

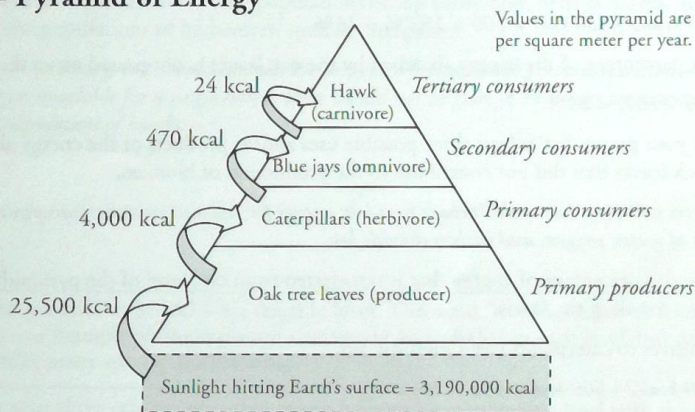
# Ecological Pyramids

How does energy flow through an ecosystem?

## Why?

Every organism in an ecosystem is either eating or being eaten. When cows eat grass, they obtain some of the energy that the grass transferred from the sunlight it absorbed. If cows could carry out photosynthesis, would they have access to more energy than they get as herbivores? Which organisms in an ecosystem require the most energy to sustain life?

## Model 1 – Pyramid of Energy



1. A unit used to measure energy is the **kcal**.
  - a. What is the source of all energy in the pyramid in Model 1?  
*Sunlight.*
  - b. How much energy does this source provide to a square meter of the Earth per year? (Be sure your answer includes units.)  
*3,190,000 kcal per square meter per year.*
2. Label the pyramid levels in Model 1 with the following: primary producers, primary consumers, secondary consumers, and tertiary consumers.  
*See Model 1.*
3. The arrows in Model 1 represent the energy available to the next level of the pyramid.
  - a. What percentage of the source energy from Question 1a is absorbed by the oak leaves in Model 1?  
 $25,500 \text{ kcal} / 3,190,000 \text{ kcal} \times 100 = 0.00799 = 0.8\%$
  - b. By what process do the oak leaves harness this energy?  
*Photosynthesis.*

4. Describe how the consumers in one level of the pyramid obtain energy from the organisms at the previous level of the pyramid.

*By eating the organisms in the previous level.*

5. Refer to Model 1.

- a. How much energy per year do the caterpillars in Model 1 obtain from eating the leaves in a square meter of the oak tree?

*4,000 kcal.*

- b. What percentage of the energy that was originally absorbed by the oak leaves is passed on to the caterpillars?

*$4,000 \text{ kcal} / 25,500 \text{ kcal} \times 100 = 15.7\% = 16\%$ .*

- c. What percentage of the energy absorbed by the oak leaves is not passed on to the caterpillars?

*$100\% - 16\% = 84\%$ .*

- d. With your group, list at least three possible uses and/or products of the energy absorbed by the oak leaves that did not contribute to the production of biomass.

*Answers will vary, but could include heat loss; energy for cellular processes; transpiration; and other forms of water, oxygen, and carbon dioxide loss.*

6. Calculate the percentage of energy that is transferred from one level of the pyramid in Model 1 to another for all of the levels.

- a. Oak leaves to caterpillars (see Question 5b).

*$4,000 \text{ kcal} / 25,500 \text{ kcal} \times 100 = 16\%$ .*

- b. Caterpillars to blue jays.

*$470 \text{ kcal} / 4,000 \text{ kcal} \times 100 = 11.8 = 12\%$ .*

- c. Blue jays to hawk.

*$24 \text{ kcal} / 470 \text{ kcal} \times 100 = 5.1 = 5\%$ .*

7. Calculate the average percentage of energy that is transferred from one level to another using your answers in Question 6. Note that this average percentage transfer is similar for many different types of energy pyramids in nature.

*$16\% + 12\% + 5\% = 33\%$ ;  $33\% / 3 = 11\%$ . (Note that most textbooks cite 10% as the average energy transfer from one trophic level to the next.)*

8. As a group, write a statement that describes the pattern of energy transfer among consumers within a pyramid of energy.


*Answers will vary, but should include the concept that there is an average of a 90% reduction in energy among consumers from one level of the pyramid to the next because only energy related to biomass is passed on, while other sources of energy (metabolism) and those lost to waste are not passed on.*

9. What percentage of the caterpillars' original energy is available to the hawk?

$$24 \text{ kcal} / 4000 \text{ kcal} \times 100 = 0.6\%.$$

10. What percentage of the oak leaves' original energy is available to the hawk?

$$24 \text{ kcal} / 25,500 \text{ kcal} \times 100 = 0.09\%.$$

-  11. Explain why an energy pyramid in any ecosystem typically is limited to four or five levels only.

*Answers will vary, but should include the concept that by the fourth level (leaves → caterpillar → blue jay → hawk), only a tiny fraction of the original energy remains. The biomass would have to increase substantially if this system were to support another trophic level beyond the hawk.*

12. Propose an explanation for why populations of top carnivores, such as hawks, are always smaller than the populations of herbivores, such as caterpillars.

*Answers will vary, but should include the concept reflected in the previous question—since so little energy is available for a single hawk, there would not be enough energy in an ecosystem to support a large population of hawks.*



## Read This!

Each level in the pyramid in Model 1 is a **trophic level**. The word “trophic” refers to feeding or nutrition. Model 1 shows one example of one organism that would be included in each level, but each level in an ecosystem includes many species of organisms.

13. List at least three other species that might be found in the trophic level with the oak trees.

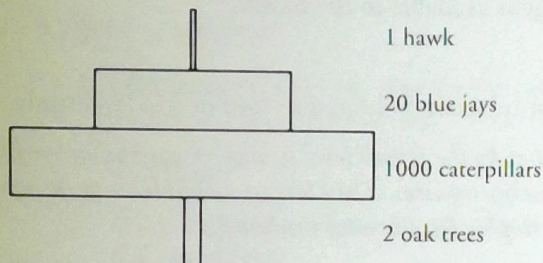
*Answers will vary. Students should suggest any photosynthesizing organism such as other trees, flowers, grasses, moss, etc.*

14. List at least three other species that might be found in the trophic level with the blue jays.

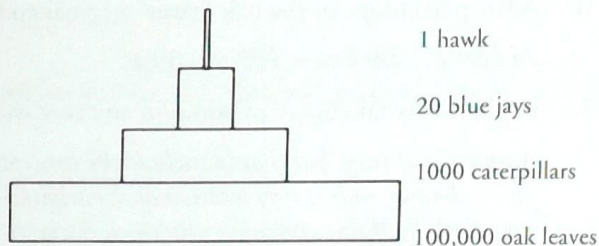
*Answers will vary. Students should suggest any secondary consumers (omnivores and carnivores that eat herbivores).*

## Model 2 – Pyramid of Numbers

Pyramid A



Pyramid B



15. Compare and contrast the two pyramids in Model 2. List at least two similarities and two differences.

*Both have the same organisms in the same trophic levels. Both have the same number of trophic levels. Pyramid A has 2 oak trees in the first trophic level while Pyramid B has 100,000 oak leaves in the first trophic level. The shape of the pyramids is different.*

16. How does the number of organisms change as you move up the levels in Pyramid A compared to Pyramid B?

*In Pyramid B, the number of organisms decreases from one level to the next. In Pyramid A, the first level has a small number of organisms and the remaining levels follow the same pattern as in Pyramid A.*

17. Are the “producers” levels in the two pyramids in Model 2 referring to the same organisms or different organisms? Explain.

*The oak tree is the same, but the caterpillars eat only the oak tree leaves.*

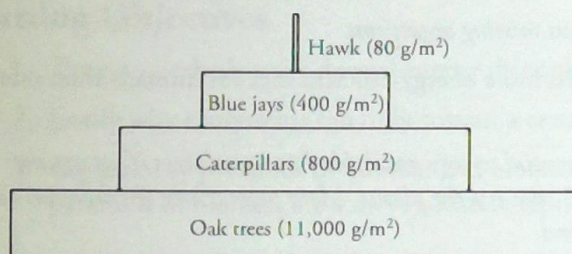
18. Which of the two pyramids in Model 2 gives a more accurate account of what occurs in this ecosystem? Use complete sentences to explain your reasoning.

*The producers in Pyramid A are two oak trees, but the actual trophic source on these two producers is tens of thousands of leaves. Only the leaves are eaten by the caterpillars, so the number of leaves is much more relevant than the number of trees.*

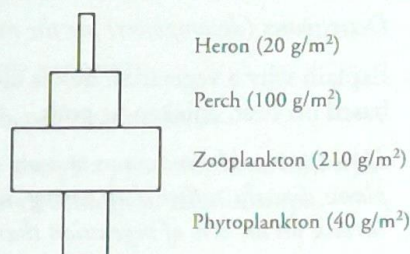


## Model 3 – Pyramid of Biomass

Pyramid X



Pyramid Y



19. Biomass is measured as grams of dry mass within an area. What is the mass of the oak trees in Pyramid X of Model 3?  
*11,000 g/m².*
20. What is the mass of the phytoplankton in Pyramid Y of Model 3?  
*40 g/m².*
21. Refer to Model 3.
- Identify the trend in biomass as you move up the trophic levels in Pyramid X.  
*The biomass decreases steadily.*
  - Is the trend in biomass in Pyramid X the same as seen in Pyramid Y? Explain your answer.  
*No. The mass of the producers is smaller than the mass of primary consumers. After that level, the biomass of each trophic level decreases steadily.*

### Read This!

Phytoplankton are microscopic aquatic organisms that are quickly consumed by microscopic animals (zooplankton). Because they are eaten so quickly there is a need for the phytoplankton to reproduce rapidly for survival.

22. Explain why the Pyramid Y ecosystem can exist with a smaller biomass at the producer level.  
*Phytoplankton reproduce rapidly, so they can sustain a large number of primary consumers.*



23. Use examples from the previous models to explain the advantage of using a pyramid of energy or biomass rather than a pyramid of numbers to explain the relationship between different trophic levels.

*Answers will vary, but should stress that biomass varies drastically with different organisms (e.g., oak tree vs. caterpillar), and the important issue is not the number of organisms, but how much of that biomass is used as food. Another important issue is the speed with which food sources grow and reproduce.*

## Extension Questions

24. What type of organisms are missing from all of the trophic pyramids shown in Models 1–3?

*Detritivores (decomposers) are the most obvious missing organisms.*

25. Explain why a vegetarian diet is considered a more energy-efficient diet for humans than one based on beef, chicken or pork.

*Humans would have access to more of the potential energy available from producers if we ate the plants directly, rather than eating the animals that eat the plants. More vegetarians (herbivores) could survive on an acre of vegetation than carnivores.*