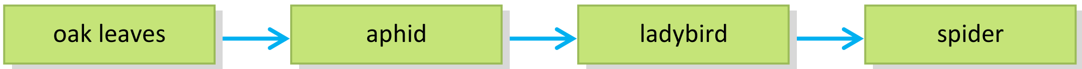
7.2 Energy transfer

Energy transfer within an ecosystem, and measuring and improving productivity and transfer

Transfer of energy between trophic levels

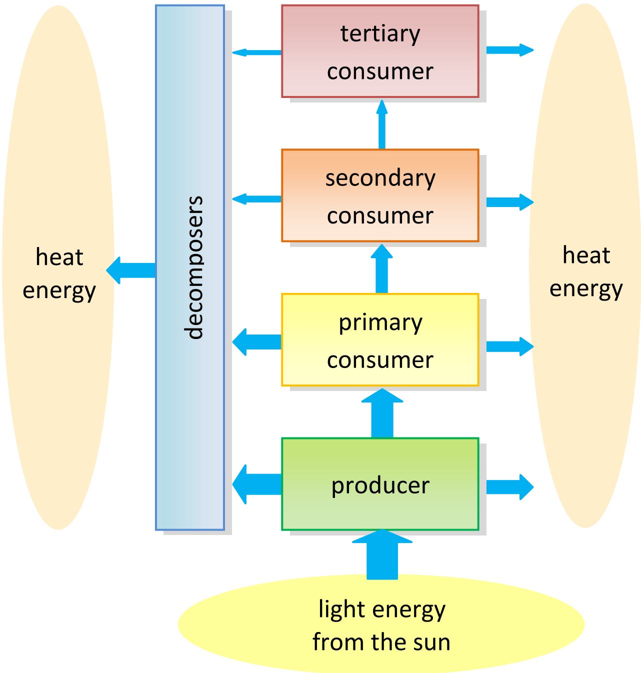
A food chain, like the simple example shown below, shows the transfer of **energy** from one living organism to another, through levels of the food chain, called **trophic levels**. A trophic level is a level at which an organism feeds, but it is important to note that an organism may occupy more than one trophic level.



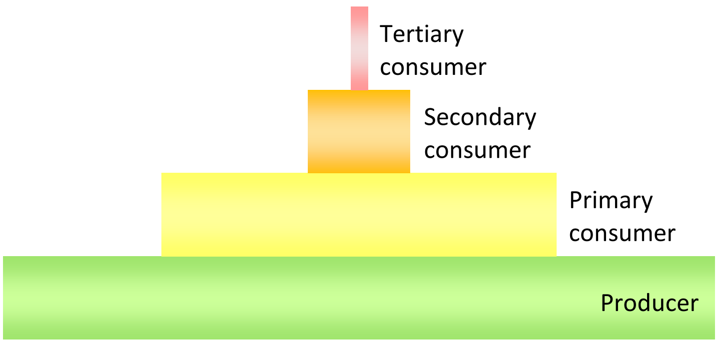
Within an ecosystem, living organisms are usually members of more than one food chain and often feed at different trophic levels in different food chains, producing a *food web*. The arrows in food chains and food webs show the direction of the flow of energy, rather than what is eating what.

Efficiency of energy transfer

At each trophic level, some energy is lost from a food chain and therefore is unavailable for the organism at the next trophic level. This is because at each trophic level, organisms are constantly performing life processes, such as respiration which releases energy from organic molecules such as glucose, which is converted to heat energy. Also, energy remains stored in dead organisms and waste materials, which is only available to the decomposers, such as fungi and bacteria.



For these reasons, there is less energy available to sustain living tissue at higher levels of the food chain, so less can be kept alive. When organisms in the food chain are of the same size, therefore, there are going to be fewer organisms at the higher levels. Ecologists can draw **pyramids of numbers** to represent this idea. The area in each bar is proportional to the number of individuals in that ecosystem.



Although a *pyramid of numbers* shows us the proportionate number of individuals of members of levels in the food chain, it is no measure of energy transfer **efficiency**. A **pyramid of biomass** can be drawn to show the amount of living tissue at each level of the chain, where the bars are proportional to the amount of *dry mass* of all the organisms at that trophic level.

Alternatively, a **pyramid of energy** can be used, as sometimes pyramids of biomass are still not very accurate – as different organisms within the same trophic level may release different amounts of energy per unit mass. A pyramid of energy involves burning the organisms, or samples of them, from the level in something called a **bomb calorimeter** and working how much heat energy is released per gram that is burnt. This is calculated from the temperature rise of a known amount of water inside the bomb calorimeter.

Productivity

Even pyramids of energy have their limitations. They only take a snapshot of an ecosystem at one moment in time, and because population sizes fluctuate over time, this may provide a distorted idea of transfer of energy efficiency. As such, ecologists like to take a look at the *rate* at which energy passes through each trophic level, drawing a pyramid of energy flow. This rate of energy flow is called **productivity**.

Productivity gives an idea of how much energy is available to the organisms at a particular trophic level, per unit area (usually one square metre), in a given amount of time (usually one year) – measured usually in $MJ/m^2/year$.

At the base of the food chain, the productivity of the plants is called the **primary productivity**. The **gross primary productivity** is the rate at which plants convert light energy into chemical energy. However, because plants lose energy through respiration, less energy is available to the primary consumer (on the next level) – and this remaining amount of energy is called the **net primary productivity**.

Improving primary productivity

When scientists measure net primary productivity (NPP), they find actual levels are between 1% and 3% of total light energy from the sun (of the 1% of sunlight energy which reaches Earth that is used for photosynthesis). With manipulation techniques, we have found ways of improving net primary productivity for agriculture. These techniques are aimed to reduce energy loss, and give bigger crop yields. Manipulation techniques include:

- Light levels can limit photosynthesis efficiency, and therefore NPP and so some crops are planted early to provide a longer growing season, whilst others (more valuable crops usually) may be grown under *light banks*
- As water levels are important (water is needed for photosynthesis), drought-resistant plants have been bred for places which are prone to drought where irrigation is more difficult
- Temperature can affect the rate of plant growth, which is why some crops are grown in controlled **greenhouses**
- A lack of nutrients available to the crops can inhibit their growth, which is why some crops are rotated: including a nitrogen-fixing plant in the cycle, for example, can replenish nitrates in the soil which are taken up by other crops
- The development of **pesticides** such as insecticides and weedkillers have increased productivity

Improving secondary productivity

The transfer of energy from the producers to the primary consumers is inefficient: the consumers make very little use of the plants' biomass (as some plants die; consumers don't eat every part of the plant; and consumers cannot digest every part of the bits they do eat, they are simply egested). Of the energy that is taken in, most is used to keep the animal alive, so even that of what is used, only little remains to be stored for growth. However, it is still possible for humans to manipulate energy transfer from producer to consumer:

- Younger animals invest more of their energy intake into growth than adult animals, and so animals are harvested when they are younger to prevent drastic energy loss from the chain
- In the past some animals have been treated with steroids to encourage growth, but this practice is now outlawed
- Selective breeding producing animals with favourable traits, such as breeds with faster rates of growth
- Animals may be treated with antibiotics to prevent energy loss wasted on pathogens and parasites