C4.2 Transfers of Energy & Matter

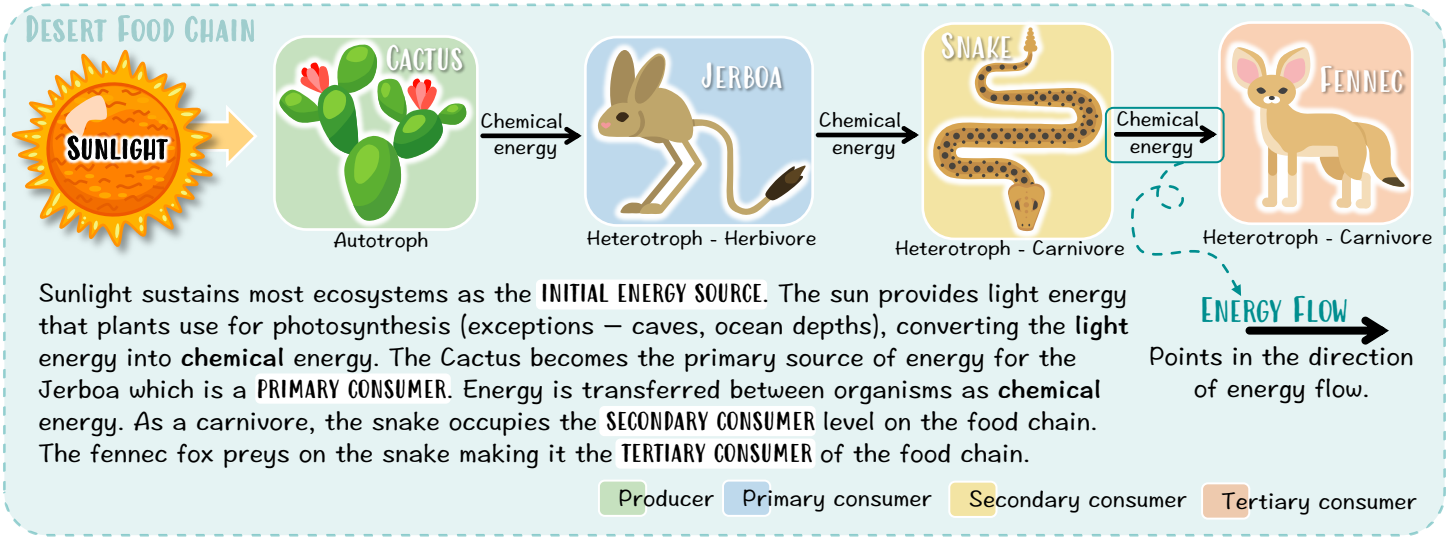
I ENERGY FLOW

Energy is one of the most important entities that allows the existence of life in our universe. Energy can exist in various forms including **light**, **chemical** and **heat** energy. Energy cannot be created nor destroyed; it can merely be converted to another form. In this chapter we will explore how energy flows through an ecosystem.

A FOOD CHAINS & FOOD WEBS

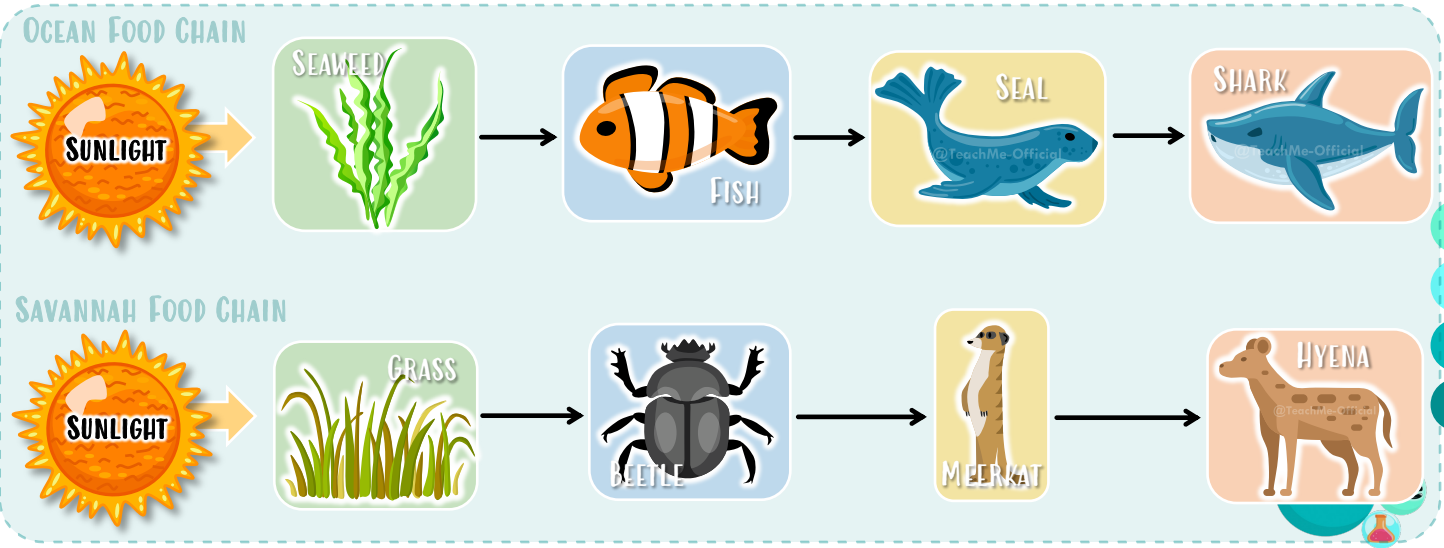
Food Chains

A food chain is a sequence of organisms showing the feeding relationships and energy flow between the different species. The position of a particular organism within the food chain is called a **trophic level**.



Sunlight sustains most ecosystems as the INITIAL ENERGY SOURCE. The sun provides light energy that plants use for photosynthesis (exceptions – caves, ocean depths), converting the **light** energy into **chemical** energy. The Cactus becomes the primary source of energy for the Jerboa which is a PRIMARY CONSUMER. Energy is transferred between organisms as **chemical** energy. As a carnivore, the snake occupies the SECONDARY CONSUMER level on the food chain. The fennec fox preys on the snake making it the TERTIARY CONSUMER of the food chain.

Each unique environment has different organisms inhabiting it, forming different food chains:



C4.2 Transfers of Energy & Matter

Feeding in different organisms

Different organisms get fed in various ways ranging from synthesizing their own food from sunlight to ingesting other organisms such as plants or other animals. Two main types of feeding include **AUTOTROPHS** and **HETEROTROPHS**.

AUTOTROPHS (Self + Feeding) — Also known as producers, they are organisms that can synthesize organic* matter (food) from inorganic* matter. Two types of autotrophs as discussed below.

(1) Photoautotrophs - Generating cellular (chemical) energy using sunlight (photosynthesis).

Ex. [Plants] Trees, algae. [Some Bacteria] cyanobacteria.

$CO_2 + H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + O_2$

Photosynthesis process in section C1.3

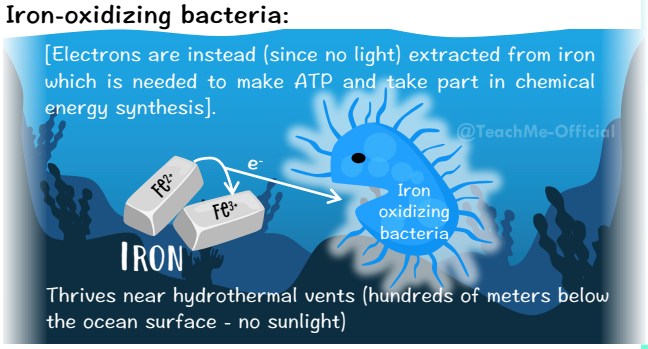
[Light energy splits water, releasing electrons, which are needed to make ATP, and take part in photosynthesis.]

(2) Chemoautotrophs - Generating cellular energy without the help of sunlight (chemosynthesis).

→ Usually associated with ARCHEA & BACTERIA

*Ex. **Iron-oxidizing bacteria**, sulfur-oxidizing bacteria, nitrogen-oxidizing bacteria.*

Iron-oxidizing bacteria:



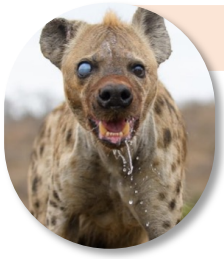
– ORGANIC MATTER –

Contain C-H bonds.
Includes the 4 macromolecules
The 4 macromolecules

- CARBOHYDRATES
- NUCLEIC ACIDS
- LIPIDS
- PROTEINS

– INORGANIC MATTER –

Do not contain C-H bonds but may contain carbon. *E.g., water, rocks, minerals, CO_2, H_2S etc.*



HETEROTROPHS (Other + Feeding) — Also known as consumers, they are organisms that obtain food by consuming organic* matter from other organisms.

They ingest and break down organic matter into their basic components (proteins → amino acids, lipids → fatty acids, and DNA/RNA → nucleotides). Then they can reassemble them into their own proteins etc... (Assimilation).

Categories:
(1) **Herbivores** – eat plants
(2) **Carnivores** – eat meat
(3) **Omnivores** – eat both

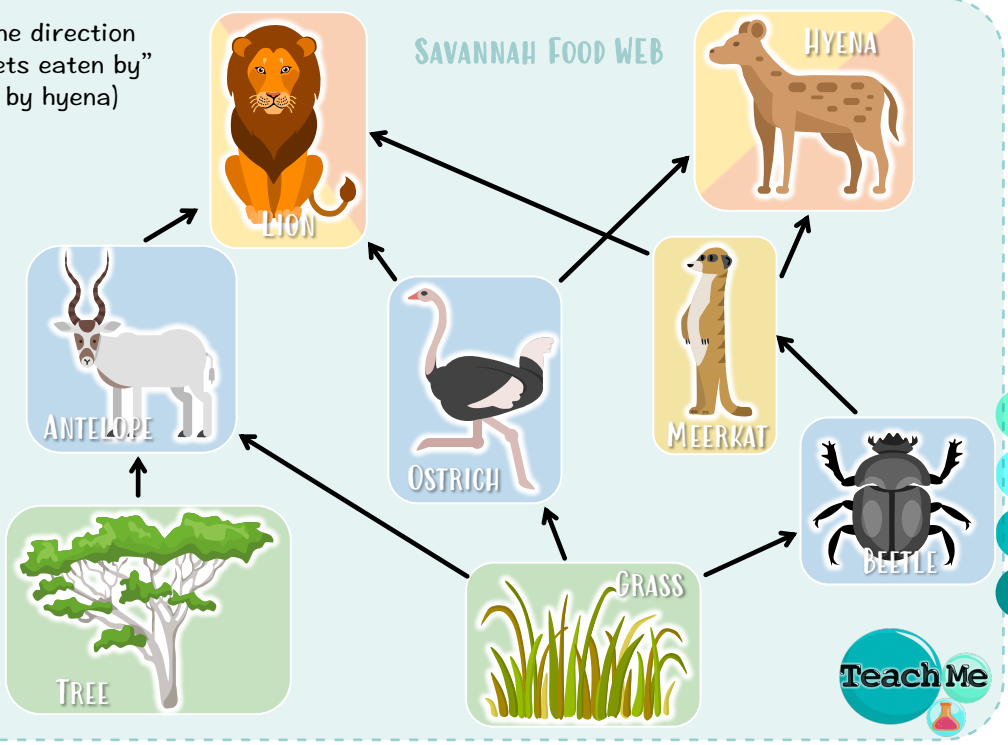
(4) **Detritivores** – decomposer
(5) **Saprotrophs** – decomposer

→ PAGE 3

Food Webs

The linkage of food chains to form a more REALISTIC picture of feeding patterns in a habitat.

You can remember the direction of the arrows as "gets eaten by" (meerkat gets eaten by hyena)



NOTICE!

Organisms can have variation in their trophic level. For example, the lion is the secondary consumer in the

"tree → antelope → lion"

food chain. BUT is the tertiary consumer in the

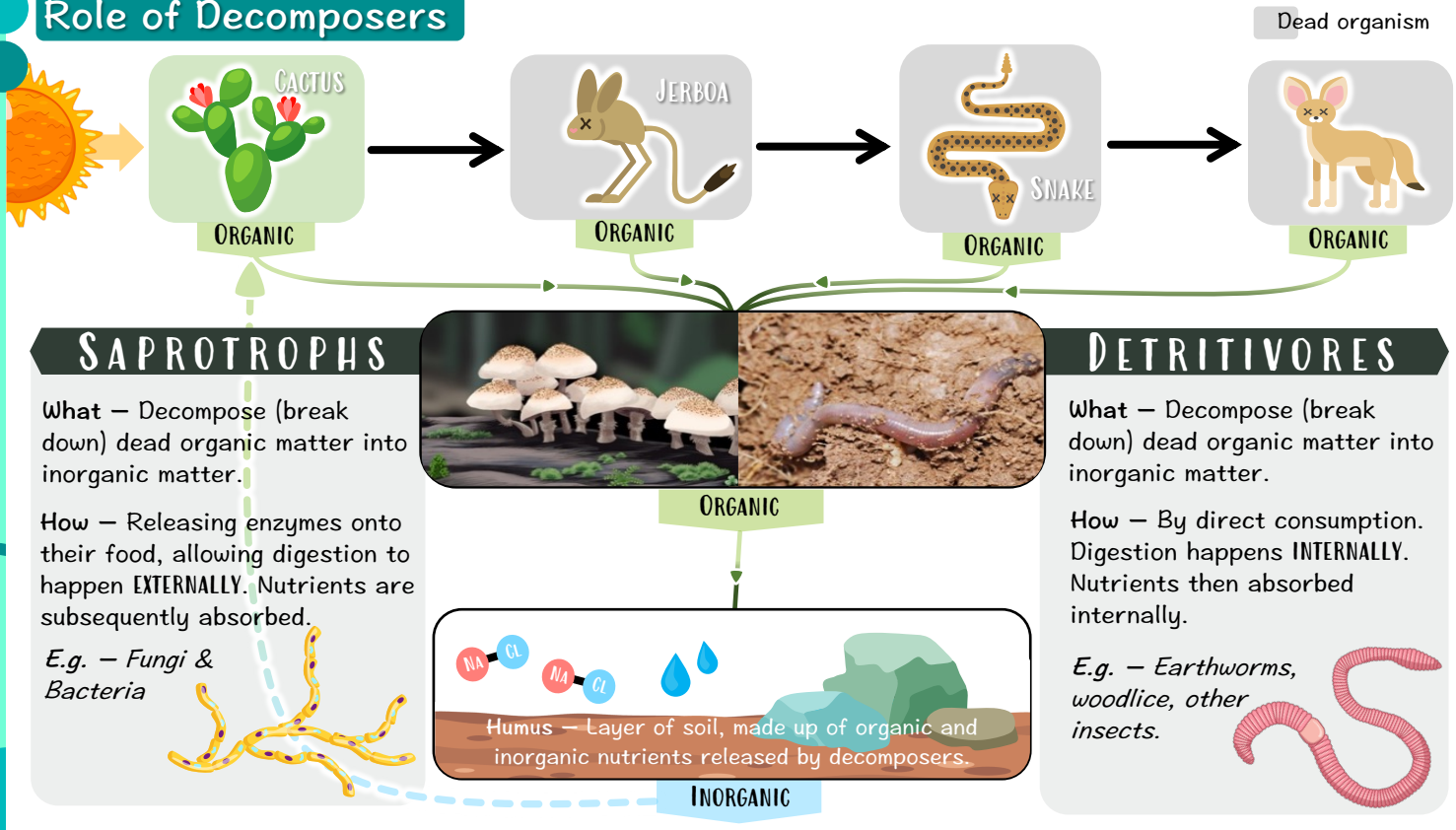
"grass → beetle → meerkat → lion"

food chain.

- Producer
- Primary consumer
- Secondary consumer
- Tertiary consumer

C4.2 Transfers of Energy & Matter

Role of Decomposers



What does decomposing or "break down" exactly mean?

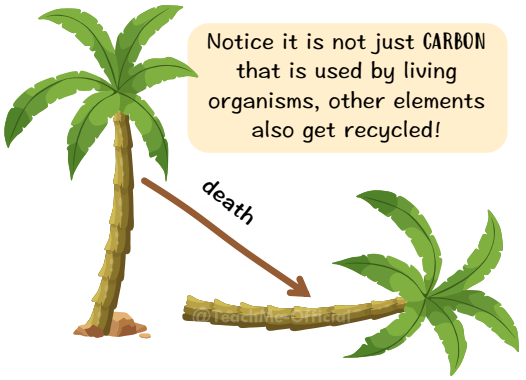
- In essence, break down refers to converting the dead organic matter into simpler organic matter and inorganic matter (RECYCLING) so that the cycle can continue (an autotroph can continue to do its job).
- In summary decomposers use some of the dead organic matter for cellular respiration. NOT all of it is purely decomposed.
- The remainder is converted or further broken down to unlock the inorganic components and simple organic compounds that is useful for autotrophs like plants to use (for example humus).

Recycling

Inorganic nutrients cannot be synthesized, and they cannot enter the system the way light energy does, they are however necessary for various life processes. Therefore, we need to recycle them! Your body is made up of CARBON but also all these elements:

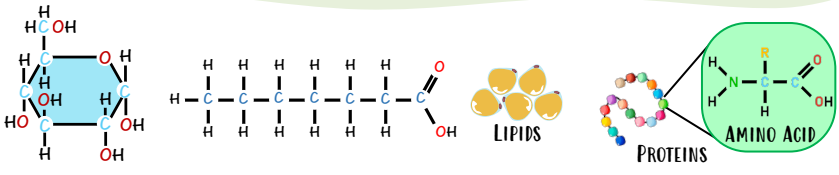
(comprising our four macromolecules)

We get these components from the food we eat, and when we die, these elements are passed on to the next trophic level, or to detritivores and decomposers.



Notice it is not just CARBON that is used by living organisms, other elements also get recycled!

Remember the structure of the four macromolecules, each component may be recycled:



e.g. proteins (organic) can be broken into ammonia then nitrates (inorganic), for further use by plants to repeat the cycle.

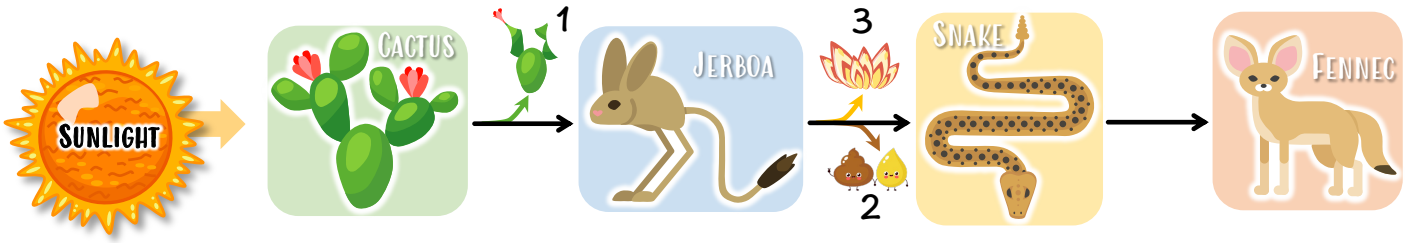
PROTEINS → AMMONIA → NITRATES

C4.2 Transfers of Energy & Matter

B Energy Pyramid

Energy Loss

Energy can **NOT BE CREATED NOR DESTROYED**, only **TRANSFORMED** from one source to another!

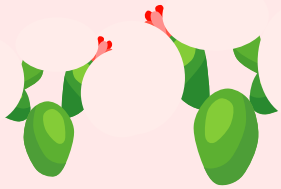


Between trophic levels, energy is passed on but not all of it. Some of this energy can get lost and doesn't get passed on to the next trophic level. There are three different reasons for energy to get lost:

1 NOT CONSUMED

E.g., Bones, hairs, death etc....

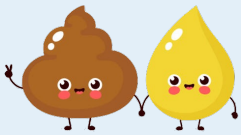
Not permanently lost, can be decomposed by detritivores (which use it as food and can recycle nutrients).



2 NOT ASSIMILATED*

E.g., Poop, urine etc...

Not permanently lost, can be decomposed by detritivores (which use it as food and can recycle nutrients).



3 CELL RESPIRATION (heat energy)

Cellular respiration generates ATP (to carry out metabolism & physical activity). While generating ATP, most of the energy is lost as heat.

Heat energy keeps us warm, but once it leaves the body it is no longer a biological energy source (not convertible back into chemical energy).

Hence, when we say "lost" we just mean it is no longer usable.

Thermogram (shows heat lost)

*Assimilation – the breakdown and absorption of nutrients from one organism to be used for building new structures in another organism.

Energy Pyramid

The energy pyramid is a diagram that represents the ENERGY TRANSFER (how much and how fast) between trophic levels.

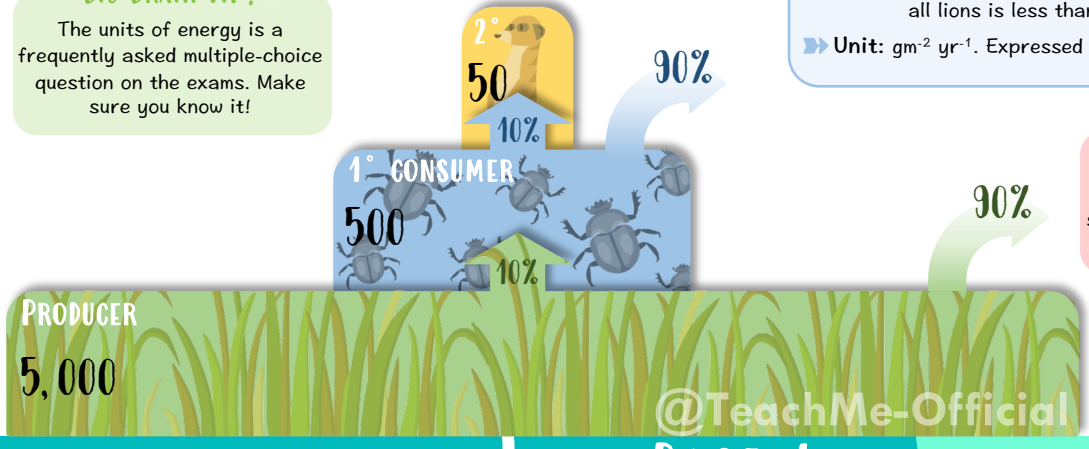
Energy:

Trend: 10% rule: only 10% passed on - 90% lost.

Unit: $KJm^{-2}y^{-1}$ OR $\frac{KJ}{m^2y^1}$

BIG BRAIN TIP!

The units of energy is a frequently asked multiple-choice question on the exams. Make sure you know it!



Don't confuse other pyramids:

Number pyramid:

- **What:** Number of organisms that occupy a trophic level.
- **Trend:** Number that occupies lower trophic levels is more. (more lion than there is springbok).

Biomass pyramid:

- **What:** Estimate of the dry mass (excluding water weight) of all the organisms within that trophic level.
- **Trend:** Biomass gets smaller up trophic levels. Total weight of all lions is less than that of all springbok.
- **Unit:** gm^{-2} yr^{-1}. Expressed in mass (includes area or volume).

BIG BRAIN TIP!

You may need to draw this pyramid for your exam. Make sure the proportions (10%) are somewhat accurate.

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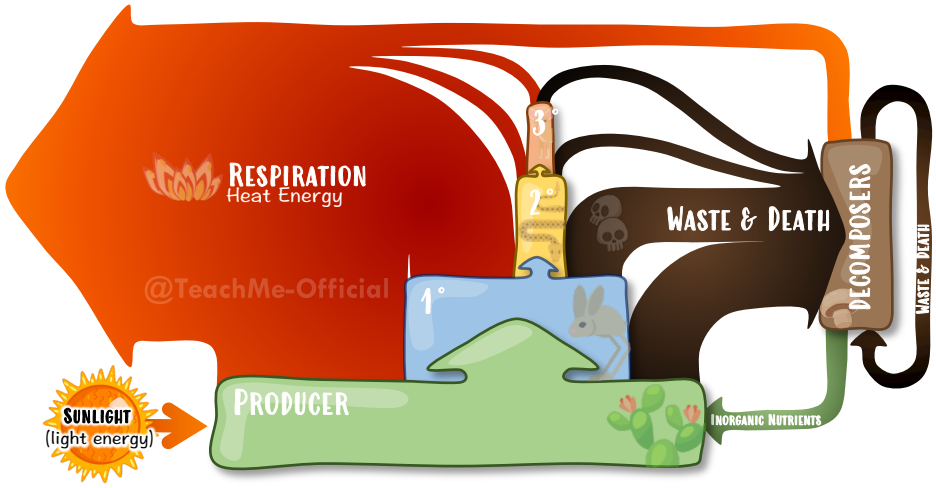
C4.2 Transfers of Energy & Matter

Summary

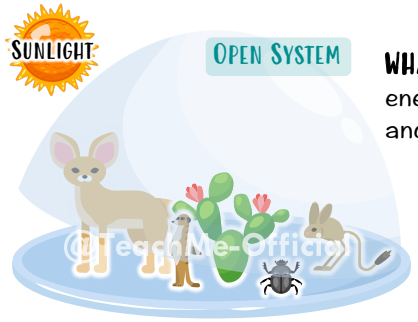
"All animals (organic + inorganic) are eventually consumed, and their organic part is released in the form of heat energy (NON-RECYCABLE), but the inorganic parts (nutrients) can be RECYCLED and returned to autotrophs."

- Food chain is almost never longer than 5 organisms.
- Since not all biomass is consumed or digested, there will be less biomass, and therefor less energy at the next level.
- Too little energy and organisms to supply another trophic level.



Open and Closed Systems

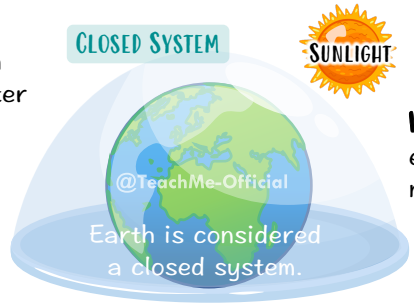
Energy enters an ecosystem in the form of sunlight and leaves in the form of heat.



Open System

WHAT: A system where both energy and matter can enter and exit.

HOW: Migration, river flow, deforestation, etc...



Closed System

WHAT: A system where only energy can pass in and out, not matter.

HENCE: Matter must be recycled.

The concept of a system depends entirely on your perspective, it can be as small or big as you want it to be.

only small amount enter: meteorites or cosmic dust.
only small amount exit: stuff sent into outer space.

Primary vs secondary production

Primary Production

WHAT: Refers to the biomass generated by the activity of producers.

INFLUENCE: Amount of sunlight reaching the producers. Sunnier area, more biomass.

Different biomes = different biomass accumulation

Cooler biomes = Lower biomass (Less sunlight)

Warmer biomes = Higher biomass (More sunlight)

GPP* = Biomass of carbon compounds made during photosynthesis.

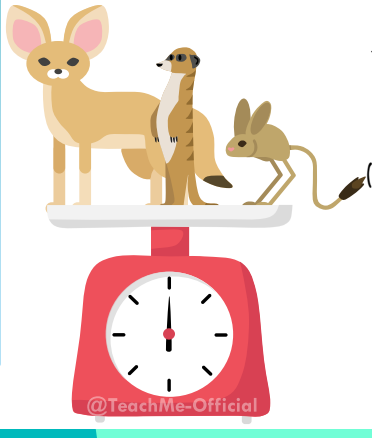
NPP* = Biomass available to consumers due to the loss of biomass during respiration in plants cells.

GPP* = Gross primary production
NPP* = Net primary production

Secondary Production

WHAT: The addition of biomass in subsequent heterotrophic levels.

HOW: Conversion of one form of carbon molecule (e.g., glucose from producers) to another (e.g., lipids) inside consumers.



Biomass production is always lower in secondary than in primary production (biomass is lost (cell respiration) from one level to the next).

Transfers of Energy & Matter

II Carbon Cycling

Carbon can exist in various forms in the biosphere (atmosphere, lithosphere, hydrosphere). NOT just atmospheric CO_2. Carbon exists in proteins, carbohydrates, lipids, and nucleic acids as well. Below we explore how carbon is cycled.

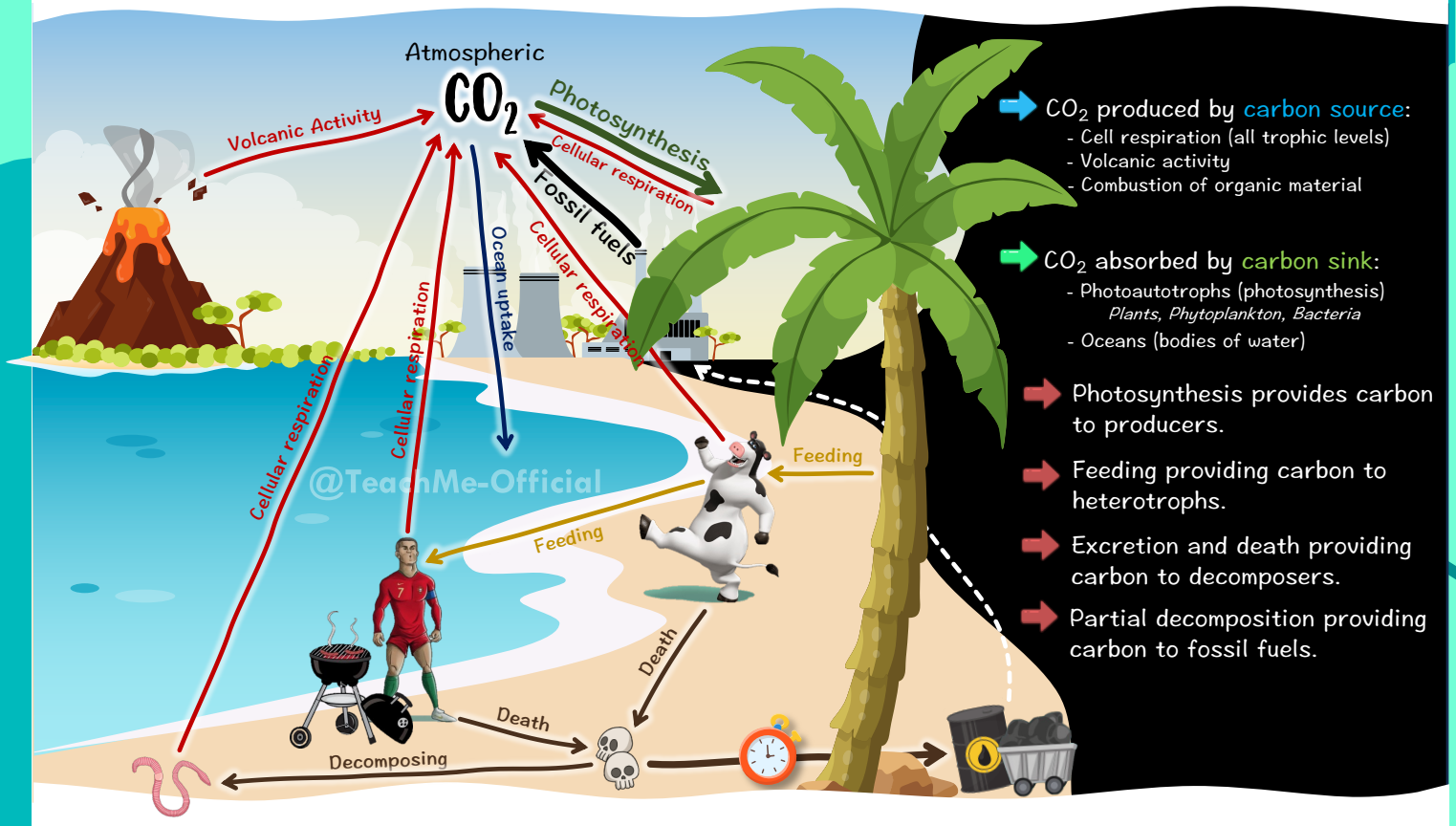
Atmosphere: the air, lithosphere: the soil, hydrosphere: water.

A The carbon cycle

Carbon source – A net producer of carbon dioxide.
E.g., Consumers, burning of fossil fuels

Carbon sink – A net absorber of carbon dioxide.
E.g., Plant, oceans.

Compared to in the past, sources and sinks have changed drastically with the introduction of FOSSIL FUEL BURNING. The carbon sources have increased while the main carbon sink being PHOTOSYNTHESIS by plants have decreased with the increase in DEFORESTATION. This leads to an overall atmospheric CO_2 increase compared to 300 years ago.

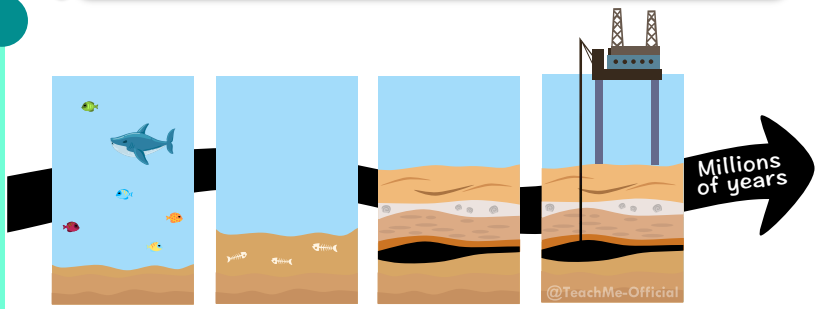


Carbon flux - the flow of carbon from one 'carbon pool' to another. It is the net difference between the carbon removal and the carbon addition. The main fluxes are caused by CELL RESPIRATION and PHOTOSYNTHESIS.

HUMANS CHANGED THE NATURAL CYCLE – we ignite forest fires sometimes by accident but often on purpose to clear land for agriculture. Humans and our hominid ancestors have known how to use and control fire for cooking and tool making for at least a million years, but its only in the most recent decades that there have been enough humans and enough forests burned to have considerable impact on the quantity of carbon dioxide in the atmosphere!

C4.2 Transfers of Energy & Matter

B Renewable & Non-renewable resources



Resources are classified based on how quickly they regenerate:

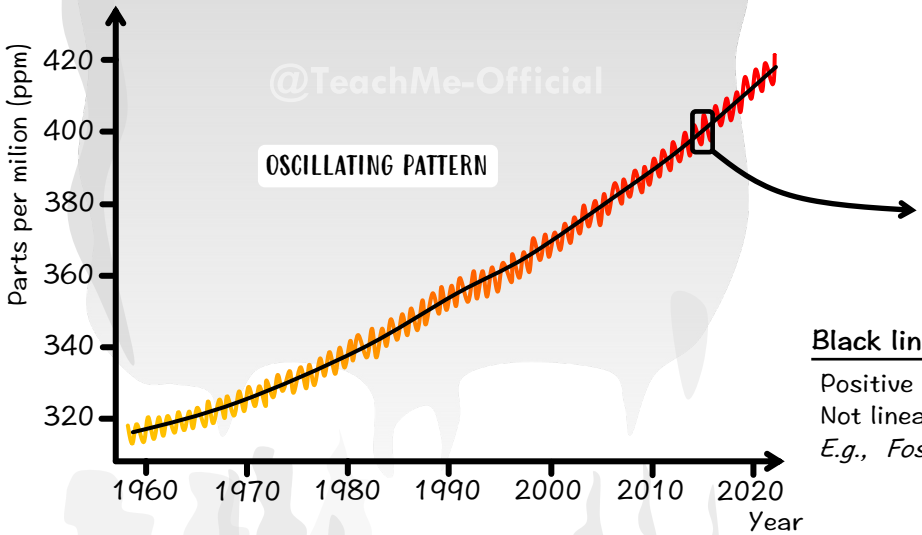
- **Renewable resources**, such as sunshine, wind, and biomass, replenish naturally on a daily basis and are sustainable if managed wisely. Extraction rate does not exceed production rate.

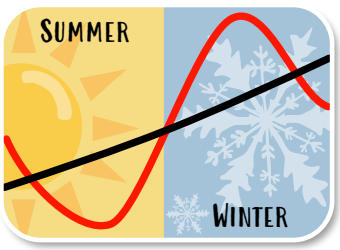
- **Long-term renewable resources**, like peat bogs and forests, take decades or centuries to regenerate, requiring careful conservation.
- **Non-renewable resources**, including coal, oil, and natural gas, take millions of years to form. These are created through the compression of organic material under sediment over time. Once used, they cannot be replaced, leading to eventual scarcity.

	Time	Examples
Renewable	Daily	Sunshine, wind, biomass, hydraulics
Long term renewable	Decades / hundreds of years	Peat bogs, forests
Non-renewable	Millions of years	Coal, crude oil, natural gas

C The Keeling Curve

This curve shows atmospheric CO_2 levels over time. Done in Hawaiian island (Mauna loa*).





Black line is the average trend.

Positive trend. Sudden increase in CO_2 over time. Not linear: mainly because of human activity. *E.g., Fossil fuel combustion for various reasons.*

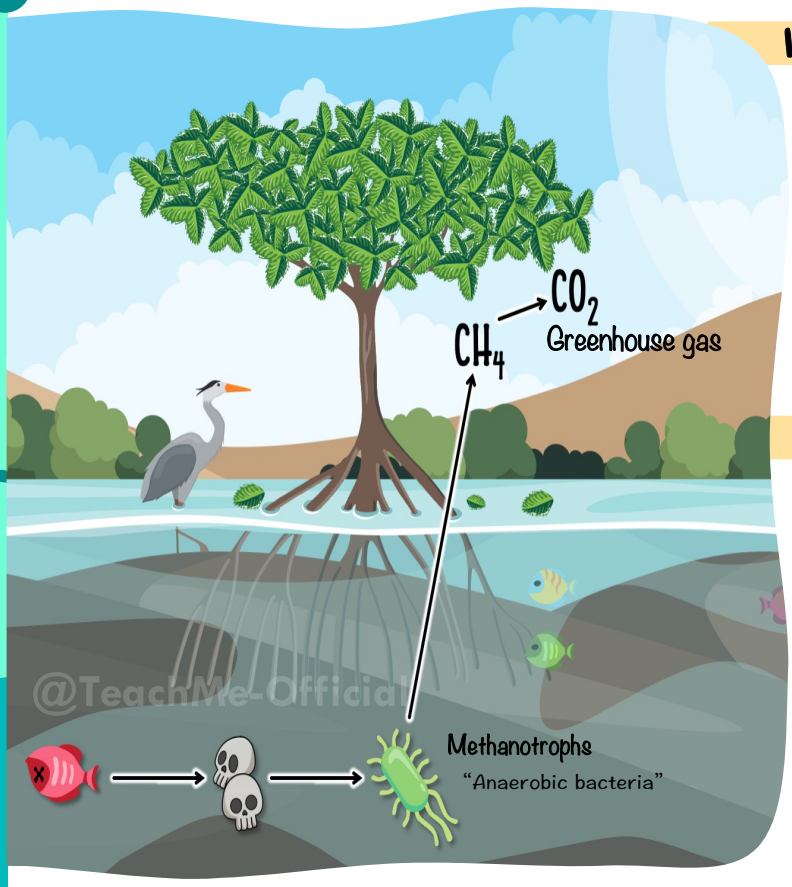
The red line has an oscillating pattern.

Pattern is due to seasonal changes. Photosynthetic organisms absorb more carbon dioxide in the summer and autumn than in the winter.

*Chosen since it is in the middle of the ocean far away from highly industrialized zones, and because of its high altitude.

Transfers of Energy & Matter

D Methane Production



Wetlands & Methane

Some archaea are **anaerobic methanogens**. They do NOT require oxygen gas. When they metabolize food, they produce methane (CH_4) (marsh gas) as a waste product.

They are common in **wetlands** since these environments provide anaerobic conditions (very low oxygen levels underwater). These bacteria are also responsible for producing methane gas in the **digestive tracts** of mammals (since the gut is also low on oxygen).

Cattle = concerns for methane and its **greenhouse effect**.

Wetlands & Peat

Peat is a form of **waterlogged soil** found in wetlands.

Heterogenous mixture: 30% composed of **dead** organic material.

Conditions required for peat formation:

(1) wet, (2) high acidity, (3) low O_2 of the soil,

These conditions make it difficult for decomposers, hence much organic matter remains undecomposed.

This matter will condense over time (from the pressure above). Can be used as fuel (cut peat is dried out). Cut into slabs, granules or blocks.

notes