Growth, Energy, and Food Webs: A Formula for Life

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Background Information

The camera sites of Web World Wonders are specifically chosen as examples of environmentally sensitive areas that, if not for state or federal protection mandates, their future existence could be threatened by human interaction. The loss of environmentally sensitive areas would cause an adaptation to life. The extent to which humans would be affected is not understood.
As humans continue to cover the earth with their buildings, parking lots, and roads, the available land for other living organisms is reduced directly. As nesting and denning habitats are reduced many of our present animals are pressured into **extinction**. Plants that normally need unrestricted habitats are forced into competitions with different organisms that are more adapted. The wastes from human consumption and industrial processes alter the plants and animals that they touch. The use of **pesticides** and **herbicides** that allow us to grow single agricultural crops on lands where normally the diversity of species is enormous further reduces available land.
Present agricultural technology is based on the elimination of specie competition by using pesticides to kill unwanted guests in our crops. Unfortunately the chemicals don't just kill in their

specific agricultural fields, but get into the air and the waterways to affect other organisms not intended for their use. The result is a rapidly changing biological landscape that is different from a past that has been very beneficial to humans.

t is true that human intelligence has put us above all other forms of life. In the past we have been able, through our technological gains, to overcome environmental difficulties that confronted us; however, at no time in our history has human population been so great and with a potential to grow exponentially. Scientists do not know what effect industrialization will have on people a hundred years from now. Will these new environments allow humans to survive in great numbers?

The environmental movement publicly had its modern beginnings in the 1960's, with the publication of *Silent Spring* by Rachael Carson. Two philosophies emerged from this era of environmental awareness. They are still with us today.

One philosophy believes that human intellectual ability will allow us to overcome any environmental problem that human populations and human consumption might manufacture. If we need more food we will find ways to increase production. If water is in short supply we will find ways to recycle it. Our fossil energy supplies will be replaced through new discoveries. New technologies will overcome any environmental problem.

On the opposite side of this argument are the believers that all is not good and that human intelligence and abilities are not infallible. This philosophy believes that we must calculate the effects of high-density human populations on the environment before we do something that might be harmful to future generations. As with any argument there are two perspectives with views on both sides. Our natural resources aren't unlimited. We live in a finite environment called the earth. All our resources are found here. We cannot create more. On-the-other-hand, the human population is not finite at this point. It is growing rapidly and carrying capacity is an area of concern for all of the world's population clusters. Again, how close are we to reaching the human **carrying capacity** of this earth? If the environment is important to human survival, then it only makes sense that we study and we learn before we act.

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What's Ecology?

The field of biology that has found new life from the concern for the environment is called **ecology**. Ecology is the study of organisms and how they interact with their environment. Of course we are most concerned about how humans interact with their surroundings, but hopefully we will see that all organisms are either directly or indirectly connected.

No matter who you are, you do not live alone. To be completely independent of all life would require that the organism capture its own energy, eliminate and remove its own waste products, successfully be immune to the harmful advances of other organisms, reproduce **asexually**, and continue to do so indefinitely no matter what physical environmental changes took place. Life is not based on a concept of isolation.

In order for a particular type of life to continue it must show great diversity throughout a large population of individuals. Only through diversity can life assure itself of having representatives that have the right genetic make-up to survive a changing environment. Green plants probably come as close to being independent as any organism can, but they find themselves in a world where they are in competition for space from other plants and for the physical resources such as light and water. They too suffer from disease and are ever endanger of being consumed by some animal or destroyed by a natural disaster. Some plants have become dependent on animals to distribute their seeds.

The relationship that exists between organisms is the same whether you look at a small area or if you inspect large ones. Life in your backyard conforms to the same principles that occur in a large forest. The same interactions are taking place. Every organism is trying to position itself for survival. Only the scale is different. Even your backyard can have interaction with a forest. A butterfly that as larvae might have existed in a forest becomes food for a spider or a bird hundreds of miles away in your backyard. All life interacts with its environment and the interaction that takes place in one area can directly or indirectly affect what takes place in another.

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What's an Ecosystem?

The unit or size of an area that ecologists use to study the interactions of organisms is called an **ecosystem**. An ecosystem is not defined by size. It can be small like the area under a boat dock, or it can be large like the whole lake. It can even be the whole earth or **ecosphere**. No matter the

size, all factors in the ecosystem are studied. Ecosystems always contain all the living organisms within the area and all the nonliving things as well. All living organisms that are found within the boundaries of the ecosystem are referred to as the **biotic factors**. The nonliving entities are called **abiotic factors**. Ecologists try to answer geographic questions about the species that are present in an ecosystem. What is their distribution within the given area? How many individuals are present? What factors are controlling their numbers?

Ecosystems also have histories. Ecologists must also try to answer questions about the origin of the particular ecosystem. How did it come about? Where is it going? These are questions that determine the evolutionary history of the ecosystem. Ecosystems are complex mechanisms that are not easily understood.

Ecosystems are therefore arbitrarily defined areas composed of both living, biotic factors and nonliving, abiotic factors that interact with each other and from these interactions the ecosystem is modified or changed over time.

There are two requirements that are basic to the success of any ecosystem. An ecosystem needs resources in the form of chemicals and a constant energy source.

The chemicals of an ecosystem are recycled over and over. The carbon in a tree today may be in an insect tomorrow and in a bird the next. The elements that compose your body could well have been in several other organisms in the past. These elements are used over and over. They are recycled.

Energy, on-the-other-hand, is not recyclable but must be renewed. Sunlight provides energy to the earth. Some of the energy strikes the earth and is converted to heat. Photosynthetic organisms capture some of the light, and through a series of chemical reactions, cause the energy to be trapped in molecules as **chemical energy**.

The process of life then passes the energy from one molecule to another. This process allows an organism to do **work**. Unfortunately, the system is not completely efficient as each time the energy is passed from one compound to another, some of the energy is lost as heat. Heat energy is lost to living organisms because it radiates from the earth out into space.

Eventually all the energy that was captured by a green plant is used or lost by life. Only if new energy is captured can the living processes continue. Chemical matter is recycled over and over, but energy must constantly be replaced.

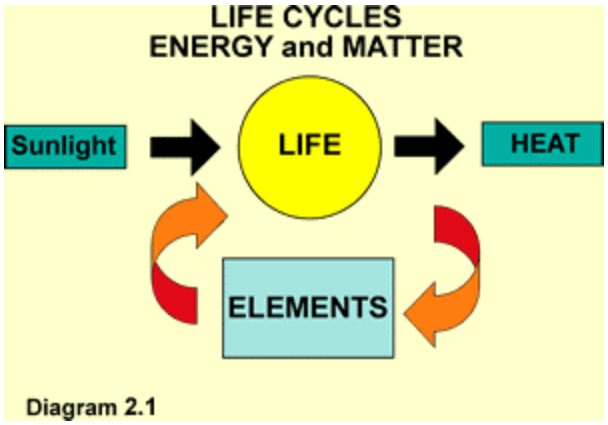

Diagram 2.1

The type of life that has developed on this earth did so by using the principles of elemental recycling and energy flow. The elements are used over and over, but energy runs a one-way course through life.

Its not hard to observe the fact that within any given ecosystem there exists a hierarchy of plants and animals that survive at the expense of some organism lower on the scale. Green plants take the sun's energy and convert it into chemical compounds that they can use to do work to live. They often have energy left over at the end of a day and store it as sugar. Some animals have developed the ability to eat the plants and use the stored energy. They too store some of the energy but in the form of fat and protein. This allows other types of animals to consume them, utilizing the same energy that was once sunlight.

The energy transfer process is not something that can continue forever. Each time the trapped sunlight is transported from one molecule to another, some of the energy is lost as heat. Heat energy cannot be recaptured by life and eventually escapes the earth into outer space. The transfer of energy between compounds is continuous within any living organism. Energy is constantly being lost.

This means that if an organism has evolved to eat green plants, then in order to get the same amount of energy as the plants did, it will have to eat more plants to replace the original energy has been lost. This is an energy debt that limits the number of organisms that can eat plants. The plant eaters lose energy in their daily lives and thus they limit the number of animals that can eat them. The population of each level is dependent upon a larger energy (food) source below them. There have been many attempts to determine how much energy has been lost at each level and most fall within the general category of about 90%. This means that only 10% of the energy at any

given level is passed up to the next level. Animals that feed upon animals that eat green plants are getting only one-tenth of one-tenth, (or one-hundredth), of the energy of the plant level. The further an animal is removed from eating a plant the greater the loss of the original amount of energy.

f energy is leaving the system, then all that remains is the elements that make up life. These elements are used over and over by life. When organisms die or eliminate waste products, special forms of life like bacteria and fungi, decompose the material and return the elements to the earth for use again by living organisms. Elements are recycled and used over by life.

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What is an Energy Pyramid?

An energy pyramid is created from relationships that living organisms have with each other as they compete for energy in the form of food. As stated before, organisms that are further removed from the level of creating their own food, have less of the original energy. This means that to feed extended levels of life requires more energy to be put into the system. Since the system loses energy as it proceeds, each subsequent level of food acquisition has less of the original energy. The result is an energy pyramid.

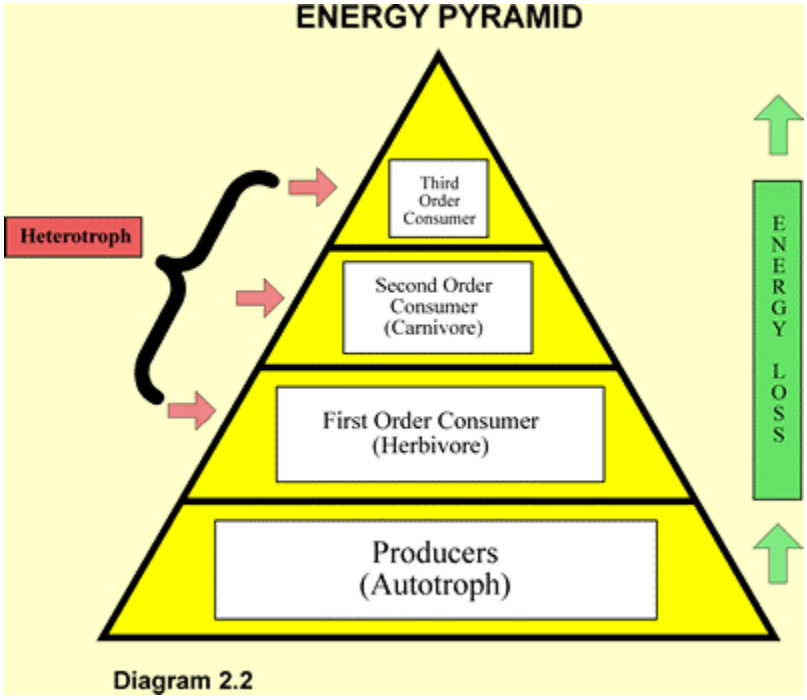

Diagram 2.2

Ecologists have developed special names for each level in the

The hierarchy of an energy pyramid is referred to as the **trophic structure.** Trophic means feeding, so the trophic structure is the feeding structure. Organisms that produce their own food such as green plants are called **autotrophs** or **producers**. (See Diagram 2.2) They represent the bottom or base of the trophic structure. All other organisms in the trophic structure are called **heterotrophs**. They are dependent upon the autotrophs for food since they have no way of capturing and storing energy by themselves. Animals that eat plants are called **herbivores** and they reside at the trophic level called the **first order consumer**. Animals that eat other animals are called **carnivores** and are either **second order consumers** or **third order consumers**. Humans and several other types of animals can digest both plant and animals. These animals fit into a special category that ecologists call **omnivores**. Humans can be found at various levels of the trophic structure depending on what they are having for dinner.

There is one other type of organism that is always under-rated but is so very important to the recycling of elements. These are the bacteria and the fungi that decompose waste and dead organisms. They are referred to as **detritivores**. Without them the earth would become buried in the biotic mass of dead organisms.

The energy pyramid it is a simplification of a very complex system. It is used to show that energy is passed through life from organism to organism and that each passing, energy is lost from the system. It takes a lot of energy to support life at the apex of the pyramid.

Does life exist at levels? Certainly the construction of an energy pyramid is a device that humans use to demonstrate the principles of energy flow; however, life is not so easily categorized and the concept of a food chain is restricted to a few circumstances. In reality energy pathways are very complicated and would better be described as food webs.

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Food Chains and Food Webs

If you were to insert a specific organism into each level of the energy pyramid it would look like diagram 2.3 below.

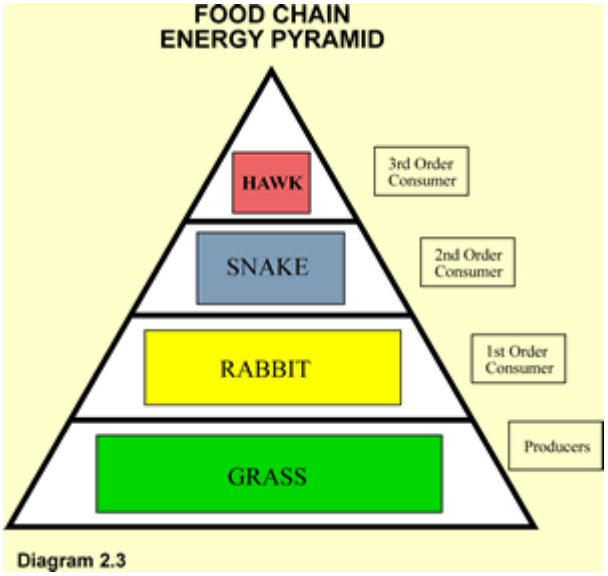

Diagram 2.3

This would be a food chain with the rabbit eating the grass and the snake eating the rabbit and it finally the hawk eating the snake. The result is a straight-line passage of energy and you get the impression that life is very simple and straightforward. As you already know, life is not just a simple chain of organism consuming organism. Instead there are so many possibilities that our chain becomes interwoven with hundreds of other chains that grow to look more like a web of a spider.

Do hawks only eat snakes? Do snakes only eat rabbits? Do snakes ever eat hawks? What are the eating habits of humans? Do they ever eat plants? Do they ever eat snakes? It is easy to see that in reality animals can be found at various levels at different times. The level at which an animal exists is determined by opportunity. What a snake eats is a result of what it finds. Only the base layer of the energy pyramid remains predictable.

The idea of a food web is more beneficial to studying the ecosystem. It shows that organisms are interrelated and that what happens to some can affect all.

In the following exercises we will study some of the concepts presented in the reading. Understanding exponential growth, energy pyramids, and food webs are all fundamental to understanding why certain ecosystems are important to human life.

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