Molecular Weight
Water Vapor	H_2O	0.25	18.01
Carbon Dioxide	CO_2	0.037	44.01
Ozone	O_3	0.01	48.00

Atmospheric particles

Earth's atmosphere also contains variable amounts of solids in the form of tiny particles, such as dust, salt, and ice. Fine particles of dust and soil are carried into the atmosphere by wind.

Winds also pick up salt particles from ocean spray. Airborne microorganisms, such as fungi and bacteria, can also be found attached to microscopic dust particles in the atmosphere.

Aerosols: small solid particles and liquid droplets in the air. They serve as condensation nuclei for cloud formation.

Air Pollutant: a gas or aerosol produces by human activity whose concentration threatens living organisms or the environment

Thickness of the Atmosphere

Most of the atmospheric mass is confined in the lowest 100 km above the sea level. The thickness of the atmosphere is only about 2% of Earth's thickness (Earth's radius = ~6500km).

Layers of the Atmosphere

The atmosphere is classified into five different layers, These layers are the

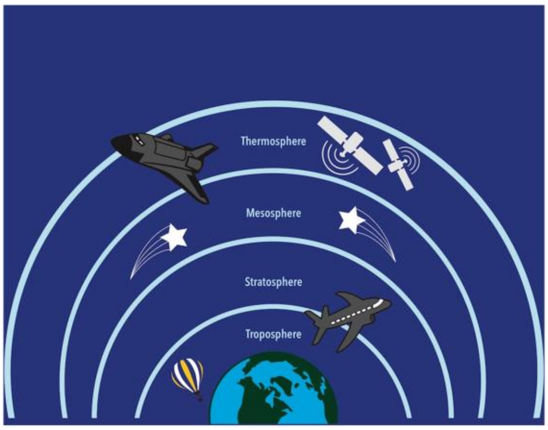
•Troposphere,

•Stratosphere,

•Mesosphere

• Thermosphere, and

•Exosphere.



Each layer differs in composition and temperature profile.

- **Troposphere**

The layer closest to Earth's surface, the troposphere, contains most of the mass of the atmosphere. Weather occurs in the troposphere. In the troposphere, air temperature decreases as altitude increases. The altitude at which the temperature stops decreasing is called the tropopause. The height of the tropopause varies from about 16 km above Earth's surface in the tropics to about 9 km above it at the poles. Temperatures at the tropopause can be as low as –60°C.

- **Stratosphere**

Above the tropopause is the stratosphere, a layer in which the air temperature mainly increases with altitude and contains the ozone layer. In the lower stratosphere below the ozone layer, the temperature stays constant with altitude. However, starting at the bottom of the ozone layer, the temperature in the stratosphere increases as altitude increases. This heating is caused by ozone molecules, which absorb ultraviolet radiation from the Sun. At the stratopause, air temperature stops increasing with altitude. The stratopause is about 48 km above Earth's surface. About 99.9 percent of the mass of Earth's atmosphere is below the stratopause

- **Mesosphere**

Above the stratopause is the mesosphere, which is about 50 km to 100 km above Earth's surface. In the mesosphere, air temperature decreases with altitude. This temperature decrease occurs because very little solar radiation is absorbed in this layer. The top of the mesosphere, where temperatures stop decreasing with altitude, is called the mesopause.

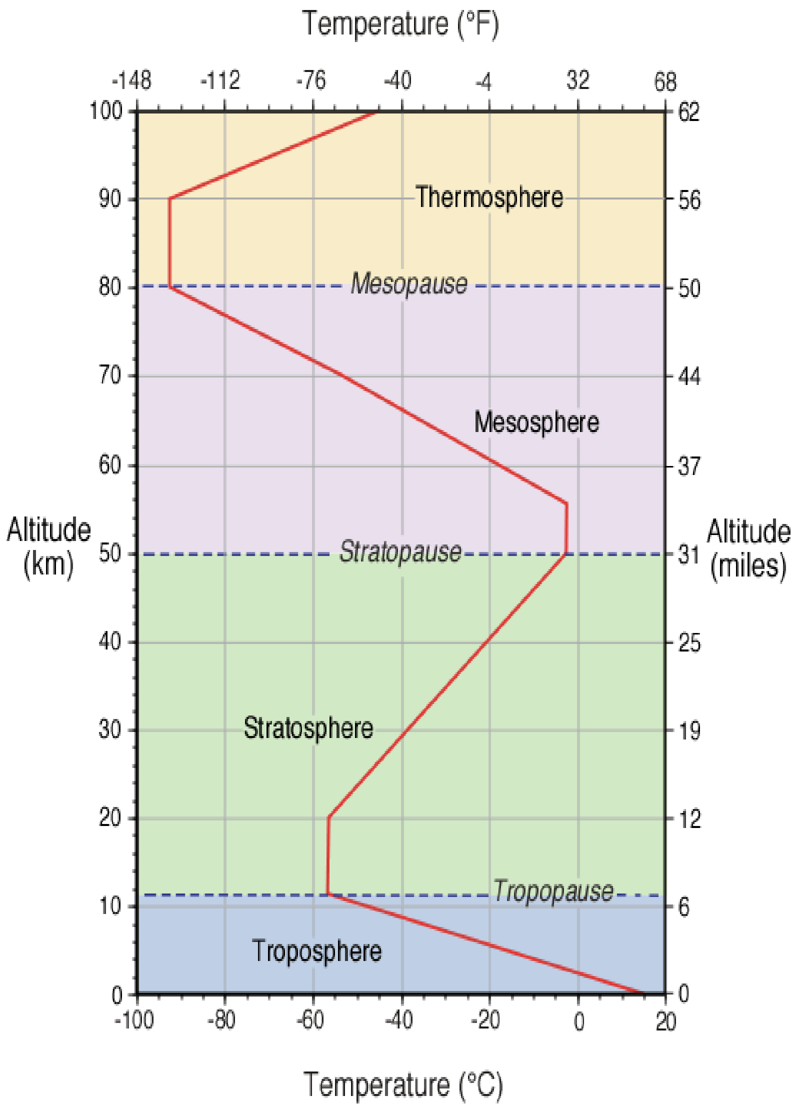
- **Thermosphere**

The thermosphere is the layer between about 100 km and 500 km above Earth's surface. Temperatures in this layer can be more than 1000°C.

The thermosphere absorbs much of the energy from the sun. It absorbs x rays and ultraviolet radiation from the sun and converts it into heat. The ionosphere, which is made of electrically charged particles, is part of the thermosphere.

- **Exosphere**

The exosphere is the outermost layer of Earth's atmosphere. The exosphere extends from about 500 km to more than 10,000 km above Earth's surface. There is no clear boundary at the top of the exosphere. Instead, the exosphere can be thought of as the transitional region between Earth's atmosphere and outer space. The number of atoms and molecules in the exosphere becomes very small as altitude increases. In the exosphere, atoms and molecules are so far apart that they rarely collide with each other



Temperature (°F)
-148
-112
-76
-40
-4
32
68
Altitude (km)
Altitude (miles)
100
90
80
70
60
50
40
30
20
10
0
62
56
50
44
37
31
25
19
12
6
0
Thermosphere
Mesopause
Mesosphere
Stratopause
Stratosphere
Tropopause
Troposphere
-100
-80
-60
-40
-20
0
20
Temperature (°C)