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PERFECT PLANET

PERFECT PLANET

WHAT MAKES PLANET EARTH A PERFECT PLANET?

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LIGHT

Light from the Sun is the energy that primarily drives the atmosphere, oceans and life on Earth. Autotrophs (many bacteria and plants) use energy from sunlight to form compounds such as sugars. Heterotrophs (other bacteria, fungi and animals) gain energy by consuming the autotrophs or their products.

WHY ON EARTH?

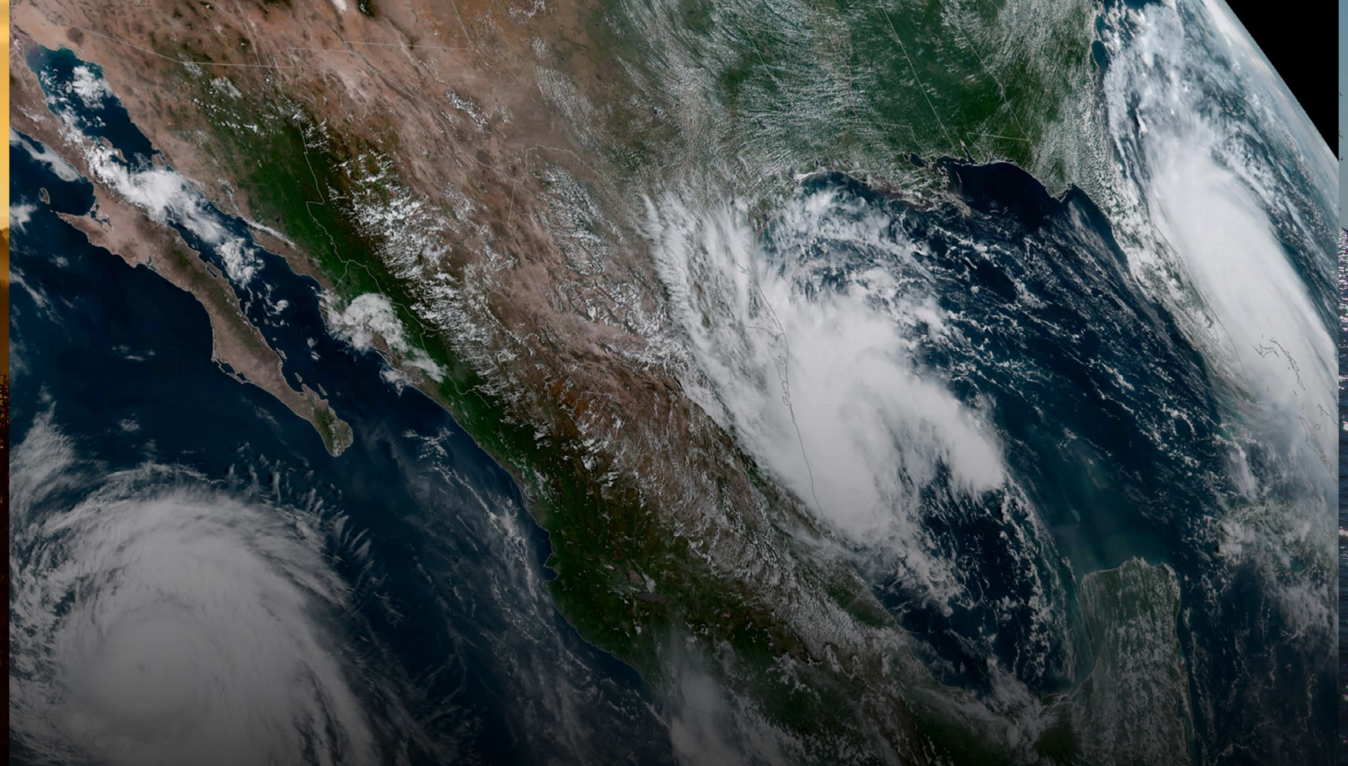
The tilt of the Earth's rotation axis (23.4°) results in seasons because in June the northern hemisphere faces toward the Sun, and more sunlight falls onto each square metre of surface, whereas in December it faces away. The tilt varies (22.1°–24.5°) on a 40,000-year timescale; even these small changes in tilt have big impacts on climate.

THE STORY SO FAR...

The word 'light' is normally used to refer to the visible wavelength region of the electromagnetic spectrum that our eyes can detect, 0.4–0.7 μm (*millionths of a metre*). All bodies emit electromagnetic waves, with temperature determining the wavelength at which most energy is emitted. For the upper layers of the Sun, at about 5500 °C, this energy is mostly in the visible range and at shorter ultraviolet wavelengths. The atmosphere is transparent at visible wavelengths, known as a 'window', and much of this energy reaches the surface, if it is not scattered by clouds. The Earth also emits electromagnetic waves, but at its cooler temperature these are in the infrared spectrum with a longer wavelength of around 10 μm. This radiation escapes to space through another window, but the atmosphere in this region is not completely transparent and several gases (including water vapour and carbon dioxide) absorb some infrared radiation.

CURRENT ISSUES

The energy from sunlight absorbed by the Earth is closely balanced by the infrared emission from Earth, which determines the Earth's temperature. If the surface emission is absorbed and reradiated by gases in the atmosphere, then the surface will become warmer than it would be in the absence of any atmosphere. A similar process can be experienced on a winter night; a frost often forms when the sky is clear, whereas the ground is warmer when the sky is cloudy and surface emission is scattered back down by the cloud particles. Changes in the amounts of absorbing gases result in climate change. Absorbing gases will tend to warm the surface, but clouds and particulates, e.g. from volcanic emissions and pollution, are more complex since they can back-scatter sunlight during the day. A small imbalance in the Earth's radiation balance is detectable by satellite instruments, indicating that the planet is heating up.



WEATHER

Weather is the response of the atmosphere to variations in solar heating across the Earth's surface. Movements of air carry heat from warmer to cooler regions. Under the influence of the Earth's rotation and gravity, these motions form complex and often irregular patterns, which we recognise as weather systems.

WHY ON EARTH?

On average, the Earth's surface absorbs over 300 W/m^2 (*watts per square metre*), of sunlight throughout the year in the tropics, but less than 100 W/m^2 at latitudes closer to the poles. Atmospheric winds and ocean currents carry heat poleward. At the latitude of Europe, the annual average atmospheric heat transport is about 3 million billion watts.

THE STORY SO FAR...

Weather impacts on all living creatures on Earth, ranging from the devastation of a great storm to the essential supply of water and nutrients in arid regions. The heat transported by the atmosphere is in the form of warmer air replacing cooler air as it moves, and latent heat, taken up as water evaporates and released again when it condenses to form rain or snow. The weather means that higher latitudes are warmer than they would otherwise be, and the tropics cooler, but the circulation patterns determine which regions are lush rainforests and which are deserts, enabling life over many habitats. The atmosphere itself is crucial for life on Earth, not simply supplying oxygen for respiration, but keeping the whole Earth's surface about 35°C warmer on average than it would be otherwise.
It also contains gases such as ozone, which absorbs ultraviolet wavelengths in sunlight that would otherwise damage living cells.

CURRENT ISSUES

Weather means the day-to-day changes that we experience, particularly in the troposphere, the lowest 10–15 km of the atmosphere. The climate, on the other hand, is the average atmospheric state compiled over many years, for different regions and times of year. The World Meteorological Organization standard is a 30-year average, updated every decade. This average smooths over individual weather events. Changes in climate do not have to mean small, persistent changes in the atmosphere, but might mean that particular weather events (e.g. a very warm day or a severe storm) become more or less frequent over the course of one 30-year period compared to an earlier one. The Earth's climate has changed hugely over its history, often over long timescales, with profound effects on life. Understanding the impacts of rapid anthropogenic changes to the climate system today requires complex models with many different, coupled processes simulated.

OCEANS

Earth's oceans dominate our planet's natural systems. They control our climate, our carbon cycle, support an incredible diversity of life and produce half of the oxygen we breathe. Having existed and supported life since shortly after Earth's formation, oceans are currently experiencing unprecedented environmental pressures from humans.

WHY ON EARTH?

Earth is the perfect planet to host oceans, primarily because of its position in the solar system's 'Goldilocks' zone of habitability. This is the zone, moving out from our Sun, which is not too hot, but not yet too cold, so planets within this zone can therefore support liquid water on their surface.

THE STORY SO FAR...

Since the oceans first formed 4.5 billion years ago, ocean basins have slowly but continually opened, closed and reopened, driven by the shifting tectonic plates. Our oceans' chemistry reflects the weathering of rocks from the surrounding continents. Life has evolved to make use of various substances dissolved in seawater to build soft (e.g. tissues) and hard (e.g. shells) body parts. Plankton are the foundation of complex ocean food webs and, through photosynthesis, they absorb as much carbon as all the trees and grasses on land. These tiny plankton also produce half of all the oxygen that we breathe. There are intimate links between geological processes in our planet's interior and life in its oceans. Hydrothermal vents occur where new crust is being added to ocean plates. This process modifies the oceans' chemistry. It affects the organisms that inhabit the oceans because the chemistry of seawater determines what types of hard body parts can be made by organisms.

CURRENT ISSUES

The cumulative impact of human activities is disrupting many delicate balances that maintain the health of our oceans. One of the most worrying and widely anticipated impacts of ongoing global warming is a weakening or collapse of the oceans' overturning circulation. This is the vast system of oceanic currents that plays a major role in maintaining our regional climates and our oceans' biological productivity by transporting enormous volumes of heat, salt, nutrients and carbon around the planet. Recent global warming is caused by rising concentrations of carbon dioxide (CO_2) in our atmosphere. The oceans may be able to help us with our 'CO_2 problem' because they have an ability to store vast amounts of CO_2 – they contain 60 times more carbon than the atmosphere. They have currently absorbed up to half of the excess CO_2 generated by human activities, but this absorption is increasing ocean acidity, threatening the survival of marine organisms and their habitats.

VOLCANOES

Volcanoes provide us with a window to the inside of the Earth. Volcanic activity is the surface manifestation of internal thermal processes and volcanoes can erupt solids (ash and rocks), liquids (lava and sulphur) and gases (mainly steam, but also SO_2, CO_2, H_2S and other gases).

WHY ON EARTH?

Earth is dynamic because it is hot inside and volcanic activity releases some of this heat. Without internal heat, there would be no volcanic activity. Most volcanoes are found near the edges of the tectonic plates and most are beneath the oceans. There are over 600 active volcanoes on land and every day about 60 erupt.

THE STORY SO FAR...

Volcanoes bring important elements to the surface and into the atmosphere. Hot fluids concentrate precious metals and rare elements beneath volcanoes but most of the gas erupted by volcanoes is actually steam. Where tectonic plates are pulling apart, such as along the middle of the Atlantic Ocean and in the east of the Pacific Ocean, volcanic fluids escape from the ocean floor at high pressure and temperature, and support vibrant ecosystems around 'black smokers'. At these depths, life is supported not by energy from the Sun, but from the volcanoes.
On land, soils around volcanoes are known to be particularly productive for agriculture, as they are rich in iron, magnesium, potassium, sulphur, phosphorous and many other trace elements. Lava and ash make excellent building materials, and geothermal power can be produced by exploiting the heat beneath the surface.

CURRENT ISSUES

A small volcanic eruption in one part of the world can impact life thousands of miles away. In 1815, the enormous eruption of Mount Tambora injected ash into the atmosphere that lowered global temperatures for many months and led to worldwide harvest failures and political unrest. In 1883, the eruption of Krakatoa caused devastating tsunamis killing tens of thousands of people, and again the climate cooled slightly. The much smaller eruption of the Icelandic volcano Eyjafjallajökull in 2010 grounded airlines and disrupted travel and trade for several weeks. Volcanoes have become tourist destinations, with tragic consequences when eruptions catch people unaware. Volcanoes have shaped our Earth, bringing life-giving minerals and heat to the surface. We still don't understand these powerful, natural phenomena particularly well and they remain very dangerous close up.

LIFE

Life is a runaway process and the number of species on Earth has increased over time, with new species providing new opportunities for others. The exceptions are, so-called mass extinction events, where a high proportion of species have gone extinct over a relatively short space of time, usually a few million years.

WHY ON EARTH?

Even though living things are found in the hottest, coldest, deepest and highest points on Earth, all of what we recognise as 'life' needs liquid water to survive, grow and reproduce. The particular range of conditions on Earth that allows water to exist as a liquid has supported the establishment and evolution of what we call 'life' on Earth.

THE STORY SO FAR...

It is easy to think of living things as being separate from or entirely dependent on environmental processes, such as nutrient and water cycling, weather, and the formation and breakdown of rocks. However, in reality living things and these environmental processes are closely intertwined. Large areas of forest such as the Amazon basin create their own weather systems that affect weather patterns across the globe.
Large herbivores play important roles in cycling nitrogen, carbon and silicon. The skeletons of marine organisms fall to the bottom of seas and, over geological time, make new limestone rock.
There is also a close relationship between diversity of life and stability. The parts of the planet that have remained most stable and hospitable to a variety of life for longest, such as some tropical forests, are also those that support the greatest diversity of life today.

CURRENT ISSUES

Extinction is a normal process, with most species lasting no more than a few million years before they go extinct. However, mass extinction events are a different phenomenon, where large numbers of species or entire groups of species go extinct very rapidly.
There have been many mass extinction events in the past but, despite that, there are still more species alive today than at any other point in Earth's history.
We are currently seeing high rates of extinction, far higher than the natural 'background' rate of extinction. These extinctions are being driven by human factors, and while this may not yet meet the definition of a 'mass extinction event', it is a cause for great concern. Ecosystems that lose species tend to be less resilient to change, so extinction threatens the delicate balances that support important processes in the Earth's system.

HUMANS

Since modern humans evolved in Africa at least 300,000 years ago, our species has become one of the most successful in the history of life. We have spread to occupy all continents and the human influence reaches around the globe and even to the depths of the oceans.

WHY ON EARTH?

The past 12,000 years, the Holocene Epoch, has been a time of unusually stable and amenable climate for modern human society development. Agricultural development has allowed humans to settle in specific locations and build sophisticated cultures and bodies of knowledge, leading to the modern, technological and urbanised nature of most human society.

THE STORY SO FAR...

The stable conditions in the Holocene epoch, and the development of agriculture, allowed human populations to increase and spread dramatically. At 10,000 years BCE, the human population was probably around 4 million individuals. By the year 1500 CE, it may have approached 500 million. The past 200 years have seen an extremely rapid rise in population from around 1 billion in 1800 to 2 billion by 1930, to 4 billion in 1975, to the present-day population of more than 7.5 billion people. Most of the increase in the twentieth century was due to reductions in child mortality and increases in life expectancy as a result of spectacular improvements in healthcare. This remarkable increase in population, combined with greater consumption, particularly in Western countries, has increased the footprint of people on the planet. There is now nowhere on Earth that is not affected in some way by human activity.

CURRENT ISSUES

Some geologists have proposed that we have entered a new epoch, the Anthropocene. This is defined by visible signs of humanity in the geological record. Although people have changed Earth's environments, we are still dependent on environmental processes and ecosystems for our survival and wellbeing.
If we continue to degrade our environment, in the way we are, this will ultimately affect humanity. Some of the effects of environmental breakdown on people around the world are, in fact, already being seen. Large populations are being affected by fires, floods and other extreme weather that has been exacerbated by climate change. We are seeing declines in wild pollinating insects, which has threatened some crops, and pollution, affecting water supplies and fisheries.
It is vital to reduce these negative impacts on Earth's environment for the future of the planet on which our species and millions of other species depend.