CONCEPT OF NATURAL SYSTEM IN PHYSICAL GEOGRAPHY

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Introduction

Location, region, human-earth relationships, place and movement are five fundamental themes of geography. Within these five themes, geography is governed by a method rather than by a specific body of knowledge, and this method is called spatial analysis. Physical geography centers on spatial analysis of all the physical elements and processes that make up the environment: air, water, weather, climate, landforms, soils, animals, plants and Earth itself. It investigates the spatial patterns and processes of Earth's natural systems and their human interactions. Process, a set of actions or mechanisms that operate in some special order, is central to geographic analysis. Numerous processes are involved in Earth's vast water-atmosphere-weather system or in continental crust movements and earthquake occurrences.

Geographers use spatial analysis to examine how Earth's processes interact over space or area. As a science, physical geographic studies use the scientific method which is very important in modern Earth sciences, in which the goal is to understand a whole functioning Earth, rather than isolated, small compartments. Such understanding allows the scientists to construct models that simulate general operations of Earth systems as we all depend on Earth's systems to provide oxygen, water, nutrients, energy, and materials to support life. The growing complexity and pressure on the human-Earth relation requires that we shift our study of geographic processes towards the more holistic or complete, perspective – such is the thrust of Earth system science. Hence, a general understanding of the system concept is essential. In this paper, attempt has been made to give a comprehensive understanding of the aspects as stated in learning objectives.

Learning Objectives:

- *Origin of the Concept of System*
- *Definition and Characteristics of System*
- *Earth System*
- *Earth System Functions, Processes and Structure*
- *Components of Natural Systems of Earth*

Origin of Concept of System

Whether considering the first systems of written communication with Phoenician cuneiform to Mayan numerals, or the feats of engineering with the Egyptian pyramids, systems thinking in essence dates back to antiquity. While modern systems are considerably more complicated, today's systems are embedded in history. Now, the word system pervades our lives daily: "Check the car' cooling system"; "How does the grading system work?"; "There is a weather system approaching". Systems of many kinds surround us. Not surprisingly, system analysis has moved to the forefront as a method for understanding operational behaviour in many disciplines.

Systems theory as an area of study specifically developed following the World Wars from the work of Ludwig von Bertalanffy, Anatol Rapoport, Kenneth E. Boulding, William Ross Ashby, Margaret Mead, Gregory Bateson, C. West Churchman and others in the 1950s. Cognizant of advances in science that questioned classical assumptions in the organizational sciences, Bertalanffy's (1950) idea to develop a theory of systems began as early as the interwar period. Systems theory as a technical and general academic area of study predominantly refers to the science of systems in initiating what became a project of systems research and practice. In general system theory (GST), he writes: *"...there exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relationships or "forces" between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general".*

Where assumptions in Western science from Greek thought with Plato and Aristotle to Newton's *Principia* have historically influenced all areas from the social to hard sciences, the original theorists explored the implications of twentieth century advances in terms of systems. Subjects like complexity, self-organization, connectionism and adaptive systems had already been studied in the 1940s and 1950s. In fields like cybernetics, researchers examined complex systems using mathematics and no more than pencil and paper. John von Neumann discovered cellular automata and self-reproducing systems, again with only pencil and paper. A few others worked on the foundations of chaos theory without any computer at all. At the same time Howard T. Odum, the radiation ecologist recognised that the study of general systems required a language that could depict energetics and kinetics at any system scale. Odum developed a general systems, or Universal language, based on the circuit language of electronics to fulfill this role, known as the Energy Systems Language. System philosophy, methodology and application are complementary to this science. It is an interdisciplinary field of science. It studies the nature of complex systems in nature, society, and science. More specifically, it is a framework by which one can analyze and/or describe any group of objects that work in concert to produce some result. This could be a single organism, any organization or society, or any electro-mechanical or informational artifact. In all these studies, systems concept is often associated with cybernetics, which is the study of feedback and derived concepts such as communication and control in living organisms, machines and organisations.

System Definition and Characteristics

The world is a concrete system, which we define as a nonrandom accumulation of matter and energy in a region in physical Space-time organized into interacting, interrelated subsystems and components. The word "system" also refers to systems of actions abstracted from the behavior of organisms (abstracted svstems) and to systems of ideas expressed in symbolic form (conceptual systems); but the first meaning will be intended here unless we specify one of the others. Concrete systems are phenomena of the physical world. They include atoms, molecules, planets, solar systems, star systems, galaxies, and; ultimately, the entire universe. Living systems of all sorts are also concrete systems, as are ecological systems with biotic and abiotic components. The various machines people make and use as well as man-machine and animal-machine systems are also concrete systems. Below atoms are electrons, protons, neutrons, and other subatomic particles. The concept of level is of major importance. Systems at any given level are more like each other in many ways than like systems at other levels. Total system variables are measurable in the same way subsystem variables are. Within levels, systems can be compared with norms established for their particular types to determine adequacy of adjustment processes. Banathy defines a perspective that iterates this view:

"The systems view is a world-view that is based on the discipline of System Inquiry and central to systems inquiry is the concept of system. In the most general sense, system means a configuration of parts connected and joined together by a web of relationships. The Primer group defines system as a family of relationships among the members acting as a whole. Bertalanffy defined system as "elements in standing relationship".

Simply stated, a system is any ordered interrelated set of things and their attributes, linked by flows of energy and matter, as distinct from the surrounding environment outside the system. The elements within a system may be arranged in a series or interwoven with one another. A system comprises any number of subsystems.

All systems share the following seven common characteristics:

1. Systems have a *structure* that is defined by its parts and processes.
2. Systems are *generalizations* of *reality*.
3. Systems tend to *function* in the same way. All systems consist of groups of parts that interact with each other according to various cause and effect processes.
4. The various parts of a system have *functional* as well as *structural relationships* between each other.
5. The fact that functional relationships exist between the parts suggests the *flow* and *transfer* of some type of *energy* or *matter*. Systems exchange energy and matter internally and/or matter beyond their defined boundary with their surrounding environment through various processes of input and output.

6. Functional relationships can only occur because of the presence of a *driving force*.
7. The parts that make up a system show some degree of *integration* - in other words the parts work well together.

The Earth System

The planet Earth is a mixed living and nonliving system. It is the suprasystem of an supranational systems as well as the total ecological system, with all its living and nonliving components. From the moment of its formation, it has been evolving, with the result that its present state is unlike its state in earlier geologic periods. Scientists are collecting the data that win increase their understanding of the past and present states of Earth as a system.

Earth System Study is very much an interdisciplinary concept that is mainly based upon the integration of knowledge from the traditional Earth Science subjects of Geology and Physical Geography. It involves the study of all of the Earth's major systems, which includes everything from the solid Earth to surface and near-surface processes, such as glaciation, oceanic circulation and climate. Earth System Science is more than just a close integration of Geoscience topics. An important part of the Earth System Science concept is to try to explain past, present and possible future changes on the Earth resulting from disturbance of its systems and interactions between them.

Earth System functions

Within Earth's systems both matter and energy are stored and retrieved, and energy is transformed from one type to another. Matter is an entity that assumes a physical shape and occupies space; energy is a capacity to change the motion of, or to do work on, matter. Depending upon flows of energy and matter, the systems may be closed or open (Fig. 1).

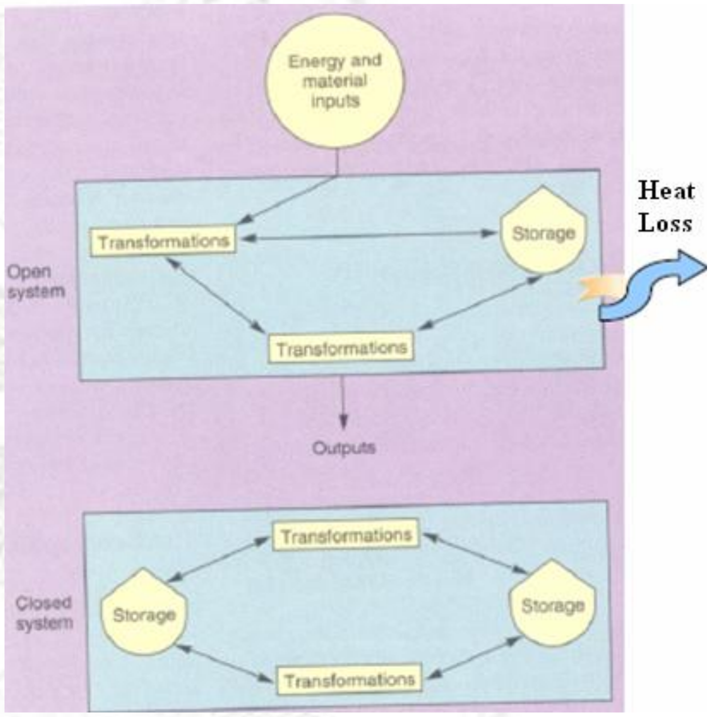


Fig. 1: Flows in Open and Closed System
(After Christopherson, 1997)

Closed System

A system that is shut off from the surrounding environment so that it is self-contained is a closed system. Although such closed systems are rarely found in nature, Earth system is essentially closed with respect to matter and resources, which are recycled within the Earth system. The only exceptions are the slow escape of lightweight gases (such as hydrogen) from the atmosphere into the space and the input of frequent but tiny meteors and cosmic and meteoric dust, although major impacts from planetoids occur every 100 million years or so.

Open System

Systems in nature are generally not self-contained. Inputs of energy and matter flow into the system and outputs of energy and matter flow from the system. Earth system is open with respect to energy that enters and exits from outside. Most Earth systems are dynamic.

Structure and Process of System

At any time, the parts of a concrete system, living or nonliving, are arranged in space in a specific pattern. This spatial arrangement is the system's structure. As the parts of the system move in relation to one another, structure changes. System change can be continuous or episodic, or may remain relatively fixed over long time spans.

Process includes both the system's function, the often reversible actions that succeed each other from moment to moment, and its history, the less reversible or irreversible changes that alter both the structure and the function of the system. Aging of organisms, decay of mountain ranges, and cooling of sun are historical processes. The regular beating of a heart is functional. The scars that result from a coronary occlusion make a permanent historical change in the heart muscle. All change in a system over time is process. Some processes exhibit cyclic patterns of behaviour, e.g. seasonal fluctuations in lake level are generally damped out in long-run. Some environmental systems exhibit medium-term change, for example, wildlife populations which fluctuate in number through periods longer than one season. Further, while dealing with the pattern of systems behavior, we need to allow for lag time, rhythms or jumps. An example of lag between input and response can be seen in day-time heating of land surface and sun height. In the same way, it takes time for rainwater from a heavy storm to become concentrated as floodwater in a valley storm. The lag time, considerable in human terms, is very short on the geologic time-scale. The structure, function, and history of a system interact. Structure changes as the system functions from moment to moment. All these can be better understood through feedback mechanisms and states of system.

Feedback Loops

As a system operates, it generates outputs that influence its own operations. These outputs function as “information” that is returned to various points in the system via pathways called feedback loops. Feedback information can control (or at least guide) further system operations. If the feedback information discourages response of the system, it is called negative feedback. Further production in the system decreases the growth of the system. It causes self-regulation in a natural system, stabilization and maintaining the system, *e.g.* a landslide looses energy as friction increases and slope flattens.

If feedback information encourages increased response of the system, it is called positive feedback, sometimes called the 'snowball' effect. Further production in the system stimulates the growth of the system, *e.g.* fire generates heat that dries air and fuel increasing the fire intensity. Unchecked positive feedback in a system can create a runway condition. In natural systems, such unchecked growth will reach a critical limit, leading to instability, disruption, or death of organisms.

Feedback loops among subsystems, and to and from the environment, are found in all living systems. In general, lower-level systems have a more limited range of adjustments than higher level systems and, within each level, the more highly evolved systems have a greater range than those below them in the evolutionary scale.

System Equilibrium

Most systems maintain structure and character over time. An energy and material system that remains balanced over time, where conditions are constant or recur, is in steady-state condition. When the rates of inputs and outputs in the systems are equal and the amounts of energy and matter in storage within the system are constant, the system is in steady-state equilibrium (Fig. 2 a). The concept of steady state is similar to the concepts of equilibrium and homeostasis (A physiological term that applies to a state of balance of the variables of an organism). One example of a steady state that must be maintained by cells and organisms is water balance. These systems must excrete water at about the same rate that they take it in or they suffer damage.

However, a steady-state system fluctuating around an average value may demonstrate a changing trend over time, a condition described as dynamic equilibrium (Fig. 2b). These changing trends of either increasing or decreasing system operations may appear gradual over time, *e.g.* long-term climate changes and the present pattern of increasing temperatures in the atmosphere and ocean, or erosion and loss of many beaches. The present rate of species extinction exhibits a downward trend in numbers of living species and change in the "balance of nature". Like many of Earth's systems, slopes exist in a state of dynamic equilibrium. Inputs of energy and matter alter the balance of the system causing it to periodically adjust, then re-establish and equilibrium. Given the nature of systems to maintain their operations, they tend to resist abrupt change.

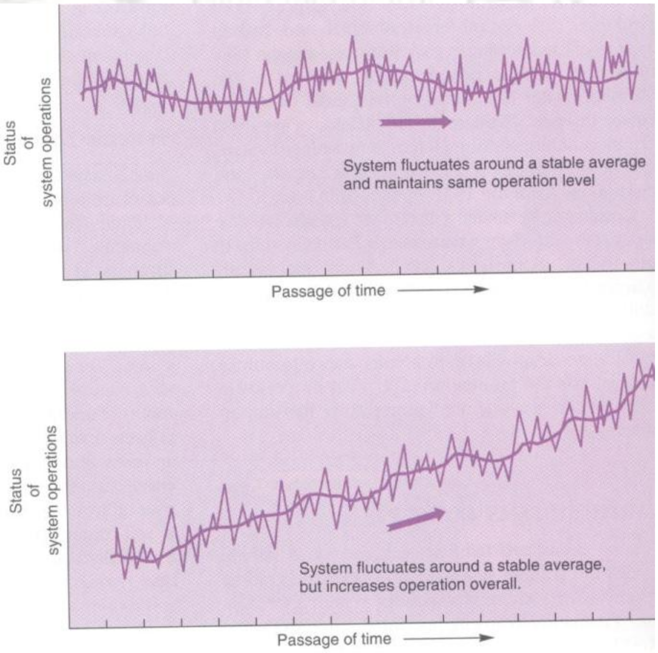


Fig.2: System Equilibrium
a) Steady State (b) Dynamic
(After Christopherson, 1997)

However, a system may reach a threshold at which it can no longer maintain its character, so it lurches to a new operational level through step function that is a rapid change or jump from one state to another.. This abrupt change places the system in a metastable equilibrium, *e.g.* a landscape such as hillside or coastal bluff that adjusts after a sudden landslide. A new equilibrium is eventually achieved among slope, materials, and energy over time. The threshold concept raises concern in the scientific community, especially if some natural systems reach such limits. The relatively sudden collapse of six ice shelves surrounding a portion of Antarctica serves as an example of systems reaching a threshold and changing to a new status, that of disintegration.

System Structures

As the point of interest is limited to open Earth systems in a state limited to condition of equilibrium or disequilibrium, a classification scheme is required that is independent both of function and state. It is provided by system structure wherein Earth systems types in increasing order of complexity have been identified as follows:

Morphological systems: They are defined in terms of their internal geometry – the number, size, shape and linkages of the components, *e.g.* stream network map, mineral substances forming crystals, joints in rocks, shorelines, entire continents and landscape systems are identifiable by their distinct shapes and patterns.

Cascading systems: These systems receive and make complex inputs and outputs of matter, energy, or both, *e.g.* cascade of solar radiation wherein incoming radiation is highly complex, extending on two sides of visible light into infra-red and ultra-violet ranges and radiation from Earth into space takes place in another band of wavelength. However, complex the system may be but both inputs and outputs are balanced. Cascading systems commonly include some kind of regulator and they also provide for storage. For example, clouds act as thermal regulator for maintenance of heat balance of Earth's surface. Other examples of these systems include cascade of precipitation on the land, the rock waste moving downslope toward river channels, the cascade of water moving through channel systems toward the sea. Whereas the internal geometry constitutes morphological system but when the viewpoint is extended to flow of water and sediment, then it becomes cascading system.

Process-response control systems: These systems change their internal geometry and/or behaviour in response to cascading inputs. The systems involved are linked together in some way, and may have components and operations in common. This process-response study is highly important in the understanding of Earth systems. It deals with how things work and also with lag time between input and response, with the connection between process and form, and with tolerance limits, *i.e.* thresholds beyond which an increase in input leads to a breakdown of system behaviour. For example, changes in lake level and area in response to increases and decreases in the cascade of precipitation or water from surrounding land. Behavior of lake's response will be different in different environments of arid and humid climates. Control systems are process-response systems in which parts of the operation are controlled by intelligence. They vary greatly in scale. On a small scale a farm is also a control system wherein soil responds to natural cascades but cropping plan is controlled by decisions of farmer.

Components of Earth's Natural System

Earth's surface is a vast area of 500 million square kilometers and it has been described as a "heat engine" Geosphere in which matter is continually cycled by convection from the hot mantle to the crust and atmosphere and back to the mantle. Geologic evidence indicates that the heat that drives these cycles and causes development of the crust and atmosphere has declined during the lifetime of the earth. Consequently, cycling of material through the system has slowed. Since, like all physical systems, this one is subject to entropy, Earth will continue to cool. Powered by radiant energy from the sun, water on Earth also moves in cycles from sea and land surfaces to the atmosphere, forms clouds, and falls back to the surface as rain or snow. The atmosphere itself is in continual motion as temperature and pressure gradients and the earth's rotation produce winds and air currents.

The open Earth systems invariably reflect the interactions between four major spheres of the planetary environment. Fig. 3 shows a simple model of three abiotic (non-living) systems overlapping to form the realm of the biotic (living) system. Each system loosely occupies a "shell" around Earth, so each is called "sphere". The abiotic spheres are the atmosphere, lithosphere and hydrosphere. The biotic sphere is called biosphere or ecosphere. Because these four systems are not independent units in nature, their boundaries must be understood as transition zones rather than sharp delimitations.

1. Atmosphere

The atmosphere is a thin, gaseous veil surrounding Earth, held to the planet by the force of gravity, mixes with elements of other planetary spheres, and occupies the spaces or voids in soils, sediments and rocks. Formed by gases arising from within Earth's crust and interior, and the exhalations of all life over time, the lower atmosphere is unique in the Solar system. It is a combination of nitrogen (78%), oxygen (21%), argon (0.9%), carbon dioxide (0.04%) water vapour and trace gases. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night. The impacts of the atmosphere on the other spheres, and vice-versa, are typically manifested in terms of climate. The temperature of the Earth's atmosphere varies with altitude of five different atmospheric layers (Fig. 4).

2. Hydrosphere

The hydrosphere encompasses water in all its forms. Earth's waters exist in the atmosphere, on the surface, and in the crust near the surface. Collectively, these three areas are the home to the hydrosphere. Water of the hydrosphere exists in its all three states: liquid, solid (the frozen cryosphere), and gaseous (water vapour). The flows and cycles of water as well as changes in its states comprise the single most important mechanism for interactions between the spheres (Fig. 5). Water occurs in two general chemical conditions, saline (97%) and a very little fresh. It exhibits important heat-storage properties and is an extraordinary solvent. Among the planets in the Solar system, only Earth possesses water in such quantity, adding to Earth's uniqueness among the planets.

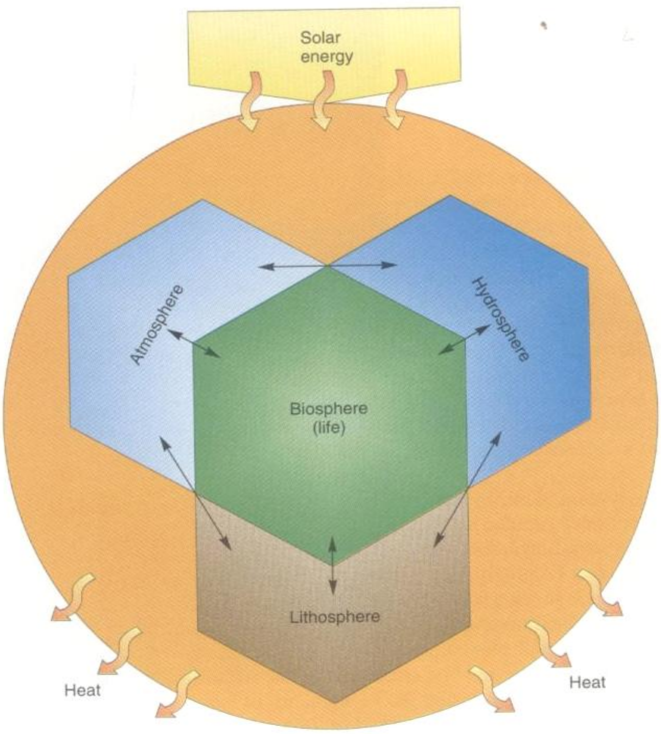


Fig. 3: Earth's Spheres

(After Christopherson, 1997)

3. Lithosphere

Earth's crust and a portion of the upper mantle directly below the crust form the lithosphere having a depth of about 100 km (Fig. 6). The crust is quite brittle compared with the layers deep beneath the surface, which move slowly in response to an uneven distribution of heat and pressure. The lithosphere refers to the solid, inorganic material of the Earth, principally rock, soil, and sediment. From the Earth surface system perspective, the most important aspects of lithospheric processes are those manifested at the surface, and the predominance of impacts of other spheres is restricted to crust. An important component of the lithosphere is soil, which generally covers Earth's land surfaces; the soil layer sometimes is referred to as the Edaphosphere.

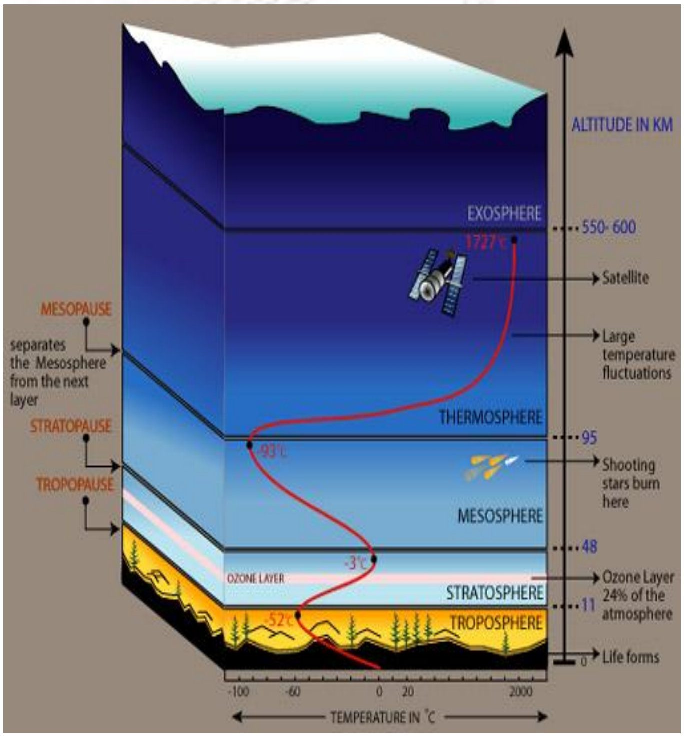


Fig. 4: Layers of Atmosphere

(Source: http://ds9.ssl.berkeley.edu/ lws_gems/3/images_3/layat510.jpg)

Various energy fluxes operate in the geomorphic system. Volcanic eruptions that carry magma from the deep interior to the surface and spew volcanic ash and gases into the atmosphere are part of this cycling process. So too are movements of the great tectonic plates into which the crust is divided. Their movement in relation to each other changes the geography of Earth. Continents change their boundaries and relative positions. Plates collide to build mountains, separate to form new seas, and slide beneath the sea bottom to be melted in the mantle as new crust is formed from upwelling magma. Tectonic strains build up and are reduced in earthquakes. Sea water moves in repetitive cycles between the ocean bottom and hot basaltic rocks below the sea floor, transferring dissolved minerals from lower layers to the sea. Matter circulates at rates and in temporal patterns characteristic of each of these cycles. Therefore, the interactions between the lithosphere and other spheres are largely controlled expressed in terms of landforms and weathered outer "skin" of the earth.

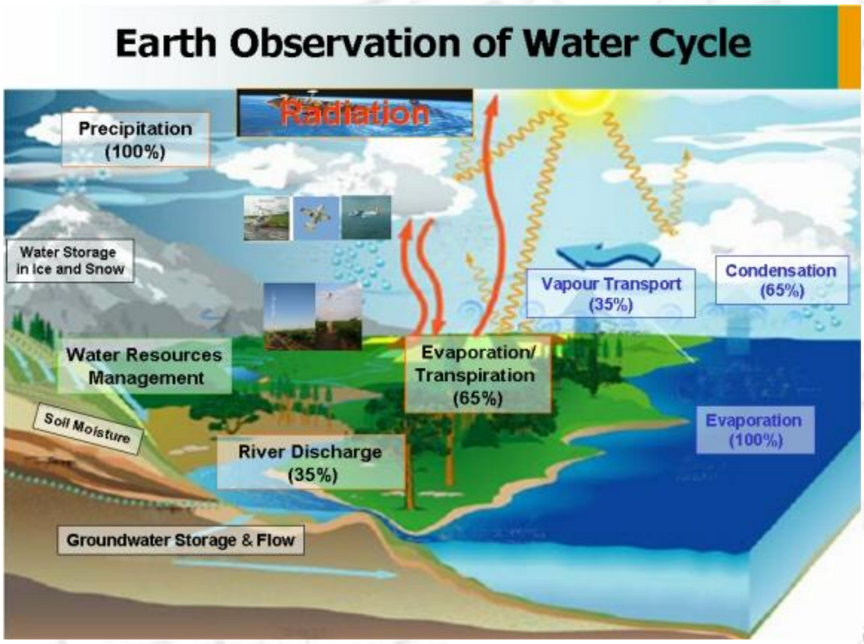


Fig. 5: Hydrological System
(Source: [http://www.itc.nl/ research/](http://www.itc.nl/research/)themes/watercycle/_pict/watercycle.jpg)

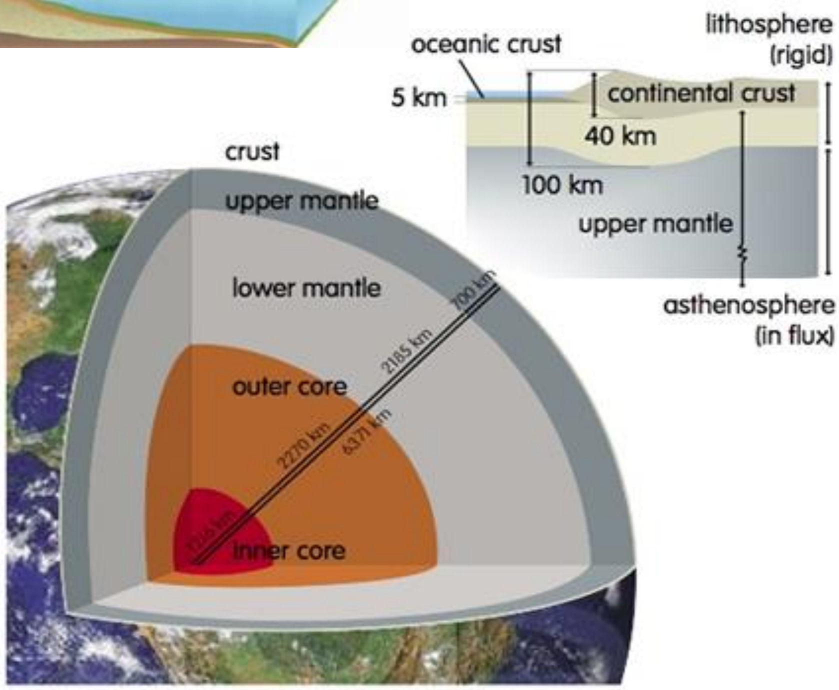


Fig. 6: Earth's Interior Layers
(After Christopherson, 1997)

4. Biosphere/Ecosphere

The intricate, interconnected web that links all organisms with their physical environment is the biosphere. Sometimes called the ecosphere, the biosphere is the area in which physical and chemical factors form the extent of life. The biosphere exists in the overlap among the abiotic spheres, extending from the sea floor to about 8 km into the atmosphere. Life is sustainable within the natural limits. In turn, life processes have powerfully shaped the other three spheres through various interactive processes. The biosphere evolves, re-organizes itself at times, faces extinctions, and manages to flourish. The impacts of the biosphere on the inorganic spheres can be equally profound, up to and including the exertion of important controls on the very composition of atmosphere, and effects on the lithosphere to the point that in some cases much of the regolith can be referred to as biomantle.

Earth’s biosphere is the only one known in the Solar system; thus, life as know it is unique to Earth. This entity, the Earth's biosphere, together with the atmosphere, oceans, and soil, forms a complex cybernetic system which seeks an optimal physical and chemical environment for life. The flow of energy causes cyclic flow of matter as explained by food chain example in Fig.7 (See Box). Thus, a forest ecosystem includes all living organisms. In these ecological systems, living systems at levels from cells to supranational systems interact with each other and with the nonliving environments upon which they depend. Local ecosystems are parts of larger systems up to the total ecological system of Earth with all its living and nonliving components.

Interactions between spheres

These spheres are closely connected. For example, many birds (biosphere) fly through the air (atmosphere), while water (hydrosphere) often flows through the soil (lithosphere). In fact, the spheres are so closely connected that a change in one sphere often results in a change in one or more of the other spheres. Such changes that take place within an ecosystem are referred to as **events**.

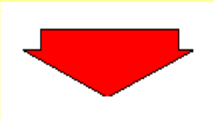
Events can occur naturally, such as an earthquake or a hurricane, or they can be caused by humans, such as an oil spill or air pollution. An event can **cause** changes to occur in one or more of the spheres, and/or an event can be the **effect** of changes in one or more of Earth's four spheres. This two-way cause and effect relationship between an event and a sphere is called an **interaction**. Interactions also occur among the spheres; for example, a change in the atmosphere can cause a change in the hydrosphere, and vice versa.

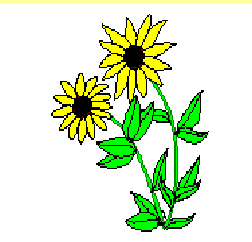
Interactions that occur as the result of events such as floods and forest fires impact only a local region, meaning the flood waters can only travel so many miles from the original stream, and only the trees that lie within the area on fire will be burned. On the other hand, the effects of events such as El Nino or ozone depletion may cause interactions that can be observed worldwide. For example, the El Nino event--a change in the ocean currents off the coast of Peru-- can cause changes in weather patterns all the

A Food Chain as an example of system

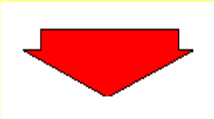
A food chain models the movement of energy in an ecosystem (a form of environmental system). Figure 7 below illustrates the movement of energy in a typical food chain. In this diagram, we begin the food chain with 100,000 units of light energy from the Sun. Note, the amount of energy available at each successive level (called trophic levels) of this system becomes progressively less. Only 10 units of energy are available at the last level (carnivores) of the food chain. A number of factors limit the assimilation of energy from one level to the next.

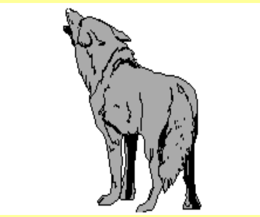
The ***Sun*** is the original source of energy, in the form of light, for the food chain. (100,000 Units of Energy)



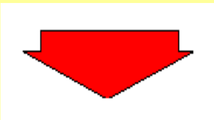


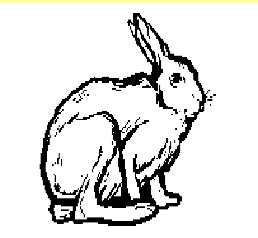
Plants capture approximately 1% of the available light energy from the Sun for biomass production by way of photosynthesis. Photosynthesis can be described chemically as: Light Energy + $6CO_2 + 6H_2O \Longrightarrow C_6H_{12}O_6 + 6O_2$.(1,000 Units of Energy)





Herbivores consume approximately 10% of the plant biomass produced in a typical food chain. (100 Units of Energy)





Carnivores capture and consume about 10% of the energy stored by the herbivores.(10 Units of Energy)

Fig.7: Model of the Grazing Food Chain Showing the Movement of Energy through an Ecosystem.
(After Pidwirny, M. (1999)

way across North America, while ozone depletion above Antarctica may result in increased levels of ultra-violet B radiation around the world. Understanding the interactions among the earth's spheres and the events that occur within the ecosystem allows people to predict the outcomes of events. Being able to predict outcomes is useful when, for example, developers wish to know the environmental effects of a project such as building an airport before they begin construction.

Understanding the interactions that occur in the earth system also helps people to prepare for the effects of natural disasters such as volcanic eruptions; this understanding allows people to predict things like how far and in what direction the lava will flow.

Challenges and Human Policy for Earth System

Exceeding carrying capacity of some parts of the Earth, depleting natural resources faster than they can be replaced, extruded wastes of human systems polluting Earth and loss of wild habitats are destroying nonhuman living systems at a rate that could extinguish 15-20% of all species on Earth by the year 2000 (Council on Environmental Quality and the Department of State). Another threat to the Earth system is apparent in the increasing amount of carbon dioxide in the atmosphere. Among the possible effects of even a relatively moderate warming would be large regional climatic changes that would alter the location of deserts, fertile areas, and marginal lands and cause large-scale dislocation of human settlements and land use.

Thus, man has certainly not been an unmixed blessing to the Earth system since, in his relatively brief tenure, he has shown an alarming capability to destroy not only himself but other critical components of the system as a whole. In fact, a new sphere called anthrosphere is now being given wide attention in the light of changing landscape and processes of Earth. At the same time, human systems are characterized by an enormous capacity to process and disseminate information.

Because of the complicated feedbacks connecting population, natural resources, capital investment, food supplies, and pollution, change in one may produce unexpected and undesirable consequences in others. In addition, short and long-term outcomes of attempts to make adjustments have made opposite effects, with the result that success in the short run in controlling a given variable may, in the long run, lead to its increase beyond its state prior to the intervention.

The Earth sciences are now in a period of advance in theory, experiment, observation, and instrumentation that is producing the necessary data. It is only now that we are beginning to study the major chemical flux rates between the major geospheres. It is these rate processes that ultimately provide the global buffer systems. We are also concerned with the interface between the atmosphere and the radiation field of space. The conclusion drawn from simulations is that unless world policy makers choose to suppress growth in the world system, the internal dynamics of the system itself will produce an undesirable equilibrium. In its concern for similar problems, the United Nations has sponsored a global input-output analysis and a set of alternative projections of the demographic, economic, and environmental states of the world.

There is today no worldwide political system with the power to set policy and secure the cooperation of the world's nations in a unified analysis, development of a remedial plan, and implementation of such a plan. Systems at the level of the society are the dominant human political systems. A great deal of supranational decision making goes on in the world in supranational and international organizations, conferences, and meetings among national deciders, but nations comply with decisions of these bodies only when they perceive that the recommended courses of action are in their own best interests. It may well be that securing such cooperation is the most important task now facing human beings as well as our mother Earth.

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