13.6 Pyramid Models

VOCABULARY

biomass
energy pyramid

KEY CONCEPT **Pyramids model the distribution of energy and matter in an ecosystem.**

MAIN IDEAS

- An energy pyramid shows the distribution of energy among trophic levels.
- Other pyramid models illustrate an ecosystem's biomass and distribution of organisms.

Connect to Your World

You have likely seen pictures of the pyramids of Ancient Egypt. Each level of a pyramid requires a larger level below it for support. Similarly, each trophic level requires a larger level beneath it to support its energy needs. Ecologists use the structure of a pyramid as a model to describe trophic levels in ecosystems. Pyramids can represent the general flow of energy in an ecosystem or the mass or number of organisms at each trophic level.

MAIN IDEA

An energy pyramid shows the distribution of energy among trophic levels.

Ecosystems get their energy from sunlight. Sunlight provides the energy for photosynthesis, and that energy flows up the food chain. However, along the way, some of the energy is dissipated, or lost. Producers use energy from sunlight to make food. Herbivores eat the plants, but burn some energy in the process. This energy is given off as heat, and the heat escapes into space. Carnivores then eat the herbivores, but again lose energy as heat. In other words, each level in the food chain contains much less energy than the level below it. Fortunately, the Sun pumps new energy into the system and allows life to continue.

Loss of Available Energy

Each meal that you consume is packed with energy in the form of proteins, fats, and carbohydrates. Your body uses this energy for many purposes such as movement and growth. The majority of the food you consume is used to keep your body at its normal temperature. Your body is very inefficient at converting what you consume into useful energy, so there will always be some material that is not used. Unused material is simply excreted as waste.

Energy in an ecosystem works in much the same way, only on a larger scale. **Biomass** is a measure of the total dry mass of organisms in a given area. When a consumer incorporates the biomass of a producer into its own biomass, a great deal of energy is lost in the process as heat and waste. The conversion of biomass from a producer into biomass of the consumer is inefficient.

Consider the simple producer-to-consumer food chain of grass–prairie dog. Photosynthesis traps energy as carbohydrates, which can be thought of as a high-quality form of energy. A hungry prairie dog then eats the grass.

CONNECT TO

CELLULAR RESPIRATION

As you learned in **Cells and Energy**, the processes of cellular respiration use ATP to maintain your body's functions. While the chemical reactions of metabolism are relatively efficient, there will always be some loss of available energy.

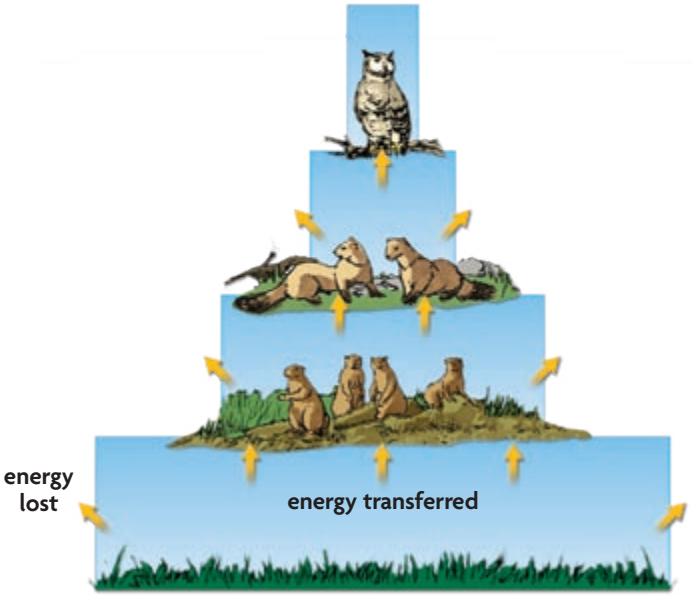


FIGURE 6.1 An energy pyramid illustrates the energy flow between trophic levels in an ecosystem. Between each tier, up to 90 percent of the energy is lost as heat into the atmosphere.

Some of the energy is used by the animal to grow. The remaining energy may be used to fuel cellular respiration or remains undigested. The dissipation, or loss, of energy between trophic levels may be as much as 90 percent, meaning that only 10 percent of the available energy is left to transfer from one trophic level to another.

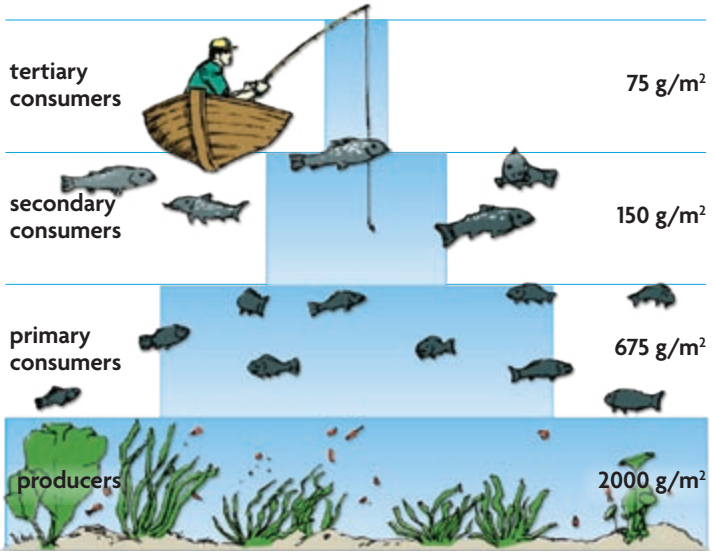
Energy Pyramids

Because energy is lost at each stage of a food chain, the longer the chain is, the more energy is lost overall. The total energy used by producers far exceeds the energy used by the consumers they support. This concept can be illustrated with an energy pyramid. An **energy pyramid** is a diagram that compares energy used by producers, primary consumers, and other trophic levels. The pyramid, therefore, illustrates how available energy is distributed among trophic levels in an ecosystem. The unit of measurement used to describe the amount of energy at each trophic level in an energy pyramid is the kilocalorie (kcal).

A typical energy pyramid has a very large section at the base for the producers, and sections that become progressively smaller above. For example, in a prairie ecosystem, as illustrated in **FIGURE 6.1**, energy flows from grass at the producer level, to prairie dogs at the primary consumer level, to black-footed ferrets at the secondary consumer level, to a great horned owl at the tertiary consumer level.

Connect **Draw an energy pyramid for the desert food chain introduced in Section 4. Use arrows to illustrate the flow of energy.**

FIGURE 6.2 The biomass pyramid depicts the total dry mass of organisms found at each trophic level.



MAIN IDEA

Other pyramid models illustrate an ecosystem's biomass and distribution of organisms.

A biomass pyramid is a diagram that compares the biomass of different trophic levels within an ecosystem. Unlike an energy pyramid, which represents energy use, a biomass pyramid provides a picture of the mass of producers needed to support primary consumers, the mass of primary consumers required to support secondary consumers, and so on.

In a pond ecosystem, such as the one illustrated in **FIGURE 6.2**, a biomass pyramid shows that the total dry mass (given in grams per square meter, or g/m^2) of algae within the pond is far greater than the dry mass of fish. This example illustrates yet again the important role producers play in maintaining a stable ecosystem.

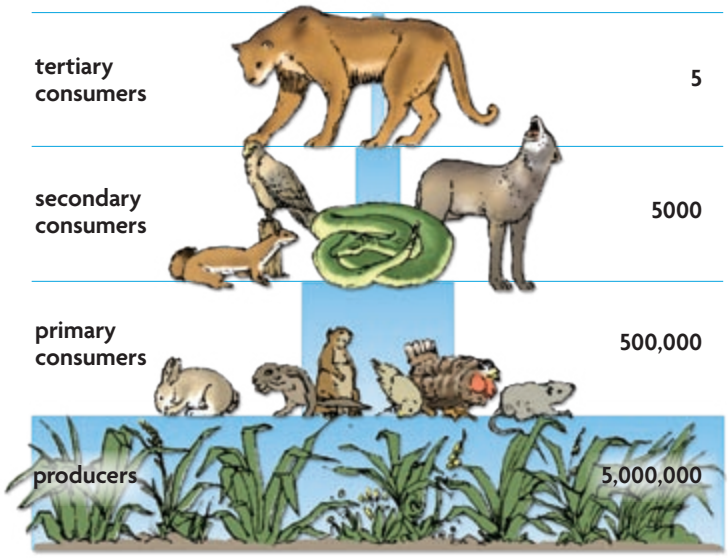


FIGURE 6.3 In a pyramid of numbers, each tier represents the actual number of individual organisms present in each trophic level.

A pyramid of numbers shows the numbers of individual organisms at each trophic level in an ecosystem. For example, a pyramid of numbers depicting a mountainous habitat, as shown in **FIGURE 6.3,** might include organisms such as grasses, snowshoe hares, gophers, coyotes, snakes, and mountain lions. This type of pyramid is particularly effective in showing the vast number of producers required to support even a few top level consumers.

In certain situations, both biomass pyramids and pyramids of numbers may occur in an inverted, or upside down, formation. Consider, for example, a pyramid of numbers based on a single tree. This single tree would be greatly outnumbered by the primary and secondary consumers, such as insects and birds, that live within it. In this case, the upper tiers of the pyramid of numbers would be much larger than the bottom tier representing the single tree.

Apply If a scientist wanted to compare the exact number of organisms at each trophic level within a desert ecosystem, which pyramid model would he or she use?

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REVIEWING MAIN IDEAS

1. How does an **energy pyramid** help to describe energy flow in a food web?
2. What is the difference between a **biomass** pyramid and a pyramid of numbers?

CRITICAL THINKING

3. **Apply** How would you draw a pyramid of numbers for a dog with fleas? What shape would the pyramid take?
4. **Calculate** If each level in a food chain typically loses 90 percent of the energy it takes in, and the producer level uses 1000 kcal of energy, how much of that energy is left after the third trophic level?

CONNECT TO NUTRITION

5. Why is an herbivorous diet more energy efficient than a carnivorous diet? Explain your answer.