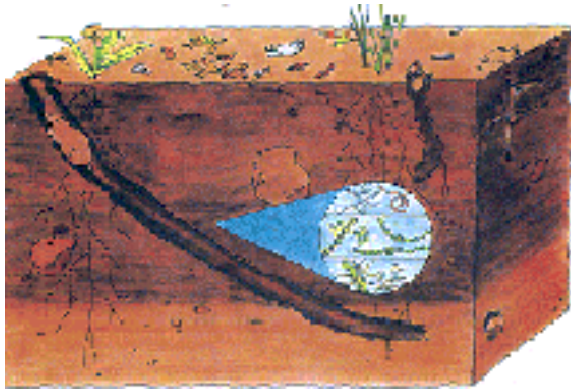
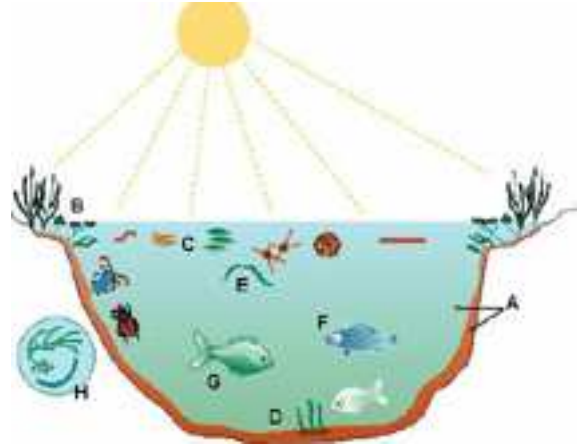


SUSTAINABLE ECOSYSTEMS PRIMER

Most of us have learned that the inter-relatedness among living and non-living elements in an environment can be described through “ecosystems”. An ecosystem can be very small: a pinch of fertile soil may contain over 30,000 protozoa, 50,000 algae, 400,000 fungi, and billions of individual bacteria...or very large: for example thousands of acres of forestland. However, they are ultimately all knit together into a global continuum.



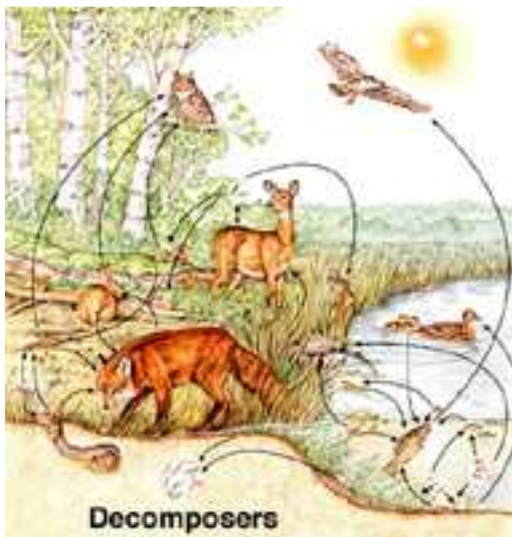
A soil ecosystem



A lake ecosystem



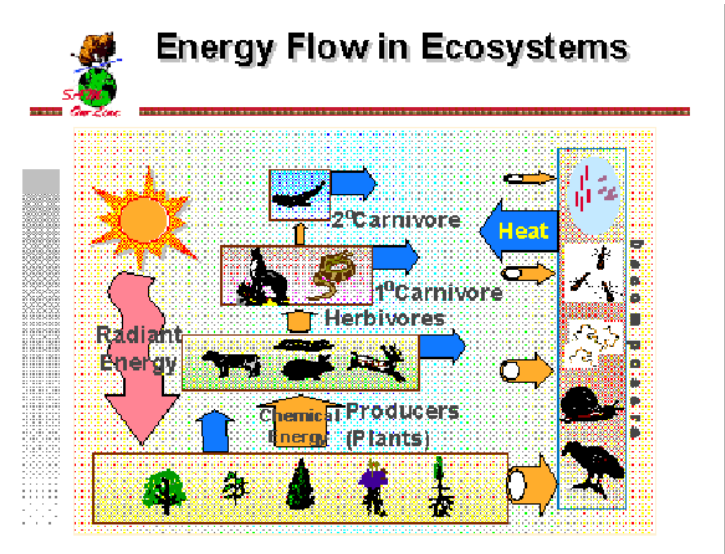
A forest ecosystem



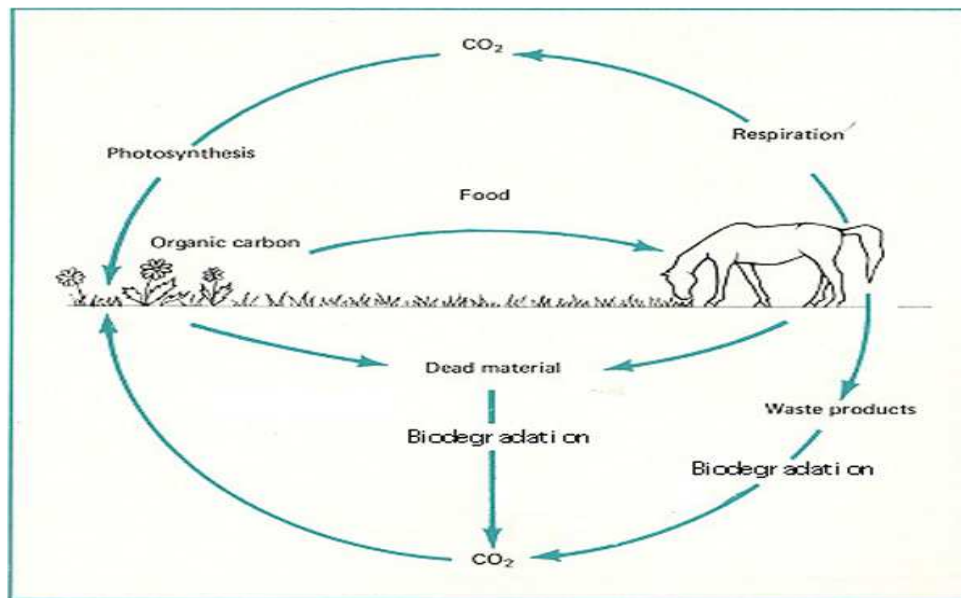
A typical ecosystem food

Within all of these systems there exist food chains, whereby one organism is the predator of certain other organisms, but may also be the prey of another organism. For example, fish may eat small insects in the water, but ducks and owls may eat the fish. When a food source disappears, the chain is disturbed. A predator may find a new food source, so that the disturbance is minor, or there may be no substitute for the lost food, and there is a large disturbance in the functioning of the food chain. Likewise, when a predator is removed, there may be negative consequences. The prey population may expand beyond the capacity of the ecosystem to support it.

The significance of food chains is that they represent the path by which animals obtain their energy. Plants have the ability to convert solar energy into chemical energy. They store the energy in the bonds between the atoms of new plant matter. When animals need energy, they consume the plant matter, break the bonds, and use the energy to construct new cells for themselves. Some of the energy they harvest is stored in the molecules of their cells, but some of it is lost to heat production or cell maintenance. In order for the ecosystem to continue to function, energy must constantly be harvested from the sun.



In addition to energy, materials cycle through ecosystems. Nutrients move from the abiotic environment through organisms and back to the environment in cycles called *biogeochemical cycles*. The food chains and nutrient cycles are intricately woven together, and the system is dynamic. Together, the community of organisms in an ecosystem survives primarily by a combination of matter recycling and a one-way flow of energy. The decomposers complete the cycle: they dispose of wastes and dead organisms by converting them into inorganic materials again.



Carbon cycling in an ecosystem

A generic ecosystem is characterized by the fact that its cycles are self-maintaining. The organisms or chemical reactions that consume certain materials are called the “sinks” for that material, while the regeneration of that material to the ecosystem is done by organisms or chemical reactions called the “sources”. For example, in the figure above, plants are a sink for atmospheric CO₂, while

microorganisms in the soil (often called the decomposers) and the horse are sources of CO₂. The cycles are maintained because the rate of production from the sources is equal to the rate of consumption by the sinks

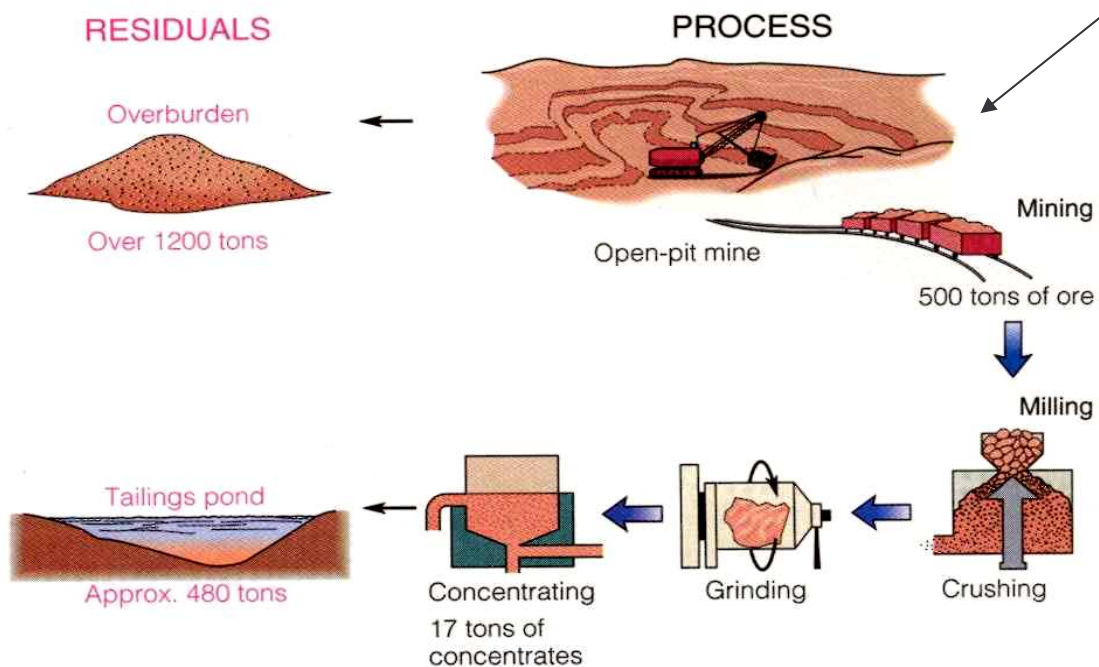
Like all organisms in ecosystems, humans use the environment as a *source* of matter and energy and as a *sink* for matter we discard (sewage, solid waste, CO₂). We are dependent on ecosystems for the source and sink services they provide. In fact, our collective economic systems rely on ecosystems for the provision of materials we sell raw or use in manufacturing and for the degradation of the wastes from these uses. Historically, we have not put any economic value on ecosystems, but in terms of dollars, they are worth a lot to us. One analysis a team from the US, Argentina and the Netherlands estimated that the very systems we take for granted and use for free are worth \$33 trillion/year. If these services were included in most cost-benefit analyses, the outcomes of what activities are “cost effective” would likely look very different.

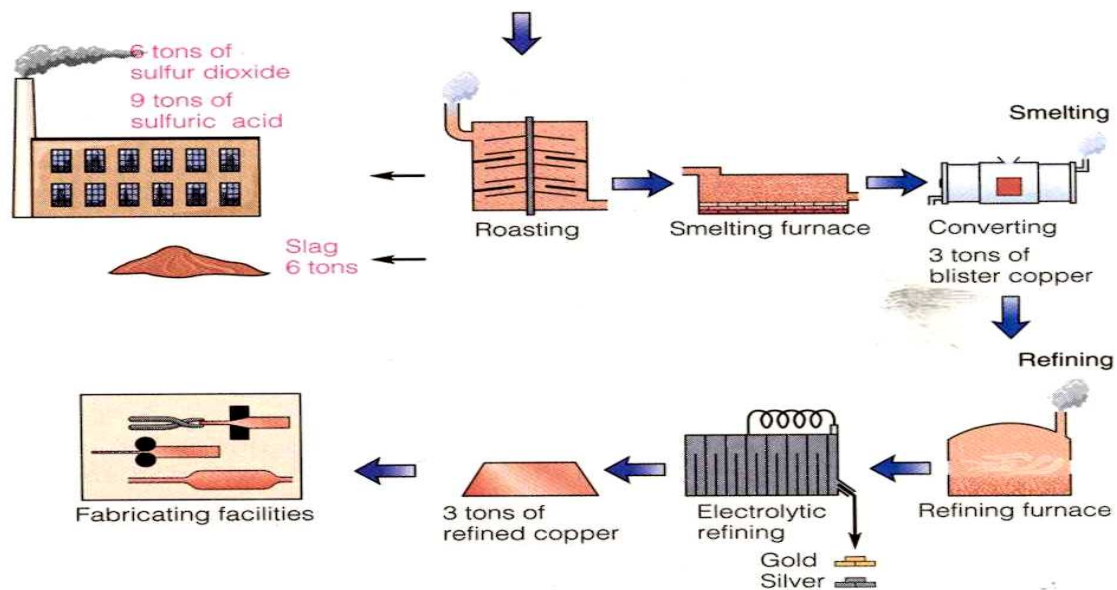
Interestingly, humans are not really necessary for any other organism in the environment to survive. However, ecosystems are necessary for us to survive. If we irreparably damage our ecosystems, we are jeopardizing *ourselves*. A list of ecosystem services to humans includes:

- | | | | |
|------------------|----------------------|---|---|
| Fertile soil | Potable water | Breathable air | Climate regulation |
| Crop Pollination | Waste detoxification | Protection of coastal Shores from erosion | Protection from the sun’s harmful UV rays |

Whether or not \$33 trillion is the right number for the cost of these services isn’t the issue – the larger point is that there is a growing realization that the benefits of proposed development projects must be weighed against the economic and social costs of lost ecosystem services. This takes us beyond “ecology” to economics and social issues.

If humans follow the natural ecosystem pattern, we will remove matter and energy at the same rate that it can be replenished. How *DO* human activities influence the ecosystems we inhabit? How are we doing? Consider the following summary of making copper pipe: It starts here with the mining →





A start with 500 tons of ore yields 3 tons of refined copper, 6 tons of waste slag, 9 tons of sulfuric acid and 6 tons of sulfur dioxide, 480 tons of mine tailings, and 1200 tons of soil that had to be removed to get to the copper. This scenario shows that we are taking material out at a faster rate than it can be returned and cycled through the ecosystem again.

In general terms, humans have not been doing well in keeping up the cycling rates of materials, and our activities have had some pretty negative impacts. One author categorized these impacts as follows:

- We influence ecosystems by removing matter faster than it can be replenished to the nutrient cycles – overharvesting
- We tax the limits of tolerance of species in the ecosystem through chemical pollution, toxic discards, atmosphere changes
- We physically restructure ecosystems by removing habitats (e.g. deforestation, plowing of grasslands, urbanization).
- We influence ecosystems by rapidly and artificially changing the balance of organisms in the system: e.g. kudzu & zebra mussels

Other comprehensive reviews indicate that half of the world’s wetlands were lost last century; fishing fleets are 40 percent larger than the ocean can sustain, and twenty percent of the world’s freshwater fish are extinct, threatened or endangered.¹

¹ World Resources Institute

How much disturbance can an ecosystem tolerate before it can no longer function?

Ecosystems are so complex, even scientists who study them cannot predict how well they will tolerate a disturbance. A healthy ecosystem is one that continues to provide benefits and maintains the capacity to respond to future requirements for benefit provision. Inertia (persistence) describes how well a living system can resist an attempt to disturb or alter it. Resilience is the ability of an ecosystem to restore itself to an original condition after being exposed to an outside disturbance that is not too drastic. For example, redwood forests have high inertia and species diversity. They are hard to alter or destroy. However, if large tracts are cleared or severely degraded, it is almost impossible to restore them –low resilience. Grasslands have low inertia, low species diversity, but high resilience.

Sometimes, the negative impacts of human activities on ecosystems are totally unanticipated:

Consequences of Human Activities



One of the new tenets that many scientists are proposing to prevent irreparable ecosystem damage is called the Precautionary Principle. The Principle maintains that where there are threats of serious or irreversible damage, lack of full scale scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. This principle addresses a problem *central* to understanding and sustaining ecosystems: We are not yet at the point where we can predict all the consequences to humans in the future when we take a current action that has environmental impacts.

Q: Why haven't we heard more about this or done something about this before?

A: Humans came into being after most ecosystems were in operation for hundreds of millions to billions of years. Ecosystem services are so fundamental and large in scale, it is easy to take them for granted. Also, we tend to think of present, short-term consequences. There is some adaptive, survival advantage to being concerned about the present. These issues require long-term, long-view thinking. Ecosystem researchers tell us that these issues require thinking in terms of the community as well as the individual. So we're going to have to start thinking in terms of groups, communities, countries, global welfare.

If we decided to do what it takes, here are some of the challenges:

- Human-initiated disruptions of ecosystems are difficult or impossible to reverse on any time scale relevant to society.
- If awareness is not increased and current trends continue, humanity will drastically alter virtually all of Earth's remaining natural ecosystems within a few decades.

As one ASCE writer put it¹:

We must balance our human desire to live as we please with an increasing set of political, economic, social and environmental constraints. We don't want to destroy or even damage severely valuable natural resources that we rely on to make life on Earth possible and comfortable for us. The problems of the environment and of social and economic equity are interrelated.

¹ASCE Web Page, Robert A. Frosch, National Academy of Engineering