MODULE 1

Syllabus:

Fundamental concepts of hazards and disasters: Introduction to key concepts and terminology of hazard, vulnerability, exposure, risk, crisis, emergencies, Disasters, Resilience.

Basic concept of Earth as a system and its component sub systems. Climate Change vis-a-vis the interrelationships of the subsystems- Green House Effect and Global warming, basic ideas about their causes and effects.

DISASTER BACKGROUND

Disasters are as old as human history but the dramatic increase and the damage caused by them in the recent past have become a cause of national and international concern. Over the past decade, the number of natural and man-made disasters has climbed inexorably. From 1994 to 1998, reported disasters average was 428 per year but from 1999 to 2003, this figure went up to an average of 707 disaster events per year showing an increase of about 60 per cent over the previous years. The biggest rise was in countries of low human development, which suffered an increase of 142 per cent.

Disasters are not new to mankind. They have been the constant, though inconvenient, companions of the human beings since time immemorial. Disasters can be natural or human-made.

Earthquake, cyclone, hailstorm, cloud-burst, landslide, soil erosion, snow avalanche, flood etc. are the examples of natural disasters while fire, epidemics, road, air, rail accidents and leakages of chemicals/ nuclear installations etc. fall under the category of human-made disasters.

WHAT IS A DISASTER?

- A disaster can be defined as "A serious disruption in the functioning of the community or a society causing wide spread material, economic, social or environmental losses which exceed the ability of the affected society to cope using its own resources".
- The Disaster Management Act, 2005 defines disaster as "a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area".
- The United Nations defines disaster as "the occurrence of sudden or major misfortune which disrupts the basic fabric and normal functioning of the society or community".
- For a disaster to be entered into the database at least one of the following criteria must be fulfilled:
  - Ten (10) or more people reported killed
  - Hundred (100) or more people reported affected
  - Declaration of a state of emergency
  - Call for international assistance

A disaster is a result from the **combination of hazard, vulnerability and insufficient capacity or measures to reduce the potential chances of risk.** A disaster happens when a **hazard impacts on the vulnerable population and causes damage, casualties and disruption.**

For a better illustration of disaster is any hazard – flood, earthquake or cyclone which is a triggering event along with greater vulnerability (inadequate access to resources, sick and old people, lack of awareness etc) would lead to disaster causing greater loss to life and property

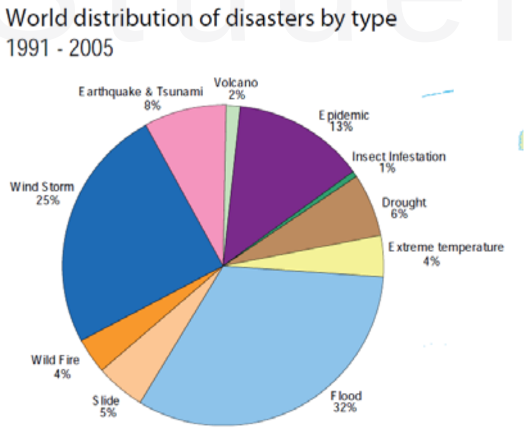
For example: an earthquake in an uninhabited desert cannot be considered a disaster, no matter how strong the intensities produced.

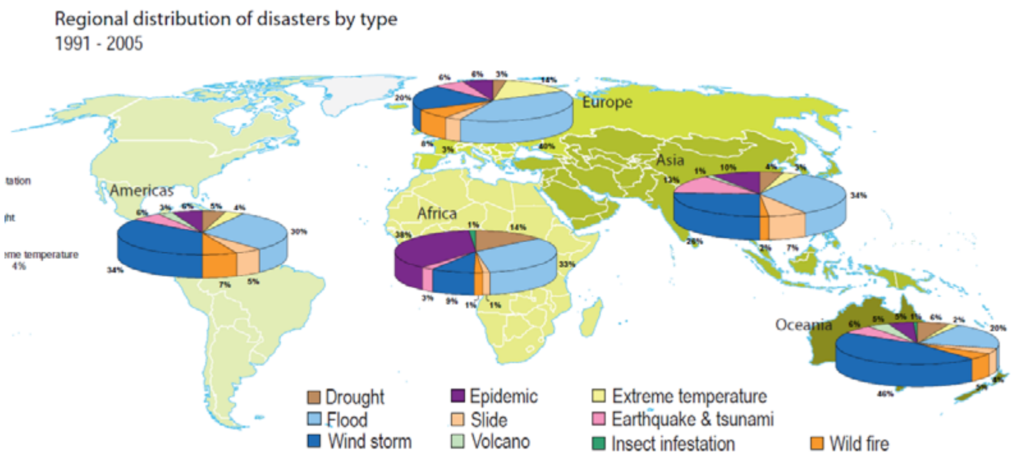
An earthquake is disastrous only when it affects people, their properties and activities. Thus, disaster occurs only when hazards and vulnerability meet. But it is also to be noted that with greater capacity of the individual/community and environment to face these disasters, the impact of a hazard reduces. Therefore, we need to understand the three major components namely hazard, vulnerability and capacity with suitable examples to have a basic understanding of disaster management.

Disaster is an event or series of events, which gives rise to casualties and damage or loss of properties, infrastructures, environment, essential services or means of livelihood on such a scale which is beyond the normal capacity of the affected community to cope with. Disaster is also sometimes described as a “catastrophic situation in which the normal pattern of life or eco-system has been disrupted and extra-ordinary emergency interventions are required to save and preserve lives and or the environment”.

DISASTERS – GLOBAL SCENARIO

Disasters - natural or human-made are common throughout the world. Disasters continue to occur without warning and are perceived to be on an increase in their magnitude, complexity, frequency and economic impact. Hazards pose threats to people and assume serious proportions in the under developed countries with dense population. During the second half of the 20th century, more than 200 worst natural disasters occurred in the different parts of the world and claimed lives of around 1.4 million people. Losses due to natural disasters are 20 times greater (as % of GDP) in the developing countries than in industrialized one. Asia tops the list of casualties due to natural disasters. Figure shows the Regional distribution of disasters by type, as prepared by Centre for Research on Epidemiology of Disaster.





There have been several natural, as well as, man-made disasters. Records of natural disasters can be traced way back to 430 B.C. when the Typhus epidemic was reported in Athens. Ten deadliest natural disasters recorded in the world are dated back to 1556 when an earthquake in Shaanxi province of China occurred on 23rd January, 1556 and 8,30,000 casualties were recorded. List of ten deadliest disasters which have occurred across the world and in India in the known history and in the last century may be seen from the respectively.

World Disaster

S.No	Name of Event	Year	Country & Region	Fatalities
1.	Earthquake	1556	China, Shaanxi	830000
2.	Earthquake	1731	China	100,000
3.	Cyclone	1737	India, Calcutta	300000
4.	Yellow River flood	1887	China	900,000–2,000,000
5.	Messina Earthquake	1908	Italy	123000
6.	Earthquake	1920	China, Gansu	235000
7.	Great Kanto Earthquake	1923	Japan	142,000
8.	Great Chinese Famine	1958-1961	China	15,000,000–43,000,000
9.	Bhola Cyclone	1970	West Bengal, India & East Pakistan (now Bangladesh)	500,000
10.	Tangshan Earthquake	1976	China	242,419

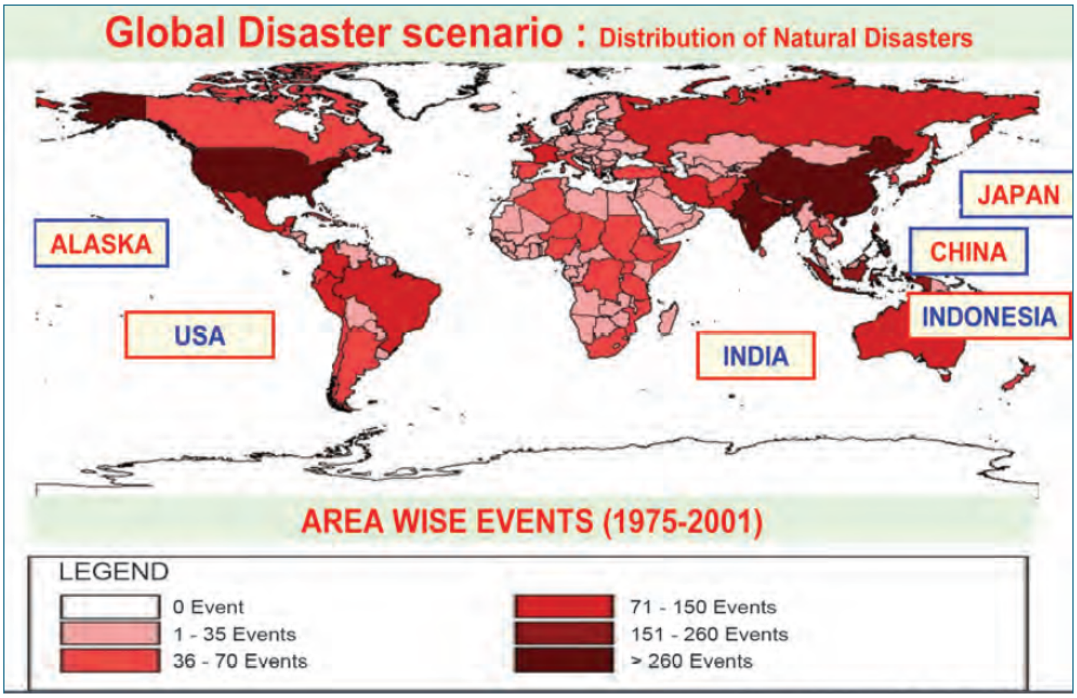
In Last Century

S.No	Name of Event	Year	Country & Region	Fatalities
1.	China Floods,	1931	China	1,000,000–2,500,000
2.	Floods	1954	China	40,000
3.	Cyclone	1970	Bangladesh, Chittagong, Khulna	300,000
4.	Bangladesh Cyclone,	1991	Bangladesh	139,000
5.	Earthquake	1999	Turkey	17,000
6.	Tsunami	2004	Indonesia, Sri Lanka, India, Malaysia, Somalia,Bangladesh, Thailand	230,210
7.	Hurricane Katrina	2005	United States of America	1,836
8.	Sichuan Earthquake	2008	China	87476 deaths including missing
9.	Cyclone nargis	2008	Myanmar	More than 138000 deaths
10.	Haiti Earthquake	2010	Haiti	31600

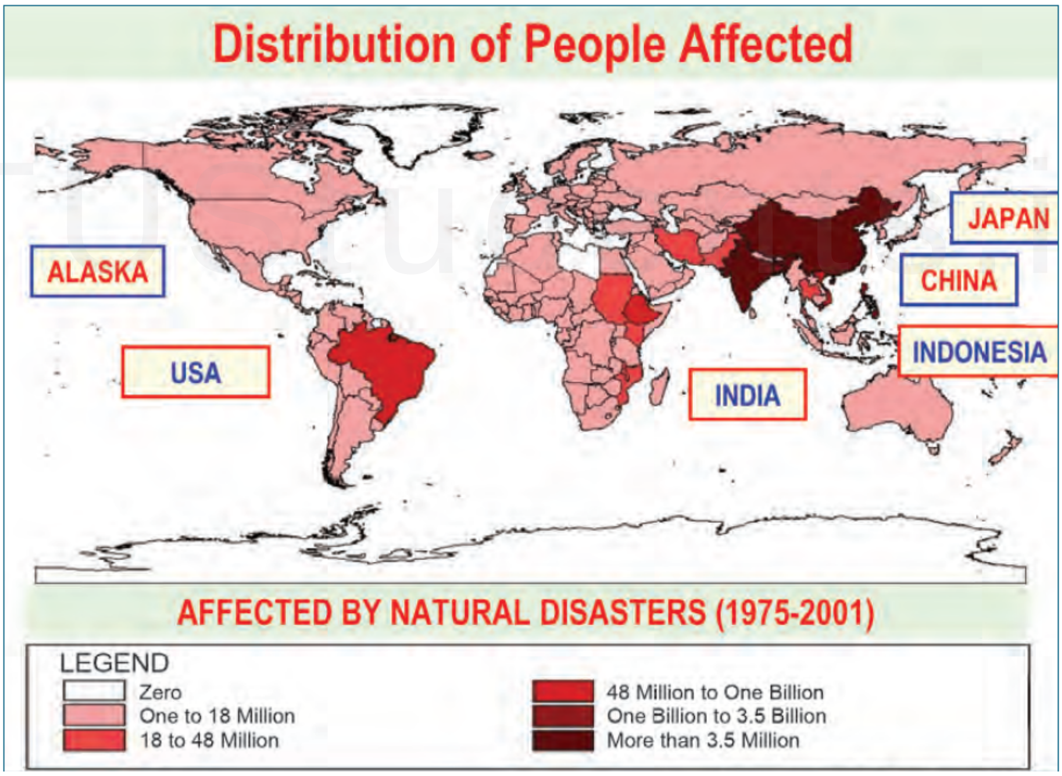
Indian Disasters

S.No	Name of Event	Year	State & Area	Fatalities
1.	Earthquake	1556	China, Shaanxi	830000
2.	Earthquake	1731	China	100,000
3.	Cyclone	1737	India, Calcutta	300000
9.	Bhola Cyclone	1970	West Bengal, India & East Pakistan (now Bangladesh)	500,000
10.	Tangshan Earthquake	1976	China	242,419
12.	Cyclone	1977	Andhra Pradesh	10000 deaths hundreds of thousands homeless 40000cattele deaths. Destroyed 40% of India's food grains
13.	Latur Earthquake	1993	Latur, Marthawada	7928 died & 30000 were injured
14.	Orissa Super Cyclone	1999	Orissa	10000
15.	Gujarat Earthquake	2001	Bhuj, Bachau, Anjar, Ahmedabad, surat Gujarat	25000 deaths 6.3 million people affected
16.	Tsunami	2004	Coastline of TamilNadu, Kerala, AP, Pandicherry, as well as the Andaman and Nicobar Islands of India	10749 deaths 5640 persons missing 2.79 million people affected 11827 hectares of crops damaged 300000 fisher flok lost their livehoods
17.	Maharshrta floods	2005, July	MP state	1094 deaths 167 Injured 54 Missing
18.	Kashmir Earthquake	2005	Kashmir	8600 deaths
19.	Kosi Floods	2008	North Bihar	527 deaths 19323 Live stock 222754 Houses damaged 3329423 persons affected
20.	Cyclone Nisha	2008	Tamil Nadu	204 deaths 800 million worth damages
21.	Cyclone Laila	2010	Srilanka and India	65 Deaths
22.	Cyclone Lehar	2013	India	None
23.	Cyclone Hud-Hud	2014	India/Nepal	124 Deaths
24.	Cyclone Komen	2015	W.B/Bihear-Odisha	None
25.	Cyclone Roanu	2016	Bangladesh, India, Myanmar	227 Deaths
26.	Kerala floods	2018	Kerala	417
27.	Cyclone Titli	2018	Andhra Pradesh & Odisha	89

Figure below shows the vulnerability scenario across the globe in terms of events and India has faced more than 260 events of disasters and over 3.5 million people affected from 1975 - 2001. It further analyses that the vulnerability of people and severity of disasters.



Global Disaster Scenario: Distribution of Natural Disasters



Distribution of People Affected

INDIA DISASTER SCENARIO:

India due to its geo-climatic and socio-economic condition is prone to various disasters. During the last thirty years' time span the country has been hit by 431 major disasters resulting into enormous loss to life and property. According to the Prevention Web statistics, 143039 people were killed and about 150 crore were affected by various disasters in the country during these three decades. The disasters caused huge loss to property and other infrastructures costing more than US $ 4800 crore. The most severe disasters in the country and their impact in term of people affected, lives lost and economic damage is given in the In India, the cyclone which occurred on 25th November, 1839 had a death toll of three lakh people. The Bhuj earthquake of 2001 in Gujarat and the Super Cyclone of Orissa on 29th October, 1999 are still fresh in the memory of most Indians. The most recent natural disaster of a cloud burst resulting in flash floods and mudflow in Leh and surrounding areas in the early hours of 6th August, 2010, caused severe damage in terms of human lives as well as property. There was a reported death toll of 196 persons, 65 missing persons, 3,661 damaged houses and 27,350 hectares of affected crop area. Floods, earthquakes, cyclones, hailstorms, etc. are the most frequently occurring disasters in India

Year	Type of Disasters	People affected	Life lost	Economic damage (USD×1000)
1980	Flood	30,000,023		
1982	Drought	100,000,000		
	Flood	33,500,000		
1984	Epidemic		3290	
1987	Drought	300,000,000		
1988	Epidemic		3000	
1990	Storm			2,200,000
1993	Flood	128,000,000		7,000,000
	Earthquake*		9,748	
1994	Flood		2001	
1995	Flood	32,704,000		
1996	Storm			1,500,300
1998	Storm		2871	
	Extreme Temp.		2541	
	Flood		1811	
1999	Storm		9,843	2,500,000
2000	Drought	50,000,000		
2001	Earthquake*		20,005	2,623,000
2002	Drought	300,000,000		
	Flood	42,000,000		
2004	Flood	33,000,000		2,500,000
	Earthquake*		16,389	
2005	Flood			3,330,000
	Flood			2,300,000
2006	Flood			3,390,000
2009	Flood			2,150,000

While studying about the impact we need to be aware of potential hazards, how, when and where they are likely to occur, and the problems which may result of an event. ***In India, 59 per cent of the land mass is susceptible to seismic hazard; 5 per cent of the total geographical area is prone to floods; 8 per cent of the total landmass is prone to cyclones; 70 per cent of the total cultivable area is vulnerable to drought.***

Apart from this the hilly regions are vulnerable to avalanches/ landslides/hailstorms/cloudbursts. Apart from the natural hazards, we need to know about the other manmade hazards which are frequent and cause huge damage to life and property. It is therefore important that we are aware of how to cope with their effects. We have seen the huge loss to life, property and infrastructure a disaster can cause but let us understand what is a disaster, what are the factors that lead to it and its impact

WHAT IS A HAZARD? HOW IS IT CLASSIFIED?

Hazard may be defined as "a dangerous condition or event that threat or have the potential for causing injury to life or damage to property or the environment." The word 'hazard' owes its origin to the word 'hasard' in old French and 'az-zahr' in Arabic meaning 'chance' or 'luck'. Hazards can be grouped into two broad categories namely natural and manmade.

1. ***Natural hazards*** are hazards which are caused because of natural phenomena (hazards with meteorological, geological or even biological origin). Examples of natural hazards are cyclones, tsunamis, earthquake and volcanic eruption which are exclusively of natural origin. Landslides, floods, drought, fires are socio-natural hazards since their causes are both natural and manmade. For example flooding may be caused because of heavy rains, landslide or blocking of drains with human waste.

2. ***Manmade hazards*** are hazards which are due to human negligence. Manmade hazards are associated with industries or energy generation facilities and include explosions, leakage of toxic waste, pollution, dam failure, wars or civil strife etc. The list of hazards is very long. Many occur frequently while others take place occasionally. However, on the basis of their genesis, they can be categorized as follows.

Geological Hazards	1. Earthquake 2. Tsunami 3. Volcanic eruption 4. Landslide 5. Dam burst 6. Mine Fire
Water & Climatic Hazards	1. Tropical Cyclone 2. Tornado and Hurricane 3. Floods 4. Drought 5. Hailstorm 6. Cloudburst 7. Landslide 8. Heat & Cold wave 9. Snow Avalanche 10. Sea erosion
Environmental Hazards:	1. Environmental pollutions 2. Deforestation 3. Desertification 4. Pest Infection
Biological Hazards:	1. Human / Animal Epidemics 2. Pest attacks 3. Food poisoning 4. Weapons of Mass Destruction
Chemical, Industrial and Nuclear Accidents	1. Chemical disasters 2. Industrial disasters 3. Oil spills/Fires 4. Nuclear
Accident related:	1. Boat / Road / Train accidents / air crash Rural / Urban fires Bomb /serial bomb blasts 2. Forest fires 3. Building collapse 4. Electric Accidents 5. Festival related disasters 6. Mine flooding

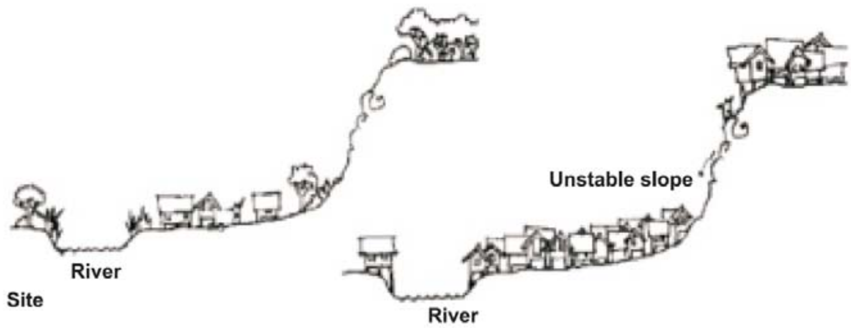
WHAT IS VULNERABILITY?

Vulnerability may be defined as "The extent to which a community, structure, services or geographic area is likely to be damaged or disrupted by the impact of particular hazard, on account of their nature, construction and proximity to hazardous terrains or a disaster prone area."

Vulnerabilities can be categorized into physical and socio-economic vulnerability.

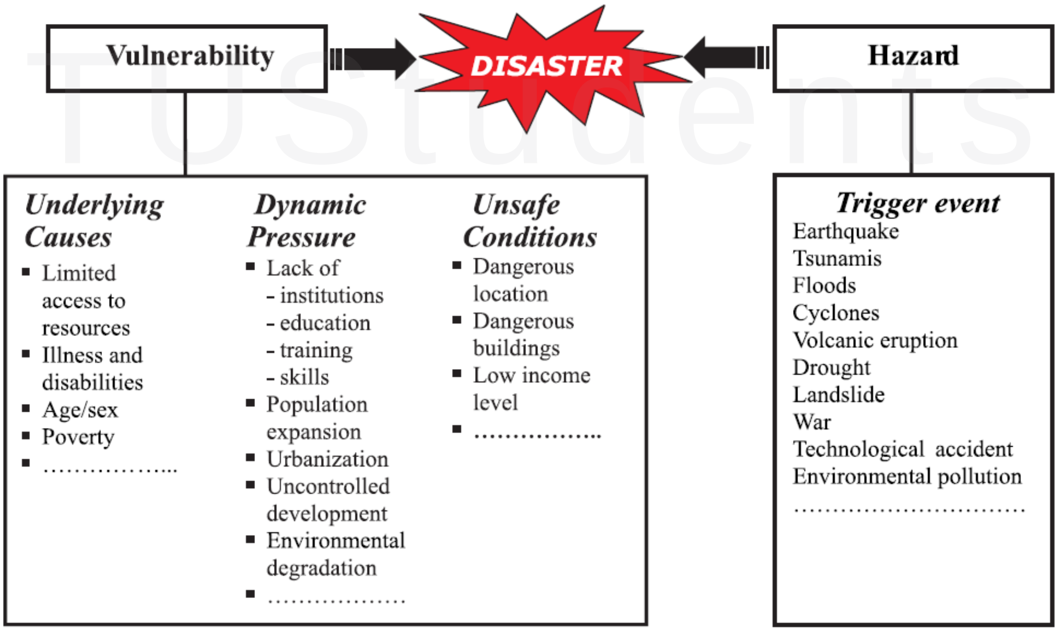
Physical Vulnerability: It includes notions of who and what may be damaged or destroyed by natural hazard such as earth- quakes or floods. It is based on the physical condition of people and elements at risk, such as buildings, infrastructure etc; and their proximity, location and nature of the hazard. It also relates to the technical capability of building and structures to resist the forces acting upon them during a hazard event. The settlements which are located in hazardous slopes.

Figure below shows the settlements which are located in hazardous slopes. Many landslide and flooding disasters are linked to what you see in the figure below. Unchecked growth of settlements in unsafe areas exposes the people to the hazard. In case of an earth- quake or landslide the ground may fail and the houses on the top may topple or slide and affect the settlements at the lower level even if they are designed well for earthquake forces.



Site after pressures from population growth and urbanization

<u>Socio-economic Vulnerability:</u> The degree to which a population is affected by a hazard will not merely lie in the physical components of vulnerability but also on the socio- economic conditions. The socio-economic condition of the people also determines the intensity of the impact. For example, people who are poor and living in the sea coast don't have the money to construct strong concrete houses. They are generally at risk and lose their shelters whenever there is strong wind or cyclone. Because of their poverty they too are not able to rebuild their houses.



<u>WHAT IS CAPACITY?</u>

Capacity can be defined as "resources, means and strengths which exist in households and communities and which enable them to cope with, withstand, prepare for, prevent, mitigate or quickly recover from a disaster". People's capacity can also be taken into account. Capacities could be:

<u>Physical Capacity:</u> People whose houses have been destroyed by the cyclone or crops have been destroyed by the flood can salvage things from their homes and from their farms. Some family members have skills, which enable them to find employment if they migrate, either temporarily or permanently.

Socio-economic Capacity: In most of the disasters, people suffer their greatest losses in the physical and material realm. Rich people have the capacity to recover soon because of their wealth. In fact, they are seldom hit by disasters because they live in safe areas and their houses are built with stronger materials. However, even when everything is destroyed they have the capacity to cope up with it.

Hazards are always prevalent, but the hazard becomes a disaster only when there is greater vulnerability and less of capacity to cope with it. In other words the frequency or likelihood of a hazard and the vulnerability of the community increases the risk of being severely affected.

WHAT IS RISK?

Risk is a "measure of the expected losses due to a hazard event occurring in a given area over a specific time period. Risk is a function of the probability of particular hazardous event and the losses each would cause." The level of risk depends upon:

- Nature of the hazard
- Vulnerability of the elements which are affected
- Economic value of those elements

A community/locality is said to be at 'risk' when it is exposed to hazards and is likely to be adversely affected by its impact. Whenever we discuss 'disaster management' it is basically 'disaster risk management'. Disaster risk management includes all measures which reduce disaster related losses of life, property or assets by either reducing the hazard or vulnerability of the elements at risk.

1. ***Preparedness***

This protective process embraces measures which enable governments, communities and individuals to respond rapidly to disaster situations to cope with them effectively. Preparedness includes the formulation of viable emergency plans, the development of warning systems, the maintenance of inventories and the training of personnel. It may also embrace search and rescue measures as well as evacuation plans for areas that may be at risk from a recurring disaster. Preparedness therefore encompasses those measures taken before a disaster event which are aimed at minimizing loss of life, disruption of critical services, and damage when the disaster occurs.

2. ***Mitigation***

Mitigation embraces measures taken to reduce both the effect of the hazard and the vulnerable conditions to it in order to reduce the scale of a future disaster. Therefore mitigation activities can be focused on the hazard itself or the elements exposed to the threat. Examples of mitigation measures which are hazard specific include water management in drought prone areas, relocating people away from the hazard prone areas and by strengthening structures to reduce damage when a hazard occurs. In addition to these physical measures, mitigation should also aim at reducing the economic and social vulnerabilities of potential disasters.

WHAT IS EXPOSURE?

The presence and number of people, property, livelihoods, systems or other elements in hazard areas (and so thereby subject to potential losses) is known as exposure. Exposure is one of the defining components of disaster risk

If a hazard occurs in an area of no exposure, then there is no risk. The extent to which exposed people or economic assets are actually at risk is generally determined by how vulnerable they are, as it is possible to be exposed but not vulnerable.

However, increasing evidence suggests that the case of extreme hazards the degree of disaster risk is a consequence of exposure more than it is a result of vulnerability. For instance, in the case of the 26 December 2004 Indian Ocean tsunami all those exposed to tsunamis were at risk, no matter their income, ethnicity or social class.

People and economic assets become concentrated in areas exposed to hazards through processes such as population growth, migration, urbanization and economic development. Previous disasters can drive exposure by forcing people from their lands and to increasingly unsafe areas. Consequently, exposure changes over time and from place to place.

Many hazard prone areas, such as coastlines, volcanic slopes and flood plains, attract economic and urban development, offer significant economic benefits or are of cultural or religious significance to the people who live there. As more people and assets are exposed, risk in these areas becomes more concentrated. At the same time, risk also spreads as cities expand and as economic and urban development transform previously sparsely populated areas.

Large volumes of capital continue to flow into hazard-prone areas, leading to significant increases in the value of exposed economic assets. If global exposure continues to trend upwards, it may increase disaster risk to dangerous levels.

Economic exposure in high-hazard areas is trending upwards. If we do not reverse this trend, disaster risk is set to increase. We need to act now to reduce exposure and build capacity and resilience in these areas of growing exposure.

When it is not possible to avoid exposure to events, land use planning and location decisions must be accompanied by other structural or non-structural methods for preventing or mitigating risk. In the case of the Boxing Day 2004 Indian Ocean tsunami, for instance, the only possible strategy to save lives would have been to reduce exposure through timely evacuation, which depends on the existence of reliable early warning systems and effective preparedness planning, and then to compensate for loss through insurance of other risk financing instruments

WHAT IS EMERGENCY?

Emergency is a disruption of the functioning of society, causing human, material or environmental damages and losses which do not exceed the ability of the affected society to cope using only its own resources.

Emergency is a situation in which normal operations cannot continue and immediate action is required so as to prevent a disaster Example – forest fire, oil spills, road accidents, outbreak of epidemics etc.

When an emergency or a disaster affect a city or a region, efforts are conducted initially to care for the wounded, to restore lifelines and basic services, and subsequently to restore livelihoods and to reconstruct communities. Such efforts can be structured in **three phases**:

- ***Response phase***, where activities such as search & rescue, rapid damage and needs assessments, and the provision of first aid are conducted; followed by the opening and management of temporary shelters for those left homeless as well as the provision of humanitarian assistance to those affected;
- ***Rehabilitation phase*** where basic services and lifelines are restored, even on a temporary basis, including the road network and other essential facilities including bridges, airports, ports and helicopter landing sites;

– ***Recovery phase*** where reconstruction efforts are carried out on the basis of a more precise assessment of damage and destruction of infrastructure. In addition, efforts are conducted to reconstruct infrastructure when needed and to restore the livelihoods of those affected

A ***disaster***, on the other hand, is characterized by impacts that overwhelm the capacities of local responders and place demands on resources which are not available locally. Hence, an event is declared as a "disaster" when there is a need for external assistance to cope with its impacts. A national government declares a state of disaster or national calamity as a way to request international humanitarian assistance and the support of the international community to cope with the impacts of the disaster

WHAT IS CRISIS?

It is any event that is going (or is expected) to lead to an unstable and dangerous situation affecting an individual, group, community, or whole society. Crisis is a smaller version which may degenerate in to a disaster if not properly managed. Crisis develops over time and disaster is sudden

WHAT IS RESILIENCE?

"Resilire" (Latin word) - to bounce back

Engineering resilience - The time taken by a system to bounce-back from shocks

Ecological resilience - The extent of disturbance a system can take without undergoing structural change

Disaster Resilience is the ability of individuals, communities, organizations and states to adapt to and recover from hazards, shocks or stresses without compromising long-term prospects for development. According to the Hyogo Framework for Action (UNISDR, 2005), disaster resilience is determined by the degree to which individuals, communities and public and private organizations are capable of organizing themselves to learn from past disasters and reduce their risks to future ones, at international, regional, national and local levels.

Disaster resilience is part of the broader concept of resilience – 'the ability of individuals, communities and states and their institutions to absorb and recover from shocks, whilst positively adapting and transforming their structures and means for living in the face of long-term changes and uncertainty'

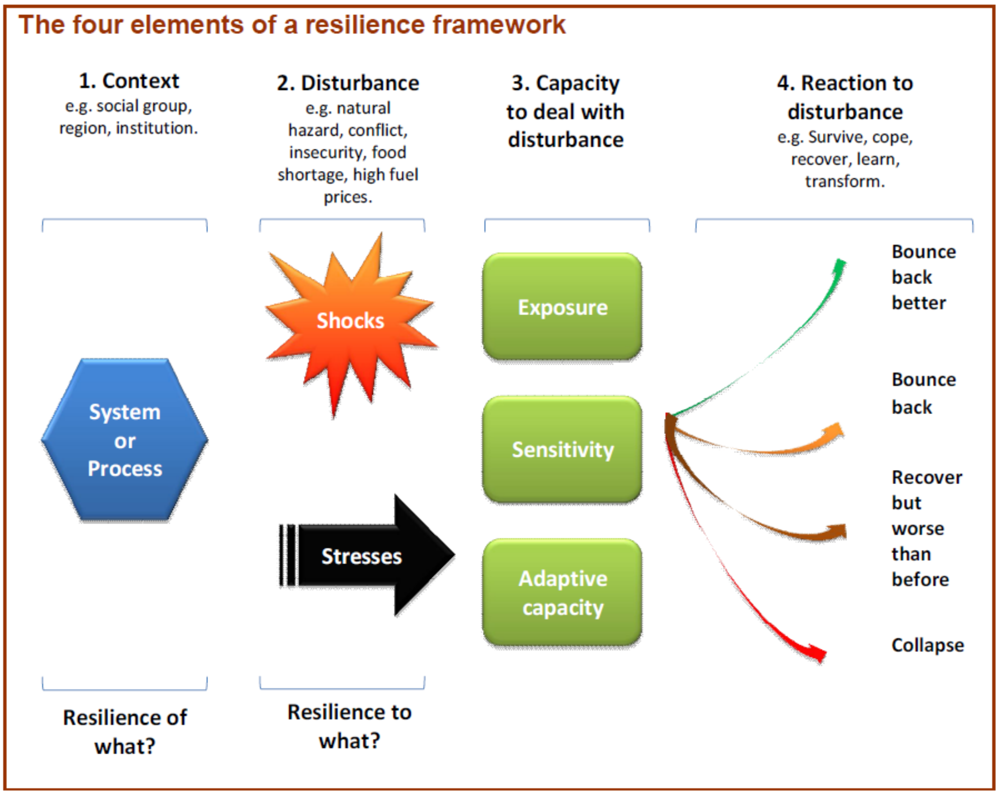
In practice, DFID's framework (DFID, 2011a, 6-7; diagram below) depicts the core elements of disaster resilience as follows:

– ***Context:*** Whose resilience is being built – such as a social group, socio-economic or political system, environmental context or institution

– ***Disturbance:*** What shocks (sudden events like conflict or disasters) and/or stresses (long-term trends like resource degradation, urbanization, or climate change) the group aims to be resilient to.

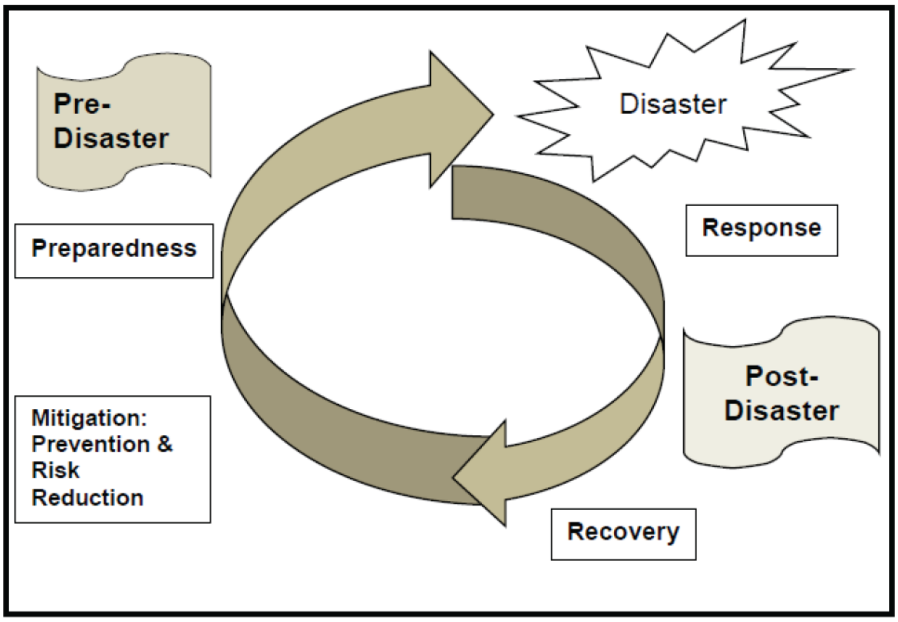
– ***Capacity to respond:*** The ability of a system or process to deal with a shock or stress depends on exposure (the magnitude of the shock or stress), sensitivity (the degree to which a system will be affected by, or will respond to, a given shock or stress), and adaptive capacity (how well it can adjust to a disturbance or moderate damage, take advantage of opportunities and cope with the consequences of a transformation).

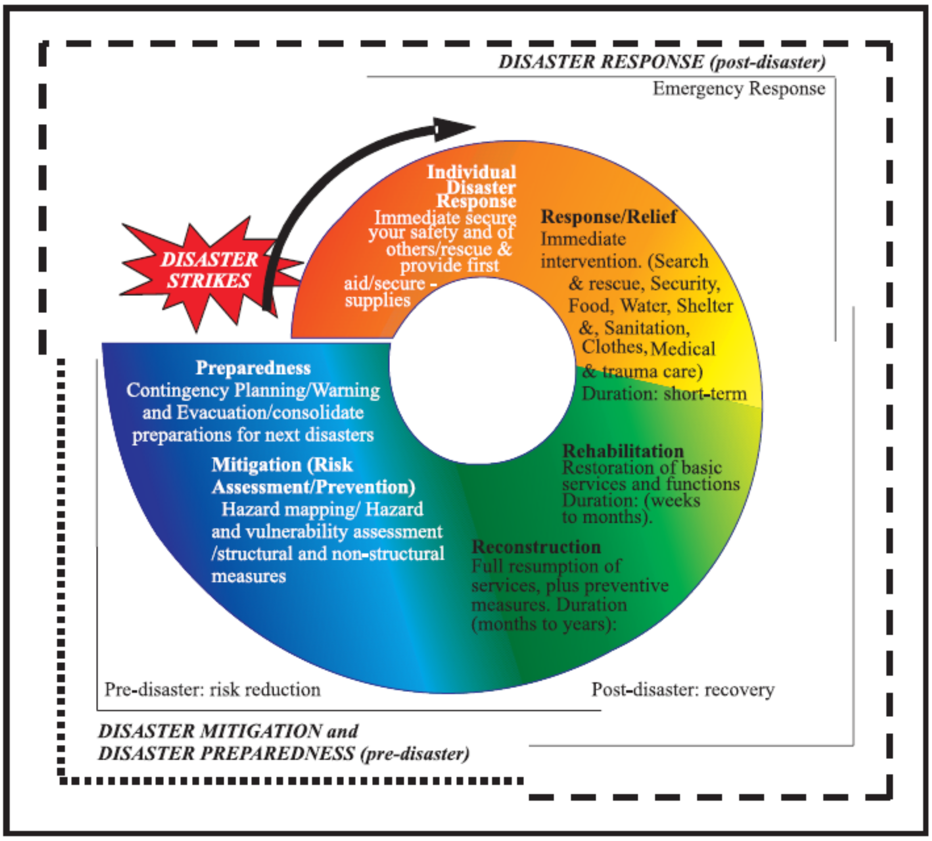
– ***Reaction:*** A range of responses are possible, including: bounce back better, where capacities are enhanced, exposures are reduced, and the system is more able to deal with future shocks and stresses; bounce back, where pre-existing conditions prevail; or recover, but worse than before, meaning capacities are reduced. In the worst-case scenario, the system collapses, leading to a catastrophic reduction in capacity to cope with the future.



DISASTER MANAGEMENT CYCLE

Disaster Risk Management includes sum total of all activities, programmes and measures which can be taken up before, during and after a disaster with the purpose to avoid a disaster, reduce its impact or recover from its losses. The three key stages of activities that are taken up within disaster risk management are:





1. ***Before a disaster (pre-disaster).***

Activities taken to reduce human and property losses caused by a potential hazard. For example carrying out awareness campaigns, strengthening the existing weak structures, preparation of the disaster management plans at household and community level etc. Such risk reduction measures taken under this stage are termed as mitigation and preparedness activities.

2. ***During a disaster(disaster occurrence).***

Initiatives taken to ensure that the needs and provisions of victims are met and suffering is minimized. Activities taken under this stage are called emergency response activities.

3. ***After a disaster (post-disaster)***

Initiatives taken in response to a disaster with a purpose to achieve early recovery and rehabilitation of affected communities, immediately after a disaster strikes. These are called as response and recovery activities. In the subsequent chapters we would discuss in detail some of the major hazards prevalent in our country its causes, impact, preparedness and mitigation measures that need to be taken up.

EARTH SYSTEM

ORIGIN OF UNIVERSE

A large number of hypotheses were put forth by different philosophers and scientists regarding the origin of the earth. The most popular argument regarding the origin of the universe is the *Big Bang Theory*. It is also called expanding universe hypothesis. Edwin Hubble, in 1920, provided evidence that the universe is expanding. As time passes, galaxies move further and further apart.

The Big Bang Theory considers the following stages in the development of the universe.

(i) In the beginning, all matter forming the universe existed in one place in the form of a "tiny ball" (singular atom) with an unimaginably small volume, infinite temperature and infinite density.

(ii) At the Big Bang the "tiny ball" exploded violently. This led to a huge expansion. It is now generally accepted that the event of big bang took place 13.7 billion years before the present. The expansion continues even to the present day. As it grew, some energy was converted into matter. There was particularly rapid expansion within fractions of a second after the bang. Thereafter, the expansion has slowed down. Within first three minutes from the Big Bang event, the first atom began to form.

(iii) Within 300,000 years from the Big Bang, temperature dropped to 4,500 K and gave rise to atomic matter. The universe became transparent.

EARTH IN THE SOLAR SYSTEM

The solar system was created about 4.6 billion years ago (about 9 billion years after the big bang), supposedly after gravitational waves from a supernova produced density anomalies in an interstellar cloud, which acted as condensation centers for the sun and the planets. In addition to hydrogen and helium generated during the big bang higher elements from the ashes of burnt-out stars were present in the cloud. After the sun had formed, its radiation pressure (solar wind) forced the light gases to the edge of the cloud where the large gas planets (Jupiter, Saturn, Uranus, Neptune) formed, whereas the earth-type planets (Mercury, Venus, Earth, Mars) developed in the vicinity of the sun.

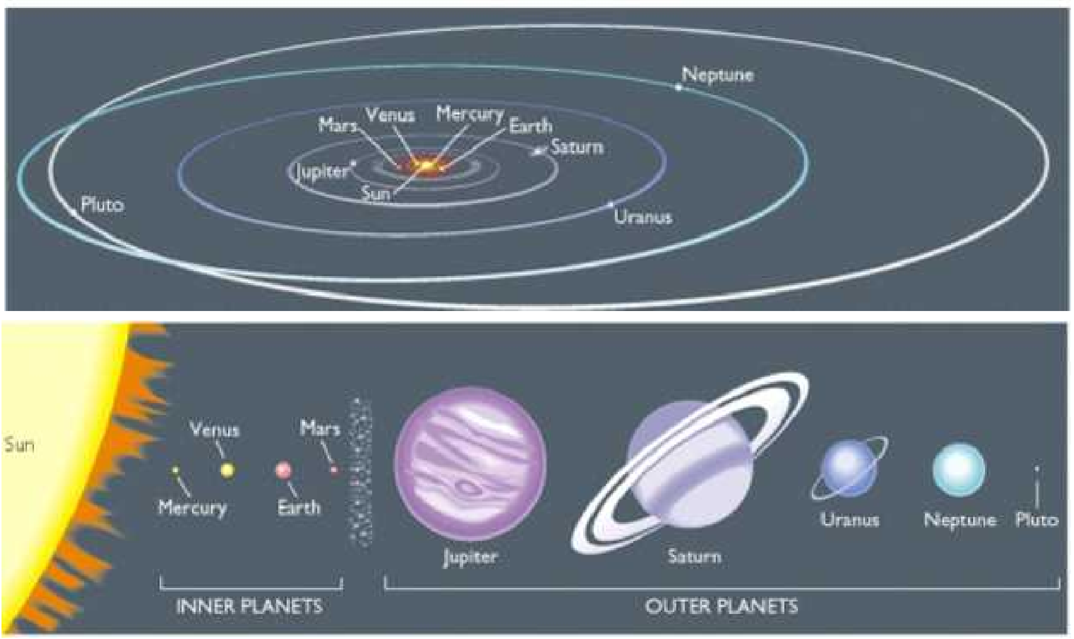


Figure: The planets of the Solar System. The upper panel displays the elliptical orbits of the planets around the sun, the lower panel shows the sizes of the planets.

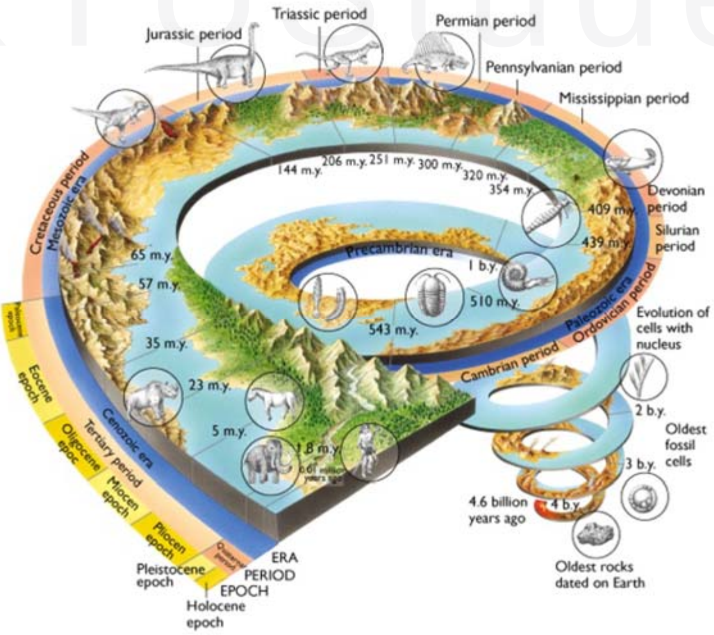
Earth is the largest of the four planets closest to the sun: it differs in many ways from all other planets. Only Earth possesses an atmosphere which supports oxygen-breathing life forms. No other planet has a hydrosphere and living systems which are comparable to our biosphere. The size of the Earth is important because it supports enough gravitational attraction to keep atmospheric gases on the planet. For example, Mercury is too small to prevent the light gases as oxygen and carbon dioxide from escaping while Venus is large enough to keep an atmosphere.

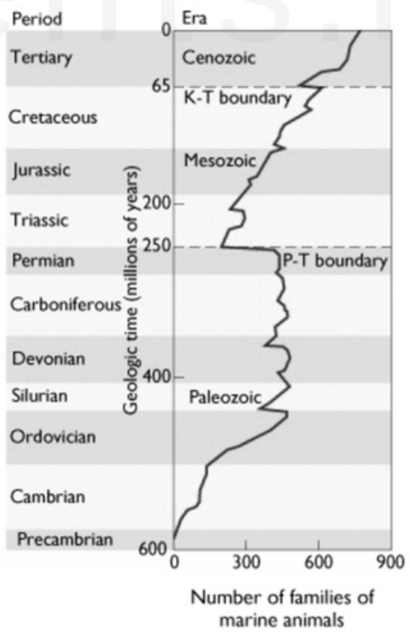
EVOLUTION OF THE EARTH

The planet earth initially was a barren, rocky and hot object with a thin atmosphere of hydrogen and helium. This is far from the present day picture of the earth. Hence, there must have been some events– processes, which may have caused this change from rocky, barren and hot earth to a beautiful planet with ample amount of water and conducive atmosphere favoring the existence of life. In the following section, you will find out how the period, between the 4,600 million years and the present, led to the evolution of life on the surface of the planet. The earth has a layered structure. From the outermost end of the atmosphere to the centre of the earth, the material that exists is not uniform. The atmospheric matter has the least density. From the surface to deeper depths, the earth's interior has different zones and each of these contains materials with different characteristics.

ORIGIN OF LIFE

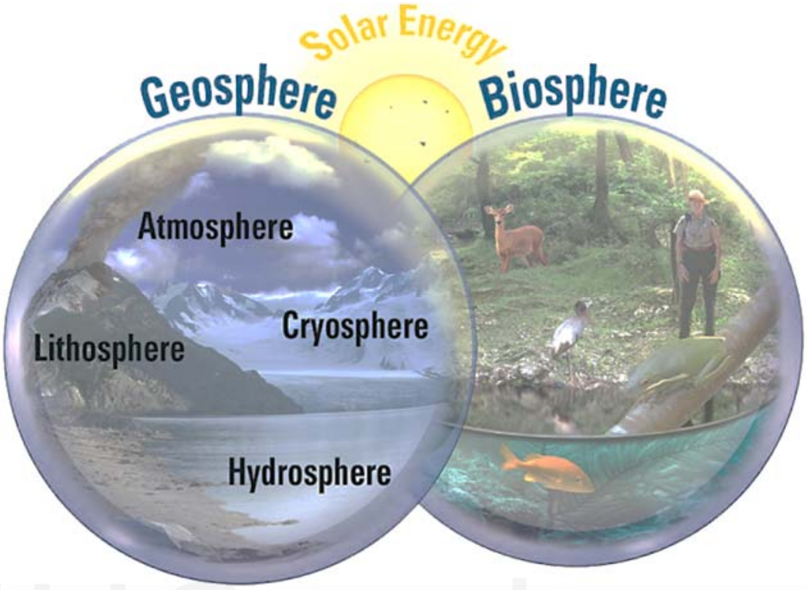
The last phase in the evolution of the earth relates to the origin and evolution of life. It is undoubtedly clear that the initial or even the atmosphere of the earth was not conducive for the development of life. Modern scientists refer to the origin of life as a kind of chemical reaction, which first generated complex organic molecules and assembled them. This assemblage was such that they could duplicate themselves converting inanimate matter into living substance. The record of life that existed on this planet in different periods is found in rocks in the form of fossils. The microscopic structures closely related to the present form of blue algae have been found in geological formations that are much older than these were some 3,000 million years ago. It can be assumed that life began to evolve sometime 3,800 million years ago.





The Earth is subject to constant change. Even the solid body of the Earth or the great polar ice caps are not steady but change over periods of tens to millions of years. These changes are essentially fueled by the sun's energy, the heat stored in the Earth's interior and energy given off through radioactive decay of minerals in the crust and upper-mantle. The living world is also affected by these large-scale processes and is involved in the exchange between various components of the Earth system.

The Earth is made up of the following subsystems: **geosphere, atmosphere, hydrosphere**, the great ice caps, the sea ice in the Polar Regions and the many mountain glaciers (**cryosphere**) and the living world (**biosphere**). On short time scales (years or tens of years) each of these subsystems is in a state of dynamic equilibrium. Consequently, the many different processes of interaction between the various subsystems tend to vary little. If longer periods of time are considered, fluctuations and transitions from one state of equilibrium to another become visible. These delicate states of equilibrium may be permanently disturbed by changes in external conditions. Most of the subsystems obey certain natural laws which will be introduced in the course of the following chapters.



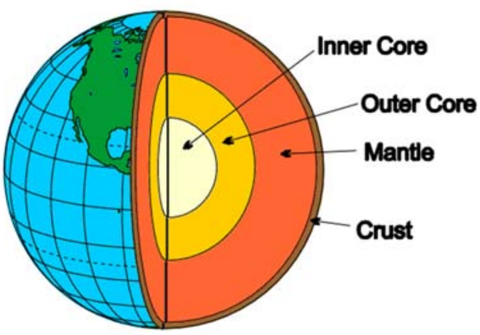
The Geosphere

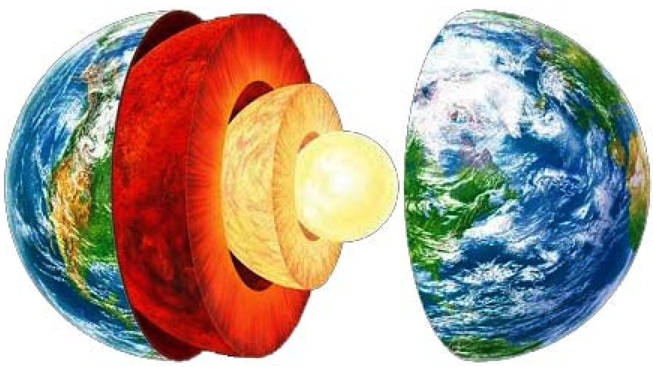
The Earth's internal structure is subdivided into crust, mantle and core and was formed very early during its development. Compared to the Earth radius, the crust is extremely thin, only 4to7 km under the oceans and about 100 km under the continents. At the mid-ocean ridges, which can be described as a series of active magma chambers

Internal Structure of Earth

Final picture based on the study of seismic waves divides earth into **3 well defined shells or zones**

1. **The Crust**
2. **The Mantle**
3. **The Core**





The Crust

- **Uppermost shell of earth**
- Study of seismic waves reveals following details about thickness of the crust

(a) Mountain areas

- Under the Himalayas, the crust is believed to be 70 – 75 km thick
- Under Hindukush Mountains it is 60 km thick
- Under the Andes it is 75 km thick

(b) Continental Areas

- The thickness varies from 30 – 40km
- Along the continental slopes thickness if the crust shows considerable variation

(c) Oceanic Areas

- The thickness varies from a maximum of 19 – 5 km in deep oceans

The Continental Crust

It is further distinguished into 3 layers: **A, B and C**

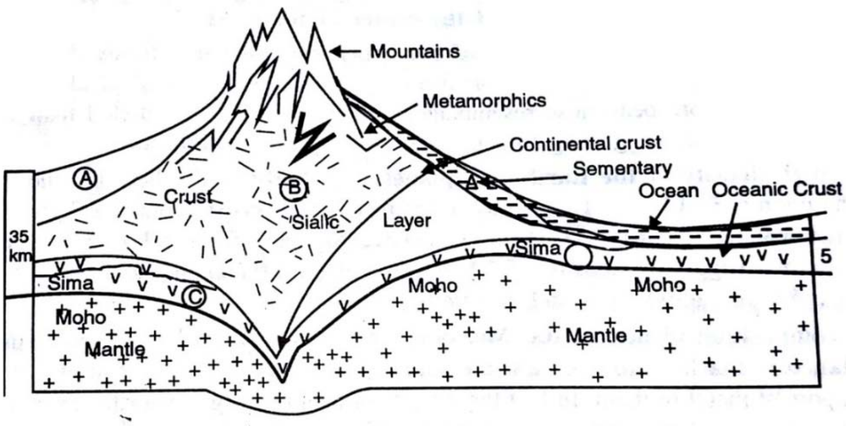
i. *The A or the upper Layer*
   - Thickness : 2 – 10 km
   - Low density : 2.2 g/cc
   - Mostly made up of sedimentary rocks

ii. *The B or Middle layer*
   - Thickness : 20km or more
   - Relatively dense : 2.4 to 2.6 g/cc
   - Sometimes also called granite layer
   - Made up mostly of granites and other igneous and metamorphic rocks

iii. *The C or lowermost layer*
   - Thickness : 25 – 40 km
   - Density : 2.8 to 3.3 g/cc
   - Made predominantly of basic minerals (rich in magnesium silicates)
   - Sometimes named as SIMA (Si – Silica, Ma – Magnesium)

The Oceanic Crust

- It is generally extension of C layer
- A & B layers of continental crust are absent from here
- Estimated to have a volume of 2.54 x 10^9 cc
- Average density of 3.00 g/cc



Structure of the Earth (not to scale)
A = Sedimentary layer; B= Granitic layer (SIAL); C= Basaltic layer (SIMA)

The Mantle

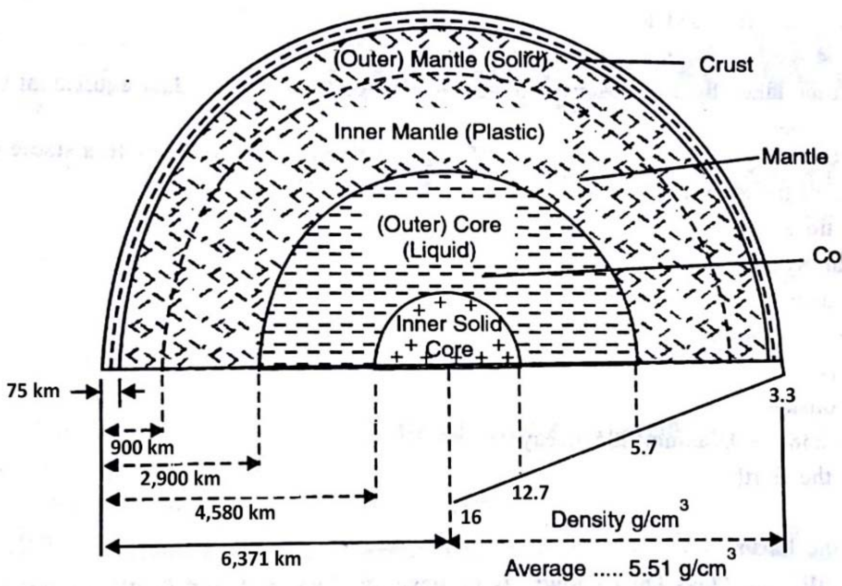
- Second concentric shell of the Earth
- Lies beneath the crust, makes upto 84% of earth's volume
- Extends **up to a depth 2900 km**
- Nature of mantle is incompletely understood
- Sub-divided into : **Upper** (Depth 100 – 900 km) **& Lower mantle** (Depth 900 – 2900 km)
- The upper mantle us further divided into 2 layers of 400 & 600 km thickness respectively
- Density ranges from : **3.3 g/cc – just below the crust**
  5.7 g/cc – at the base of mantle
- A part of upper mantle (100 – 500 km depth) is in plastic state rather than solid state – **Asthenosphere** (Source of volcanic activity). The asthenosphere is believed to be **located entirely in upper mantle** and support the slowly moving tectonic plates
- **Lithosphere –** the rigid outer part of the earth, consisting of the crust and upper mantle.

The Core

- Innermost concentric shell of the Earth
- The core boundary **begins at depth of 2,900 km from the surface and extends to center of earth at 6,371 km**
- Sub-divided into : **Outer Core & Inner Core**

Outer Core	Inner Core
• Depth : 2,900 km – 4,580 km • Behaves more like a liquid	• Thickness : 1,790 km • Solid metallic body

- **Density :** 5.7 g/cc – at the base of mantle
  9.9 g/cc – at top of the mantle
  12.7 g/cc – at boundary of inner core
  13.0 g/cc – at the center of earth



The Hydrosphere

The Earth is a 'water planet'. A good two-thirds of its surface, more specifically 362,000 km^2 of area, is covered with water. The large oceans are an essential prerequisite for the existence of the biosphere. They were the cradle of the first life on Earth and provide an indispensable habitat for numerous organisms. The mean depth of the World Oceans is 3,700 m and thus much larger than the mean elevation of the continents, given by 875 m. The total volume of water in the ocean is about 1.35 x 10^{9}km^3 while the water in frozen state on Earth amounts to only 24.4 x 10^{6}km^3 (water in lakes is about 190,000km^3). Ocean water, however, is saline whereas water on land and specifically in the frozen state in glaciers and ice caps is fresh water. The hydrosphere has a direct influence on weather and climate conditions on Earth, with the worldwide oceanic circulation playing a particularly important role.

The Atmosphere

The composition of the atmosphere has changed fundamentally in the course of the Earth's history due to a number of different biological, chemical and physical processes. The early atmosphere of the Earth consisted mainly of nitrogen and carbon dioxide. Thus, it was similar to the present atmospheres of the planets Venus and Mars. Only with the emergence of life and biochemical processes lasting several billion years did the current atmosphere of about 78% nitrogen, 21% oxygen and 1% other gases evolve. This development of the Earth has been possible due to a number of fortunate circumstances, the most important one being the distance of the Earth from the sun, which enabled the formation of a proto-ocean at an early state in its evolution. Any change in orbit parameters might have led to completely different conditions.

The Earth's atmosphere provides only a thin protective cover from outer space. The thickness of the entire atmosphere is about one twentieth of the Earth's radius. The atmosphere is subdivided into four layers of varying heights, based on the mean vertical temperature distribution: the troposphere between the surface of the Earth and an altitude of 11 km, the stratosphere between 11 km and 50 km, the mesosphere between 50 km and 85 km, and the thermosphere from 85 km to about 300 km.

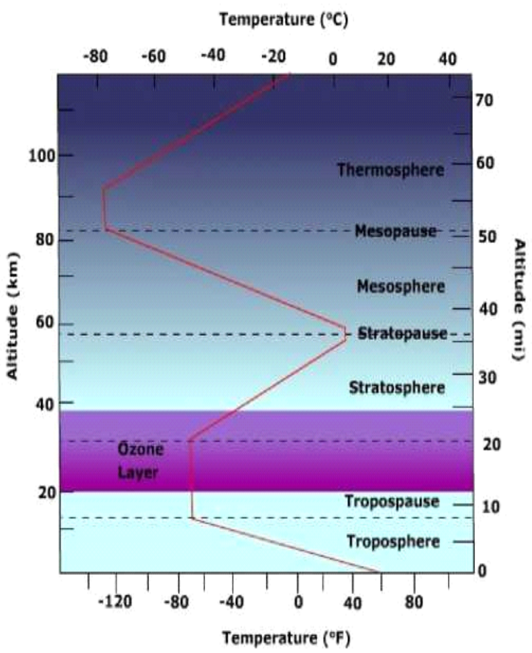


Figure: Vertical temperature profile of the Standard Atmosphere.

Each layer is characterized by a uniform change in temperature with increasing altitude. In some layers there is an increase in temperature with altitude, whilst in others it decreases with increasing altitude. The top or boundary of each layer is denoted by a 'pause', where the temperature profile abruptly changes.
The stratosphere could be called the Earth's 'sun-glasses'. This is where most of the ultraviolet solar radiation, which is harmful for man and all living organisms, is filtered out. This is mainly achieved by ozone, a molecule consisting of three oxygen atoms. About 90% of the total quantity of ozone is to be found in the stratosphere.

The Biosphere

With the exception of the ice sheets of Antarctica and Greenland, the land on Earth is populated by a large variety of living organisms. According to conservative estimates at least eight million different species of animals and plants exist on Earth.

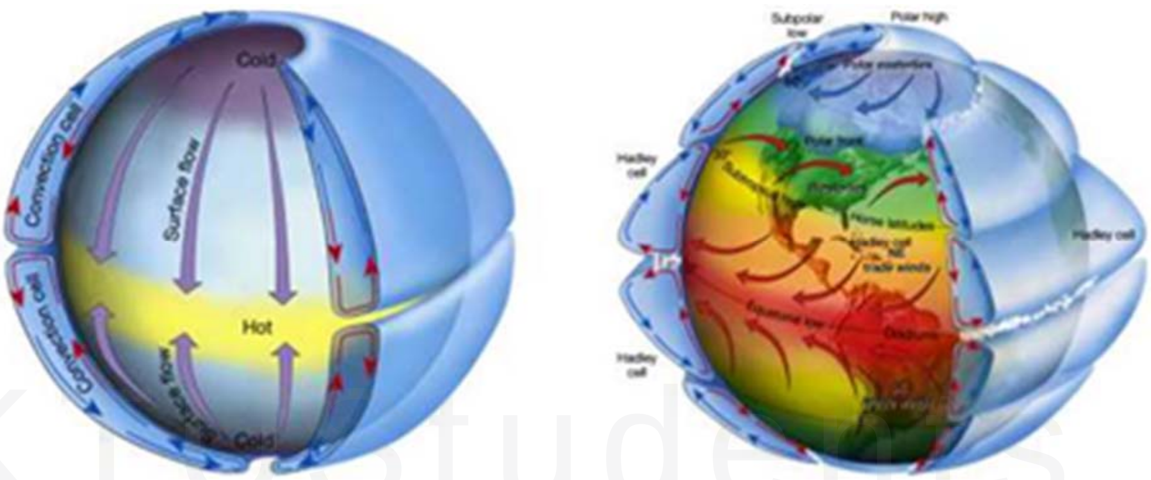


Figure: The circulation of the atmosphere. The left panel is for idealized, non-rotating planet where only the Hadley cell exists. The right panel is for the real Earth with Hadley and Ferrel cells. The corresponding surface winds are shown schematically.

Life on Earth originated from the ocean. This is where the first microorganisms emerged, whose remains have been discovered in rocks up to four billion years old. The oldest known organisms are primitive cells without a nucleus (prokaryotes). A first biosphere developed after unicellular algae began to release oxygen into the atmosphere due to photosynthetic conversion of carbon dioxide. Cells with nucleus (eukaryotes) developed much later in Earth history, about two billion years ago. During the next 400 million years evolution created an enormous multiplicity of species.

The biosphere is a consumer and producer of greenhouse gases. Carbon dioxide in the atmosphere is reduced by plants in photosynthesis. Methane is stored in permafrost soils and gas hydrates on the ocean bottom. Both gases are currently released to the atmosphere by human activities and reinforce the greenhouse effect.

The term ***ecosystem*** describes a holistic concept comprising the total of organisms in a specified spatial unit, their physical conditions and the numerous interactions between the living and non-living components of the system. An ecosystem can either be an isolated pool within an arid region or a whole ocean. It is assumed that each element in the ecosystem is linked directly or indirectly with the other elements and influences them.

The link between living and non-living components of the ecosystem is maintained by two coupled processes: ***the flow of energy and the exchange of nutrients.*** As the major source of energy, the sun is the pre-requisite for plant photosynthesis. In this process carbon dioxide, water and other biogenous elements such as nitrogen, phosphorus and sulphur are converted into protein, fats and starches via a number of intermediate stages. These substances can be called the building blocks of life. The organisms participating in photosynthesis are producers in the ecosystem.

On the other hand there are consumers — e.g. bacteria, fungi and animals — which mainly feed on the producers' organic material. This transfer of organic substance from the producer to numerous consumers, taking place in several steps, is called a food chain. As a final link of this chain, organisms break down animal and plant substances into their inorganic constituents. These serve as food for the producers. Due to the transformation of organically bound energy from one component of a food chain to another, more and more energy is gradually lost. In contrast to this loss, the nutrient budget of the ecosystem largely remains unchanged. The nutrients are only transferred between living and non-living components.

GLOBAL CYCLES

Most of the exchange processes in the Earth system occur in the form of closed loops. While they constantly influence each other they obey certain natural laws. The major energy source for these processes is the sun, which enables the flow of matter through the system.

In the environment, energy can be in the form of radiation (solar or short-wave radiation and infrared or long-wave radiation), sensible heat (thermal energy), latent heat (heat released when water goes from the gas to the liquid or solid state), kinetic energy (energy of motion including winds, tides, and ocean currents), potential energy (stored energy), and chemical energy (energy absorbed or released during chemical reactions).

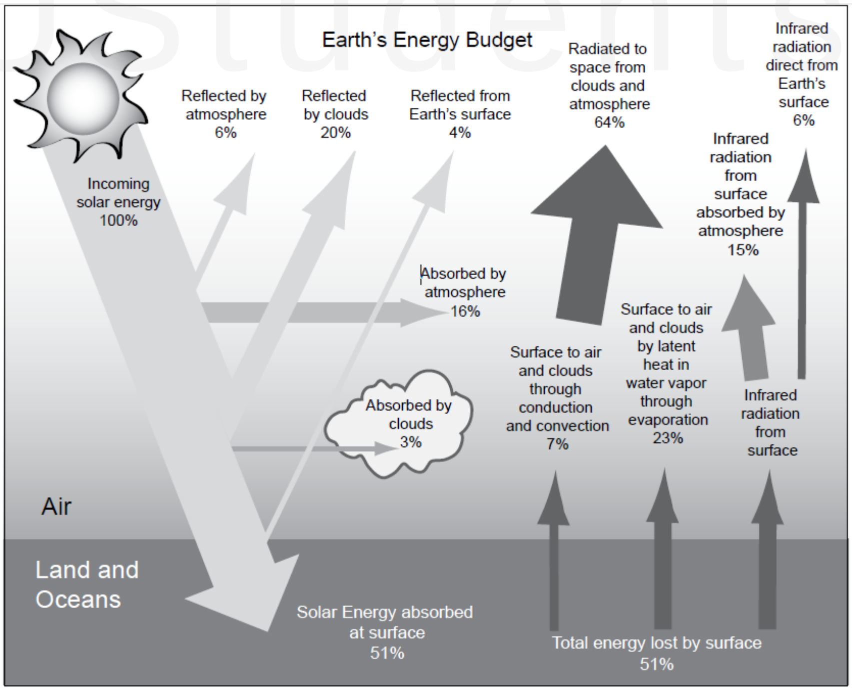


Figure: Schematic Diagram of the Earth's Energy Budget

The energy cycle is intertwined with the hydrologic cycle. Some of the energy in the sunlight reaching Earth's surface causes evaporation from surface water and soils. The atmosphere transports the resulting water vapor until it condenses in clouds, releasing the latent energy that evaporated the water. Water droplets and ice particles in clouds grow in size until they form precipitation, falling to the surface as rain, snow, sleet, or hail. Once the precipitation falls, the water can remain frozen on the surface to melt at a later time, evaporate again into the atmosphere, fill spaces in the soil, be taken up by plants, be consumed by animals, leach through the soil into groundwater, run off the land surface into rivers, streams, lakes and ultimately into the oceans or become part of a surface water body. Snow and ice reflect more sunlight back to space than ocean water or most other types of land cover, so the amount of snow or ice covering Earth's surface affects the energy cycle.

The major cycles that connect the different parts of the Earth are the energy cycle, the water cycle (hydrologic cycle, and the cycles of important individual elements (e.g., carbon, nitrogen). Each cycle is made up of reservoirs, places where energy, water, and elements are stored for a period of time (e.g., chemical energy, sea ice, oceans, carbon dioxide), fluxes, the movement of energy and matter from one reservoir to another (e.g., radiation, precipitation, transpiration, ocean currents, wind, river flow) and processes that change the form of energy, water, and elements (e.g., photosynthesis, condensation, fire).

Energy from the sun flows through the environment, heating the atmosphere, the oceans, and the land surface, and fueling most of the biosphere. Differences in the amount of energy absorbed in different places set the atmosphere and oceans in motion and help determine their overall temperature and chemical structure. These motions, such as wind patterns and ocean currents redistribute energy throughout the environment. Eventually the energy that began as sunshine (short-wave radiation) leaves the planet as Earth shine (light reflected by the atmosphere and surface back into space) and infrared radiation (heat, also called long wave radiation) emitted by all parts of the planet which reaches the top of the atmosphere. This flow of energy from the sun, through the environment, and back into space is a major connection in the Earth system; it defines Earth's climate.

The Water Cycle

In contrast to all other planets of the solar system Earth has water in great abundance and in all three states: gaseous, liquid and solid. By far the greatest share (97%) of the Earth's water is found in the oceans, 2% is bound as ice and the rest (1%) is accounted for by ground water, soil water, surface water, the atmosphere and the biosphere. This 3% of the total quantity consists mainly of fresh water. The fraction of water bound in ice caps depends strongly on the temperature of Earth; during the coldest stage of last ice age, the average sea level was about 120 m deeper than today, the water being bound in large ice shields. Rivers and lakes contain less than a thousandth of the total water on Earth, and the atmosphere only a very small fraction of that.

Although the atmosphere contains only a trace amount of the total water on Earth, it acts as an important pathway for transferring water from one reservoir to another. This is because the residence time of water in the atmosphere is quite small; on average a water molecule that is evaporated stays only about 10 days in the atmosphere before it precipitates again. Most of the water that evaporates precipitates over the ocean; only less than a third precipitates over land.

Water plays a crucial role in many global exchange processes. Carbon, nitrogen, phosphorus and oxygen are transported in the Earth system through the medium of water in liquid state. Knowledge of the magnitude and variability of the hydrological cycle is particularly important for understanding the Earth system. Even slight changes in the proportions of components in the water cycle can have considerable ecological consequences (e.g. flooding, drought and the processes of desertification). The hydrologic cycle is intimately coupled to the energy balance and the redistribution of heat, because evaporation and precipitation result in large amounts of heat being transferred.

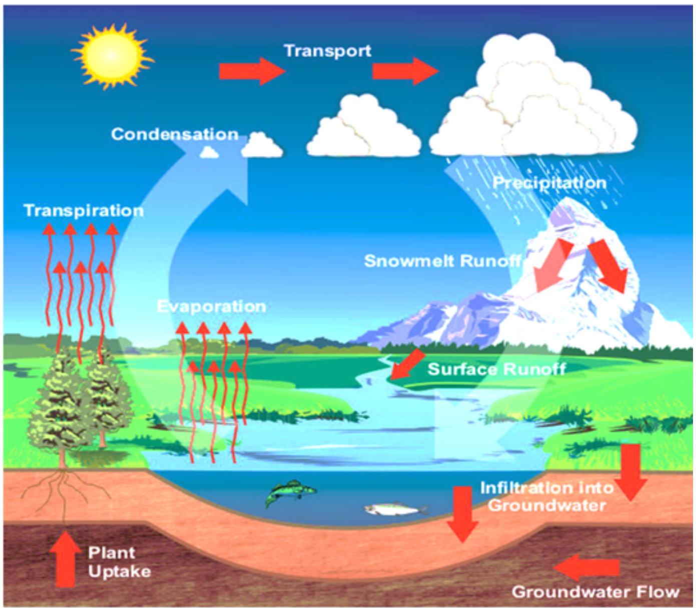


Figure: The water cycle of the Earth.

Water participates in a global cycle as vapor, liquid or ice. It evaporates into the atmosphere, where it is transported in the gaseous state following atmospheric circulation patterns. Later it condenses and falls as rain or snow on the Earth.

The Bio-geochemical Cycle

Each of the chemical elements undergoes chemical reactions, but the total amount of each on Earth remains essentially fixed. In this way, the environment consists of a set of cycles for water, carbon, nitrogen, phosphorous, etc. Since the cycles of the elements involve life, chemicals, and the solid Earth, they are collectively known as biogeochemical cycles.

An important issue of long-term climate variability and global changes are biological nutrient inventories and cycles: carbon, nitrogen, sulphur and phosphorus. These bio-geochemical cycles link the most important reservoirs of these elements: the hydrosphere, components of the solid Earth, the biosphere and the atmosphere. The processes which mainly drive these cycles include the constant oxidation of living and dead biomass by atmospheric oxygen. An important issue of long-term climate variability and global changes are biological nutrient inventories and cycles: carbon, nitrogen, sulphur and phosphorus. These bio-geochemical cycles link the most important reservoirs of these elements: the hydrosphere, components of the solid Earth, the biosphere and the atmosphere. The processes which mainly drive these cycles include the constant oxidation of living and dead biomass by atmospheric oxygen.

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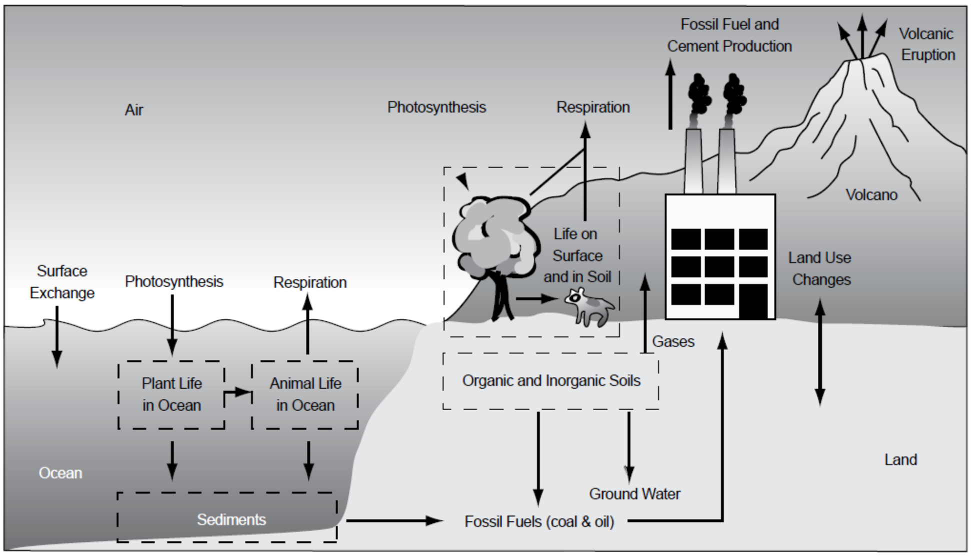

CLIMATE SYSTEM

The term 'climate' is used for long-term average weather conditions, conventionally taken over 30 years. At the same time, 'climate' denotes a specific state of equilibrium in the energy balance and global energy transports. The climate system is usually defined as consisting of the atmosphere, the ocean, and sea ice and ice sheets. Conditions of the land surface are prescribed, as well as all external forcing factors, as e.g. the greenhouse gas concentrations. It is a dynamic system which at most times is in a transient equilibrium. Changes in the climate system are forced through external impacts, e.g. changing carbon dioxide, volcano output, or the orbital parameters of the Earth, and through internal interactions. The solar power has increased by about 30% since its birth; the continents have changed over millions of years; Earth alters its orbit with prominent periods of 100,000, 41,000, 23,000 and 19,000 years; the contents of greenhouse gases has varied from years to billions of years.

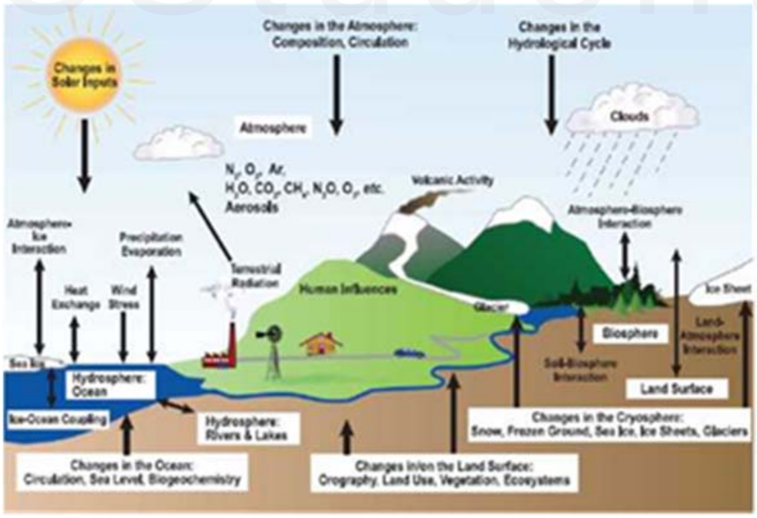

Figure: Schematic view of the components of the climate system, their processes and interactions.

Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing long wave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space.

CLIMATE CHANGE

Climate change is a phrase that is essentially self-explanatory, it is the change in the climate of a country, region, or the world over, and is believed to be caused either directly or indirectly by the activity of the human race.

The type of climate we experience now might be prevailing over the last 10,000 years with minor and occasionally wide fluctuations. The planet earth has witnessed many variations in climate since the beginning. Geological records show alteration of glacial and inter-glacial periods. The geomorphological features, especially in high altitudes and high latitudes, exhibit traces of advances and retreats of glaciers. The sediment deposits in glacial lakes also reveal the occurrence of warm and cold periods. The rings in the trees provide clues about wet and dry periods. Historical records describe the vagaries in climate. All these evidences indicate that *change in climate is a natural and continuous process.*

India also witnessed alternate wet and dry periods. Archaeological findings show that the Rajasthan desert experienced wet and cool climate around 8,000 B.C. The period 3,000- 1,700 B.C. had higher rainfall. From about 2,000-1,700 B.C., this region was the centre of the Harappan civilisation. Dry conditions accentuated since then.

Climate in the recent past

Variability in climate occurs all the time. The nineties decade of the last century witnessed extreme weather events. The 1990s recorded the warmest temperature of the century and some of the worst floods around the world. The worst devastating drought in the Sahel region, south of the Sahara desert, from 1967-1977 is one such variability. During the 1930s, severe drought occurred in southwestern Great Plains of the United States, described as the dust bowl. Historical records of crop yield or crop failures, of floods and migration of people tell about the effects of changing climate.

Causes of Climate Change

Climate refers to the long-term average of the aggregation of all components of weather—precipitation, temperature and cloudiness, for example. The climate system includes processes involving ocean, land and sea ice in addition to the atmosphere.

The Earth system encompasses the climate system. Many changes in Earth system functioning directly involve changes in climate. However, the Earth system includes other components and processes, biophysical and human those are important for its functioning. Some Earth system changes, natural or driven by humans, can have significant consequences without involving changes in climate. Global change should not be confused with climate change; it is significantly more, indeed, climate change is part of this much larger challenge.

The causes for climate change are many. They can be grouped into **astronomical and terrestrial causes**. The ***astronomical causes*** are the changes in solar output associated with sunspot activities. Sunspots are dark and cooler patches on the sun which increase and decrease in a cyclical manner. According to some meteorologists, when the number of sunspots increase, cooler and wetter weather and greater storminess occur. A decrease in sunspot numbers is associated with warm and drier conditions. Yet, these findings are not statistically significant.

An another astronomical theory is Millankovitch oscillations, which infer cycles in the variations in the earth's orbital characteristics around the sun, the wobbling of the earth and the changes in the earth's axial tilt. All these alter the amount of insolation received from the sun, which in turn, might have a bearing on the climate.

Climate Change – Inter relationships with earth subsystems

Geosphere

The global distribution of water and land at the Earth's surface significantly affects the circulations in the ocean and the atmosphere. Thus, plate tectonics contribute to the development of climate and to changes in global environment. Volcanic eruptions, even though local in origin, can affect the Earth system as a whole. They devastate wide areas of land and drastically change the habitat of flora, fauna and man, and — for climate purposes — the volcanic output reflects in the substance composition of the atmosphere. Submarine volcanoes create and destroy groups of islands. Some large volcanic events cause eruptions of volcanic ash reaching the stratosphere, where it remains for many years, substantially influencing the radiation balance of the Earth. Identification of volcanic ash of particular volcanic events in ice cores obtained in the Arctic and the Antarctic provide evidence for the worldwide distribution of volcanic ash in the atmosphere.

Volcanism is considered as another cause for climate change. Volcanic eruption throws up lots of aerosols into the atmosphere. These aerosols remain in the atmosphere for a considerable period of time reducing the sun's radiation reaching the Earth's surface. After the recent Pinatoba and El Cion volcanic eruptions, the average temperature of the earth fell to some extent for some years. The most important anthropogenic effect on the climate is the increasing trend in the concentration of greenhouse gases in the atmosphere which is likely to cause global warming.

Hydrosphere

It is generally accepted that the oceanic circulation has a profound influence on the mean state of the Earth's climate and on climate changes on decadal and longer time scales. Large-scale transports of heat and fresh water by ocean currents are key climate parameters. The stratification and circulation in the upper ocean is crucial for the penetration of heat and substances into the ocean.

The circulation is determined by the structure and strength of the wind systems, the regional distribution of precipitation patterns, and the heat exchange with the atmosphere. The shape of the sea floor, particularly the great deep-sea basins, also has a decisive influence on ocean current systems.

The World Ocean plays a twofold role in the Earth's climate system. On the one hand climate fluctuations are caused by long-term changes in the heat distribution of the ocean. On the other hand the thermal 'inertia' of the great water masses slows down climatic changes. The close link between ocean and atmosphere is also effective on shorter time scales. This is seen by the close correspondence between the surface temperature of the ocean and the air temperature close to the ground. The surface winds also strongly contribute to changes in the oceanic circulation and thus regional weather conditions.

Biosphere

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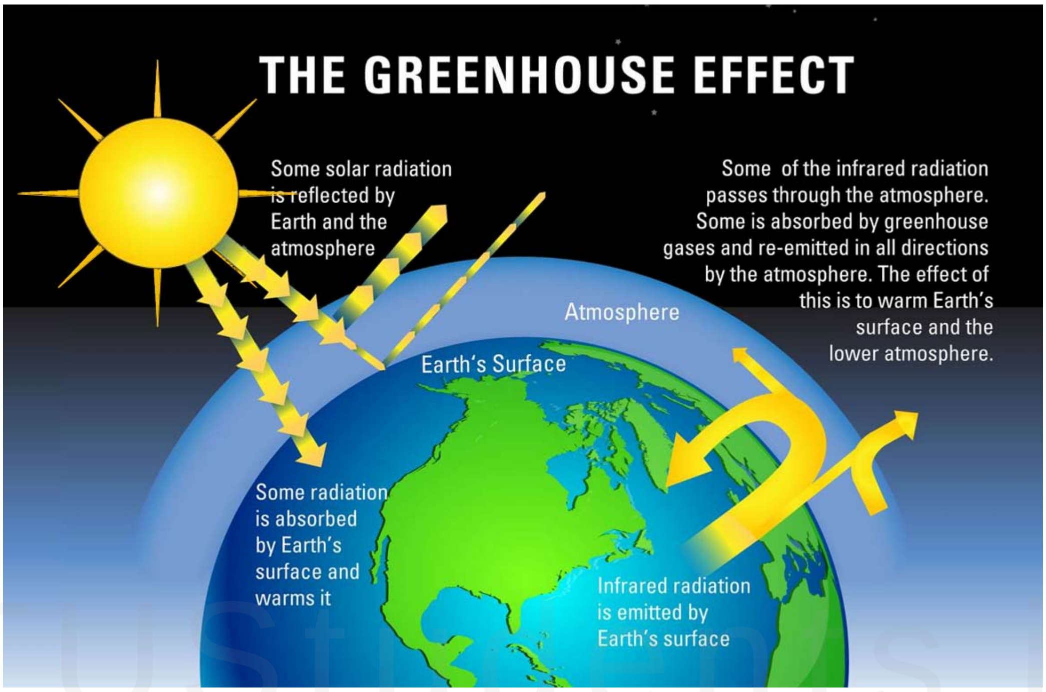
GLOBAL WARMING

The continuous rise in temperature of the planet is really upsetting. The root cause for this is *global warming*. Global warming begins when sunlight reaches the Earth. The clouds, atmospheric particles, reflective ground surfaces and surface of oceans then sends back about 30 % of sunlight back into the space, whilst the remaining is absorbed by oceans, air and land. This consequently heats up the surface of the planet and atmosphere, making life feasible. As the Earth warms up, this solar energy is radiated by thermal radiation and infrared rays, propagating directly out to space thereby cooling the Earth.



However, some of the outgoing radiation is re-absorbed by carbon dioxide, water vapours, ozone, methane and other gases in the atmosphere and is radiated back to the surface of Earth. These gases are commonly known as *greenhouse gases* due to their heat-trapping capacity. It must be noted that this re-absorption process is actually good as the Earth's average surface temperature would be very cold if there was no existence of greenhouse gases.

The dilemma began when the concentration of greenhouse gases in the atmosphere was artificially increased by humankind at an alarming rate since the past two centuries. As of 2004, over 8 billion tons of carbon dioxide was pumped thermal radiation is further hindered by increased levels of greenhouse gases resulting in a phenomenon known as human enhanced global warming effect.

GREENHOUSE EFFECT

While other planets in the solar system of the Earth are either roasting hot or bitterly cold, Earth's surface has relatively mild, steady temperatures. Earth enjoys these temperatures because of its atmosphere, which is the thin layer of gases that cover and protect the planet.

However, 97 % of climate scientists and researchers agree that humans have changed the Earth's atmosphere in dramatic ways over the past two centuries, resulting in global warming. To understand global warming, it is first necessary to become familiar with the greenhouse effect. As Figure below depicts, the natural greenhouse effect normally traps some portion of heat in such a way that our planet is safe from reaching freezing temperatures while human enhanced greenhouse effect leads to global warming. This is due to burning of fossil fuels which increase the amount of greenhouse gases (carbon dioxide, methane and oxides of nitrogen) present in the atmosphere.

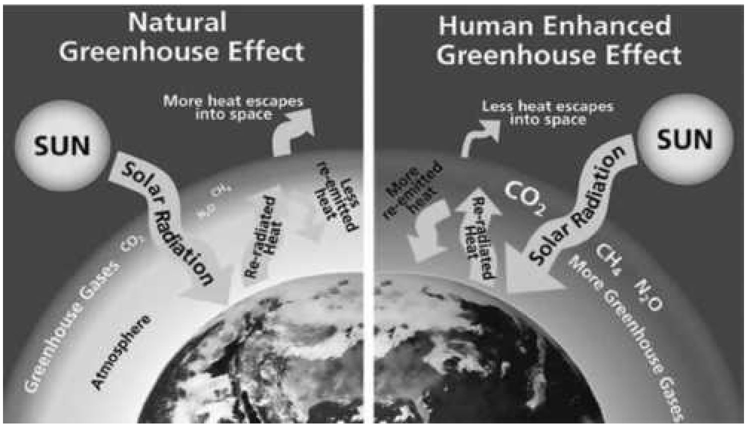


Figure: Types of greenhouse effects

Due to the presence of greenhouse gases, the atmosphere is behaving like a greenhouse. The atmosphere also transmits the incoming solar radiation but absorbs the vast majority of long wave radiation emitted upwards by the earth's surface. The gases that absorb long wave radiation are called greenhouse gases. The processes that warm the atmosphere are often collectively referred to as *the greenhouse effect.*

Greenhouse Gases (GHGs)

The primary GHGs of concern today are carbon dioxide (CO_2), Chlorofluorocarbons (CFCs), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Some other gases such as nitric oxide (NO) and carbon monoxide (CO) easily react with GHGs and affect their concentration in the atmosphere.

The effectiveness of any given GHG molecule will depend on the magnitude of the increase in its concentration, its life time in the atmosphere and the wavelength of radiation that it absorbs. The chlorofluorocarbons (CFCs) are highly effective. Ozone which absorbs ultra violet radiation in the stratosphere is very effective in absorbing terrestrial radiation when it is present in the lower troposphere. Another important point to be noted is that the more time the GHG molecule remains in the atmosphere, the longer it will take for earth's atmospheric system to recover from any change brought about by the latter.

The largest concentration of GHGs in the atmosphere is carbon dioxide. The emission of CO_2 comes mainly from fossil fuel combustion (oil, gas and coal). Forests and oceans are the sinks for the carbon dioxide. Forests use CO_2 in their growth. So, deforestation due to changes in land use, also increases the concentration of CO_2. The time taken for atmospheric CO_2 to adjust to changes in sources to sinks is 20-50 years. It is rising at about 0.5 per cent annually. Doubling of concentration of CO_2 over pre-industrial level is used as an index for estimating the changes in climate in climatic models.

Chlorofluorocarbons (CFCs) are products of human activity. Ozone occurs in the stratosphere where ultra-violet rays convert oxygen into ozone. Thus, ultra violet rays do not reach the earth's surface. The CFCs which drift into the stratosphere destroy the ozone. Large depletion of ozone occurs over Antarctica. The depletion of ozone concentration in the stratosphere is called the ozone hole. This allows the ultra violet rays to pass through the troposphere.

Figure below shows pictorially the distribution of greenhouse gases. These gases are playing their negative part in increasing the havoc of global warming. They are continuously causing an increase in the earth's temperature.

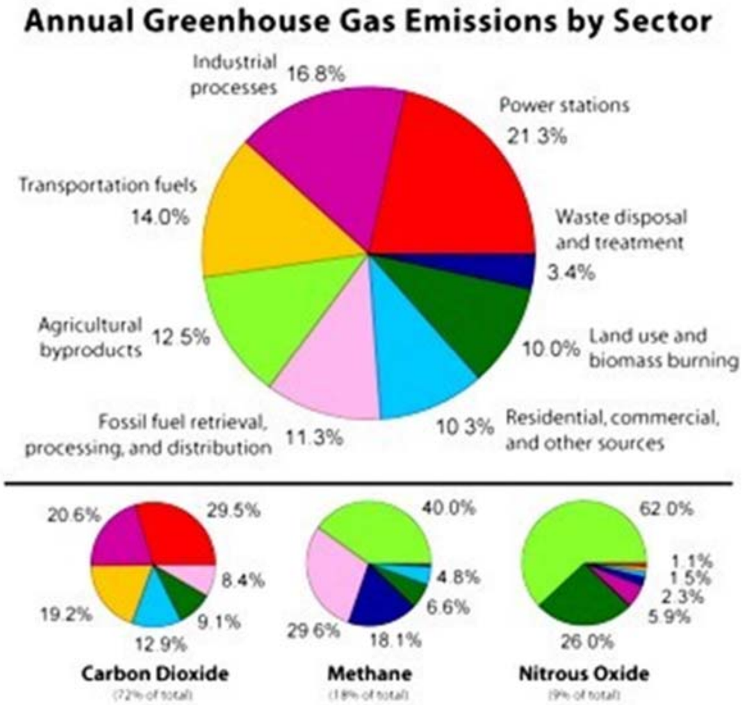


Figure: Distribution of greenhouse gases

CAUSES OF GLOBAL WARMING

The major cause of global warming is the greenhouse gases. They include carbon dioxide, methane, nitrous oxides and in some cases chlorine and bromine containing compounds. The build-up of these gases in the atmosphere changes the radiative equilibrium in the atmosphere. Their overall effect is to warm the Earth's surface and the lower atmosphere because greenhouse gases absorb some of the outgoing radiation of Earth and re-radiate it back towards the surface.

The second major cause of global warming is the depletion of ozone layer. This happens mainly due to the presence of chlorine- containing source gases. When ultraviolet light is present, these gases dissociate releasing chlorine atoms which then catalyses ozone destruction. Aerosols present in the atmosphere are also causing global warming by changing the climate in two different ways. Firstly, they scatter and absorb solar and infrared radiation and secondly, they may alter the microphysical and chemical properties of clouds and perhaps affect their lifetime and extent. The scattering of solar radiation acts to cool the planet, while absorption of solar radiation by aerosols warms the air directly instead of permitting sunlight to be absorbed by the surface of the Earth. The human contribution to the amount of aerosols in the atmosphere is of various forms. For instance, dust is a by-product of agriculture. Biomass burning generates a mixture of organic droplets and soot particles. Many industrial processes produce a wide diversity of aerosols depending on what is being burned or generated in the manufacturing process. Moreover, exhaust emissions from various sorts of transport produce a rich mixture of pollutants that are either aerosols from the outset or are transformed by chemical reactions in the atmosphere to form aerosols.

GLOBAL WARMING: THE EFFECTS

Predicting the consequences of global warming is one of the most difficult tasks faced by the climate researchers. This is due to the fact that natural processes that cause rain, snowfall, hailstorms, rise in sea levels is reliant on many diverse factors. Moreover, it is very hard to predict the size of emissions of greenhouse gases in the future years as this is determined majorly through technological advancements and political decisions. Global warming produces many negative effects some of which are described here. Firstly, extra water vapour which is present in the atmosphere falls again as rain which leads to floods in various regions of the world. When the weather turns warmer, evaporation process from both land and sea rises. This leads to drought in the regions where increased evaporation process is not compensated by increased precipitation. In some areas of the world, this will result in crop failure and famine particularly in areas where the temperatures are already high. The extra water vapour content in the atmosphere will fall again as extra rain hence causing flood. Towns and villages which are dependent on the melting water from snowy mountains may suffer drought and scarcity of water supply. It is because the glaciers all over the world are shrinking at a very rapid rate and melting of ice appears to be faster than previously projected. According to Intergovernmental Panel on Climate Change (IPCC), about one-sixth of the total population of the world lives in the regions which shall be - affected by a decrease in melting water. The warmer climate will likely cause more heat waves, more violent rainfall and also amplification in the severity of hailstorms and thunderstorms. Rising of sea levels is the most deadly effect of global warming, the rise in temperature is causing the ice and glaciers to melt rapidly. This will lead to rise of water levels in oceans, rivers and lakes that can pilot devastation in the form of floods.

Global warming can severely affect the health of living beings. Excess heat can cause stress which may lead to blood pressure and heart diseases. Crop failures and famines, which are a direct consequence of heating up of earth, can cause a decline in human body resistance to viruses and infections. Global warming may also transfer various diseases to other regions as people will shift from regions of higher temperatures to regions of comparatively lower temperatures. Warmer oceans and other surface waters may lead to severe cholera outbreaks and harmful infections in some types of sea food.

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