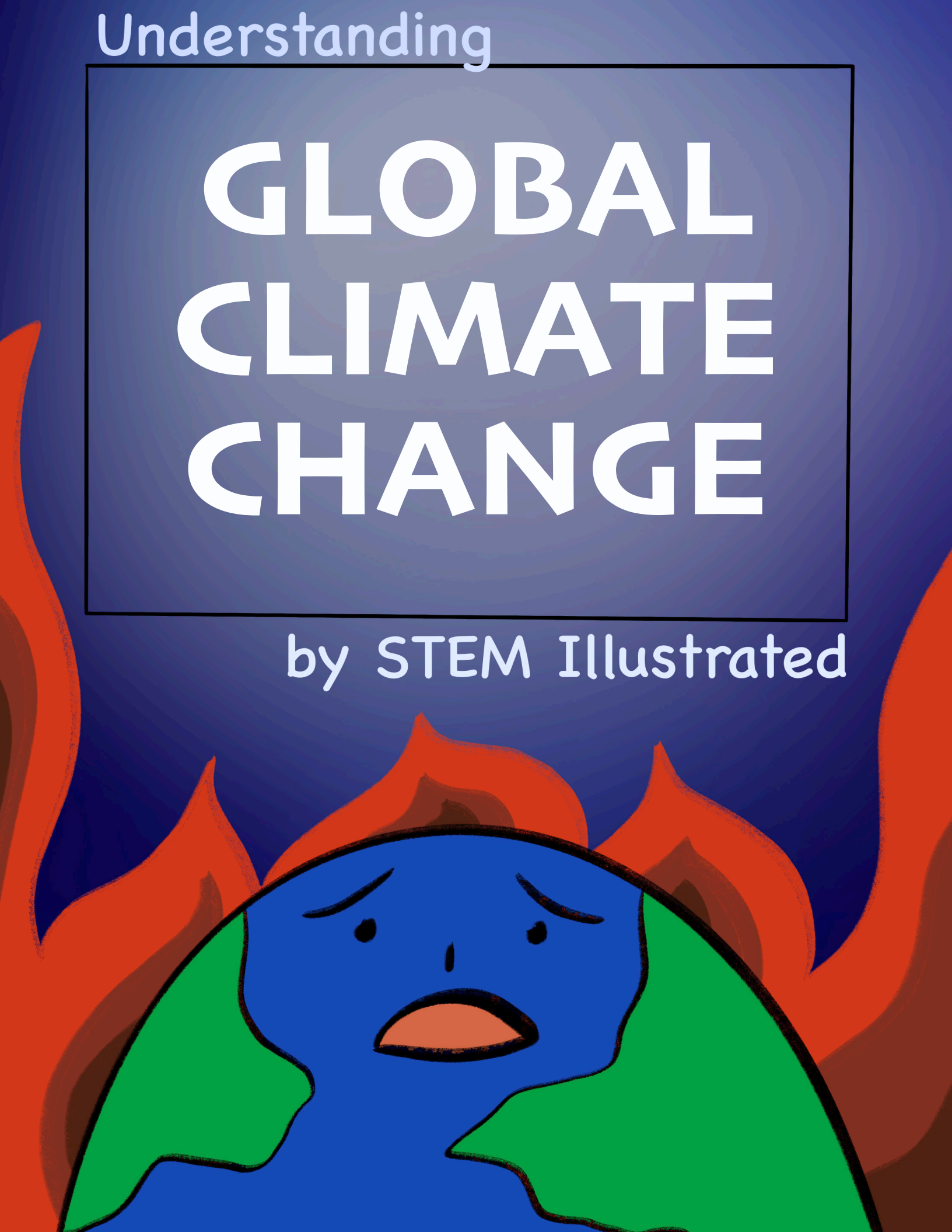
Understanding

GLOBAL CLIMATE CHANGE

by STEM Illustrated



STEM Illustrated Board

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STEM Illustrated, a publication created by students of The Lawrenceville School, aims to turn difficult STEM concepts into fun, comprehensive graphic chapters to encourage and foster STEM education.

To everyone who wants to learn
more about the natural world.

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Sources

National Geographic
National Oceanic and Atmospheric Administration (NOAA)
Natural Resources Defense Council (NRDC)
The National Aeronautics and Space Administration (NASA)
The Nature Conservancy
University Corporation for Atmospheric Research (UCAR)
World Meteorological Organization (WMO)
World Wildlife Fund (WWF)

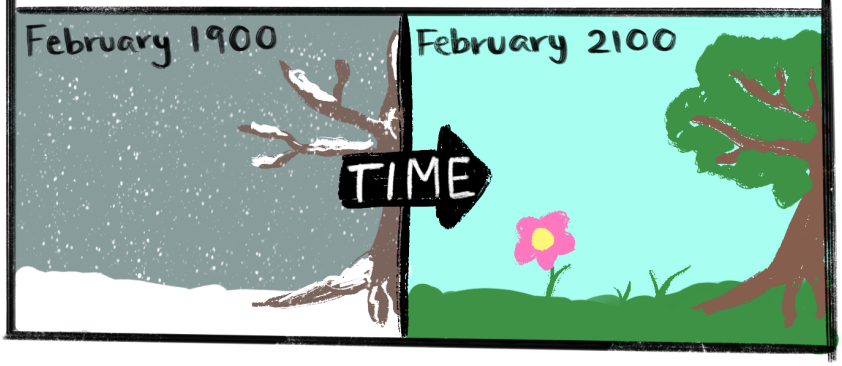
Introduction

What is CLIMATE CHANGE?

According to NOAA, climate is the average weather over time of a certain place. New Jersey has a wetter climate than a desert, for example, even if it isn't always raining!

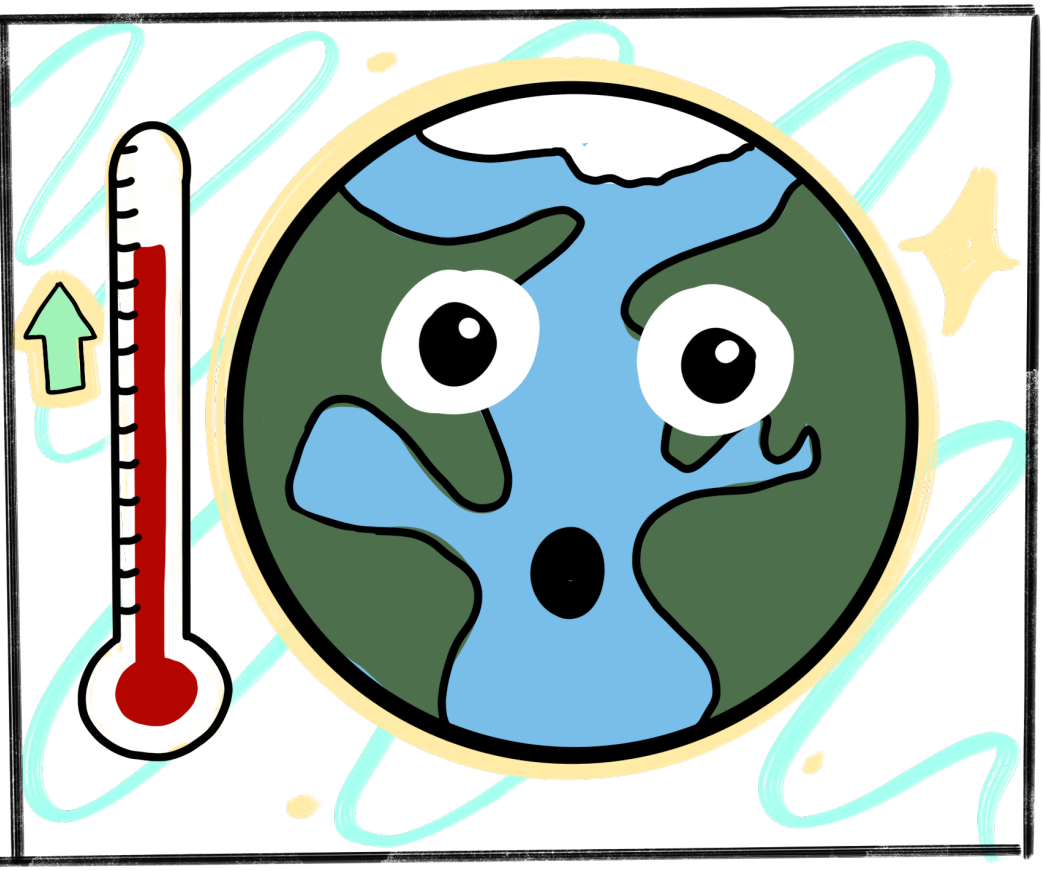
As the planet WARMS and COOLS, the climate CHANGES.

Climate change is a long-term shift in the climate.

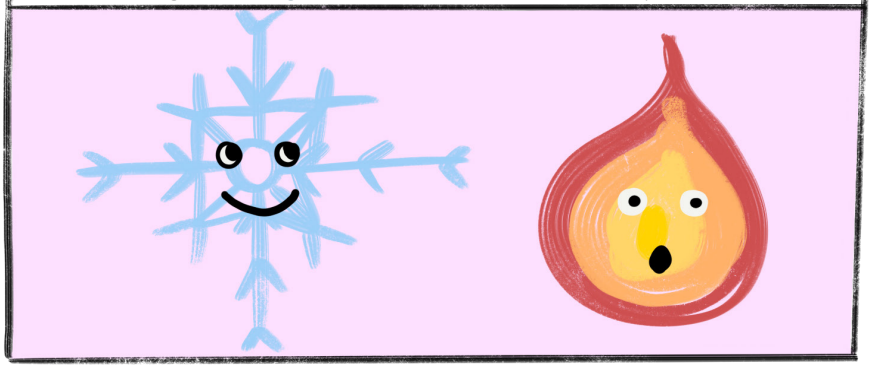


GLOBAL WARMING

is a type of climate change where the planet gets a lot warmer. It is the heating of Earth over time.



There have been many changes in the Earth's climate for millions of years. The Earth has been through ice ages and even hotter temperatures.



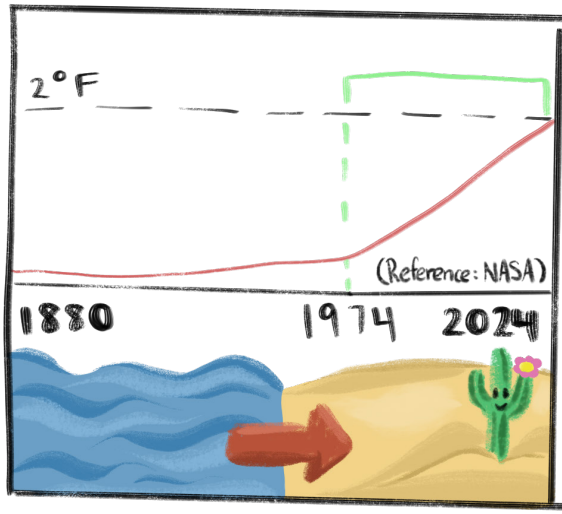
However, all the past changes happened over hundreds of thousands of years. Now, the temperatures are rising much faster than before.

According to NASA, since 1880, the average global temperature has risen by around

1.1°C,

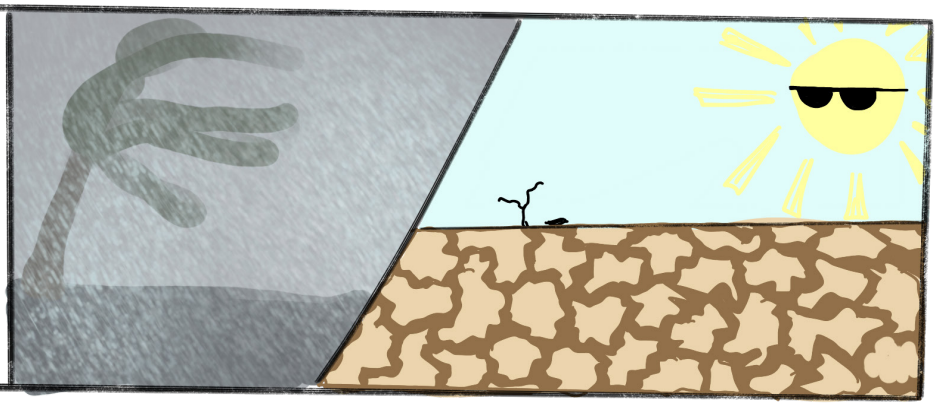
or

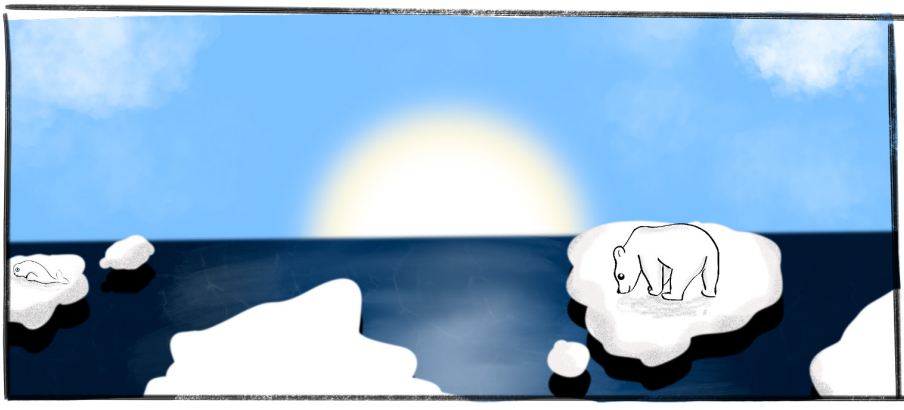
1.9°F.



Most of this warming happened within the past 50 years. While 1 or 2 degrees may not seem like a lot, that increase can cause many drastic changes to the Earth's climate.

Changes in climate cause big shifts in weather patterns that can hurt people, including extreme events like hurricanes and droughts. Think about Hurricane Sandy and heat waves.





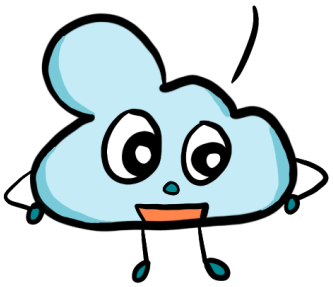
Changes in climate will also hurt animals like polar bears who depend on sea ice to hunt and survive. As per NASA, Arctic sea ice is melting at a rate of around 9% every 10 years.

Climate Change: Causes, Effects, and Remedies

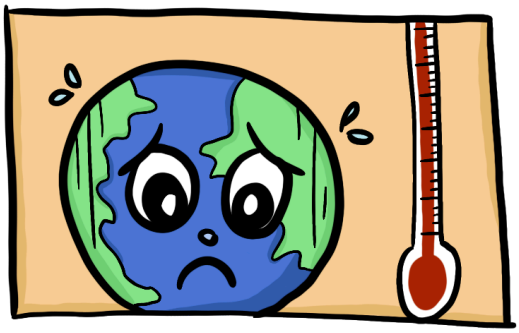
The Greenhouse Effect

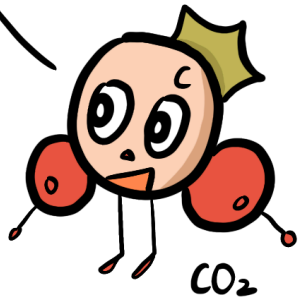
So what is the

GREENHOUSE EFFECT?

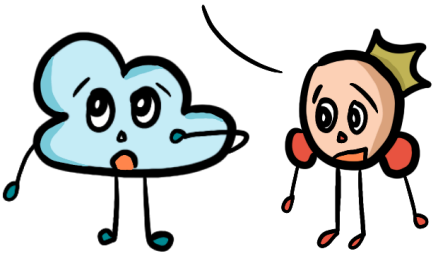


It is a natural process that causes the Earth to **WARM UP!**



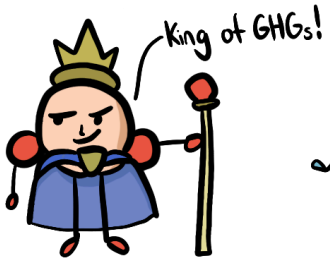


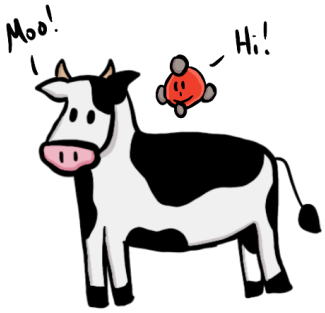
The greenhouse effect occurs when **greenhouse gases**, GHGs, trap **heat** from the **sun** within the **Earth's atmosphere.**



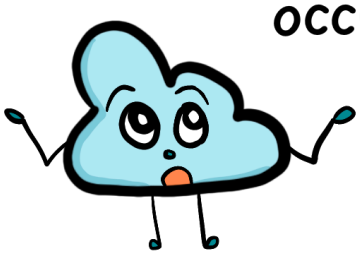
MAIN GHGs

Carbon Dioxide (CO_2)	Water Vapor (H_2O)	Methane (CH_4)	Nitrous Oxide (N_2O)

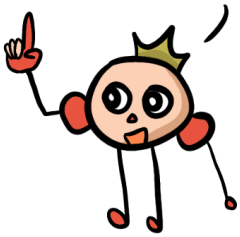




So... How does the greenhouse effect occur?

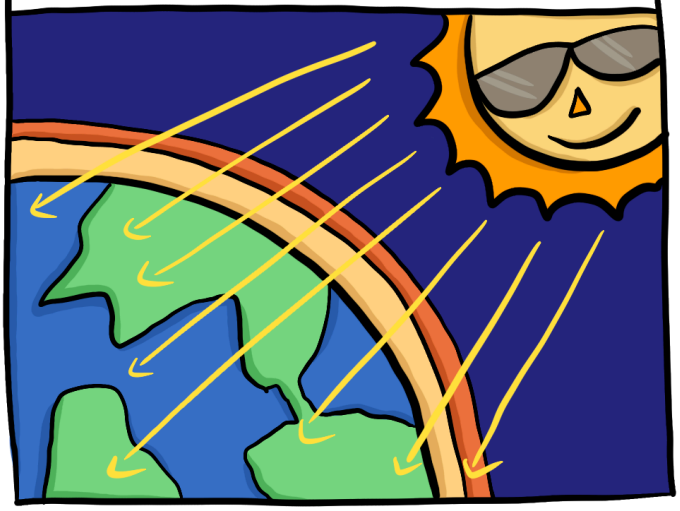


That's a great question!

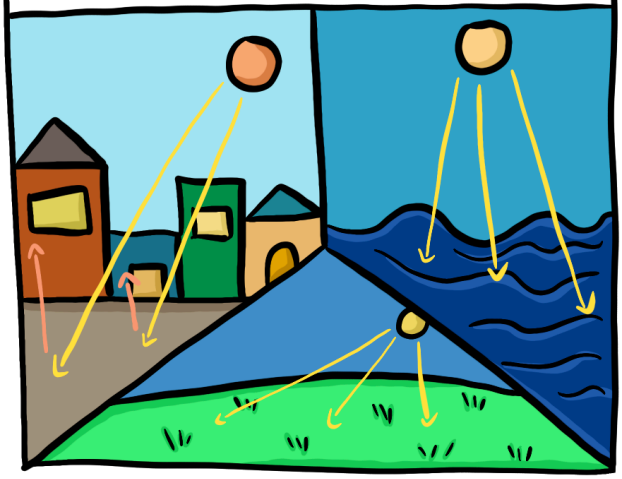


The Process EXPLAINED

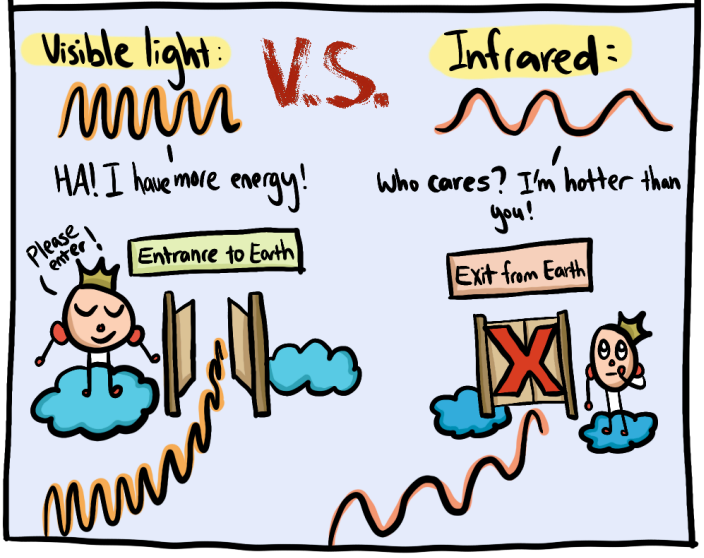
First, light energy enters the Earth in the form of visible light.



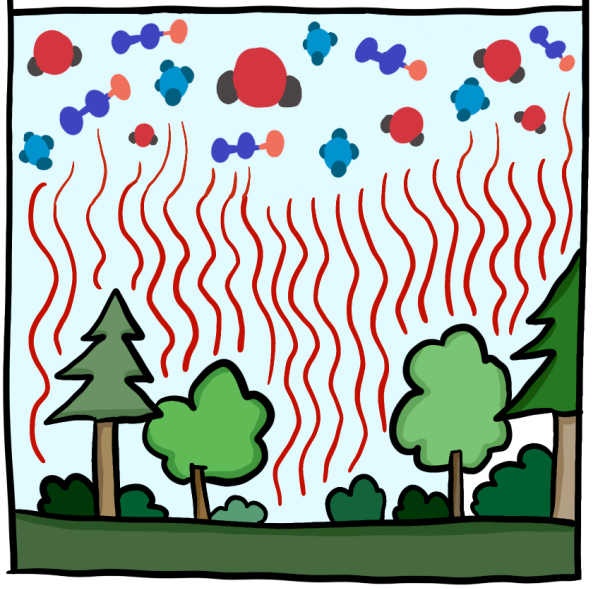
Part of the energy gets absorbed by the Earth's surface, and the other part gets reflected off the ground as infrared radiation, also known as heat.



Greenhouse gases, however, do not let infrared radiation escape the Earth as well as they let visible light into the Earth. This is because infrared has a longer wavelength and therefore less energy, making infrared harder to penetrate the atmosphere.

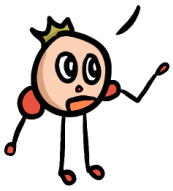


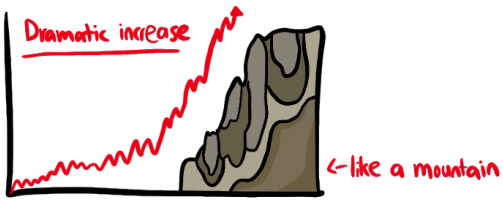
Because of this, heat gets trapped, which contributes to global warming, the gradual and widespread heating of the Earth.



THE ENHANCED GREENHOUSE EFFECT

While the greenhouse effect is a **NATURAL** phenomenon, as we need heat in the Earth's atmosphere, humans are causing an **ENHANCED** greenhouse effect in which temperatures increase at a faster rate.



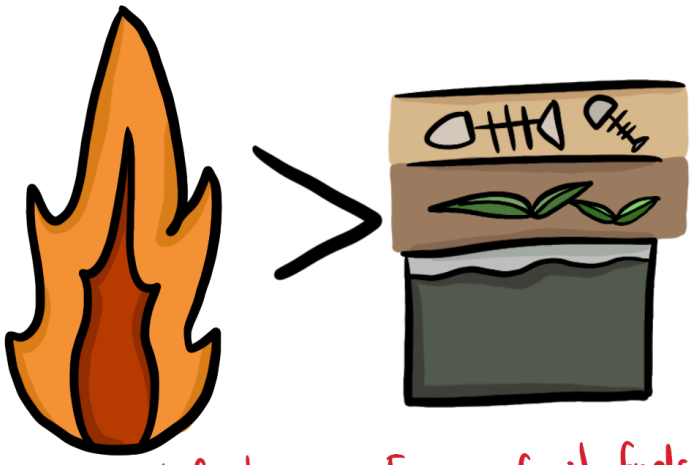


So why do humans accelerate this rise in global temperature?

One big reason is the **BURNING** of **FOSSIL FUELS**, which consist of coal, oil, and natural gas.

When burned, fossil fuels release large amounts of carbon dioxide (C) and water vapor, both GHGs, into the atmosphere. The more GHGs, the more heat trapped in the Earth.

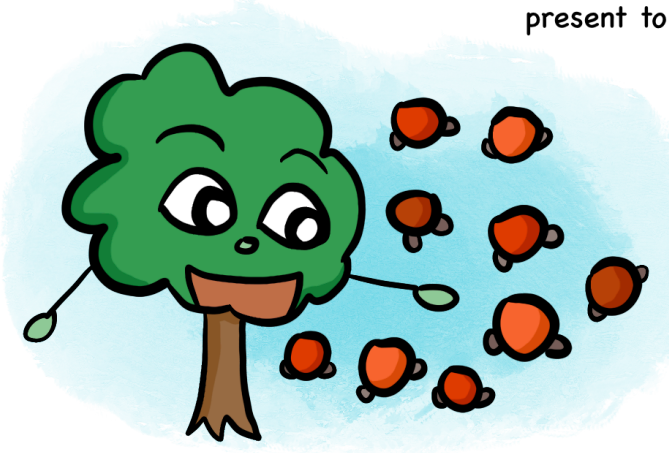
Also, burning fossil fuels is a lot quicker than the process of forming fossil fuels, which takes millions of years.



Burning fossil fuels > Forming fossil fuels

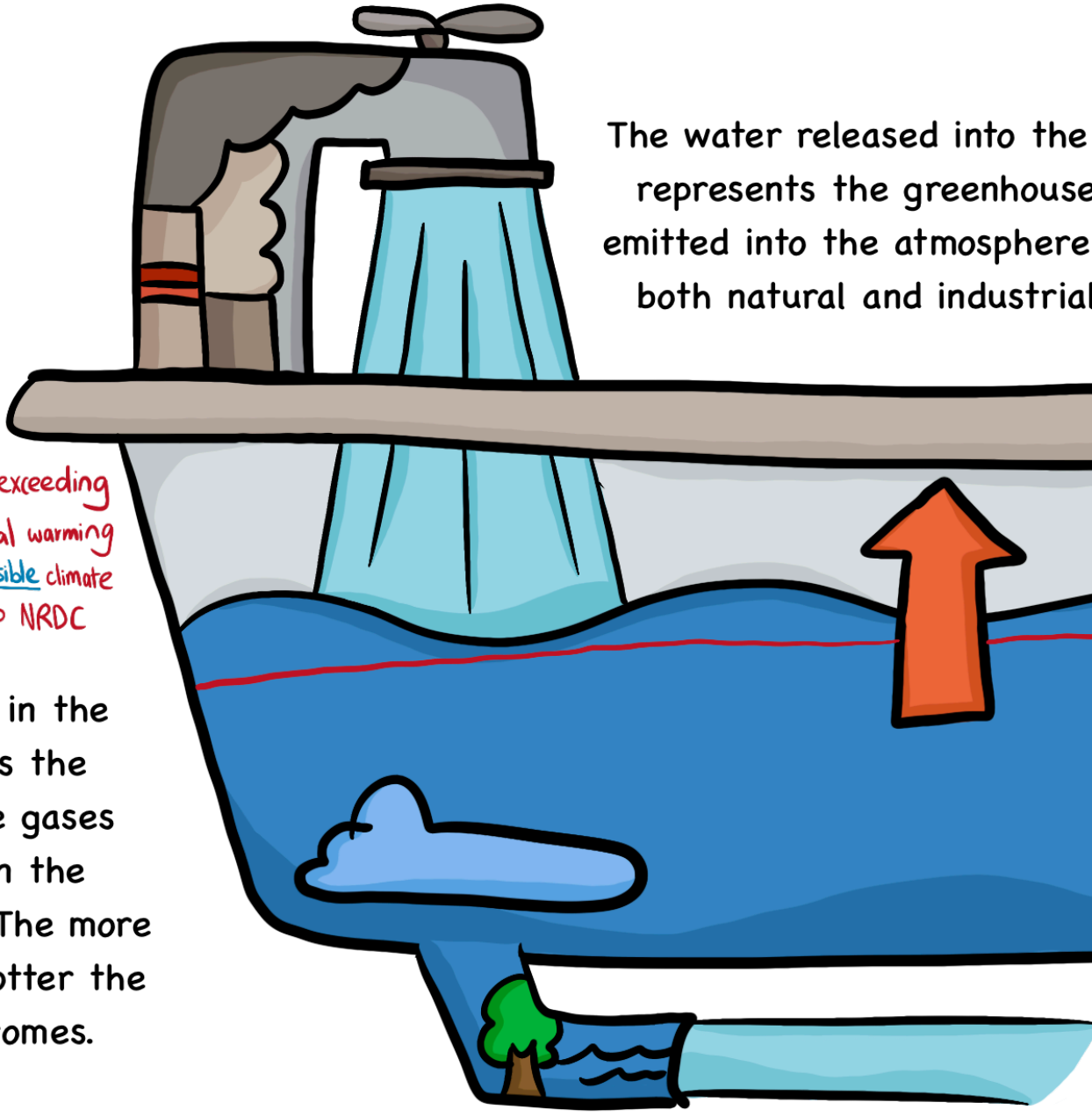
Another big reason is **DEFORESTATION.**

Trees sequester, i.e. take in and store, carbon by tucking it into their cells. Thus, if we cut down trees, there is less carbon taken out of the atmosphere, meaning that more GHGs would be present to trap heat.



THE BATHTUB ANALOGY

To better understand the enhanced greenhouse ef



The water released into the
represents the greenhouse
emitted into the atmosphere
both natural and industrial

The tipping point-exceeding 1.5°C or 2.7°F of global warming
• May cause irreversible climate impacts, according to NRDC

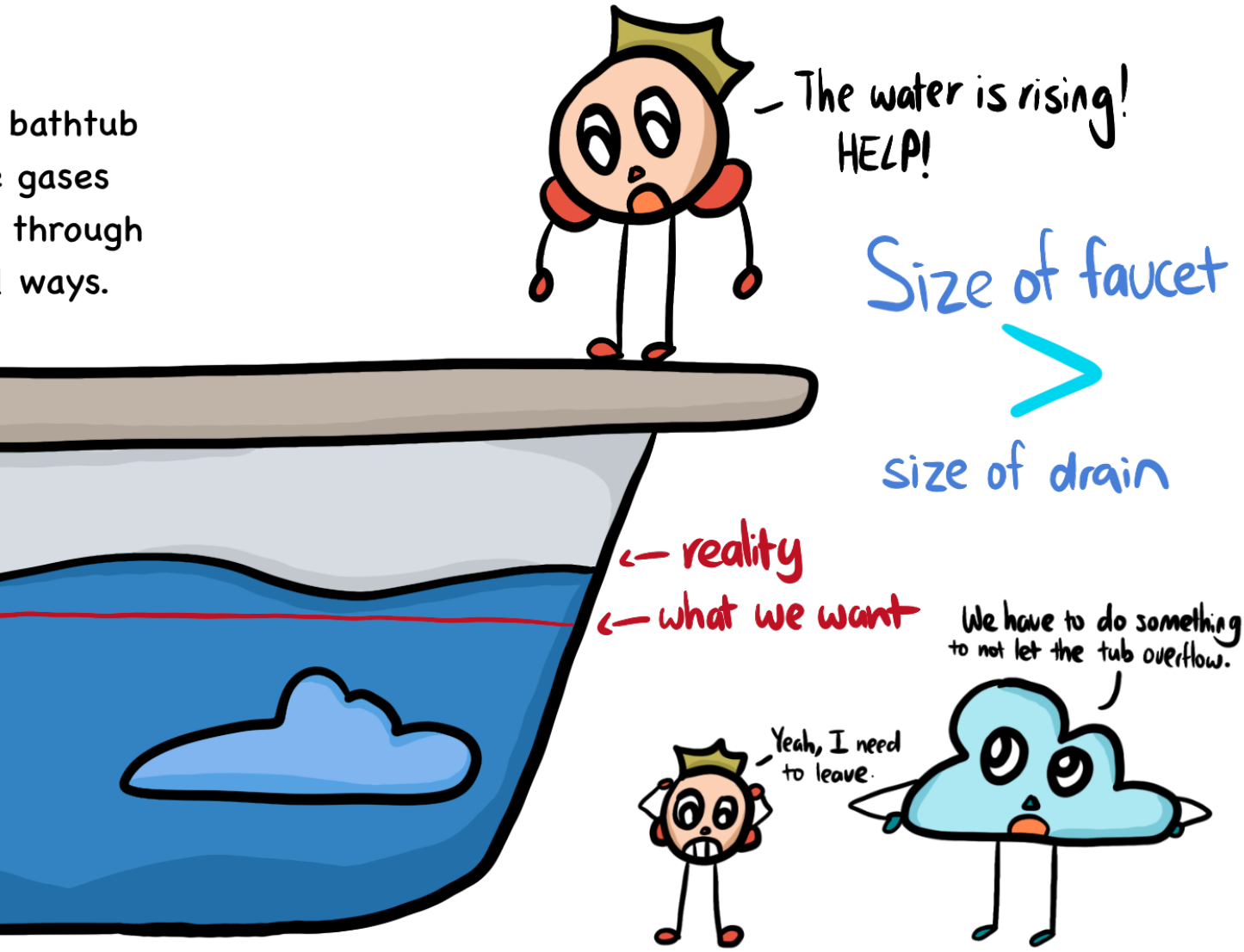
The water in the bathtub is the greenhouse gases present in the atmosphere. The more GHGs, the hotter the Earth becomes.

The water going down the drain is the sequestered greenhouse gases such as those taken in by trees or absorbed by the ocean.

Overall, th
excess am

ffect, we can use an analogy of a bathtub.

bathtub
gases
through
ways.

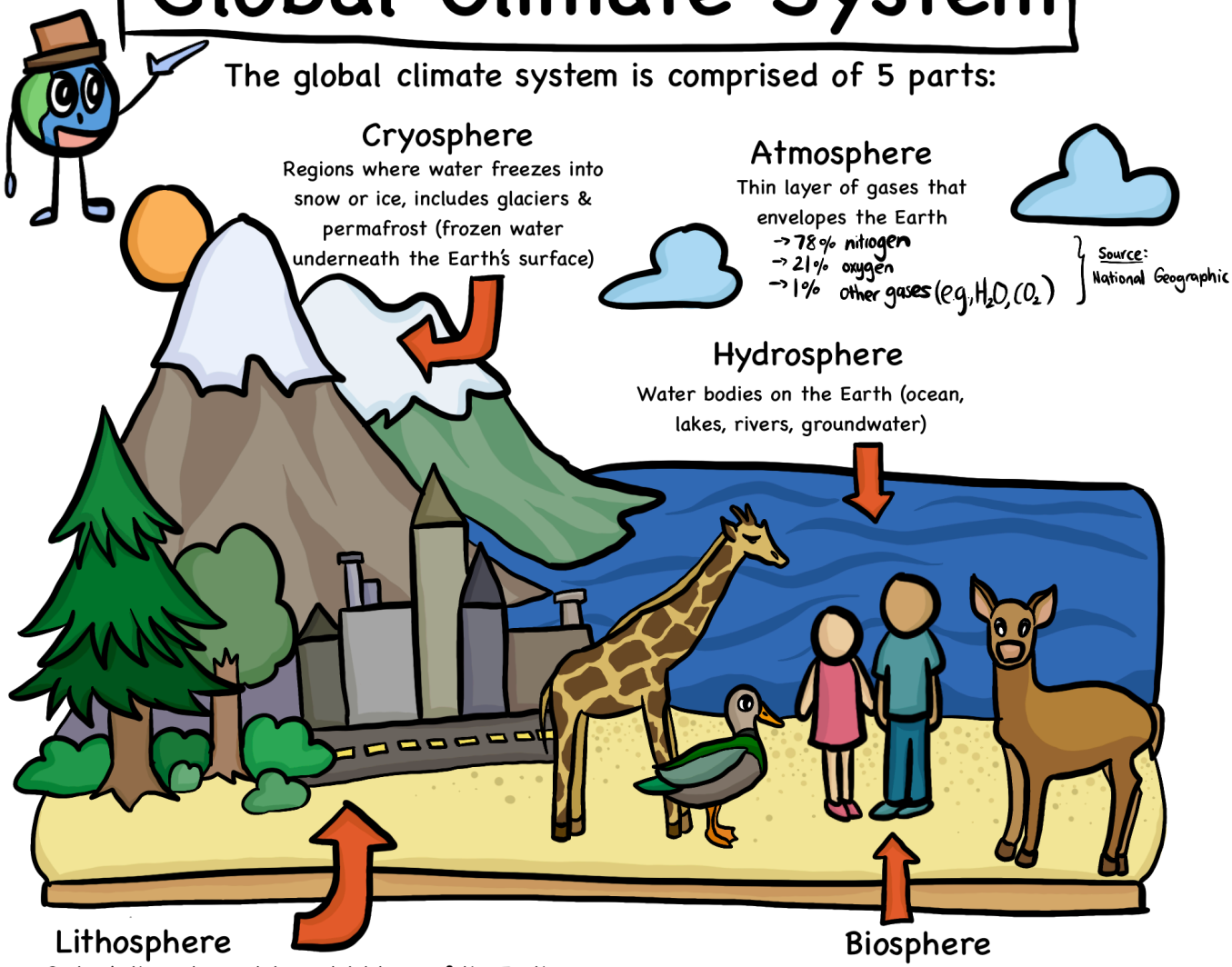


The water level in the bathtub is constantly rising because of the continuous release of greenhouse gases (the water coming from the faucet) into the atmosphere (the bathtub), thus making the Earth heat up faster.

e Earth is heating up at a much faster pace due to the
nount of greenhouse gases in the atmosphere in a way
that is harmful to the organisms on Earth.

Global Climate System

The global climate system is comprised of 5 parts:



Cryosphere
Regions where water freezes into snow or ice, includes glaciers & permafrost (frozen water underneath the Earth's surface)

Atmosphere
Thin layer of gases that envelopes the Earth
- → 78% nitrogen
- → 21% oxygen
- → 1% other gases (eg, H_2O, CO_2)

Source: National Geographic

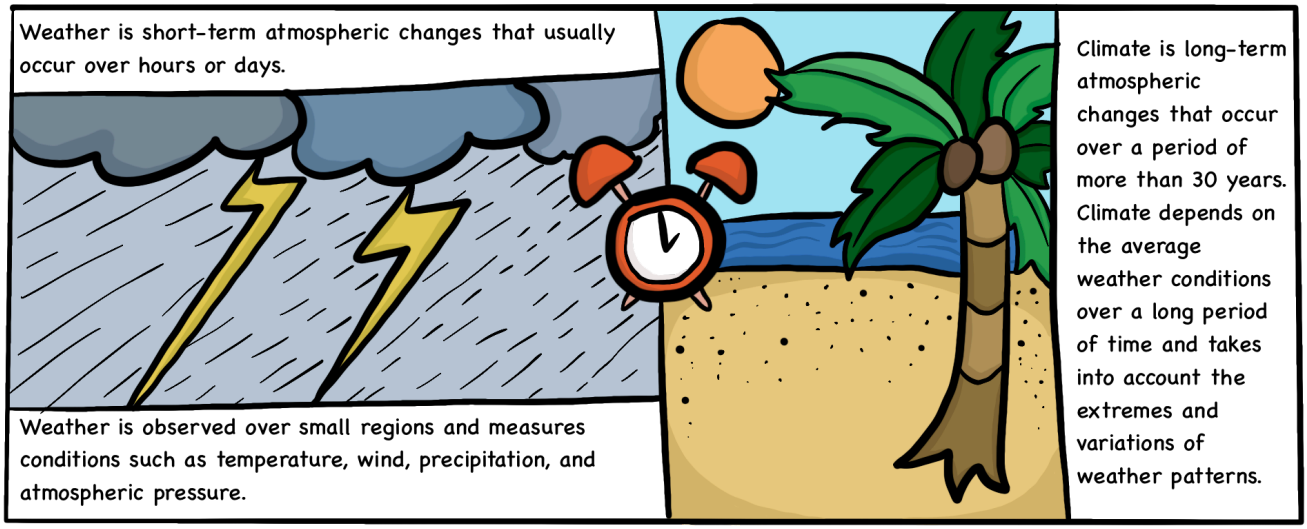
Hydrosphere
Water bodies on the Earth (ocean, lakes, rivers, groundwater)

Lithosphere
Or land, the outermost terrestrial layer of the Earth (e.g., soil, rocks, roads, and buildings)

Biosphere
Living organisms: plants, animals, bacteria, etc.

These components influence the weather conditions across the Earth, which in turn impact the climate in these regions.

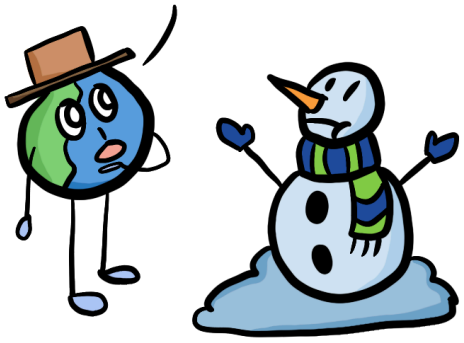
Weather v. Climate



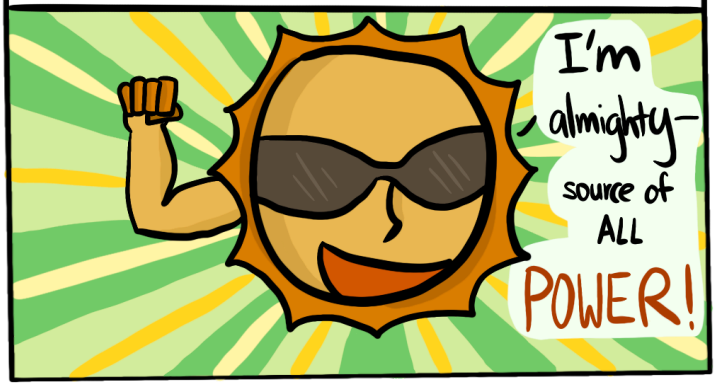
DIFFERENCE IS IN TIME.

For example, while there could be colder than usual days in the Amazon rainforest, the region still has a warm, tropical climate.

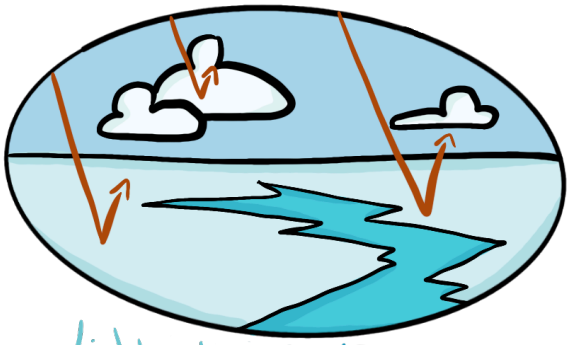
How does each part of the global climate system influence the Earth's climate?



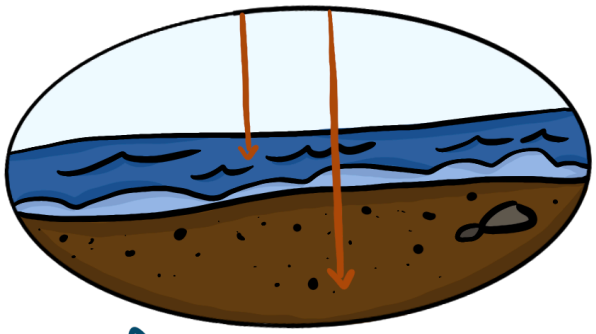
First, it is important to know that the sun is the driving factor of the Earth's climate system because it supplies the Earth with energy.



According to WMO, the Earth absorbs around 70% of the energy and reflects the remaining 30% back into space.



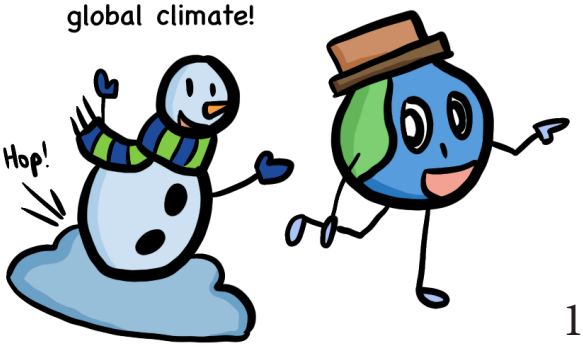
Light colors REFLECT energy



Dark colors ABSORB energy

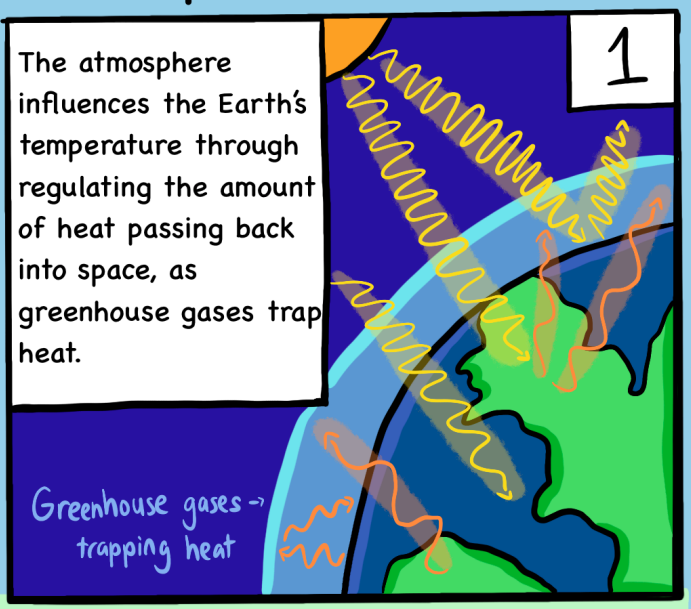
The absorbed energy is what keeps the Earth from freezing. According to UCAR and NOAA, if all the energy were reflected, the average temperature of the Earth would be around -19°C, or -1°F, compared to a 20th century average of 13.9°C, or 57.0°F.

Now, let's see how the global climate system influences the global climate!

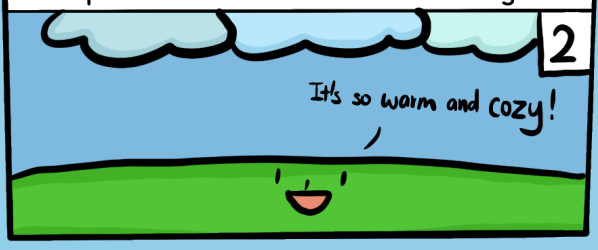


Atmosphere

The atmosphere influences the Earth's temperature through regulating the amount of heat passing back into space, as greenhouse gases trap heat.



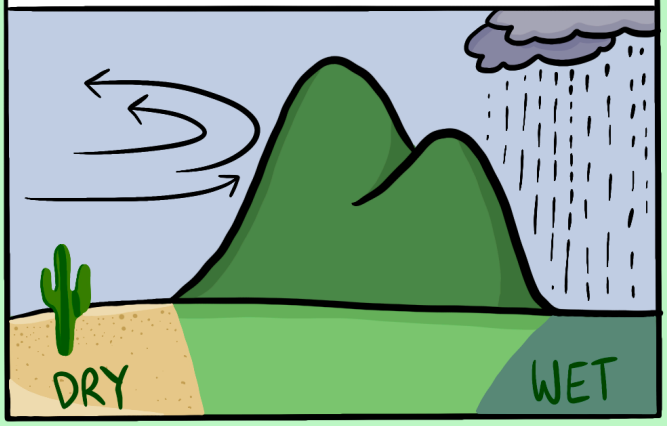
Normally, the trapped heat is beneficial and prevents the Earth from freezing.



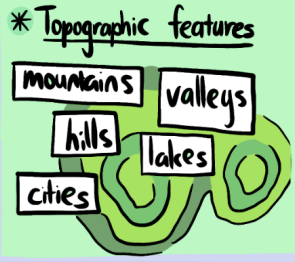
Yet, human-based emissions such as those from factories and cars are drastically increasing the amount of greenhouse gases in the atmosphere, thus causing an unprecedented rate of global warming.

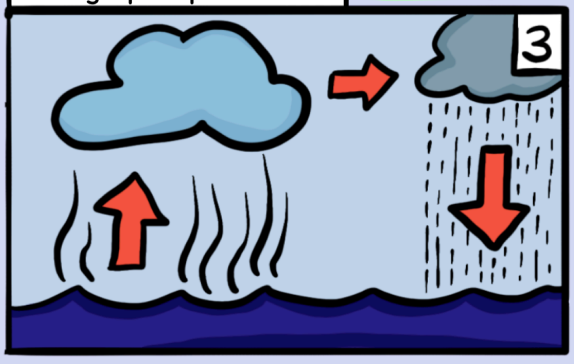
Lithosphere

The dark color of soil absorbs energy, while topographic features* such as mountains affect wind direction and areas of rainfall.



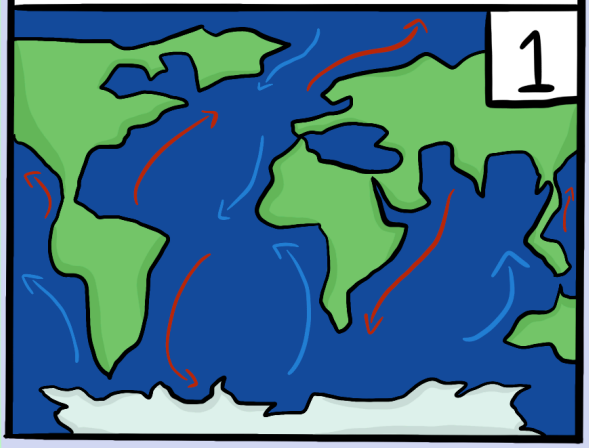
The water vapor released into the atmosphere condenses to form clouds and ultimately returns to the Earth's surface through precipitation.



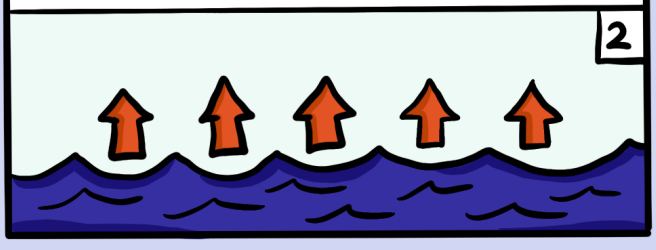


Hydrosphere

The dark blue of the ocean absorbs energy, and the ocean distributes its heat through transporting warm water to cooler regions and cold water to warmer regions in the form of ocean currents.

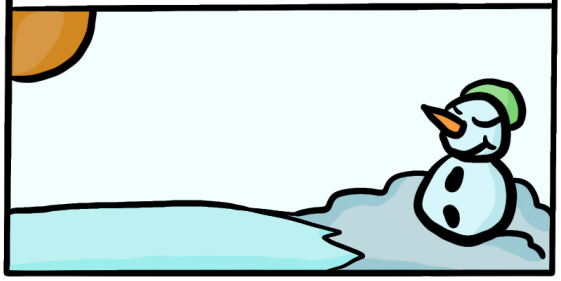


When water evaporates, the temperature near the water surface cools.

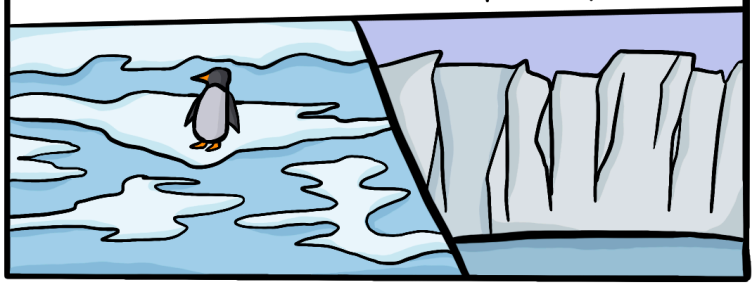


Cryosphere

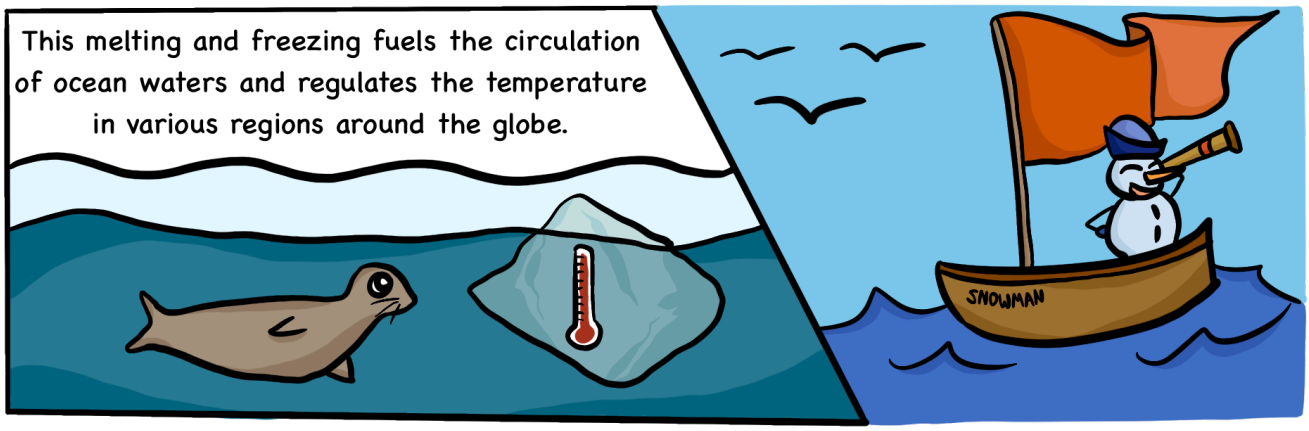
Ice and snow reflect the energy of the sun back into the atmosphere.



Additionally, ice and snow melt and freeze during summers and winters, respectively.

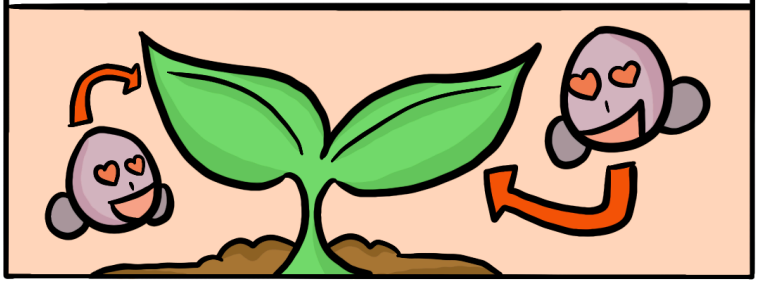


This melting and freezing fuels the circulation of ocean waters and regulates the temperature in various regions around the globe.

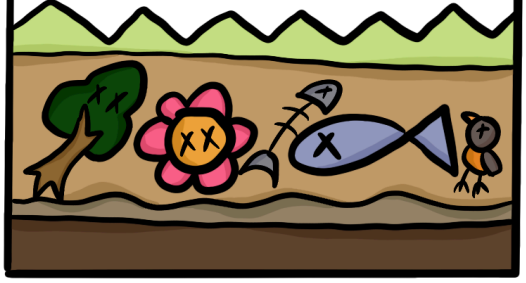


Biosphere

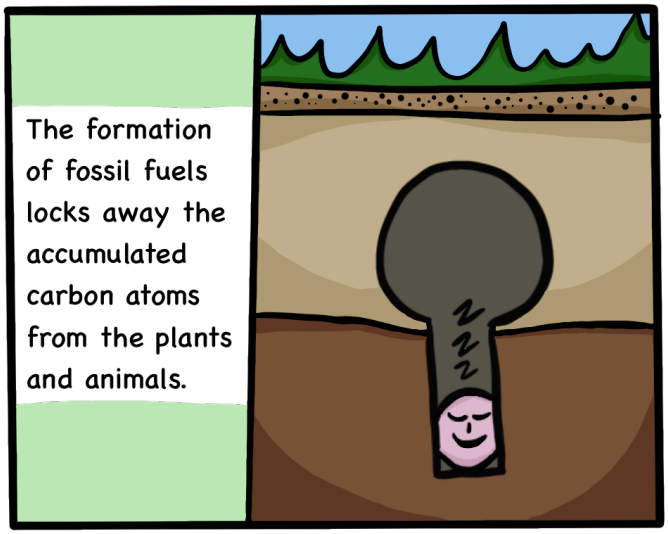
Plants intake C through photosynthesis, thus reducing the greenhouse gases in the atmosphere and slowing the rate of global warming.



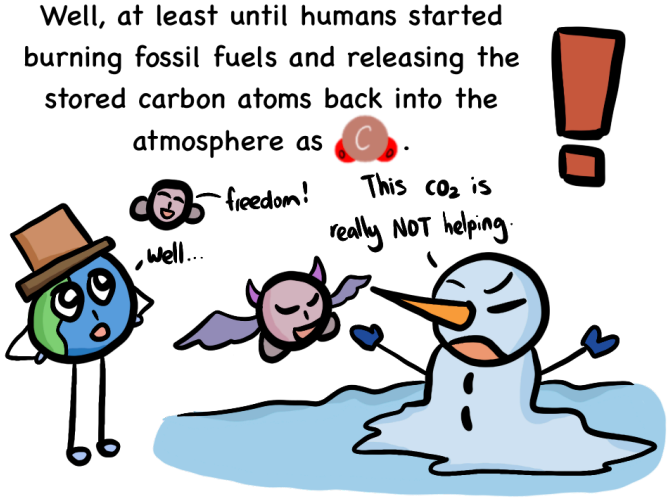
In addition, over millions of years under high temperatures and pressures, deceased plants and animals formed fossil fuels.



The formation of fossil fuels locks away the accumulated carbon atoms from the plants and animals.



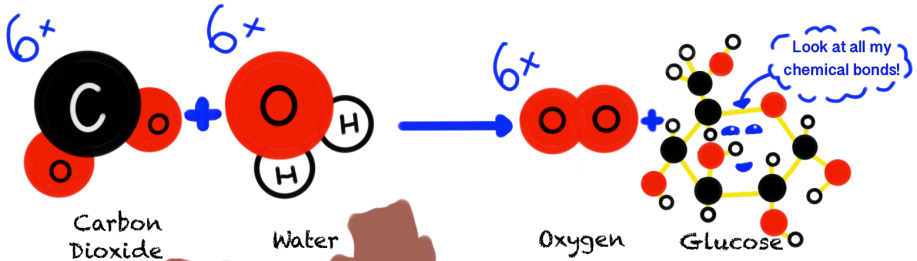
Well, at least until humans started burning fossil fuels and releasing the stored carbon atoms back into the atmosphere as C.



WHAT IS PHOTOSYNTHESIS?

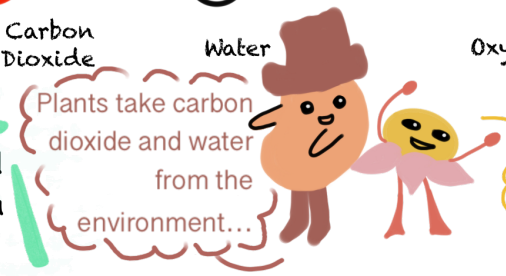
Myth:
Plants turn energy from the sun into food. This is not the full story!

Truth:
Plants turn **carbon dioxide (CO_2)** and **water (H_2O)** into **oxygen** and **glucose.** The glucose molecules, a type of sugar, are the commonly known "food." They have high amounts of **chemical potential energy,** which is stored in a glucose's chemical bonds. Glucose molecules have a lot of chemical bonds.



1

and H_2O molecules have low **chemical potential energy**, so the plants need extra energy to convert these low-energy molecules into high-energy glucose. This is because <u>energy can neither be created nor destroyed</u>.



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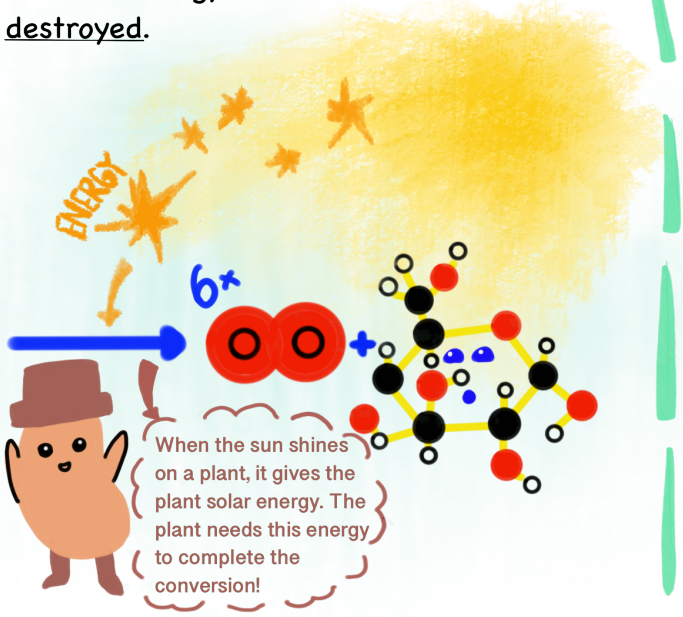
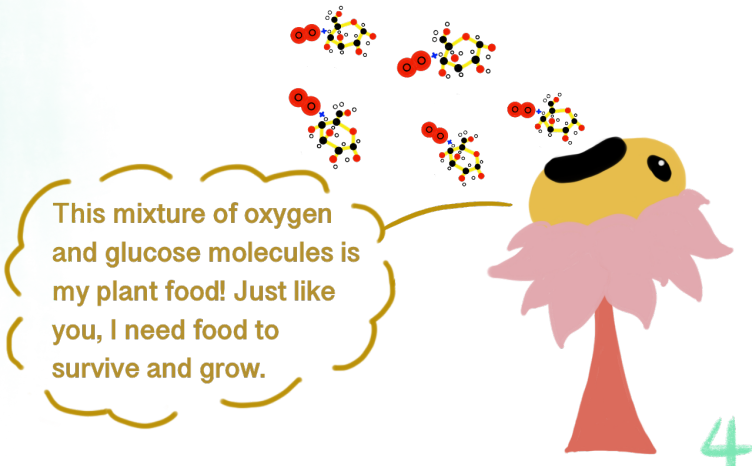
Afterwards, the plants harness the energy in the glucose molecules to perform a variety of functions through a process known as cellular respiration—what a wonderful way to lead into the next section!



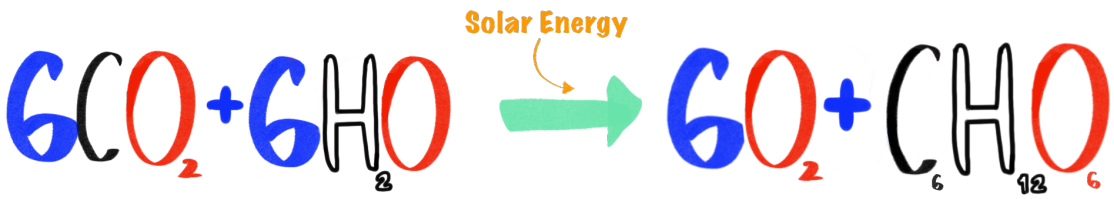
This is where the sun comes in! During photosynthesis, **solar energy** from the sun enters the plant and is transformed into the chemical potential energy stored in glucose molecules.

3



4

This is PHOTOSYNTHESIS:



What do you think CELLULAR RESPIRATION is?

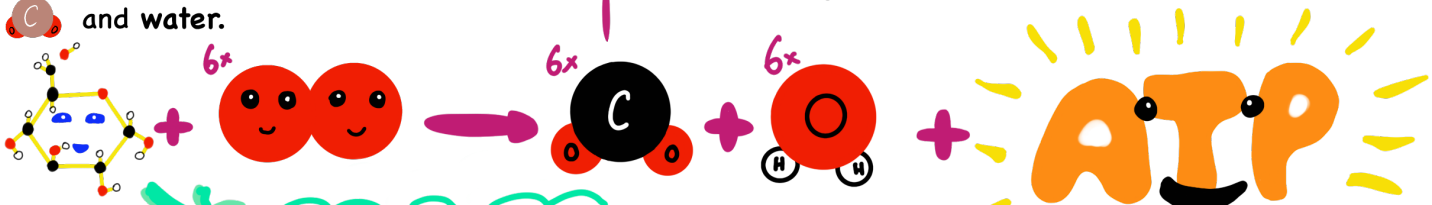
WHAT IS CELLULAR RESPIRATION?

Now I'm curious. What is cellular respiration all about? First, to be clear, photosynthesis occurs mainly in plants, while cellular respiration occurs in all living organisms, which include both plants and animals.

That's right! Cellular respiration happens in humans too!

Cellular respiration is like reverse-photosynthesis. It occurs when living organisms turn **glucose** and **oxygen** into C and **water**.

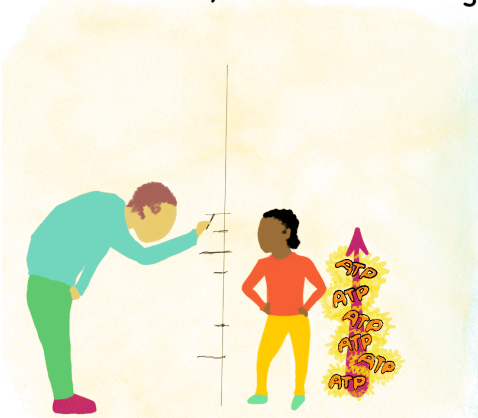
During the process, energy is released. This is because glucose is a high-energy molecule, while C and water are low-energy molecules.



Remember us? We're the **products** of photosynthesis, but we're also the **reactants** of cellular respiration!

I'm ATP, aka **a**denosine **tri**phosphate. I'm an energy-carrying molecule. All living things need energy, and I am found in all living things!

Most of this released energy is harnessed and used to carry out important bodily functions such as growth and movement; however, since energy transformations are never 100% efficient, some of the energy would be lost to heat.



This is why people feel hot when they exercise! Their bodies are performing cellular respiration to fuel the exercise, and heat comes as the byproduct of cellular respiration.

So, this is the equation for CELLULAR RESPIRATION!

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$$

Look, it is almost the opposite of PHOTOSYNTHESIS!

Have you ever wondered why

PLANTS ARE GOOD FOR THE ENVIRONMENT?

Well, it's because of photosynthesis.

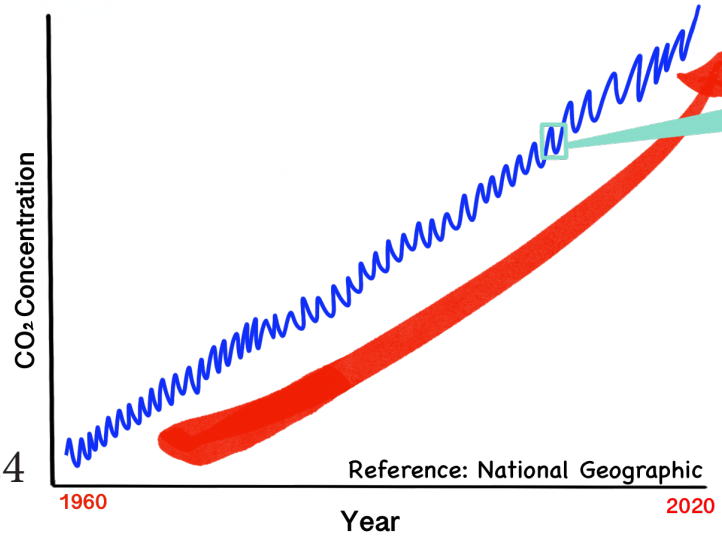
Through photosynthesis, plants take in large amounts of CO_2 from the air and store the carbon molecules in the form of glucose. This process decreases the amount of CO_2 in the air.

Have you ever heard of the KEELING CURVE?

It's a curve showcasing monthly CO_2 concentrations in the atmosphere. The reason it fluctuates from low to high on a yearly basis is due to how in the summer, there is an abundance of sunlight, so the plants can perform photosynthesis at a rapid pace and take in CO_2 from the air. Yet, in the winter, there is a scarcity of sunlight and the plants don't have leaves, so the plants would not be able to perform as much photosynthesis as in the summer, which results in a higher CO_2 concentration in the atmosphere.

KEELING CURVE

Monthly Average Carbon Dioxide Concentration

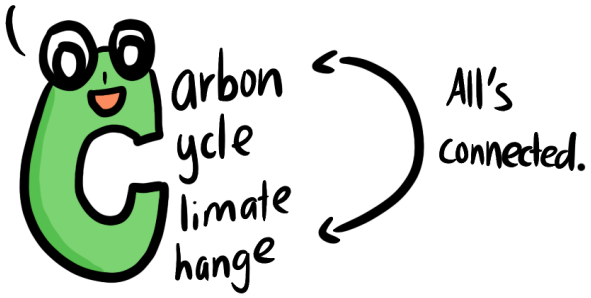


When there are lots of sunlight, plants have enough solar energy to conduct photosynthesis. Plants need solar energy to convert CO_2 and water into their fuel.

Sadly, the curve shows how there has been a steady and rapid rise in atmospheric CO_2 over the past 60 years. If this continues, the Earth would keep on getting warmer at a faster pace, which can lead to increased extreme weather events and natural disasters.

The Carbon Cycle

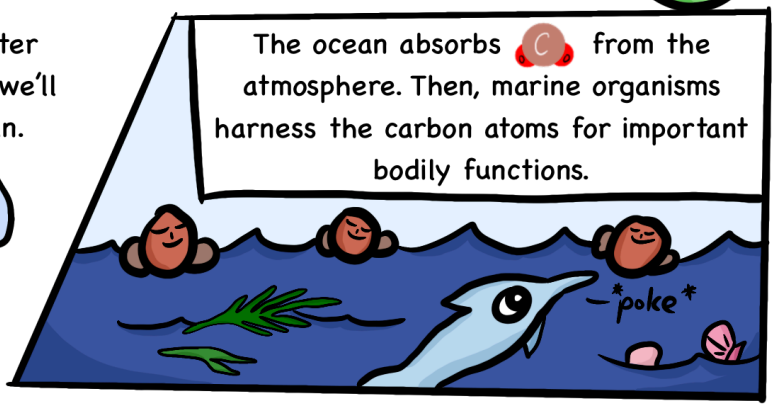
Understanding the carbon cycle is crucial to understanding climate change.



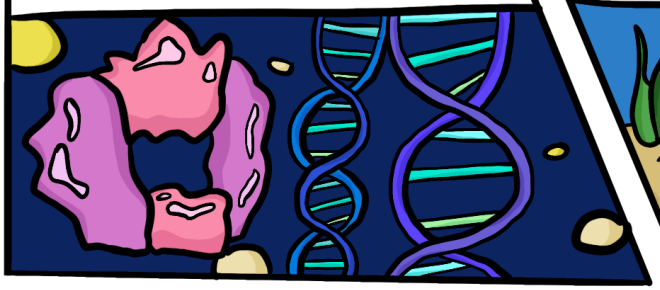
The amount of carbon atoms in the Earth never changes, as **matter is neither created nor destroyed.**

Carbon cycles through land and water ecosystems in numerous ways. Here, we'll explore its cycle through the ocean.

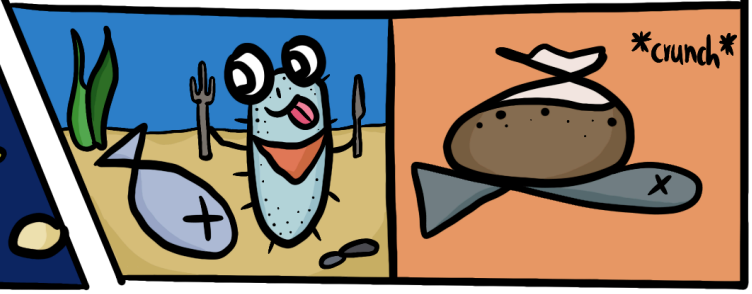
The ocean absorbs C from the atmosphere. Then, marine organisms harness the carbon atoms for important bodily functions.



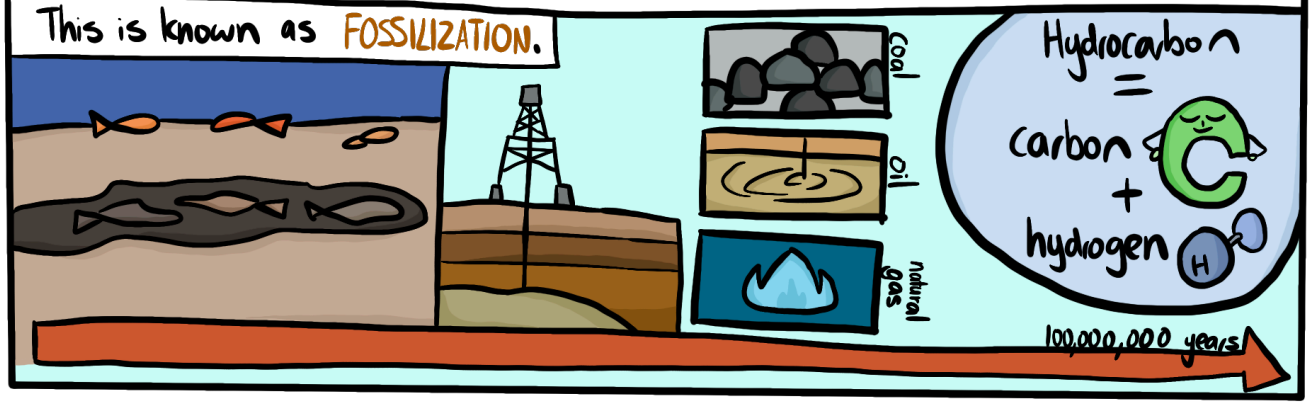
Carbon atoms are the foundation of all living organisms, forming proteins and DNA.

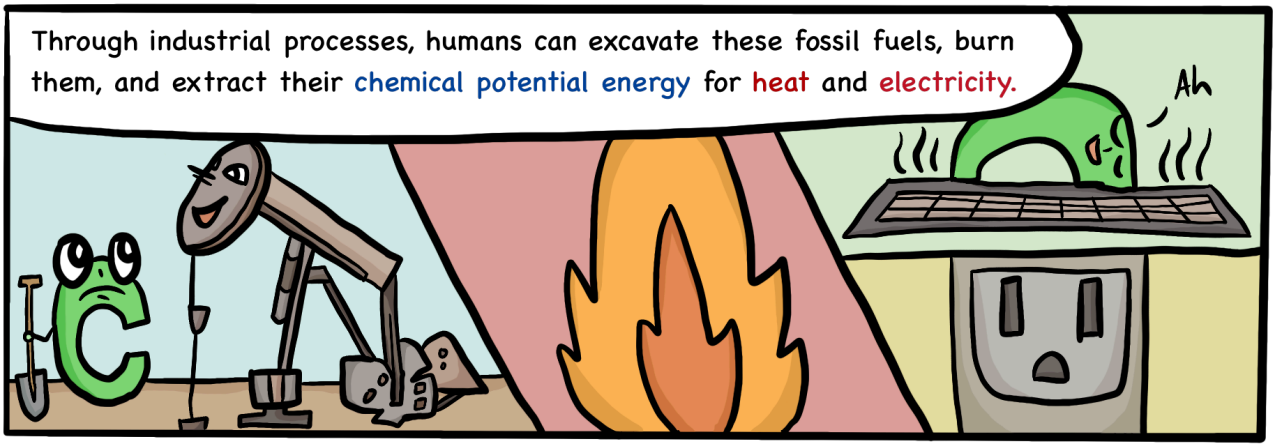


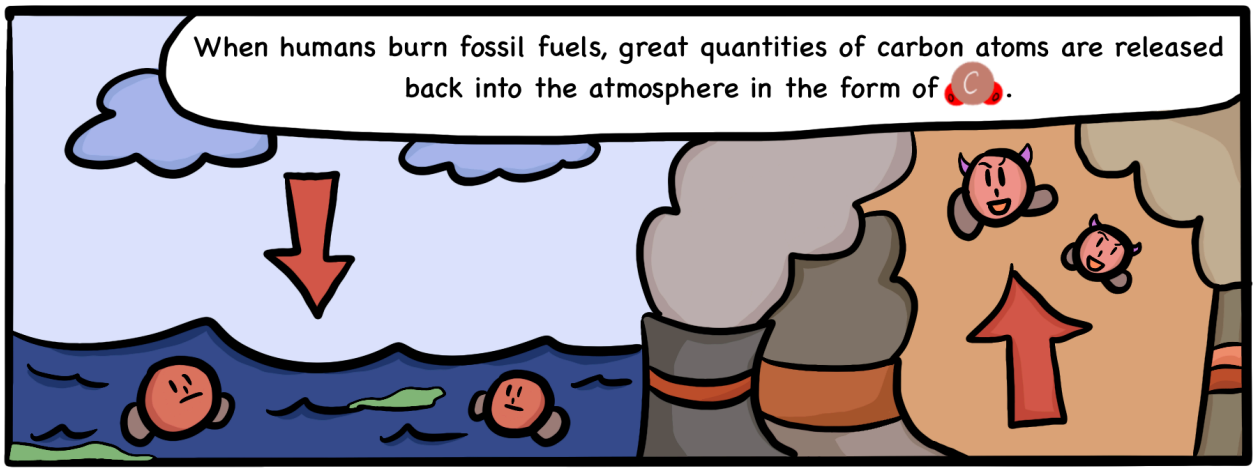
After marine organisms die, they are either decomposed by bacteria, in which the bacteria then obtains the carbon atoms, or are buried by sediments.

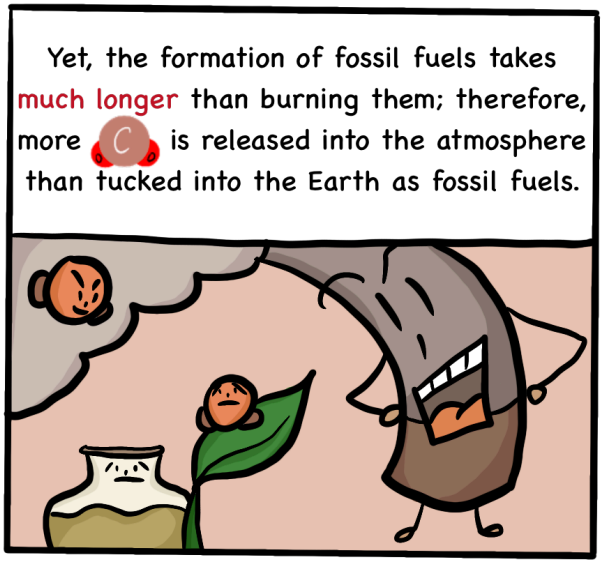


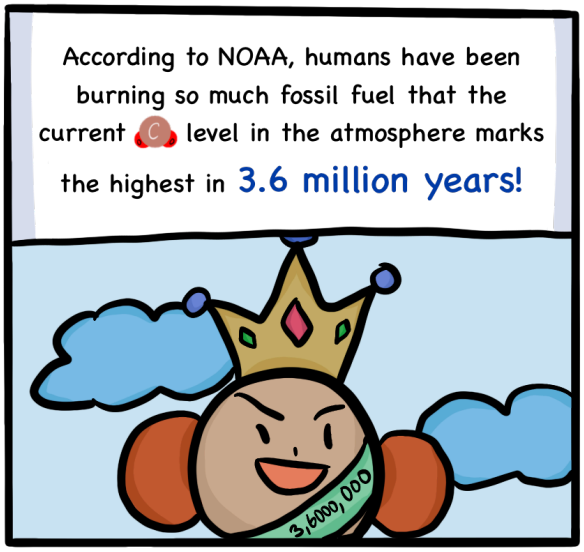
Over hundreds of millions of years under high temperatures and pressures, the buried organisms compress, undergo chemical reactions, and turn into fossil fuels. Fossil fuels are made primarily of hydrocarbon compounds.



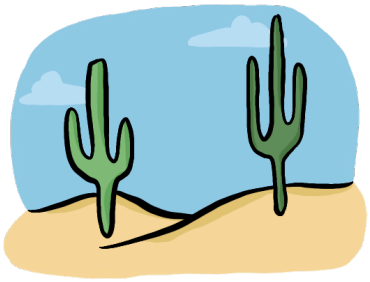


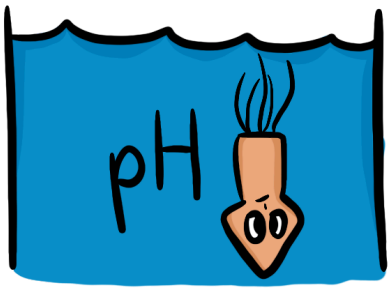


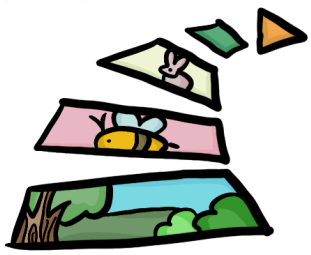


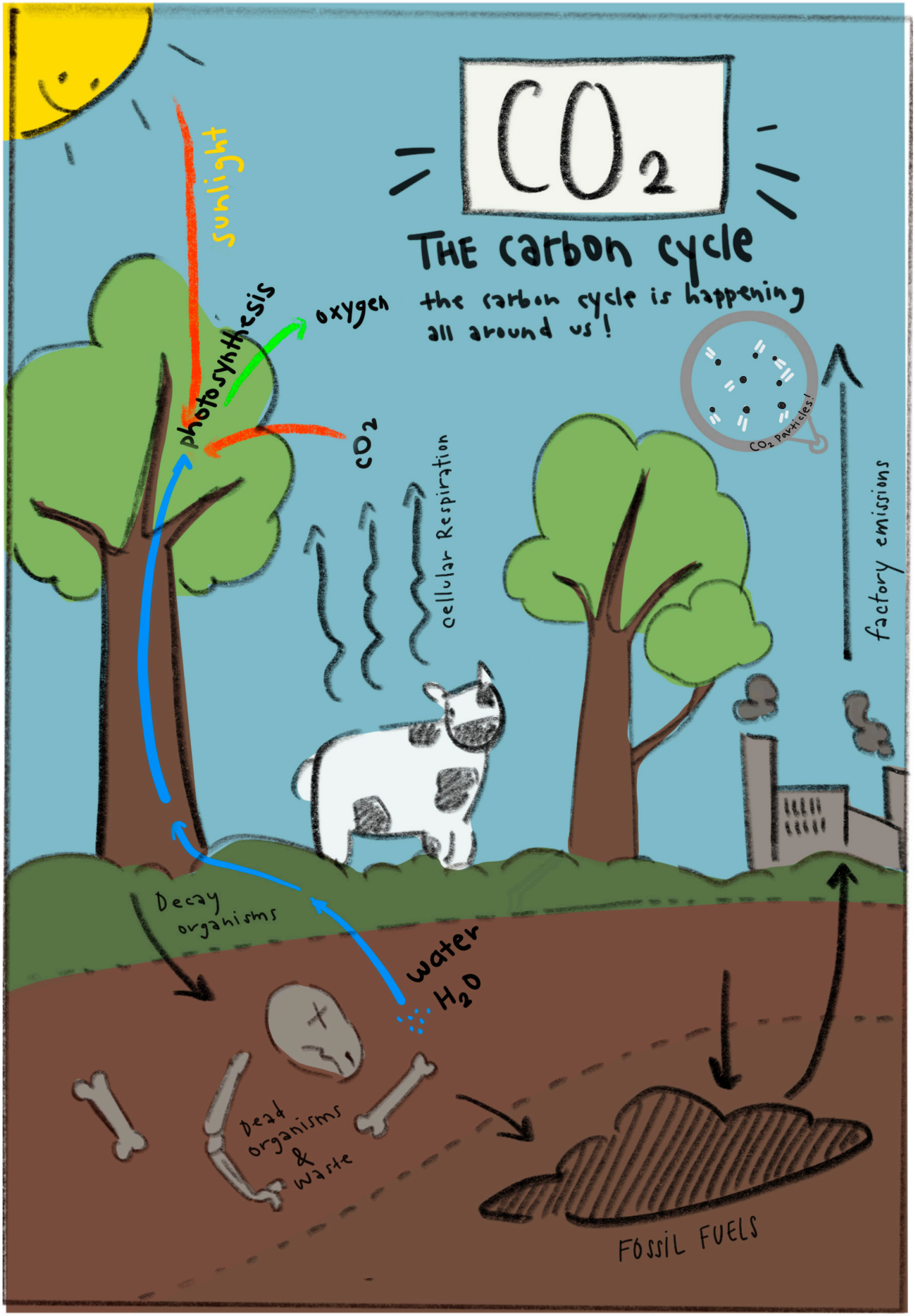


The massive amounts of C cause harmful effects such as climate change, ocean acidification, and the disruption of both terrestrial and marine ecosystems.



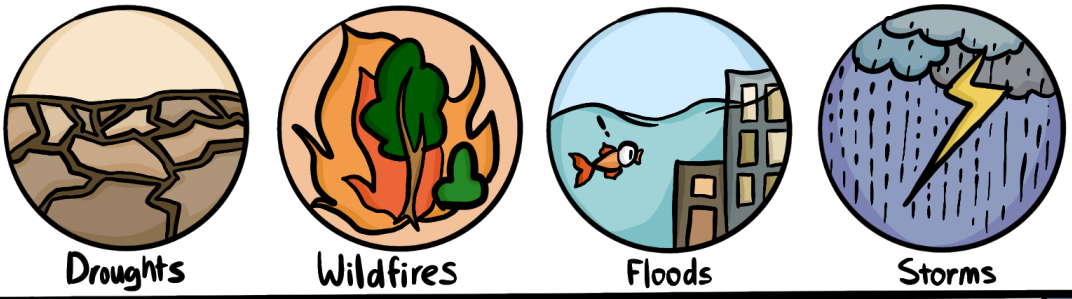


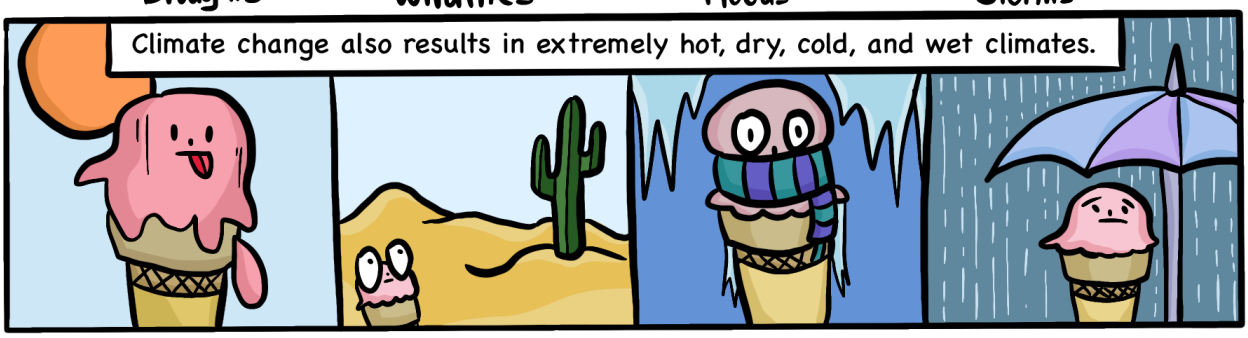


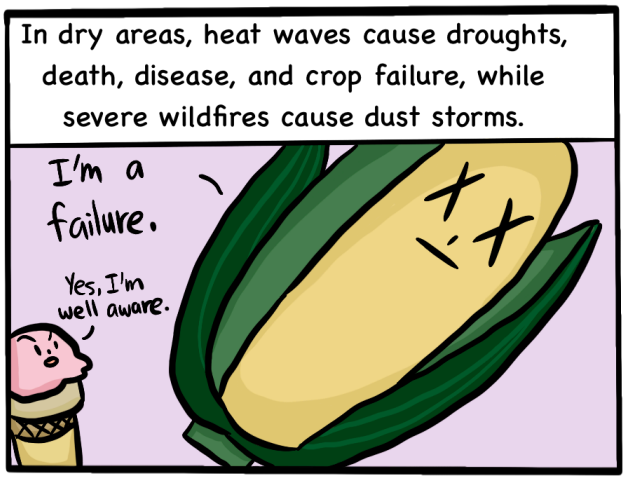

CO_2
THE carbon cycle
the carbon cycle is happening all around us!
sunlight
photosynthesis
oxygen
CO_2
cellular Respiration
CO_2 Particles!
factory emissions
Decay organisms
water H_2O
Dead organisms & waste
FOSSIL FUELS

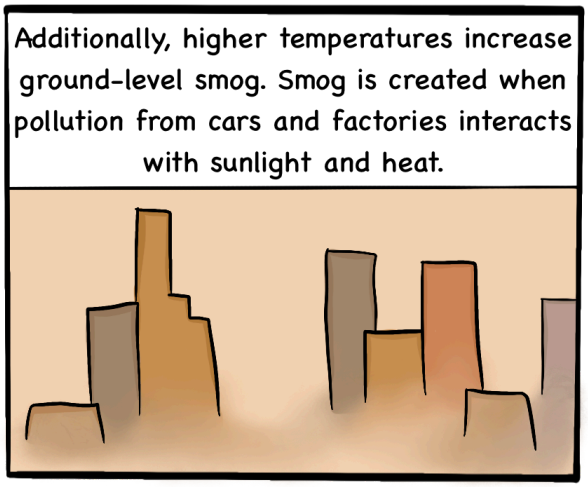
Harmful Impacts of Climate Change

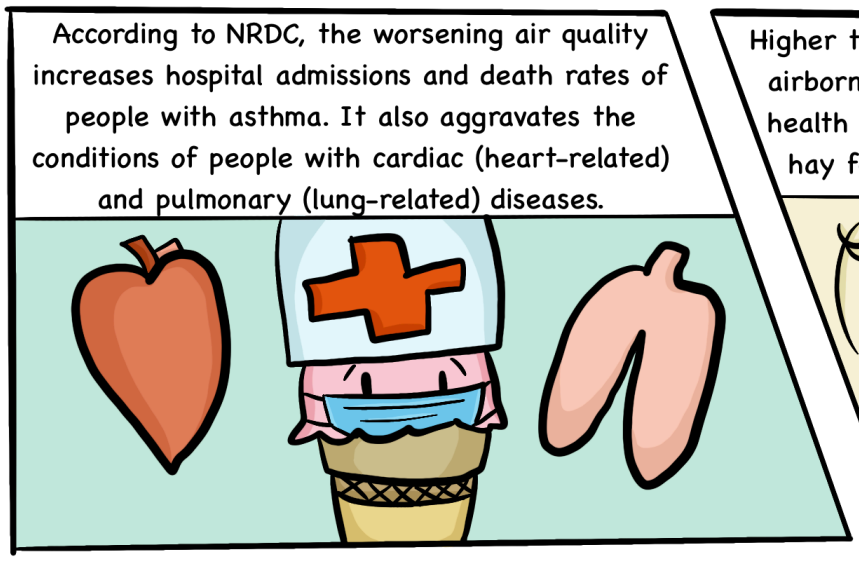
Climate change has caused extreme heat events and intense natural disasters over the past decades.

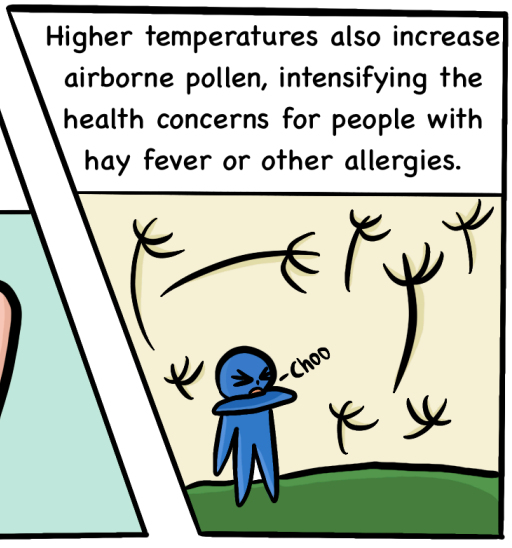






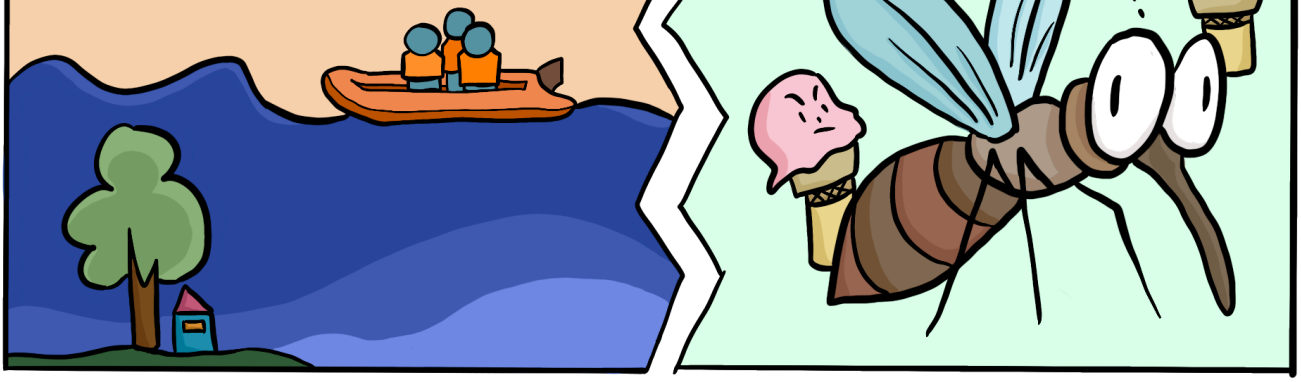




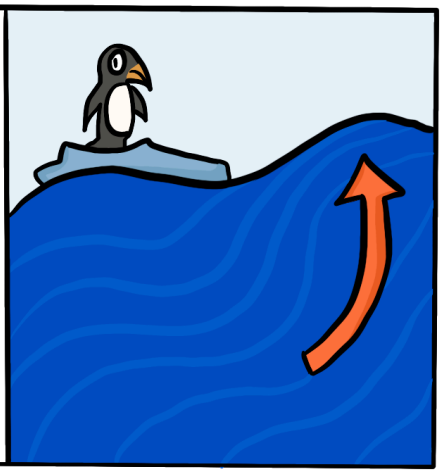


In wet regions, heavy rain causes bodies of water to overflow. The floods damage properties, endanger the lives of citizens, and create toxic spills from industrial wastewater treatment plants.

Humid regions also create an ideal environment for nurturing disease-carrying insects such as mosquitoes.



Furthermore, global warming causes rising sea levels because the melting ice sheets funnel great volumes of water into the ocean.



The rising seas threaten coastal communities, entire island nations, and many of the world's biggest cities.

Amsterdam

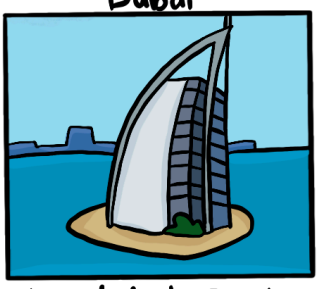
Netherlands

New Orleans

United States

London

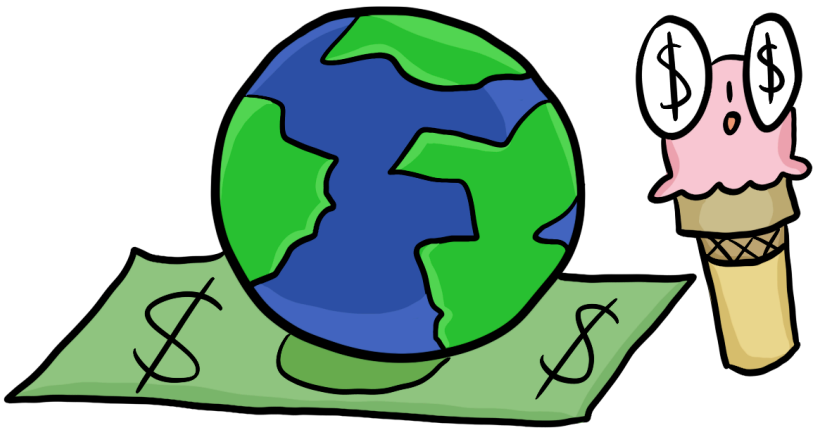
United Kingdom



Dubai

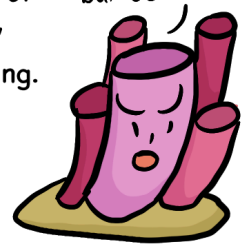
United Arab Emirates

Moreover, climate change comes with a high cost. Based on data from NOAA, severe weather and climate events in 2021 totaled **$145 billion** in damage in the U.S.

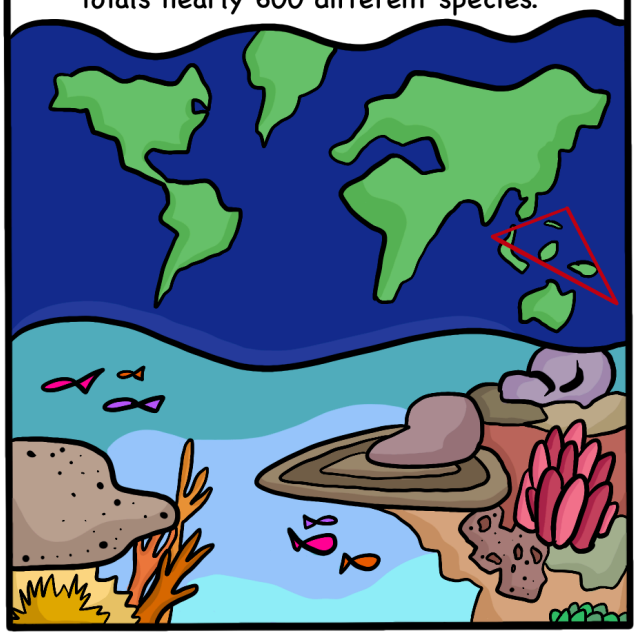


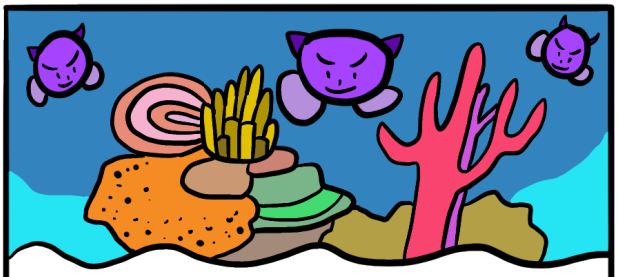
Coral Triangle

The Coral Triangle is one of the ecosystems heavily impacted by global warming.

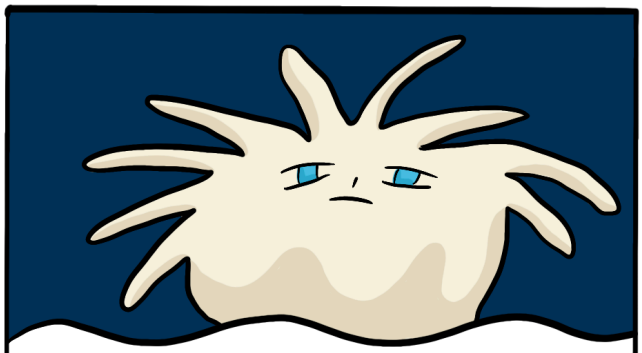


According to WWF, the Coral Triangle, located in the Western Pacific Ocean, hosts 75% of the world's coral species, which totals nearly 600 different species.



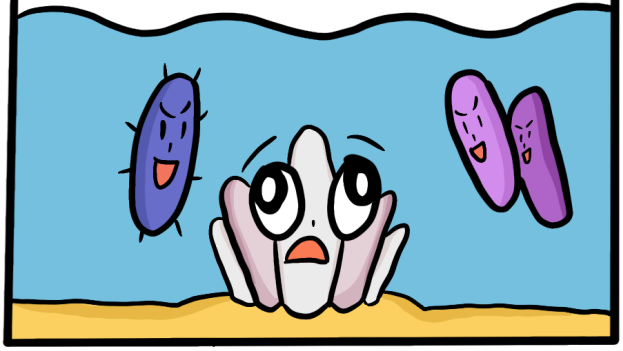


Sadly, global warming causes warming seas as well as ocean acidification that destroy the coral reef ecosystems.



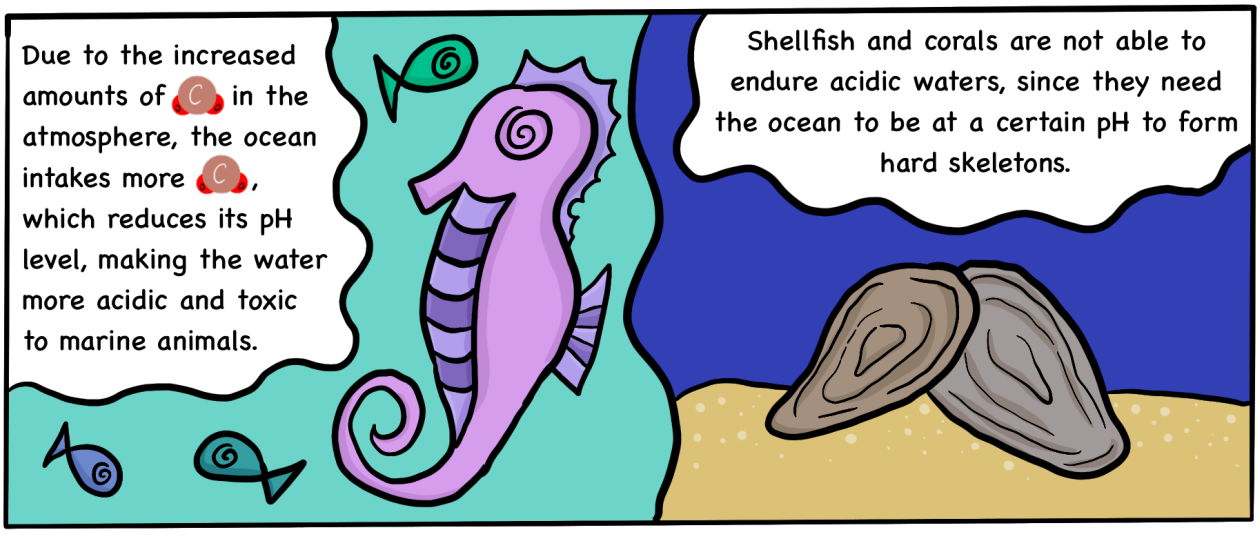
The warm water causes a phenomenon known as coral bleaching. When corals face warm waters, they expel an algae known as zooxanthellae that lives in their tissues.

Without the algae, the coral loses its major food provider and turns white. Although corals can survive coral bleaching, they become more vulnerable to disease.



A note on ocean acidification:

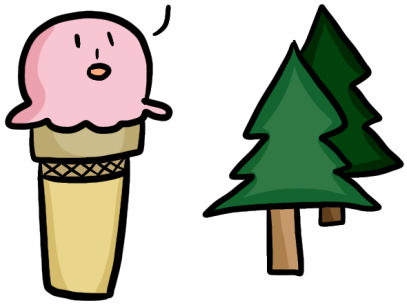
Due to the increased amounts of CO_2 in the atmosphere, the ocean intakes more CO_2, which reduces its pH level, making the water more acidic and toxic to marine animals.



Shellfish and corals are not able to endure acidic waters, since they need the ocean to be at a certain pH to form hard skeletons.

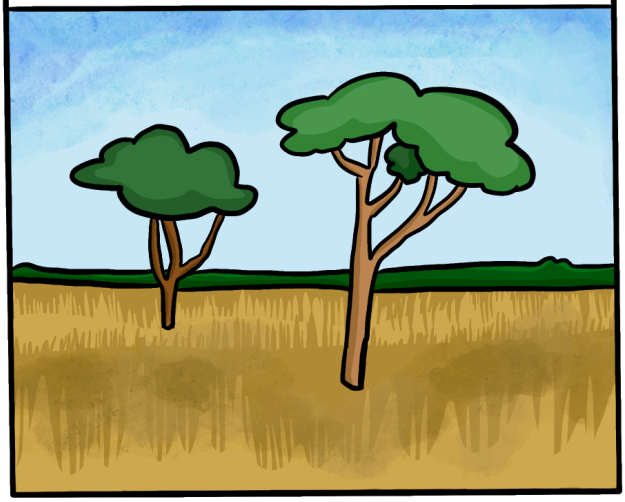
Amazon rainforest

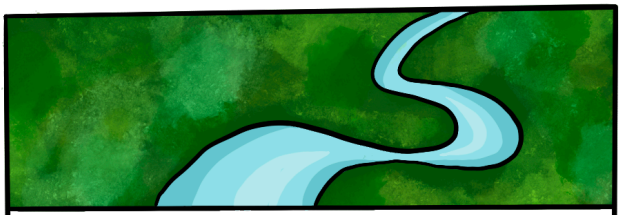
Another heavily impacted ecosystem is the Amazon rainforest.



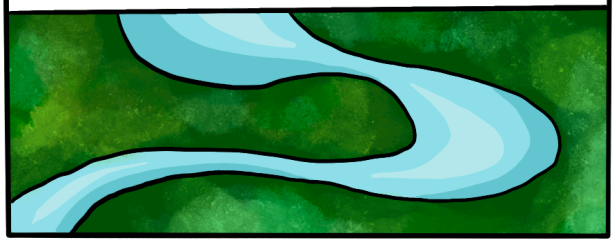
By the year 2050, WWF states that the temperature of the Amazon rainforest could increase by 2°C to 3°C. Additionally, decrease in rainfall and shifting weather patterns would lead to widespread droughts.

In fact, according to WWF, 30% to 60% of the Amazon rainforest could turn into dry, mostly treeless savanna.



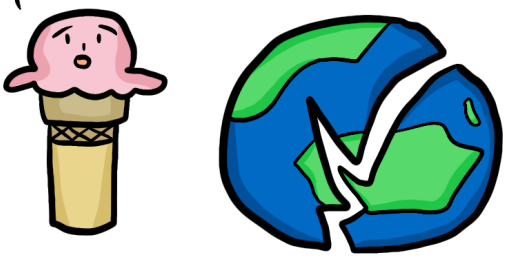


These climate-induced changes in the Amazon rainforest could lead to increased soil erosion, poor soil quality, degradation of freshwater ecosystems, and the spread of diseases.



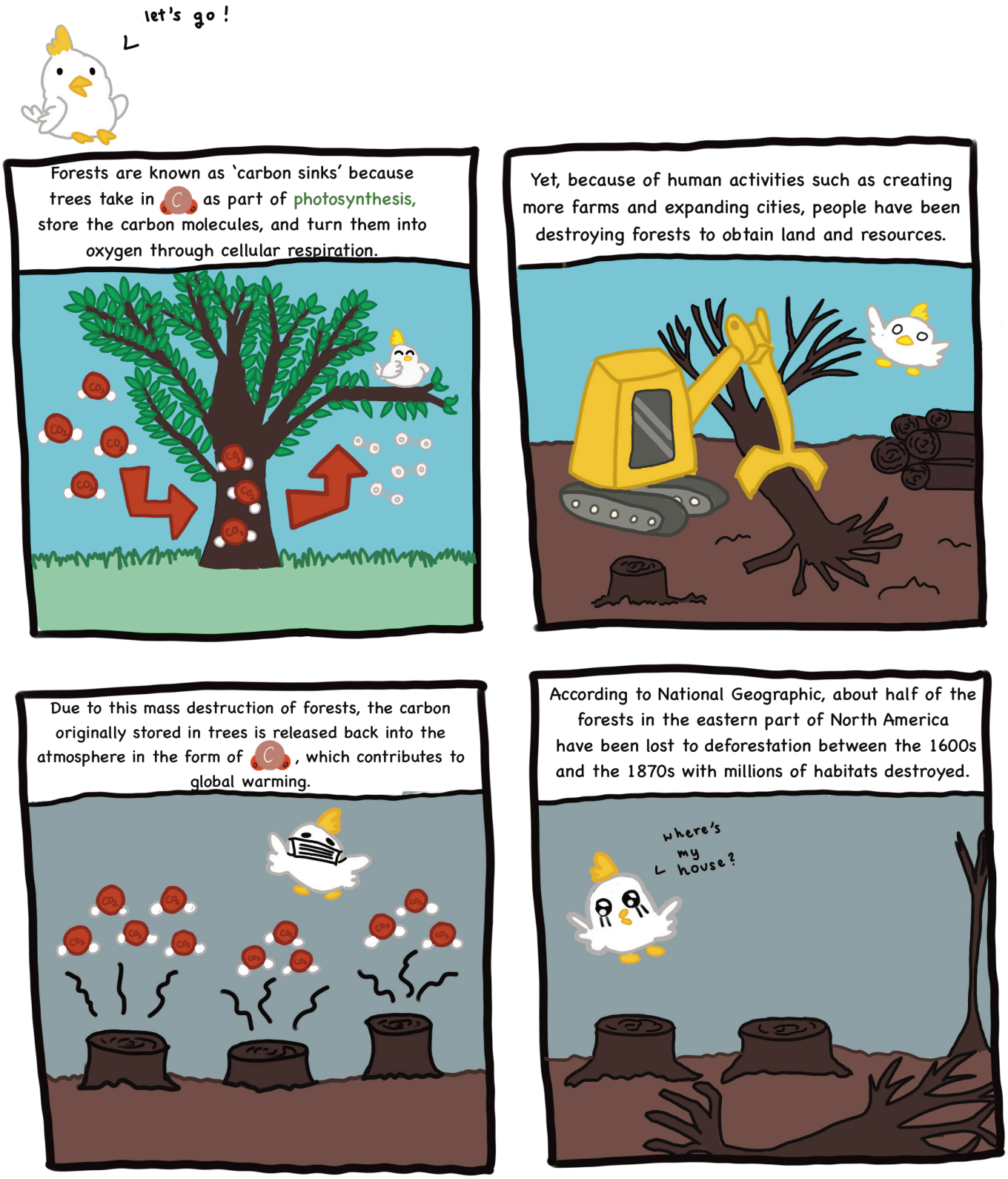
Then, all the industrial tradeoffs and technological advancements would be futile if humans could not even have a habitat.

With all these changes, the Earth might not be habitable in the future.



So... How can humans slow the increase of global temperatures?

One way is through reforestation!

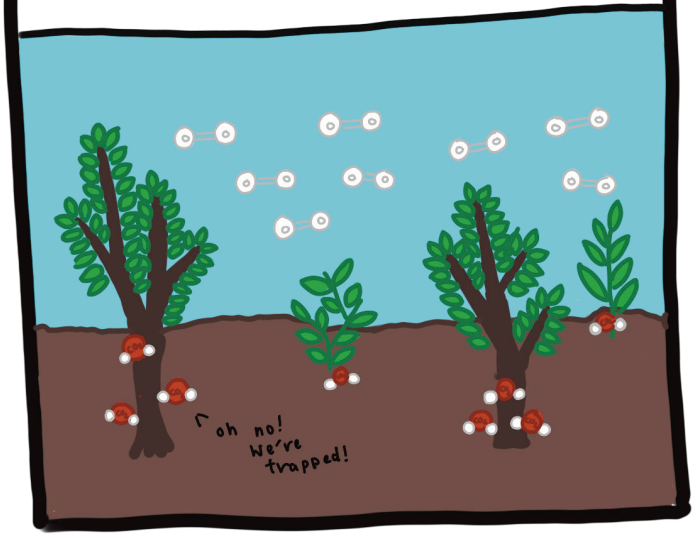


Deforestation and reforestation continued...

To combat the destructive effects of deforestation, an effort to renew forests has emerged.

Yes there is! The process of reforestation allows new trees to be planted in areas of damage.

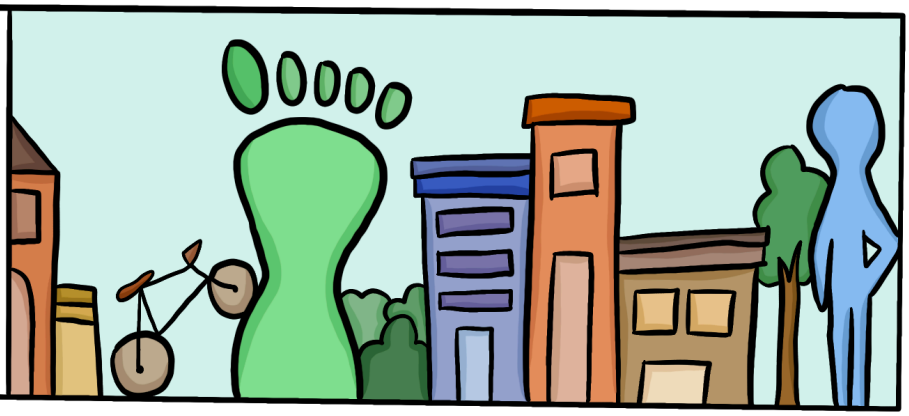
The planting of new trees allows for a renewed storage of carbon molecules via photosynthesis, thus reducing the amount of C in the atmosphere.



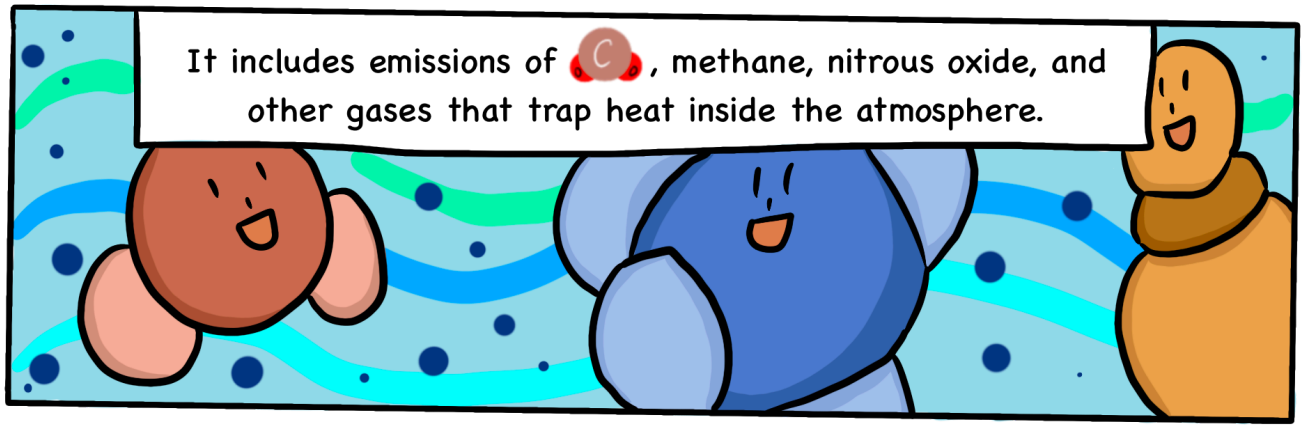
Reforestation increases carbon sinks and restores the habitats of all organisms.

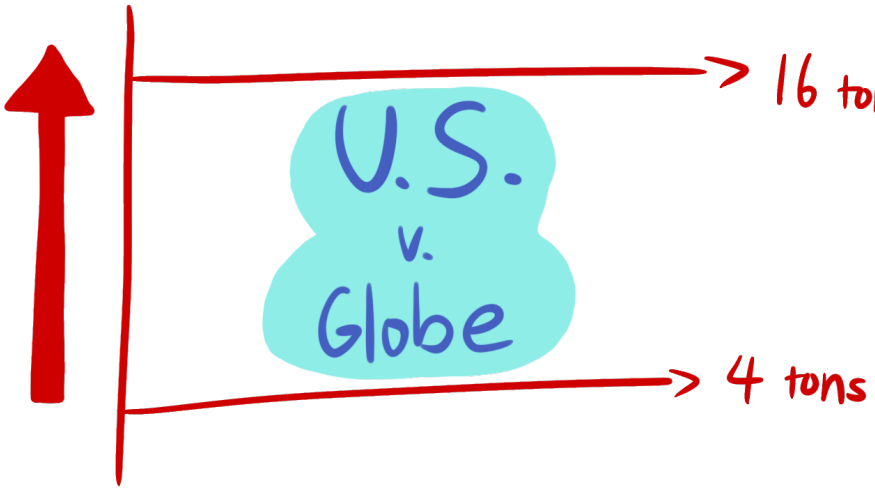
Carbon Footprint

Carbon footprint is the total amount of greenhouse gas emissions generated by an activity, institution, service, product, person, etc.



It includes emissions of CO_2, methane, nitrous oxide, and other gases that trap heat inside the atmosphere.

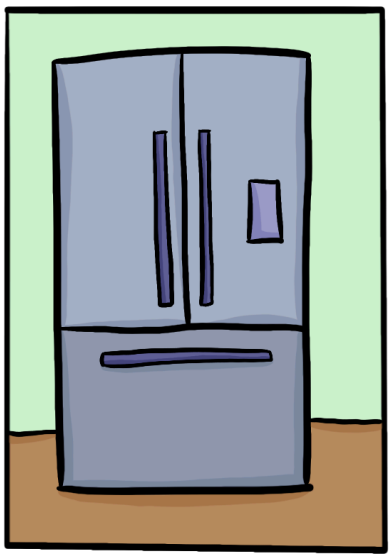


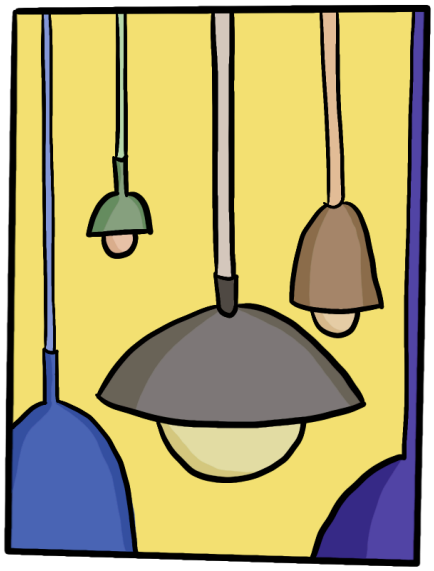


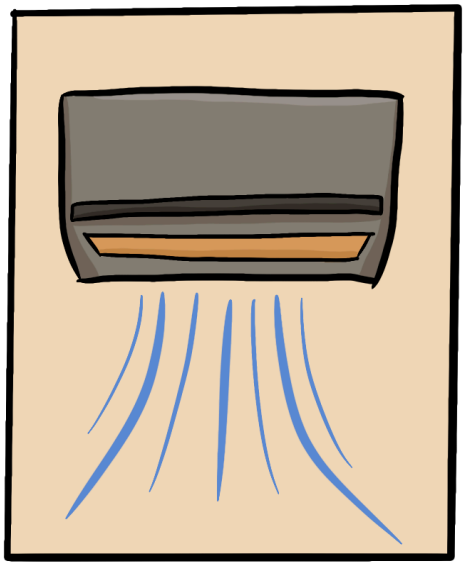
Based on data from The Nature Conservancy, the current average carbon footprint for a U.S. citizen is **16 tons** every year, while the global average is around **4 tons.**

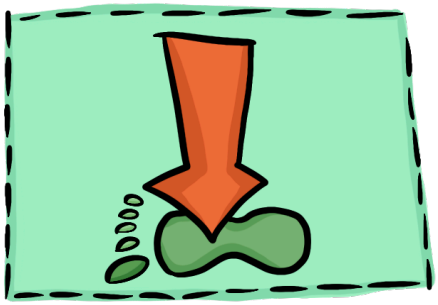
The largest contributor of carbon footprint is the burning of fossil fuels, which provides energy for transportation, electricity, industry, agriculture, and forestry.

Other commercial and residential usages of the energy harnessed through fossil fuel burning include refrigeration, ventilation, lighting, electrical appliances, and air conditioning.







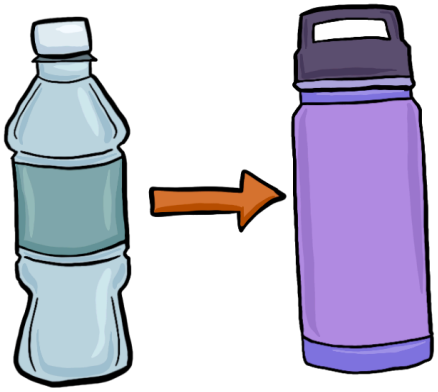


Here are some ways to reduce one's carbon footprint on an **individual and societal** level:

Personal habits

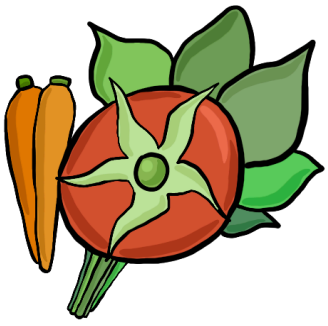
1

Stop buying single-use plastic water bottles, and start using a sturdy, reusable water bottle.



2

Transition to a plant-based diet.



3

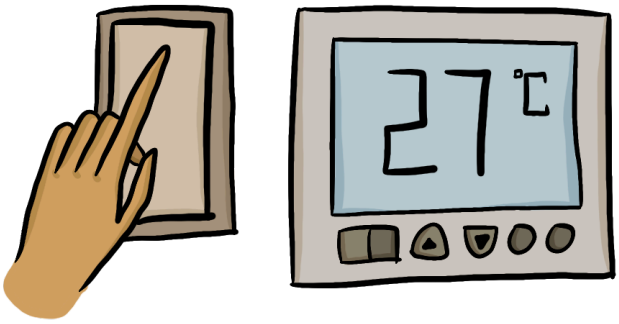
Avoid fast fashion and buy clothes that you can wear many times.

4

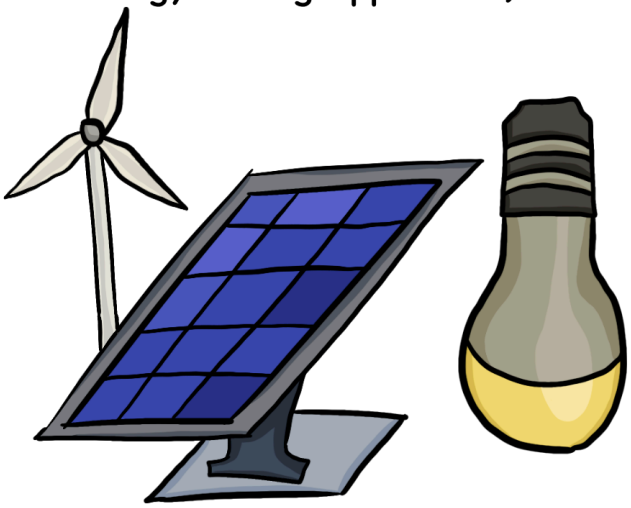
Take shorter showers.

Household

1 Reduce energy use (e.g. turn off lights when not using them, adjust thermostat before traveling).

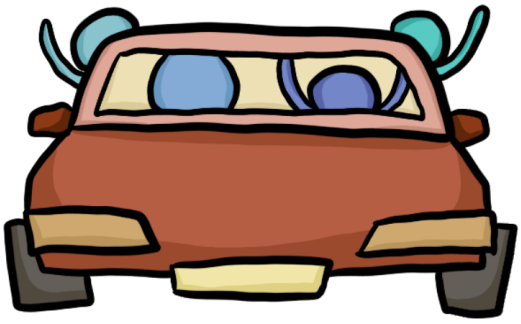


2 Transition to renewable energy sources (e.g. solar panels, wind power, and energy-saving appliances).

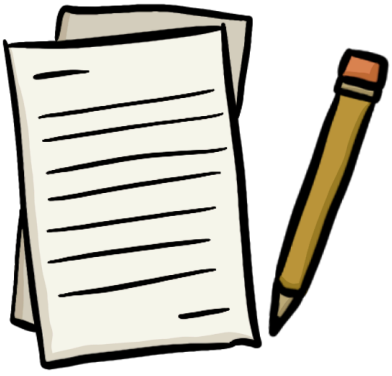


Social habits

1 Biking or carpooling with friends.



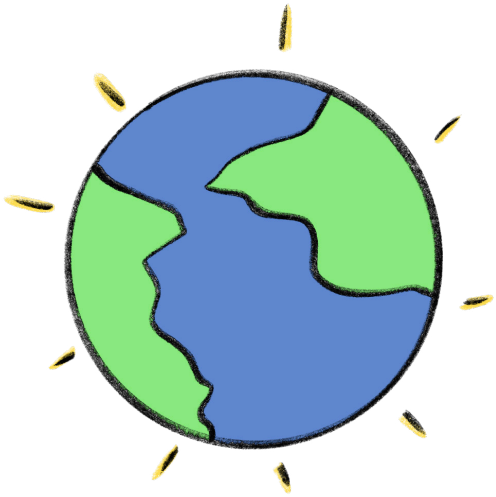
2 Write and sign letters to Congress to advocate for climate action.



LET'S TAKE ACTION NOW.

"We are the first generation to feel the effect of climate change and the last generation who can do something about it."
Former President Barack Obama - 2014 UN Climate Summit

The END.

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