*i*Journals: International Journal of Social Relevance & Concern (IJSRC)
ISSN-2347-9698
Volume 9 Issue 8 August 2021

Energy Metabolism and its Flow in Ecosystem

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Abstract

Energy metabolism is the process of generating energy (ATP) from nutrient. In ecosystem, the complex network of processes involved in energy metabolism is distributed among different components within cells and in different organs of the body. Metabolism of energy is also involved with energy flow in ecosystems. The operation of an ecosystem then is consistent with the law of thermodynamics that deal with the relationships between energy and matter in system.

Key words: energy, metabolism, thermo-dynamics, bio-energy, solar radiation.

Introduction

Energy metabolism is the process of generating energy (ATP) from nutrients. Metabolism comprises a series of interconnected pathways that can function in the presence or absence of oxygen. Aerobic metabolism converts one glucose molecule into 30-32 ATP molecules, Formation or anaerobic metabolism is less efficient than aerobic metabolism.

The complex network of processes involved in energy metabolism is distributed among different compartments within cells and in different organs of the body. These processes function to generate ATP "on demand" to generate and store glucose, triacylglycerols, and proteins in times of plenty for use when needed, and to keep the concentration of glucose in the blood at the proper level for use by organs such as the brain, whose sole fuel source, under normal conditions, is glucose. The major energy metabolism pathways include glycolysis, glycogen degradation and synthesis, gluconeogenesis, the pentose phosphate pathway and triacylglycerol and fatty acid synthesis, which are cytosolically based, and fatty acid oxidation, the citric acid cycle, and the oxidative phosphorylation, which are confined to the mitochondria A mitochondrion Amino acid degradation occurs, in part, in both compartments. The mediated membrane transport of metabolites therefore also plays an essential metabolic role.

The brain normally consumes large amounts of glucose, muscles under intense ATP demand such as in sprinting degrades glucose and glycogen an aerobically, thereby producing lactate, which is exported via the blood to the liver for reconversion to glucose through gluconeogenesis During moderate activity, muscle generate ATP by oxidizing glucose from glycogen, fatty acids and Ketone bodies completely to carbon-dioxide (CO_2) and water (H_2O) via the citric acid and oxidative phosphorylation. Adipose tissue stores triacylglycerol and releases fatty acids into the bloodstream in response to the organism's metabolic needs. These metabolic needs are communicated to adipose tissue by means of the hormones insulin, which indicates a fed state in which storage in appropriate, and glucagon, epinephrie and norepinephrine, which signal a need for fatty acid release to provide fuel for other tissues. The liver, the body's central metabolic clearing house, maintains blood glucose concentrations by storing glucose as glycogen in times to plenty and releasing glucose in times of need both by glycogen breakdown and by gluconeogenesis. It also converts fatty acids to ketone bodies for use by peripheral tissues. During a fast, it breaks down amino acids resulting from protein that degradation to metabolic intermediates that can be used to generate glucose. The kidney filters out urea from the blood, recovers important metabolite maintain pH balance. To do so glutamine is broken down to produce NH_4^+ for H^+ excertion. The resulting d-ketoglutarate product in converted to CO_2 to resupply HCO_3^- to the blood to maintain its buffering capacity. During starvation the kidney d-ketoglutarate from glutamine breakdown gluconeogenesis.

AMP-dependent protein kinas (AMPK), the cell's fuel gauge, senses the cell's need for ATP and activates metabolic break down pathways while inhibiting biosynthesis pathways. Adiponetin, an adipocyte hormone that increases insulin sensitivity, acts by activating AMPK. Appetite is suppressed by the actions of leptin, a hormone produced by adipose tissue, insulin, produced by the β cells of the pancreases, and PYY_{3-36} produced by the gastrointestinal tract which act in the hypothalamus to inhibit the secretion of neuropeptide Y (NPY) and stimulate the secretion of x-MSH and CART. This decreases the appetite and hence food intake.

Ghrelin, a hormone secreted by the empty stomach, opposes the actions of leptin insulin and PYY_{3-36} stimulating appetite and good intake. Leptin also acts in peripheral tissues to stimulate energy expenditure by fully acid oxidation and therogenesis.

During Prolonged starvation, the brain slowly adapts from the use of glucose as its sole fuel source to the use of ketone bodies, thereby shifting the metabolic burden from protein breakdown to fat breakdown. Diabetes mellitus is a disease in which insulin either is not secreted or does not efficiently stimulate its target tissues, leading to high concentrations of glucose in the blood and urine .Cells "strave" in the midst of plenty since they cannot absorb blood glucose and their hormonal signals remain those of starvation. Abnormally high production of Ketone bodies is one of the most dangerous effects of uncontrolled diabetes. Metabolic syndrome is caused by obesity, physical inactivity and possibly genetic determinants. It symptoms can be relieved by substances that activate AMPK.

Energy: Energy is defined as the capacity to do work, which is the product of a given distance

Work = Force x Distance

It is one of the fundamental components of any system. Energy exists in a variety of such as electrical, mechanical, chemical heat and light energy. These different terms of energy care inter convertible.

Thermodynamics:- Thermodynamics deals with to heat work and temperature, and their relation to energy, radiation and physical properties of matter. It is principally based on a set of four laws which are universally valid when applied to systems that fall within the constrains implied by each,

Zeeroth Law:- If two systems are each in thermal equilibrium with a third, they are also in thermal equilibrium with each other. If there is no net flow of thermal energy between them they are connected by a path permeable to heat. Thermal equilibrium obeys the zeeroth law of thermodynamics. A system is said to be in thermal equilibrium with itself if the temperature within the system is spatially uniform and temporally constant.

First law of thermodynamics:- In a process without transfer of matter, the change in internal energy ΔU, of a thermodynamic system is equal to the energy gained as heat Q, less the thermodynamic work, w, done by the system on its surroundings.

$$\Delta U = Q - W$$

For processes that include transfer of matter, when two systems, which may be different chemical compositions, initially separated only by an impermeable wall, and other wise isolated are combined into a new system by the thermodynamic operation of removal of the wall, then

$U_o = U_1 + U_2$

U_o = Internal energy of the combined system

$U_1 + U_2$ = denote the internal energies of the respective separate systems.

Entropy:- The degree of randomness or disorder in the arrangement of a system is measured by a state function called the entropy.

The second law of Thermodynamics

Every biological system can exchange energy and matter with its environment. Thus, to predict whether or not a process is likely to be favourable in an open system, considers how entropy changes in both the system, and the surroundings This over all entropy change is commonly referred to as the entropy of the universe,

$$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$$

The third law of a Thermodynamics

It is a statistical law of nature regarding entropy and the impossibility of reaching absolute zero of temperature. This law provides an absolute reference point for the determination of entropy. The entropy determined relative to this point is the absolute entropy. Alternate definitions include the entropy of all systems and of cell states of a system are smallest at absolute zero, "or equivalently at it are impossible to reach the absolute zero of temperature by any finite number of processes."

Bio-energy: Energy made from biomass or bio-fuel. Biomass is any organic material which has absorbed sunlight and stored it in the form of chemical energy. The IPCC (Intergovernmental Panel on Climate change) defined bio energy as a renewable form of energy).

CONCEPTS R*ELA*TED TO ENERGY

Energy is defined as the ability to do work. The behaviour of energy is described by the following laws:-

The first law of thermodynamics or the law of conservation of energy, states that energy may be transformed from one form into another but is neither created nor destroyed. Light, for example is a form of energy, it can be transformed into work, heat, or potential energy a food, depending on the situation, but no it is destroyed.

The second law of thermodynamics or the law of entropy may be stated stated in several in the ways, including following: No process involving an energy transformation will spontaneously occur unless there is a degradation of energy from a concentrated form into a dispersed form. For example, heat is tend to a hot object will spontaneously become dispersed into the coolar surroundings

SOLAR RADIATION AND THE ENERGY ENVIRONMENT

Organisms at or near the surface of Earth are constantly irradiated by the solar radiation and by long wave thermal radiation from nearby surfaces. Both contribute to the climatic environment. Solar radiation reaching the surface of Earth consists of three components; visible light and two invisible components, shorter wave ultraviolet and longer wave infrared, Because of its dilute, dispersed nature, only a very small fraction (at most 5%) of visible light can be converted by photosynthesis into the much more concentrated energy of organic matter for the biotic components of the ecosystem, Extraterrestrial sunlight reaches the ionosphere at a rate of 2 geal.cm^{-2} min^{-1} (the solar constant) but is attenuated exponentially as it passes through the atmosphere, at most, 67% (1.34 gcal.cm^{2} mm^{-1}) may reach the surface of Earth at sea level at noon on a clear summer day. Solar radiation is greatly altered as it passes through cloud cover, water and vegetation The daily input of sunlight to the autotrophic layer of an ecosystem averages about 300 to 400 g.cal/cm^{2} (= 3000 to 6ooo K.cal/m^{2}) for an area in the North Temperate zone, such as United States,

Energy Flow in Ecosystem -

The behaviour of energy in ecosystem can be termed energy of low due to unidirectional flow of energy. From energetic point of view it is essential to understand for an ecosystem.

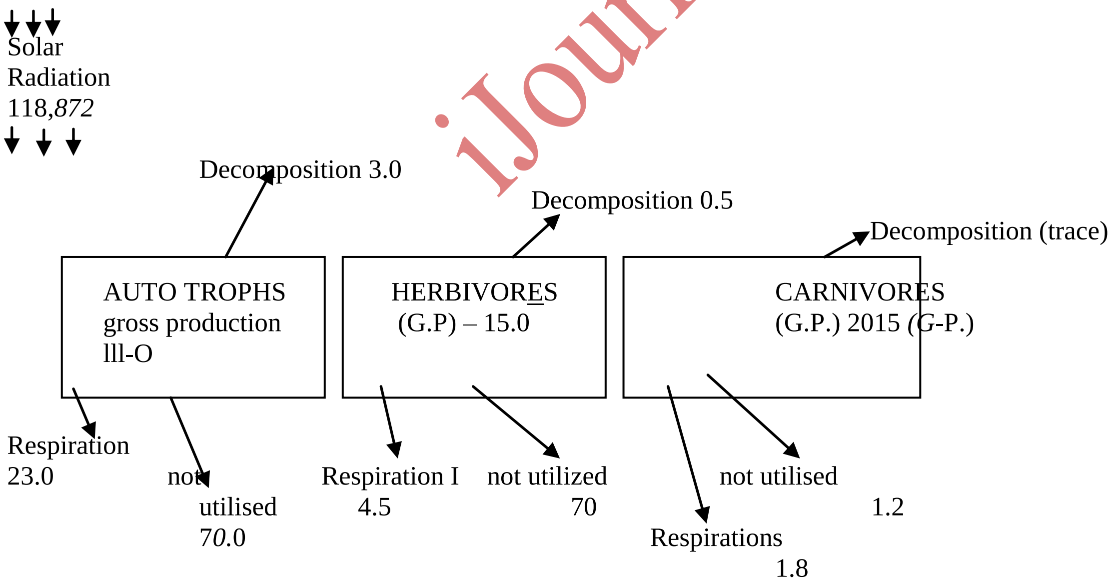
(i) The efficiency of the producers in absorption and conversion of solar energy.

(ii) The use of this converted chemical form of energy by the consumers.

(iii) The total input of energy in form of food and its efficiency of assimilation.

(iv) The loss through respiration, heat, excretion, etc.

(v) The Gross net production.



Energy flow diagram for a lake in g.cal/ Cm^{2}/Yr

out of the total incoming solar radiation (118.872 g/cal Cm^{2}/Yr), 118.761 g.cal/Cm^{2}/Yr remain unutilized and thus gross production (net production plus respiration) by autotrophs is lll g.cal/Cm^{2}/Yr with an efficiency of energy capture of 0-10%. It may be also being noted that 21% of this energy, or 23 g.cal/Cm^{2}/Yr is consumed in metabolic reactions of autotrophs for their growth, development, maintenance and re-production. It may be seen further that 15 g.cal/Cm^2/Yr are consumed by herbivores that graze or feed on autotrophs this amounts to 17% of net autotroph production. Decomposition 3geal/$cm^{2/}$yr accounts for about 3-4% of net production. The remainder of the plant material, 70 gcal/cm^2/yr 79.5% of net production is not utilised at all but becomes part of the accumulating sediments. It may be also noted that various pathways of loss are equivalent to account for total energy capture of the autotrophs i.e. gross production. Also collectively the three upper 'fates' (decomposition, herbivory and not utilised are equivalent to net production. If the total energy incorporated at the herbivores level, i.e. 15 g.cal/Cm^2/Yr, 30% or 4.5 g.cal/Cm^2/Yr is used in metabolic reactions. Thus, there is considerably more energy lost via respiration by herbivores (30%) than by autotrophs (21%). Again there is considerable energy available for the carnivores, namely 10.5geal/ Cm^2/Yr or 70%, which is not entirely utilised in fact only 3-0 g.ceal/Cm^2/ Yr or 28.6% of net production passes to the carnivores. This is more efficient utilisation of resources than occurs at autotroph herbivore transfer level. At the carnivore level about 60% of the carnivores' energy intake is consumed in metabolic activity and the remainder becomes part of the not utilised sediments only an insignificant amount is subject to de composition yearly. This high respiratory loss compares with 30% by herbivores and 21% by autotrops in this ecosystem.

CONCLUSION AND RECOMMENDATIONS

Energy trapped by autotrophs which is passed or through a chain of consumers' right up to the top of trophic structure in an ecosystem. At each step in the food chain respiratory activity and decomposition of dead organic remains dissipate a large amount of solar energy. The successive trophic levels are thus smaller and smaller in terms of energy content, biomass and usually numbers as well. The energy captured by green plants also supports the life activity of decomposers and is finally scattered in the environment. The flow of energy is, therefore, unidirectional.

These factors - unidirectional flow and efficiency of energy utilization - account for the requirement of a continual source of energy to preclude collapse of an ecosystem. An ecosystem simply cannot maintain itself if deprived of energy income for any extended period of time.

The operation of an ecosystem, then, is consistent with the law of thermodynamics that deal with the relationships between energy and matter in a system. The total energy input to an ecosystem in budgetary fashion. The first law of thermodynamics says, in various ways, that the sum total of energy in a system is a constant of more familiarly, that energy, can neither be created nor destroyed. Energy may change form but not amount. But as energy moves through an ecosystem, it does change form, ultimately to heat, which is not directly usable by the system. Thus the system tends to run down, dissipating its energy and leasing its organized structure. This is the nature of the second law of thermodynamics, a tendency towards entropy on maximum dis-organization of structure and maximum dissipation of usable energy. This trend is countered by the continual input of energy from the outside.

The rapid advances in science and technology have put the scientists and technologists on their heels to cope up with the simultaneous changes that have occurred during the past decades. Various types of revisions, rectifications as well as modifications and sometimes even together innovated ideas that developed in numerous fields of specializations have required to be incorporated with the advanced level concepts in order to keep pace with the recent researches advanced to the concerning fields of the study. The innovative techniques have put the researches on consistent 'think' and 'rethink' level to entertain higher concepts related to the ecology. The study of such concept as energy metabolism should be considered with flow of energy in the ecosystems of land, aquatic (fresh water as well as marine water) resources, mountains desert and air etc. and interrelationship in between plants and animals.

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