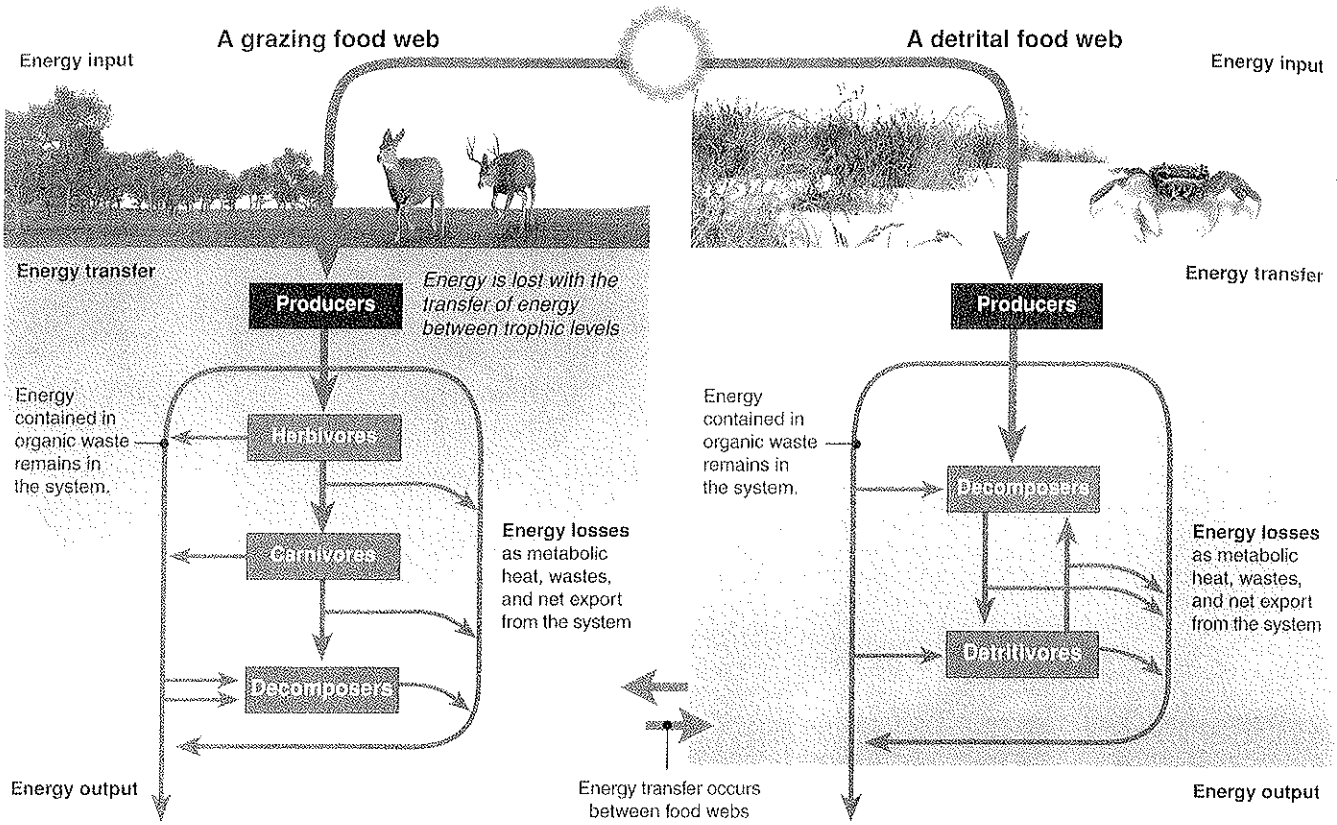
Energy Inputs and Outputs

Light is the initial energy source for almost all ecosystems and photosynthesis is the main route by which energy enters most food chains (but see *Cave Food Webs*). Energy flows through ecosystems in the high energy chemical bonds within **organic matter** and, in accordance with the second law of thermodynamics, is dissipated as it is transferred through trophic levels. In contrast, nutrients move within and between ecosystems in **biogeochemical cycles** involving exchanges between the atmosphere, the Earth's crust, water, and living organisms. Energy flows through trophic levels rather inefficiently, with only 5-20% of usable energy being transferred to the subsequent level. Energy not used for metabolic processes is lost as heat.



1. Discuss the nature of food chains. Include reference to trophic levels, producers, and first and second order consumers:

2. Describe the differences between **producers** and **consumers** with respect to their role in energy transfers:

3. With respect to energy flow, describe a major difference between a detrital and a grazing food web:

4. Distinguish between detritivores and decomposers with respect to how they contribute to nutrient cycling:

Related activities: *Food Chains, Food Webs, Energy Flow in an Ecosystem*

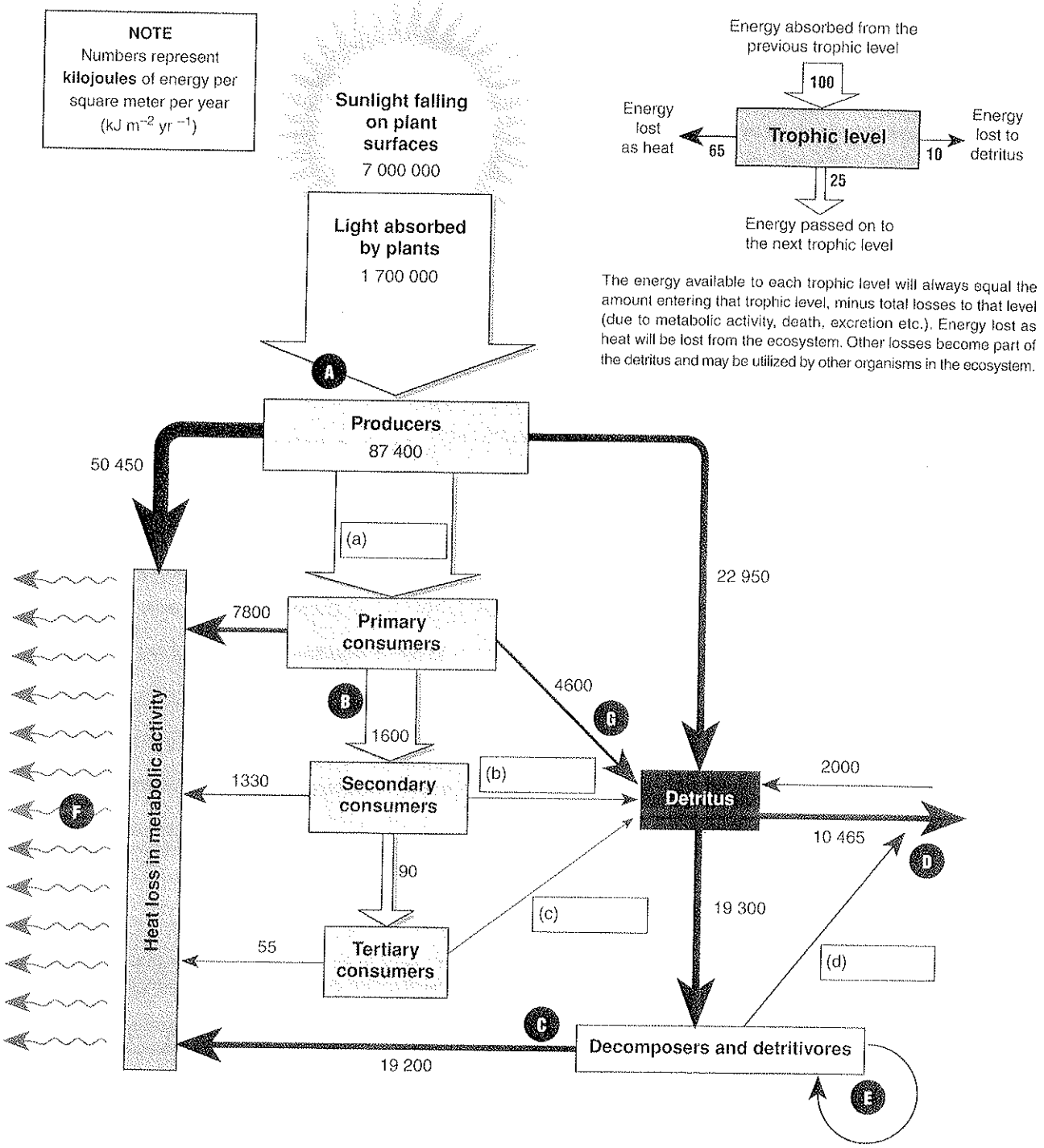
Energy Flow in an Ecosystem

The flow of energy through an ecosystem can be measured and analyzed. It provides some idea as to the energy trapped and passed on at each trophic level. Each trophic level in a food chain or web contains a certain amount of biomass: the dry weight of all organic matter contained in its organisms. Energy stored in biomass is transferred from one trophic level to another (by eating, defecation etc.), with some being lost as low-grade heat energy to the environment in each transfer. Three definitions are useful:

- **Gross primary production**: The total of organic material produced by plants (including that lost to respiration).
- **Net primary production**: The amount of biomass that is available to consumers at subsequent trophic levels.
- **Secondary production**: The amount of biomass at higher trophic levels (consumer production). Production figures are sometimes expressed as rates (**productivity**).

The percentage of energy transferred from one trophic level to the next varies between 5% and 20% and is called the **ecological efficiency** (efficiency of energy transfer). An average figure of 10% is often used. The path of energy flow in an ecosystem depends on its characteristics. In a tropical forest ecosystem, most of the primary production enters the detrital and decomposer food chains. However, in an ocean ecosystem or an intensively grazed pasture more than half the primary production may enter the grazing food chain.

Energy Flow Through an Ecosystem



The energy available to each trophic level will always equal the amount entering that trophic level, minus total losses to that level (due to metabolic activity, death, excretion etc.). Energy lost as heat will be lost from the ecosystem. Other losses become part of the detritus and may be utilized by other organisms in the ecosystem.

1. Study the diagram on the previous page illustrating energy flow through a hypothetical ecosystem. Use the example at the top of the page as a guide to calculate the missing values (a)–(d) in the diagram. Note that the sum of the energy inputs always equals the sum of the energy outputs. Place your answers in the spaces provided on the diagram.

2. Describe the original source of energy that powers this ecosystem: _____

3. Identify the processes that are occurring at the points labeled **A – G** on the diagram:

   A. _____ E. _____

   B. _____ F. _____

   C. _____ G. _____

   D. _____

4. (a) Calculate the percentage of light energy falling on the plants that is absorbed at point A:

   Light absorbed by plants ÷ sunlight falling on plant surfaces x 100 = _____

   (b) Describe what happens to the light energy that is not absorbed: _____

   _____

5. (a) Calculate the percentage of light energy absorbed that is actually converted (fixed) into producer energy:

   Producers ÷ light absorbed by plants x 100 = _____

   (b) State the **amount** of light energy absorbed that is **not** fixed: _____

   (c) Account for the difference between the amount of energy absorbed and the amount actually fixed by producers:

   _____

   _____

6. Of the total amount of energy **fixed** by producers in this ecosystem (at point **A**) calculate:

   (a) The total amount that ended up as metabolic waste heat (in kJ): _____

   (b) The percentage of the energy fixed that ended up as waste heat: _____

7. (a) State the groups for which detritus is an energy source: _____

   (b) Describe by what means detritus could be removed or added to an ecosystem: _____

   _____

8. In certain conditions, detritus will build up in an environment where few (or no) decomposers can exist.

   (a) Describe the consequences of this lack of decomposer activity to the energy flow: _____

   _____

   (b) Add an additional arrow to the diagram on the previous page to illustrate your answer.

   (c) Describe three examples of materials that have resulted from a lack of decomposer activity on detrital material:

   _____

   _____

   _____

9. The **ten percent law** states that the total energy content of a trophic level in an ecosystem is only about one-tenth (or 10%) that of the preceding level. For each of the trophic levels in the diagram on the preceding page, determine the amount of energy passed on to the next trophic level as a percentage:

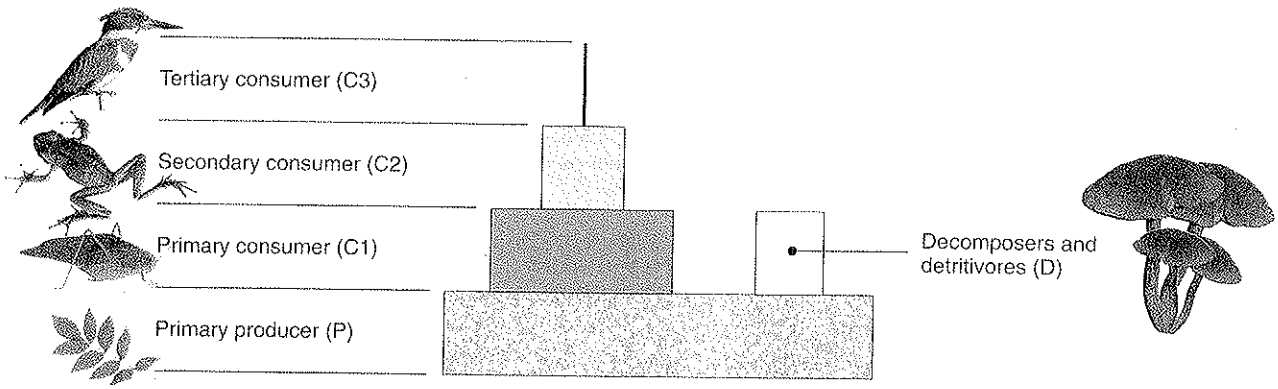
   (a) Producer to primary consumer: _____

   (b) Primary consumer to secondary consumer: _____

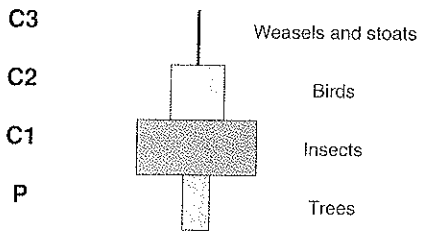
   (c) Secondary consumer to tertiary consumer: _____

Ecological Pyramids

The trophic levels of any ecosystem can be arranged in a pyramid shape. The first trophic level is placed at the bottom and subsequent trophic levels are stacked on top in their 'feeding sequence'. Ecological pyramids can illustrate changes in the **numbers**, **biomass** (weight), or **energy** content of organisms at each level. Each of these three kinds of pyramids tell us something different about the flow of energy and materials between one trophic level and the next. The type of pyramid you choose in order to express information about the ecosystem will depend on what particular features of the ecosystem you are interested in and, of course, the type of data you have collected.

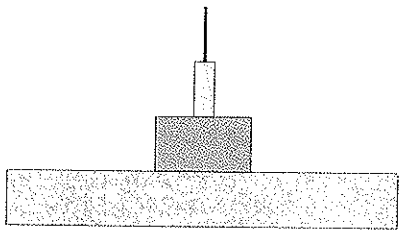


The generalized ecological pyramid pictured above shows a conventional pyramid shape, with a large number (or biomass) of producers forming the base for an increasingly small number (or biomass) of consumers. Decomposers are placed at the level of the primary consumers and off to the side. They may obtain energy from many different trophic levels and so do not fit into the conventional pyramid structure. For any particular ecosystem at any one time (e.g. the forest ecosystem below), the shape of this typical pyramid can vary greatly depending on whether the trophic relationships are expressed as numbers, biomass or energy.



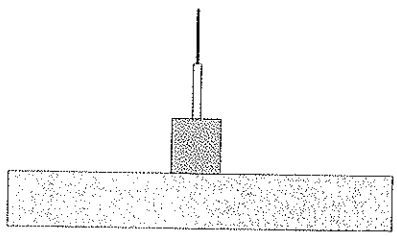
Numbers in a forest community

Pyramids of numbers display the number of individual organisms at each trophic level. The pyramid above has few producers, but they may be of a very large size (e.g. trees). This gives an 'inverted pyramid' although not all pyramids of numbers are like this.



Biomass in a forest community

Biomass pyramids measure the 'weight' of biological material at each trophic level. Water content of organisms varies, so 'dry weight' is often used. Organism size is taken into account, so meaningful comparisons of different trophic levels are possible.



Energy in a forest community

Pyramids of energy are often very similar to biomass pyramids. The energy content at each trophic level is generally comparable to the biomass (i.e. similar amounts of dry biomass tend to have about the same energy content).

1. Describe what the three types of ecological pyramids measure:

   (a) Number pyramid: _____

   (b) Biomass pyramid: _____

   (c) Energy pyramid: _____

2. Explain the advantage of using a biomass or energy pyramid rather than a pyramid of numbers to express the relationship between different trophic levels:

   _____

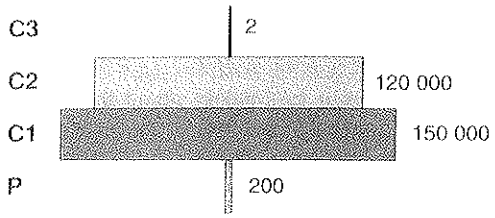
   _____

   _____

3. Explain why it is possible for the forest ecosystem (on the next page) to have very few producers supporting a large number of consumers:

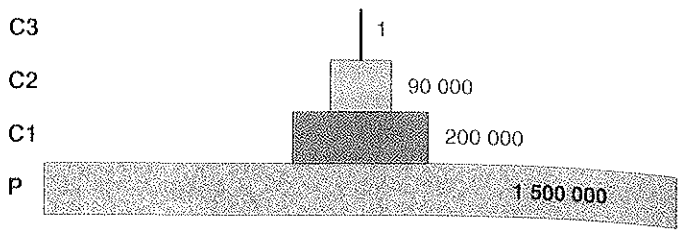
   _____

   _____



Pyramid of numbers: forest community

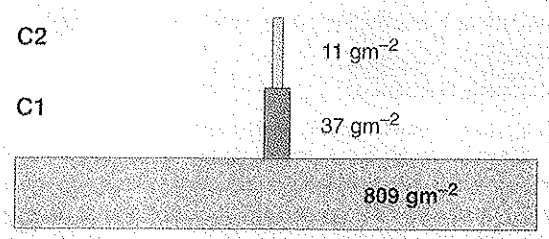
In a forest community a few producers may support a large number of consumers. This is due to the large size of the producers; large trees can support many individual consumer organisms. The example above shows the numbers at each trophic level for an oak forest in England, in an area of 10 m^2.



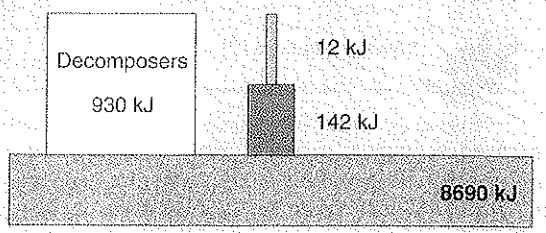
Pyramid of numbers: grassland community

In a grassland community a large number of producers are required to support a much smaller number of consumers. This is due to the small size of the producers. Grass plants can support only a few individual consumer organisms and take time to recover from grazing pressure. The example above shows the numbers at each trophic level for a derelict grassland area (10 m^2) in Michigan, United States.

Pyramids for a Plankton Community



Biomass



Energy

The pyramids of biomass and energy are virtually identical. The two pyramids illustrated here relate to the same hypothetical plankton community. A large biomass of producers supports a smaller biomass of consumers. The energy at each trophic level is reduced with each progressive stage in the food chain. As a general rule, a maximum of 10% of the energy is passed on to the next level in the food chain. The remaining energy is lost due to respiration, waste, and heat.

4. Determine the **energy transfer** between trophic levels in the plankton community example in the above diagram:

   (a) Between producers and the primary consumers: _____

   (b) Between the primary consumers and the secondary consumers: _____

   (c) Explain why the energy passed on from the producer to primary consumers is considerably less than the normally expected 10% occurring in most other communities (describe where the rest of the energy was lost to):

   _____

   _____

   (d) After the producers, which trophic group has the greatest energy content: _____

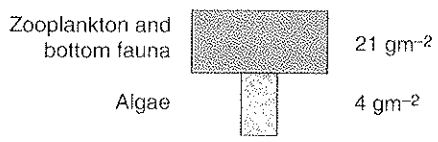
   (e) Give a likely explanation why this is the case: _____

   _____

   _____

An unusual biomass pyramid

The biomass pyramids of some ecosystems appear rather unusual with an inverted shape. The first trophic level has a lower biomass than the second level. What this pyramid does not show is the rate at which the producers (algae) are reproducing in order to support the larger biomass of consumers.



Biomass

5. Give a possible explanation of how a small biomass of producers (algae) can support a larger biomass of consumers (zooplankton):

   _____

   _____

   _____