UNIT 3 LECTURE 4
ENERGY FLOW IN AN ECOSYSTEM

Italics indicate text given on slide

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The existence of living world depends upon the flow of energy and circulation of materials through the ecosystem. The energy is required for the performance of all the life activities. The living organisms utilize solar energy. In photosynthesis, this radiant energy is transformed into chemical energy and in cellular metabolism the chemical energy is again transformed into mechanical or heat energy.

Energy flow is the movement of energy through an ecosystem: from the external environment through a series of organisms and back to the external environment. It is one of the fundamental processes common to all ecosystems.

The source of energy is the sun. The sun is a thermonuclear fusion reactor. Every second, some 4.2 million tons of the sun's mass is converted into 10^{26} calories of energy. Although the rate of conversion of mass into energy on the sun is enormous, the sun is so large that there is enough of it left to allow this process to go on for billions of years. The specific energy releasing reaction taking place on the sun is the fusion of hydrogen into helium. The difference, or the lost mass due to the fusion reaction is converted into energy according to the equation $\boldsymbol{E = mc^2}$**.**

The energy generated from solar mass emerges in the form of electromagnetic radiation including light, heat and other forms of energy. About 99% of the radiation that reaches the earth is in the range encompassing visible light, near-infrared, and ultra violet radiation. The earth intercepts only 1/50 millionth of the sun's energy output at a constant rate (about 2 gcal / cm^2 / min.). This constant is called **solar flux** or **solar constant**. Solar flux is the amount of radiant energy that crosses an unit area or surface per unit of time.

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*Energy can be defined as the capacity to do work (Odum, 1971). According to the **first law of thermodynamics**, light energy of the ecosystem is converted into potential energy of the food by producers and according to the **second law**, the energy accumulated by the producer pass on to the consumers in the form of eating and being eaten with a gradual loss of energy from the base to the apex of the food pyramid of an ecosystem. The measure of this gradual loss of energy is called **entropy**.*

The first law of thermodynamics specifies that energy can be neither created nor destroyed by any process or event but that energy can be changed from one form to another. In other words, the total amount of energy in the universe or in any closed system is always the same, though the proportions of the various forms of energy may vary.

According to the second law of thermodynamics, each time energy is converted from one form to other, a part of energy is lost in the form of heat (entropy). No energy conversion is 100% efficient. Spontaneous processes are those in which entropy tends to increase. Energy transformation in which entropy could decrease are not likely to occur spontaneously.

An ecosystem must lie between a **source** of usable energy and a **sink** for degraded energy. The ecosystem is said to be intermediate between the energy source and the energy sink. The energy source, ecosystem, and energy sink form a thermodynamic system.

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About 1/10th of one per cent of the energy that the earth gets from the sun is fixed or converted into chemical energy by plants in photosynthesis. The conversion of solar energy into chemical energy constitutes primary production. Primary production or productivity is the rate at which the photosynthetic equation moves from left to right.

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

In the absolute sense productivity means the total amount of this reaction that occurs in an unit time. A part of the sugar formed in photosynthesis becomes plant matter while the rest is used for respiration. In effect, in plant respiration, plants reverse some of the photosynthesis they carry out. As the proportion of photosynthesis that leads to accumulated plant mass varies from plant to plant and with varying conditions of a plant's physical/chemical environment, it has been useful to distinguish net production and gross production.

In all the earth's ecosystems, both terrestrial and marine, about 160 to 170 billion metric tons of dry organic matter are produced annually. This amount of organic mater is presented to the earth by plants each year and constitutes **net primary production**. The **gross primary productivity** of an ecosystem is the total rate of conversion of solar energy into chemical energy in that system**. Net primary productivity** is the rate at which plants make chemical energy available to consumers and decomposers or for storage or export. Depending upon the type of plant and other factors, the amount of organic matter used up in plant respiration ranges from 15% to 75% of the total amount of organic matter produced by the plants.

Of the net primary production in an ecosystem, herbivores and decomposers may not consume all of the organic matter produced by plants in any given period. The expression **net community productivity** is sometimes used to describe the rate at which organic matter is accumulated in an ecosystem. Net community production is equivalent to net primary production minus the organic matter respired or used by consumers and decomposers.

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Plants utilize some of the chemical energy that they produce for their own activities. The same pattern applies to herbivores and to carnivores higher up in the food chain. Herbivores and to carnivores take some of the energy they capture and utilize it for carrying out the metabolic activities. Some of the energy assimilated or fixed at each level is available to the next level up. In every case, some of it ends up going to the decomposers.

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Energy efficiency is the ratio of output to input. Generally, the more energy an organism gets, the more it has for its own use. However, organisms differ in how efficiently they use the energy they obtain. A more efficient organism has an advantage over a less efficient one. Energy efficiency is usually defined as the amount of useful work obtained from some amount of available energy. Efficiency can therefore be defined for both artificial and natural systems.

A common ecological measure of energy efficiency is called food chain efficiency, or ***trophic level efficiency****, which is the ratio of production of one trophic level to the production of the next lower trophic level.* This efficiency is never very high. Green plants convert only 1 to 3% of the energy received from the sun during the year to new plant tissues.

The efficiency with which herbivores convert the potentially available plant energy into herbivorous energy or the efficiency with which carnivores convert herbivores into carnivorous energy is usually less than 1%. Depending on the ecosystem, and certain physical/chemical factors, up to 50% of the chemical energy present in the form of producers is transferred to the primary consumers. In turn, somewhere between 5% and 30% of the energy present in the form of primary consumers makes its way to the secondary consumers or carnivores. On the average, about 10% of the energy entering a particular feeding level is transferred to the next level. That is, if 10% of the energy available in the form of plants ends up being incorporated into secondary consumers, then 10% of that 10% is available to the next, or tertiary level of consumption. This is known as the 10% law.

Many other kinds of energetic efficiencies are widely used in ecological studies like ***growth efficiency****, or gross production efficiency, which is the ratio of the material produced by an organism or population to the material ingested or consumed.* The amount consumed is much less than the maximum amount available.

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1. **Energy flow is unidirectional:**
   The solar energy trapped by the autotrophs cannot be returned to solar system again and similarly the energy of primary consumers cannot go back to autotrophs and from secondary to primary consumer and so on. That is, energy can flow from one trophic level to the next one but cannot return back.

2. **Progressive decrease in energy utilization at each trophic level:**
   During energy flow there is a progressive decrease of energy from one trophic level to the next because some energy is lost as heat during metabolism in each trophic level.

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Energy flow models are basically of three types:

Single Channel Energy Flow Model:

Such model is characterized by unidirectional flow of energy through different trophic levels, involving a single food-chain and indicating dissipation of energy at each transfer

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Y – shaped Energy Flow Model

Known also as **Two-Channel Energy Flow Model**, it includes both the grazing and detritus food-chain of an ecosystem. Such models are more realistic than single channel models in view of the fact that:

- *They conform to the basic stratified structure of ecosystems.*
- *They separately indicate the direct consumption of living plants and utilization of dead organic matter both in space and time.*
- *The detritivores differ greatly in size-metabolism relations and in study techniques.*

The proportion of the net primary production energy that flows down the two pathways varies with different ecosystems, as well as with seasonal or annual cycles in the same ecosystem. However, in all ecosystems, the grazing and detritus food-chain are inter-connected, so shifts in energy flows can occur quickly in response to forcing function inputs from outside the system.

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Universal Energy Flow Model:

It is applicable to any living component of any ecosystem. For any given trophic level, such figure consist of a 'box' representing the 'biomass' at any given time and pathways through it representing the flow of energy. The size of the box is proportional to the total biomass at the trophic level. Energy enters the trophic level as the food is ingested by the organism. Some of the ingested energy is not

used and egested out, while the rest is assimilated. Some of the assimilated energy is used in respiration or is stored in the form of fat. The rest is used for growth or egested. The rest amount of energy or biomass or production becomes available for the trophic level. Such model may well represent the dynamics of an entire trophic level or of a single individual within the trophic level. Thus, universal model the energy inputs and outputs of a particular individual or of all the individuals at a trophic level.