Teacher Tune-up

Quick Content Refresher for Busy Professionals

Food Webs and Trophic Levels

What are producers, consumers, and decomposers?

Ecologists use various models to understand energy transfers among species. In terms of how energy gets captured and passed around in the form of food, species can play three broad roles: producers, consumers, and decomposers.

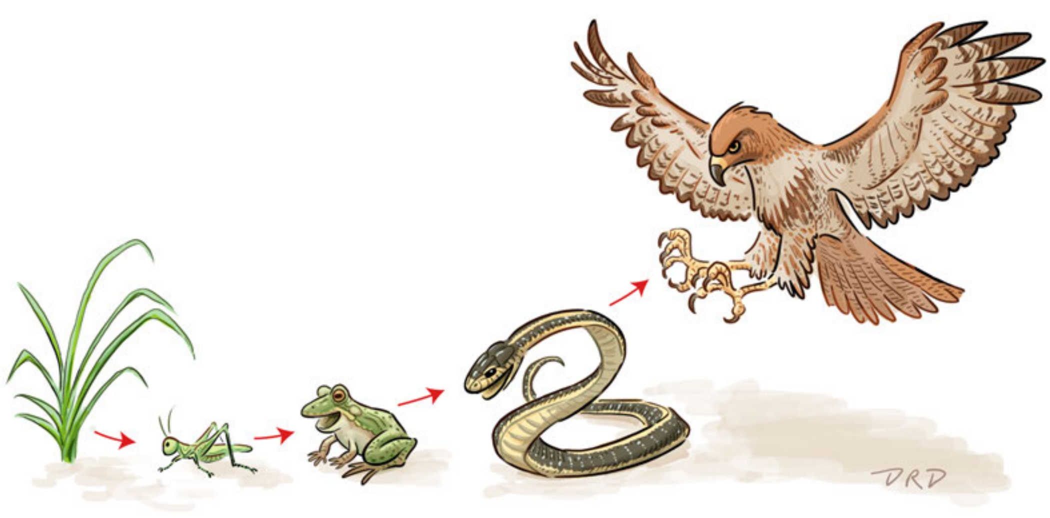
Think plants, animals, and mushrooms. Well, okay, it's a little more complicated than that.

Producers make their own food, usually through photosynthesis (but sometimes through chemosynthesis, as in the case of prokaryotic producers harnessing energy from hot springs in the sunless depths of the ocean). Producers are autotrophs, from "auto," meaning self, and "troph," signifying food or nutrition. By contrast, consumers feed on other organisms, whether producers, other consumers, or decomposers. Decomposers feed on the dead organic matter of producers, consumers, and other decomposers. Consumers and decomposers are both heterotrophs, meaning they get their food from other organisms instead of making it from scratch like autotrophs.

With these three general roles in mind, let's consider how their interactions determine the flow of energy in an ecosystem.

What are food chains?

The food chain is one simple, linear model that demonstrates how energy flows through an ecological community. A food chain starts with a producer and then proceeds through a sequence of consumers, each of which eats the creature ahead of it in the chain. For example, here's an illustration of a food chain where grass produces chemical energy by photosynthesis, then grasshoppers consume the grass, then frogs consume the grasshoppers, then snakes consume the frogs, and finally hawks consume the snakes.



Also, all along the line, decomposers like bacteria and fungi feed on excreted and dead matter from the various links in the chain.

From this concrete sequence of creatures, we can abstract some important ideas that apply to other food chains and govern the transfer of energy in many different ecosystems.

What are trophic levels?

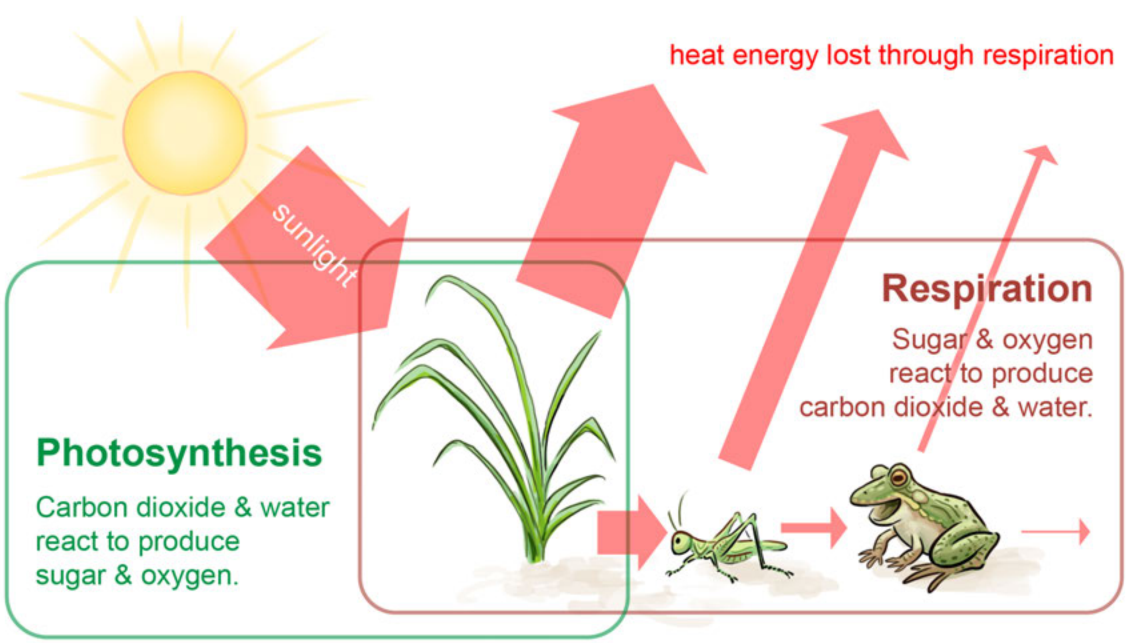
Each species in a food chain represents a so-called trophic level—a feeding level—in an ecosystem. Different ecosystems possess a common pattern of trophic levels, with more energy available at lower levels, and available energy decreasing as you proceed to higher levels.

Consider our food chain above. The illustration shows one organism per link in the chain, a representation that leaves out the number of organisms at each trophic level. In the real world, several acres of grass plants could support a respectable crowd of grasshoppers, a smaller number of frogs, an even smaller number of snakes, and just a few hawks. What's more, the other species in an ecosystem that share the trophic levels of the organisms in our representative chain have a similar population distribution. Along with the grasses, there may be tons of other plants. Along with the grasshoppers, there are likely to be many other herbivores. Along with the frogs, there may be some shrews and other primary carnivores. Along with the snakes, a few weasels and other secondary carnivores. And along with the hawks, an owl or two, maybe a bobcat or coyote on a good day.

So our linear chain is actually more like a pyramid, narrowing as we move toward the predators at the apex. And it isn't just the number of individual organisms that diminishes with each higher trophic level. The total amount of chemical potential energy bound up in their collective bodies also diminishes with each level. In short, the higher you go through the trophic levels, the less there is to eat.

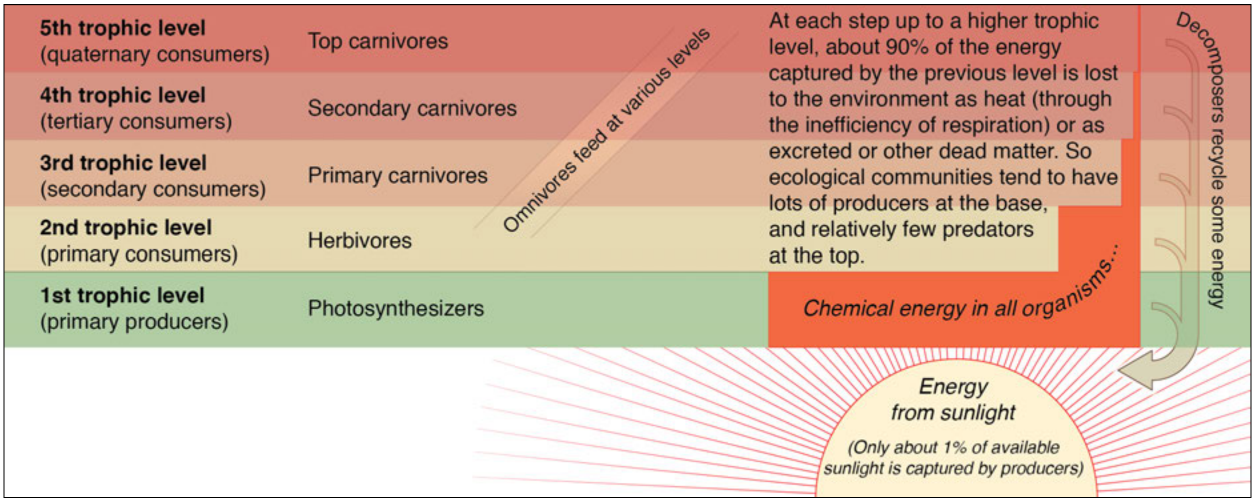
The energy that the plants and other producers stockpile at the first step in the chain gets gradually lost along the way, until only a few top predators are supportable at the far end of each food chain. Why is that?

Well, follow the energy. Organisms are using energy all the time, to grow, repair themselves, move, and reproduce. Once the producers have captured solar energy through photosynthesis and made it available to themselves and their consumers in the form of sugar molecules, both producers and consumers access some of this energy through cellular respiration. And it turns out respiration is not all that efficient. As a general rule, only about ten percent of the chemical potential energy an organism acquires is incorporated into its own body and becomes available as food to whatever creature comes next in the food chain. The other 90 percent is lost to the



environment in the form of heat (and also of excreted or dead material that decomposers feed on). That inefficiency applies to every link in the food chain.

The loss of energy at each step where organisms consume each other applies not only within particular food chains, but across the ecological community as a whole. That is to say, it applies not just to the step from grass to grasshoppers, but from all plants to all herbivores. It applies not just to the step from grasshoppers to frogs, but from all herbivores to all primary carnivores, and so on. It applies at each step up to a higher trophic level.



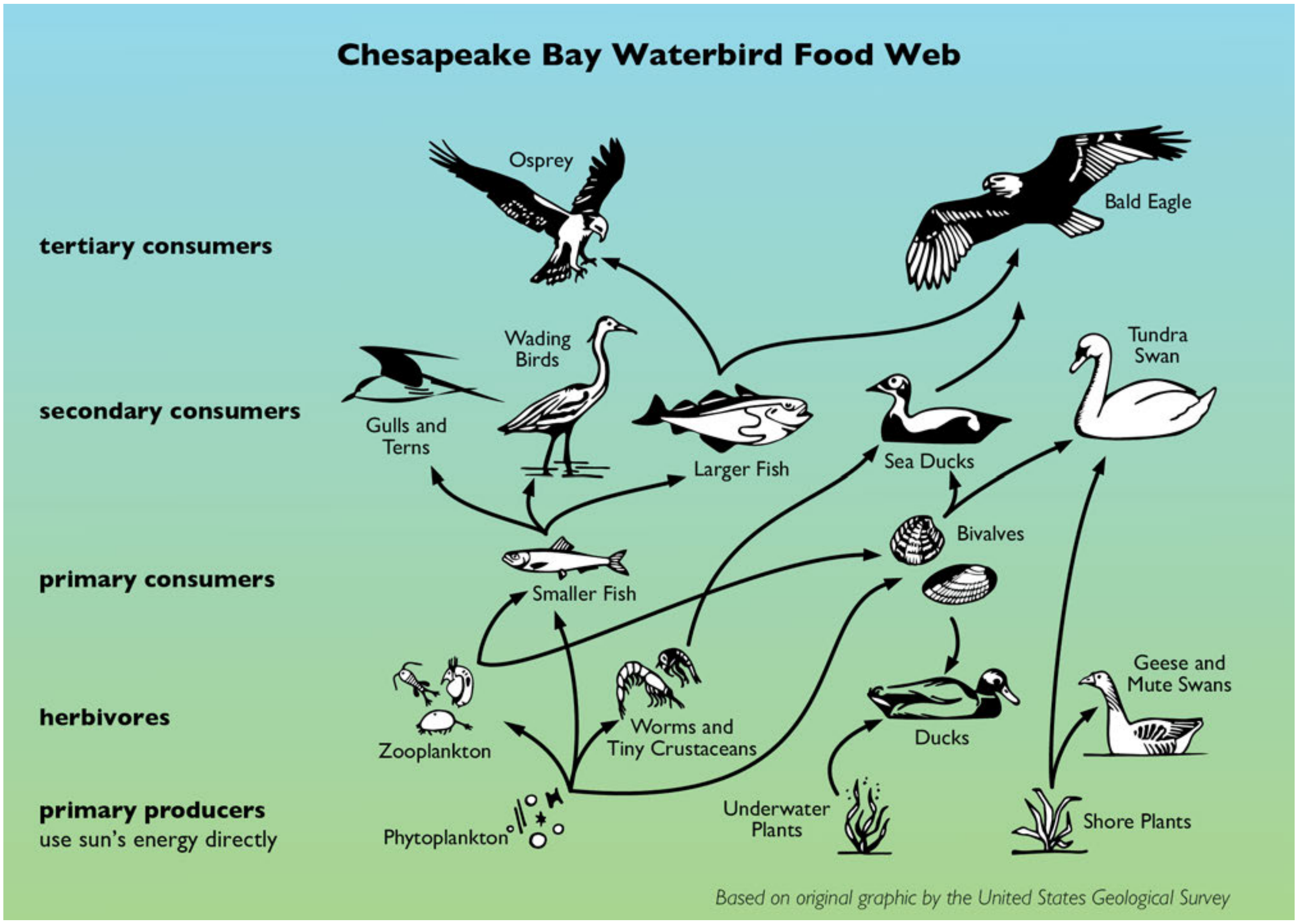
Because the total amount of chemical energy available to be eaten tapers off so quickly as it moves up through the trophic levels, most ecosystems can only support four or five trophic levels, with fewer and fewer individuals at each higher level. The trophic economy being what it is, it just isn't feasible for there to be a super-duper predator—a dragon, perhaps—that makes its living by eating lions and tigers and bears, oh my.

Speaking of bears, they and other omnivores dine at various trophic levels, and don't necessarily fit as neatly into this scheme as strict carnivores and herbivores. Bears might be classified as top carnivores because they generally don't have natural predators, and they do sometimes prey on fairly large animals; but they also eat insects and berries. Raccoons and rats are smaller, less powerful omnivores belonging somewhere lower on the trophic scale. Omnivores present just one example of how nature doesn't always conform perfectly to simplified trophic models. Consider as well the Venus flytrap, a photosynthetic producer that moonlights as a carnivore.

What are food webs?

A food chain climbing up through the trophic levels of an ecological community is a useful but relatively abstract representation of what is going on in that community. The pathways of predation sometimes branch, zigzag, or skip a level. Some consumers are generalists, while others specialize in catching certain prey. To give a more nuanced representation of feeding relationships than a food chain shows, ecologists sometimes use food webs.

Like food chains, food webs generally use arrows to show who's eating whom. The vertical placement of species in a food web usually corresponds at least roughly to trophic level, with producers at the bottom of the image and top predators at the top. Food webs help show the complex routes by which energy propagates through ecological communities.



How does community structure help explain the vulnerabilities of ecological communities?

Thinking in terms of food chains and webs helps clarify some of the things that can go awry in an ecological community.

The collapse of any population in an ecosystem (due to disease, overhunting, or other causes) can disrupt the ecosystem severely because each trophic level depends on the ones below it. It's easy to see how the loss of primary producers or herbivores can create a crisis for hungry consumers at higher trophic levels. But the damage from loss of species does not flow in only one direction. Though it might not seem intuitively obvious, the loss of predators can be bad for creatures at lower trophic levels.

Sea otters, for example, are predators vital to the health of the kelp forests of the Pacific Northwest. When the otters were hunted nearly to extinction in the nineteenth century for their fur, many kelp forests were destroyed. Why? Sea otters feed on urchins that feed on kelp. When the otters are missing from the food web, the urchin population explodes and the kelp is destroyed. The kelp forest provides food and shelter to many different organisms in near-shore marine environments. Without otters present to keep the urchin population in balance, the whole system breaks down, harming hundreds of other species. As populations of protected sea otters rose in the twentieth century, many kelp forests rebounded, restoring habitats for a multitude of organisms.

Because otters play a special role in maintaining the stability of their ecological community, they are often called a keystone species. There are other keystone species, many of them predators but some of them herbivores (like the snowshoe rabbits that comprise an outsized portion of the second trophic level of the arctic food web) or plants (like the saguaro cactuses of the Sonoran desert, which provide water and habitat to many other species).

Pollinators (like hummingbirds in the Sonoran desert) and habitat modifiers (like dam-building beavers and tree-suppressing, savannah-promoting elephants) can be keystone species.

Removing species, especially keystone species, from an ecological community can cause trouble. Another kind of trouble comes from adding invasive non-native species to a community.

Yellow star thistle, which is limited by insectile consumers in its native Mediterranean range, spreads like wildfire in the American west, where it has no natural consumers. Unchecked, it outcompetes native plants, disrupting and transforming the environments it invades. Similarly, brown tree snakes (from Australia, Papua New Guinea, and eastern Indonesia) that were accidentally released on the island of Guam have devastated native bird populations there, because the snakes have no natural predators on Guam. Not all non-native species cause such trouble. Those that are invasive thrive partly by finding an energy source in the community they invade, while not being a good energy source for any of the native species. Invasive non-native species divert the established flow of energy, starving competitors at their own trophic level and/or cutting off resources for the levels above them. If allowed to propagate uncontrolled, invasive species eventually find themselves in a new ecological equilibrium. But the biodiversity of the habitats they colonize is liable to be decimated along the way.

Tags: food web, food chain, trophic level, ecological community, consumers, producers, decomposers, photosynthesis, respiration, keystone species, ecosystem, energy