Linking STEM and SDGs in the primary school!

The Pale Blue Dot Programme (PBD)

MODULE 2

The formation and development of the earth

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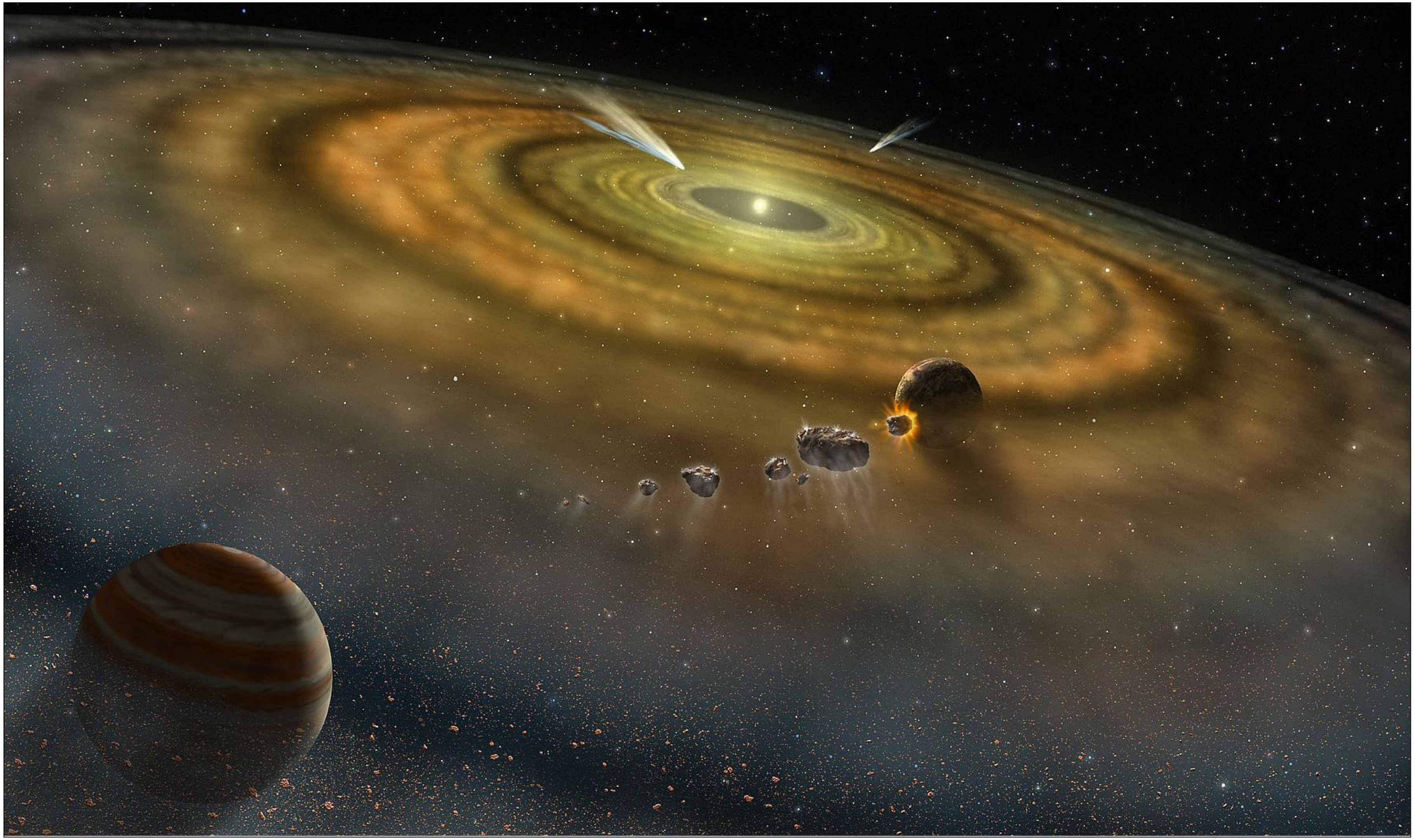


The formation of the solar system. Source: NASA

Content

1. The history of the formation and development of the earth - basic knowledge for teachers

In Module 1, we learned about some of the Earth's special properties. We compared the Earth with the Moon and also with the other planets and discovered the important role that its atmosphere and mass play in its habitability.

In this module, we will now ask ourselves how the Earth and the other planets were formed and when and how life on Earth began. The history of the Earth's formation is based on scientific knowledge and theories that are supported by observations, analyses and experiments.

1.1 The origin of the earth's chemical elements

The first question we ask ourselves is: where do the many different elements that make up the earth come from? Astronomy provides an answer: all the chemical elements we know, helium, the oxygen we breathe, carbon, iron, iodine, silicon and so on, were created inside stars. Yes, we are stardust!

The stars we see in the sky are not simply scattered all over the universe, but are concentrated in our home galaxy, which we call the Milky Way. The Milky Way consists of around 200 billion stars as well as clouds of gas and dust. It looks like a huge flat disk with a diameter of around 150,000 light years. This means that a beam of light would take 150,000 years to travel from one side of the galaxy to the other. Our solar system is located at the edge of the galaxy.

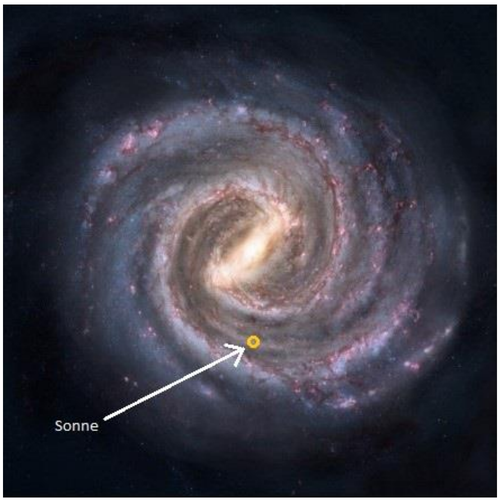


Figure 1: Right: Artistic representation of the Milky Way from above. Image: Public domain, Marking and annotation: Christine Freitag

When we look from the earth to the sky, we therefore see the Milky Way as a bright band. In ancient times, people believed that this band consisted of the milk of the goddess Hera and therefore called it the “Milky Way”.

The stars we see in the sky were formed from the gas and dust clouds of the Milky Way. A star begins its life as a cloud of gas and dust. Due to its own gravity, this cloud is drawn closer and closer together and eventually forms a dense, hot sphere. If it is hot enough inside, hydrogen atoms begin to fuse together and form helium nuclei. This so-called fusion process releases energy, which is emitted to the outside as light and heat. The star begins to glow!

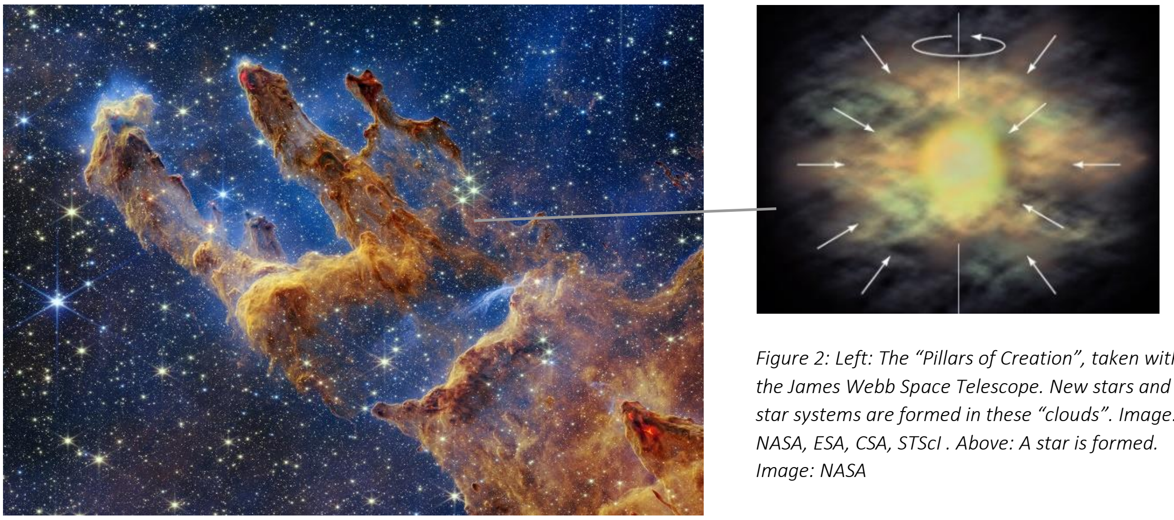


Figure 2: Left: The "Pillars of Creation", taken with the James Webb Space Telescope. New stars and star systems are formed in these "clouds". Image: NASA, ESA, CSA, STScI . Above: A star is formed. Image: NASA

Stars similar to our sun eject their outer shell at the end of their life and become so-called white dwarfs. Heavier stars are so hot inside that they can produce the elements up to iron through various fusion processes. At the end of their lives, they then explode in a supernova explosion. This is so powerful that it produces all the elements we know of. The energy released during the explosion causes the dying star to shine for a few days as brightly as all the stars in a galaxy combined. The stellar shell is thrown away and the core of the star collapses. The ejected material from the star's shell contains all the elements known to us.

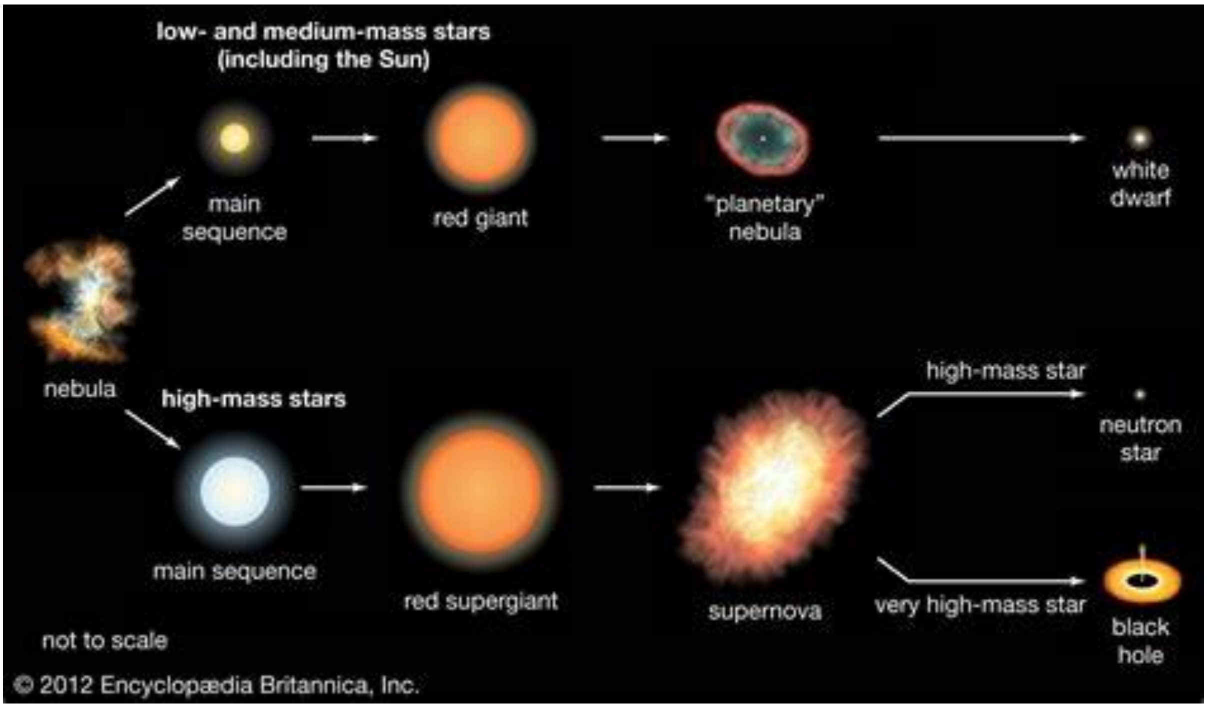
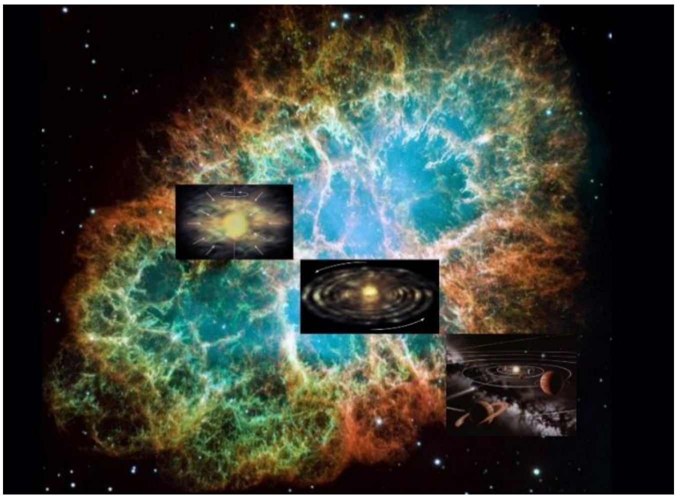


Figure 3: Star formation and evolution from a cloud of gas and dust. Image: British Encyclopedia

Overall, the life cycle of a star depends on its initial mass. Heavier stars have shorter life spans (a few million years) and end in a supernova explosion, while smaller stars live longer and eventually end up as white dwarfs. The material that is created when a star dies and is thrown into space mixes with the gas and dust clouds in the galaxy. New stars and planets can then form from this material.



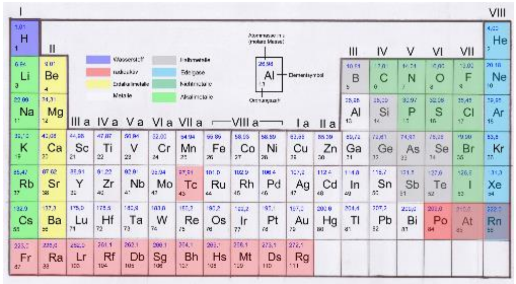


Figure 4: Left: Remnants of a supernova explosion known today as the Crab Nebula. Image NASA, ESA. Above: All the elements we know from chemistry (periodic table) are created in stars.

1.2 The formation of our solar system

Our solar system was formed around 4.6 billion years ago, in a quiet region of the Milky Way. After the death of a heavy star that exploded in a supernova, the elements that were thrown away in this explosion mixed with a large cloud of gas and dust. This cloud then began to collapse. As it rotated around itself, it became flatter and flatter and finally formed a disk. In the middle of this disk, a rather small star with a lifespan of around 10 billion years, our sun, was formed.

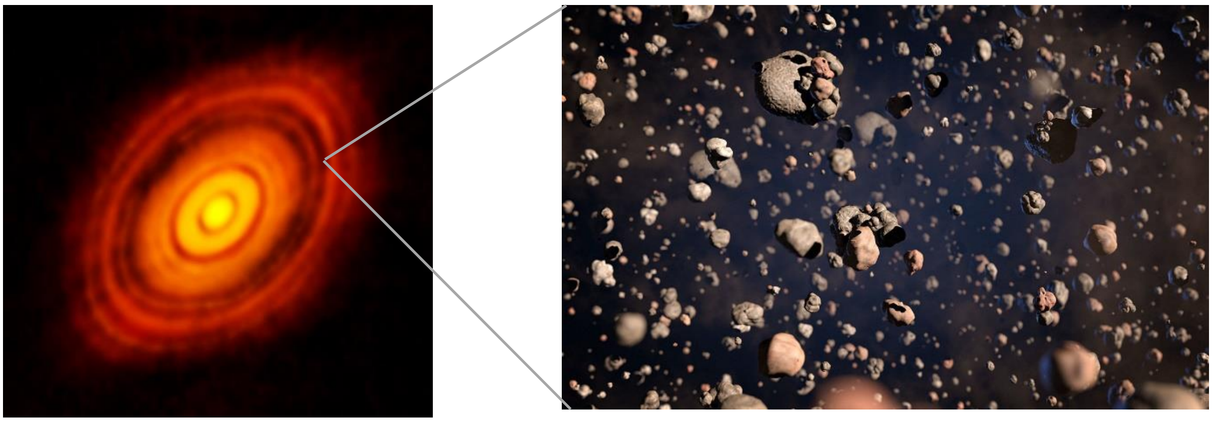


Figure 5: The young star HL Tauri with its protoplanetary disk, photographed by ALMA. This is what the formation of our solar system could have looked like. Image: ALMA (ESO/NAOJ/NRAO)

Tiny dust particles began to stick together in the disk around the sun. They formed larger and larger dust flakes, which eventually became small clumps. Collisions with other particles in the disk caused them to grow further and further. The larger lumps attracted other lumps through their gravitational force until several large bodies were formed. Some of them eventually became so heavy that they took on a round shape due to their own gravitational pull. One of these was our Earth. Some of these so-called protoplanets gathered a thick shell of gas around them and thus became gas or ice giants. Others could only accumulate a very thin shell of gas or none at all. These are the rocky planets and moons.

1.3 The development of the earth and the formation of the moon

In the beginning, the earth was a hot and unfriendly place and the young earth was bombarded by meteorites and asteroids. As a result, its surface became so hot that the rocks there melted. The entire planet was therefore covered by a layer of liquid magma. During this time, the Earth collided with another planet about half the size of the Earth, called Theia. As a result of this violent collision, material was ejected from the Earth's mantle and collected around our planet. Within a few hours, this debris clumped together and formed the moon. The rest of the small celestial body merged with the Earth and its ferrous core sank deep into the interior of our planet. This event is documented by analyses of moon rocks. During the Apollo missions, rock samples from the Moon were brought back to Earth and their analyses revealed that the Moon is made of material very similar to that of the Earth.

Figure 6: Artistic impression of the collision between Theia and the young Earth. Image: NASA/GSFC

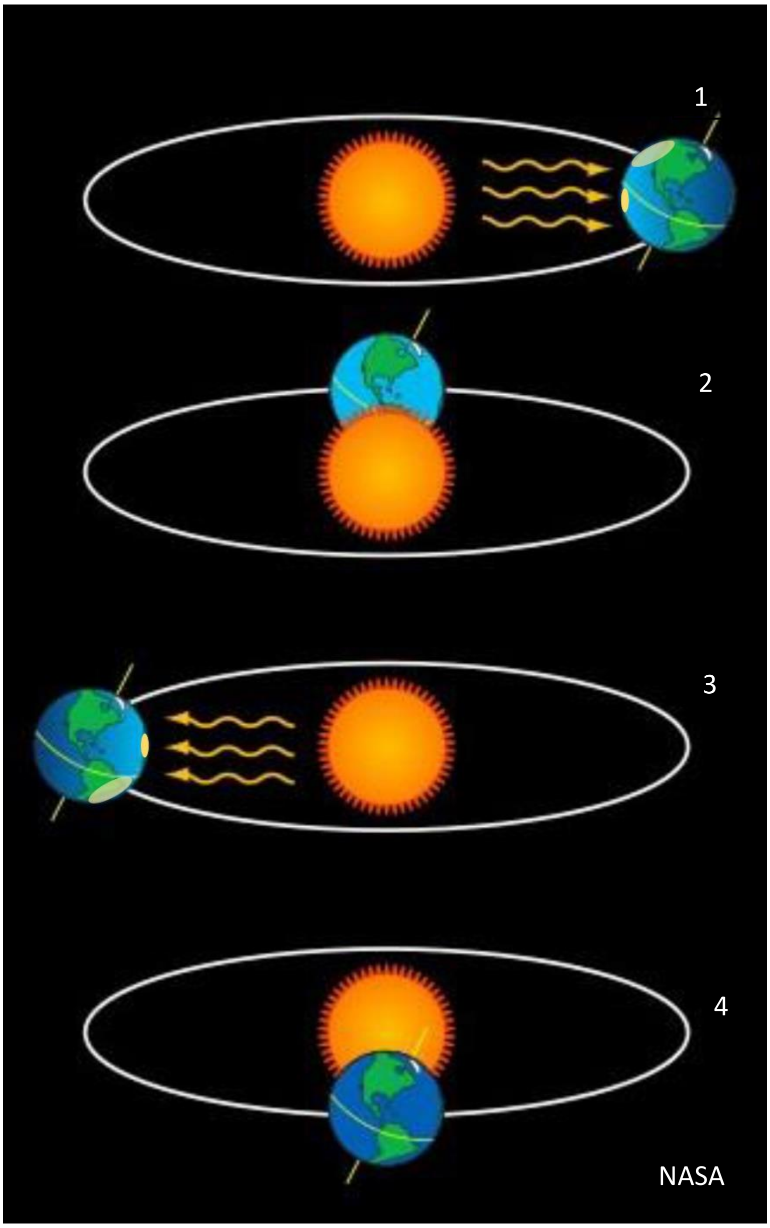
Before the moon was formed, the earth rotated around itself very quickly, namely in only about 6 hours. In addition, its axis lurched wildly back and forth. If the Earth had already had an atmosphere, the weather conditions on it would have been very chaotic. Winds of over 400 km/h would have been blowing on the Earth.

Abbildung 7: Durch die Anziehungskraft des Mondes stabilisierte sich die Rotationsachse der Erde. Bild: Nasa/Scorza

The mutual gravitational pull of the earth and moon slowed down the rotation of our planet to 24 hours and the earth's rotation axis stabilised - inclined - at 23.5°. This allowed a stable climate to develop and the four seasons emerged in our latitudes.

1.4 The origin of the seasons

The seasons strongly influence our everyday lives and the way we eat and dress throughout the year. The seasons are caused by the tilted axis of the earth and the resulting different intensity and angle of incidence of the sun's radiation on the earth's surface. Let us consider the earth with its tilted axis in its orbit around the sun:



1. In this position of the earth around the sun, the sun's rays hit the ground at an angle in the northern hemisphere and are distributed over a large area. **It is therefore winter in the north.** At the same time, in the south, the sun's rays hit a much smaller area almost vertically. **It is summer there.**

2. In this position, the sun's rays are just as intense in the north as in the south. Spring begins in the north and autumn begins in the south. It is equinox.

3. In this position around the sun, the sun's rays hit a much smaller area in the northern hemisphere intensely and vertically. **It is summer there**. In the south, the sun's rays hit the ground at an angle and are distributed over a large area. **It is winter there.**

4. In this position, the sun's rays are just as intense in the north as in the south. Autumn begins in the north and spring begins in the south. It is equinox.

There is a widespread *misconception* that the seasons occur because the earth is at different distances from the sun during the year. **But this is absolutely wrong!** Just as wrong is the explanation that one time the southern hemisphere and one time the northern hemisphere are closer to the sun. As the Earth as a whole is about 150 million kilometres away from the sun, these few kilometres difference in the distances of the two hemispheres to the sun make no difference.

1.5 The formation of the Earth's magnetic field

When the Earth and Theia collided, parts of the very strong, iron-rich small planet sank deep into the Earth's interior. As a result, melted iron is still rising in the Earth's interior today, cooling down and sinking back down to the centre of the Earth. This melted iron has an electrical charge and generates an electric current through its movement. As a result, a strong magnetic field is created around the earth. This is very important for life on Earth, as the magnetic field protects the Earth from the solar wind and cosmic radiation. Without this protection, life would not be possible on the surface of the earth.

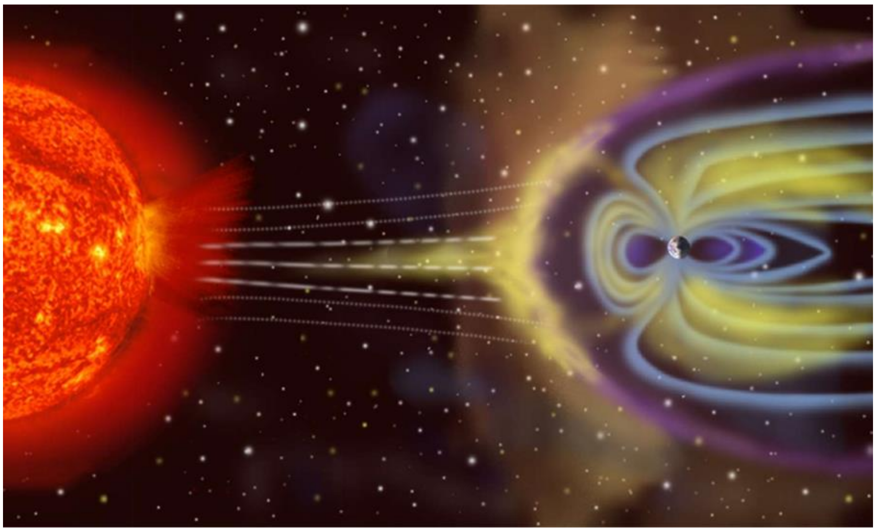


Figure 8: The Earth's magnetic field protects us from solar wind and cosmic radiation. Without this magnetic field, life on the surface of the earth would not be possible. Sizes and distances are not shown to scale. Image: NASA

1.6 How the water came to earth

When the Earth slowly cooled and the magma on the surface became solid, the Earth was dry. The water we have on Earth today came mainly from asteroids, which often contain a large amount of ice. Soon after the formation of the moon, a large number of asteroids hit the earth. The ice in them evaporated and accumulated as water vapour in the atmosphere. As the Earth cooled, the vapour condensed into clouds and then fell to Earth as rain. It rained for hundreds of thousands of years! This created a huge ocean called Panthalassa, which covered the entire surface of the earth.

Figure 9: Artistic representation of the early Earth with asteroids that brought water to Earth. Image: NASA

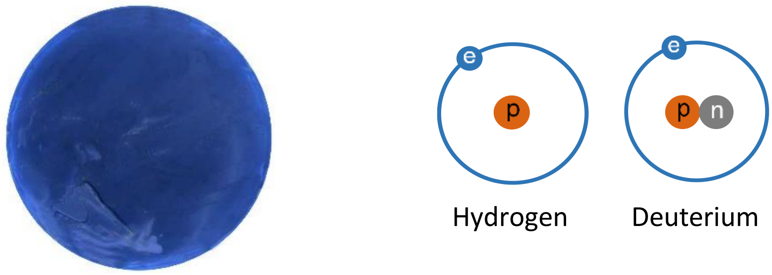


Figure 10: Top left: The Earth completely covered by the ocean Panthalassa. Image: NASA. Top right: Atoms of hydrogen and deuterium

To find out where the water on Earth comes from, scientists have analysed the water on comets and asteroids and compared it with the water on Earth. For this purpose, they used the fact that there are two slightly different hydrogen atoms. *The ordinary hydrogen atom, which has only one proton in its nucleus (top left), and the deuterium atom, whose nucleus consists of a proton and a neutron (top right).* The analyses showed that the water on asteroids has the same ratio of hydrogen to deuterium as is found on Earth. The water on comets, on the other hand, contains more deuterium. Scientists have even discovered that the water we find on Earth today originated from the asteroids in the asteroid belt between Mars and Jupiter.

1.7 The habitable zone of the solar system

Today, our solar system consists of four rocky planets (Mercury, Venus, Earth and Mars), four gaseous planets (Jupiter, Saturn, Uranus and Neptune) and hundreds of dwarf planets such as Pluto. In addition, there are two asteroid belts in our solar system: one between Mars and Jupiter and another outside Neptune. Comets also fly through our solar system on very elliptical orbits from far outside.

Of all the planets in our solar system, Earth is just at the right distance from the sun for water to occur on its surface in liquid form: about 150 million kilometres from the sun. Closer to the sun, the water would evaporate, further away it would freeze. This zone around a star, in which liquid water can occur, is known as the habitable zone. In our solar system, the Earth lies in the centre of the habitable zone, while Venus and Mars are at its edges.

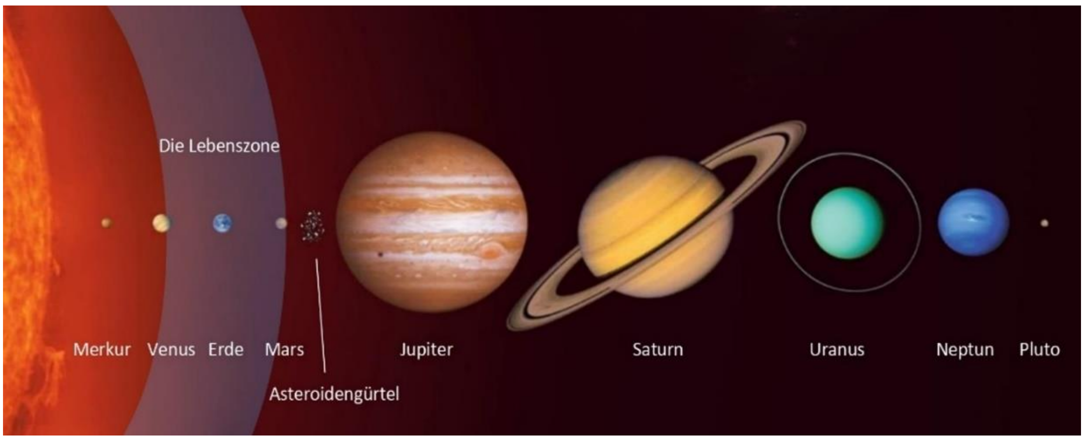


Figure 11: Illustration of the solar system with the habitable zone marked. The size of the planets and the sun are shown to scale. The distances between them, however, are not. Image: NASA

Although asteroids have also hit the surfaces of Mars and Venus, there is no liquid water there today. Because of its proximity to the sun, the water on Venus was split into hydrogen and oxygen atoms and the light hydrogen escaped into space, while the oxygen combined with carbon to form carbon dioxide (CO_2). As we will see, CO_2 is a greenhouse gas and absorbs heat. This is why Venus has an average temperature of 450 °C day and night! Mars is also just within the life zone, but because it is significantly smaller and lighter than the Earth, it has a weaker gravitational pull and was therefore unable to hold its water vapour. Today it only has a very thin atmosphere. Earth is therefore the only planet that fulfils the conditions necessary for life to develop in its oceans.

Around 1.5 billion years after the formation of the Earth, the first continents began to form and the climate became somewhat more stable. This was only possible because of the many important features already mentioned that make the Earth habitable. Here is a brief summary: To make the earth habitable, we need the moon (for stable rotation), the earth's magnetic field (to protect it from solar wind and cosmic radiation), an earth that is large enough (to hold an atmosphere), liquid water (the earth must be at the right distance from the sun) and a slight greenhouse effect (due to the atmosphere). With so many coincidences, we can speak of luck (or perhaps a miracle) that we exist.

1.8 The origin of life

The history of the earth continues when the first simple creatures (single-celled organisms) emerged in white smokers in the oceans around 3.8 billion years ago. Over the next 3 billion years, the oceans were colonised exclusively by microorganisms. Cyanobacteria began to absorb CO_2 in the oceans via photosynthesis and release oxygen (O_2), which accumulated in the atmosphere. This later made life on land possible. Around 600 million years ago, the first plants and animals (multicellular organisms) appeared in the water; they then colonised the land. Over time, new species have emerged. In total, there have been several mass extinctions in the history of the earth. The most famous was around 66 million years ago when the dinosaurs became extinct after a meteorite impact and mammals were given the opportunity to evolve and become the dominant land animals. Humans only appeared around 300,000 years ago. This is very late compared to the length of the Earth's history.

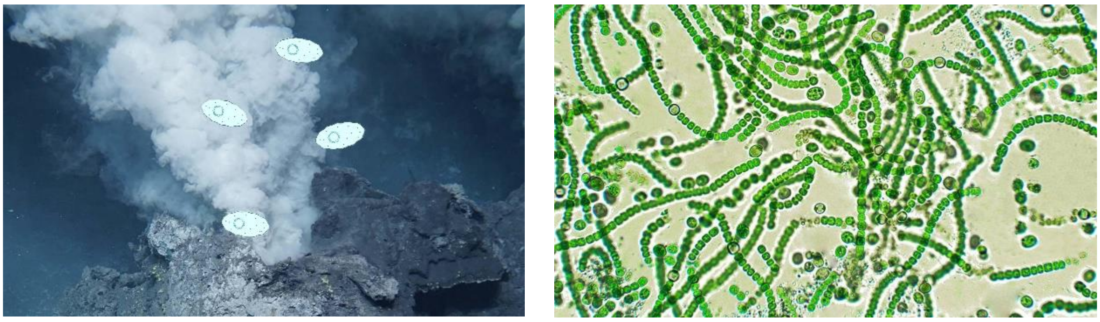


Figure 12: The first living organisms were simple cells that developed around white smokers under water (left). These evolved into cyanobacteria, which together with other individuals were the only living organisms in the first 3 billion years of the Earth's history! Image: Photo: MARUM - Centre for Marine Environmental Sciences, University of Bremen.

Conclusion: The exploration of space and the Earth has shown us that our planet is unique and that we must protect it. Earth is the only planet in the solar system on which life is possible. It is therefore our duty to preserve it for ourselves and future generations. The Earth is our blue pearl!

2. Module 2: The formation of the earth and life on it for children

Module Description: Many children may not realize that the Earth was completely different in the past, that it took billions of years in evolution for a Homo sapiens to emerge and that our lifespan covers only a tiny fraction of Earth's history. Similar to the vast distances in space, the enormous time scales and completely different planetary conditions should be introduced through stories and activities. This section is therefore dedicated to the formation and evolutionary processes. *The children are shown that the earth has not always existed, nor has the moon or the water on the earth's surface, and that both the earth's surface and its atmosphere have changed over time, leading to environmental conditions that have made life on it possible with an enormous diversity of species.*

2.1 From stardust to the planets!

Description: In this section, children will realize that the sun is just one of many stars in our home galaxy, the Milky Way. They will also learn how a large planet is formed from dust. For this purpose, they will observe the growth of dust flakes over a longer period of time and realize that it takes a while for larger clumps of dust to form. They will also understand how a planet is eventually formed from small lumps.

Activity 2.1.1: The Milky Way, our home galaxy

Total Duration:

Goal: The children understand that the sun is part of the Milky Way, just like many other stars.

Material:
- poster 21 (The Milky Way)
- Craft materials for the Milky Way model (see document "Templates")

Participatory activities: Building a model of the Milky Way

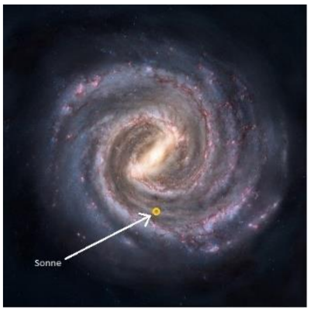
Keywords: Solar system, galaxy, Milky Way, star, gas and dust cloud

Step 1: What is the Milky Way? min

Learning arrangement: Children sitting in a semi-circle around the teacher

Teacher: ***"We have already learned a lot about our solar system with its sun, planets, moons, asteroids and comets. But where is the solar system actually located? Are we just floating around somewhere in space?"*** (Ask the children if they already know anything about it.) ***"Our solar system is located in a galaxy we call the Milky Way."***

Teacher showing poster 21 of the Milky Way: ***"This is the Milky Way, our home galaxy. But there are also countless other galaxies. These galaxies contain many stars and planets, but also large clouds of dust and gas. One of the stars in the Milky Way is the sun. It is located here, together with the Earth and the other planets we have already learned about."*** Show the position on the poster.



Step 2: Build a model of the Milky Way

min

Learning arrangement: Children work at their tables

Realisation: The children each make a model of the Milky Way out of cardboard. The children can stick clouds of gas and dust on it using absorbent cotton and paint stars in between using glow-in-the-dark paint. The children can also mark the position of the solar system on their model with a yellow bead. The Milky Way model can be rotated. You can find detailed instructions in the document "Templates".

Teacher: ***"The stars in the Milky Way do not sit at a fixed point but orbit around the center, just as the planets orbit around the sun."***

Let the children rotate their Milky Way models in front of the background.

Step 3: Reflexion

min

The children answer the following questions in their Pale Blue Dot booklet:

What is the Milky Way?

What is there in a galaxy?

Activity 2.1.2: The formation of the earth

Total Duration:

Goal: By looking at dust flakes, children learn how dust flakes grow into larger lumps. They experience how a planet is formed from small lumps.

Material:

- poster 22 (formation of the solar system) and poster 23 (early solar system)
- small boxes with dust flakes in different “stages”
- flipbook on the formation of planets (in development)
- modelling clay, brown and orange

Participatory activities: activating prior knowledge, Experiment

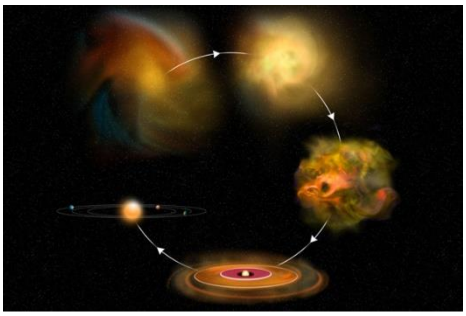
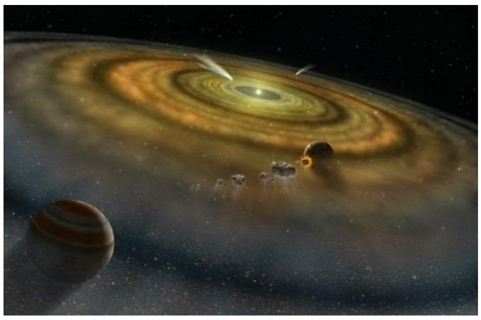
Keywords: Dust disc, rotation, protoplanet, gravity

Step 1: Formation of the solar system

min

Learning arrangement: Children sitting in a semi-circle around the teacher

Teacher shows poster 22 of the formation of the solar system: ***„Our solar system has not always existed. It was formed from a large cloud of gas and dust that rotated. In the process, the cloud became flatter and flatter until it finally formed a disc. The sun formed in the centre and the planets began to form in the disc around it. Rocky planets like the Earth once began as a pile of small grains of dust that stuck together.“***

The formation of the solar system (left, source: Saxton/NSF/AUI/NRAO; right source: NASA)

Step 2: Dust flakes under the bed

min

Learning arrangement: children work in groups of 3-4 children

Activating prior knowledge:

“What happens if you don't clean under the bed for a long time? Does the dust always look the same?“

Wait for the children's answers.

Teacher: ***"You have just heard that the Earth, just like the other planets, formed from a disc of dust. You can carry out a little experiment on this at home over the next few weeks. Find a place under your bed and don't clean it for the next few weeks! Then you can observe how small dust flakes get bigger and bigger over time."***

Realisation: Let the children, working in small groups, put the boxes of dust flakes in chronological order. Which dust flake took the longest to grow and was therefore the last to form? Which was the first?

Also ask the children to hold the cans of dust flakes up to the light and describe what they see. (The larger flakes are denser, so less light passes through them).

Step 3: The earth grows - story

min

Learning arrangement: Children sitting in a semi-circle around the teacher

Teacher: ***"The dust flakes in the disc around the sun became larger and denser until they finally formed small clumps. These pieces attracted each other through their gravity, broke apart, were pressed together and thus formed ever larger and denser pieces over time. The earth was formed from such a lump.***

After the Earth had gained so much mass that it became a round object due to its own gravity, it did not yet look like a blue planet, but rather like a huge, orange-coloured sphere. At this time, the Earth's surface was extremely hot because its surface had been hit countless times by small clumps orbiting the sun. These clumps melted and became part of the Earth."

Step 4: Recreate the growth of earth using modelling clay.

min

Learning arrangement: Children work at their tables

Realisation: The children can now make their own model of the early Earth out of modelling clay and actively re-enact the process of its creation.

They may start with many small lumps that break and stick together until a large round object forms in their hands.

Step 5: Reflexion

min

The children answer the following questions in their Pale Blue Dot booklet in writing or by drawing pictures.

How did the planets form?

From what did they form?

What did the Earth look like in the past?

2.2 The earth continues to evolve

Description: In order to honour the uniqueness of the earth, it is important to teach the children that the earth was not a life-friendly place in the beginning. It took many steps for the initially glowing earth to become the wonderful place that it is today and on which life could develop.

In this step, the children therefore discover what the earth looked like shortly after it was formed. Through stories, they learn that the moon was not always there and accompanied the earth on its orbit around the sun. They hear about how the moon was formed and its importance in stabilising the Earth's rotation. The children also learn how the Earth's atmosphere was formed and how water came to Earth.

Activity 2.2.1: The formation of the moon

Total Duration:

Goal: Pupils learn how the moon was formed and recognise its significance for life on Earth.

Material:

- poster 23 (hot earth), poster 24 (formation of the moon) and poster 25 (stabilisation of the earth's rotation axis)
- Poster 14 (astronaut on the moon)
- Model of the hot earth
- Model of Theia
- Model of the hot moon
- Flip book on the formation of the moon (in development)

Participatory activities: activating prior knowledge

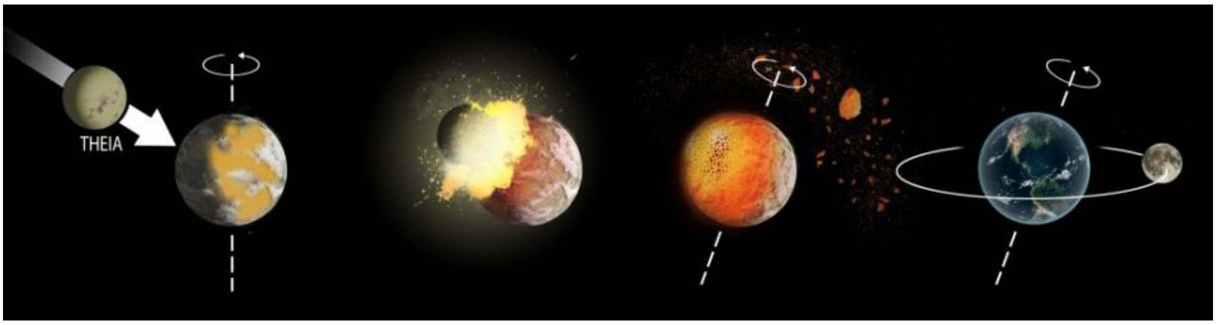
Keywords: Orbit, lurching, rotation axis, Apollo mission, moon rock

Step 1: Story of the formation of the moon

min

Learning arrangement: Children sitting in a semi-circle around the teacher

Teacher showing poster 23, 24 and 25: ***"The moon was not always there, accompanying the earth on its orbit around the sun. In the earliest times, when the Earth was very hot and still alone, it rotated very quickly and lurched back and forth. A day on earth had a duration of only 6 hours! But one day something amazing suddenly happened: a large protoplanet, about the size of Mars called Theia, collided with the Earth. Millions of small pieces of Earth and Theia were shot into space. These lumps began to orbit the Earth, and within a few hours they clumped together and formed the Moon! Since then, the Earth has been pulling on the Moon by gravity, and the Moon has been doing the same to the Earth. The Earth's rotation became much slower and its axis stabilised. This gave the Earth its four seasons and a stable climate."***



(Source: NASA)

Step 2: How do we know that?

min

Learning arrangement: Children sitting in a semi-circle around the teacher

Activating prior knowledge:

"How do we know so much about the past? What does an archaeologist do, for example?"
Wait for the children's answers.

Teacher showing poster 14 of the astronauts on the moon: ***"Remember the Apollo missions. Not only did humans land on the moon for the first time, they also brought moon rocks back to earth. It turned out that these rocks were made of the same material that we find here on Earth!"***

(Image credit: NASA): The astronauts collected moon rocks.

Step 3: Reflexion

min

The children answer the following questions in their Pale Blue Dot booklet:

How did the moon form?

What changed after the moon was formed?

Activity 2.2.2: Visualise the origin of the seasons

Total Duration: 20 min

Goal: The children discover how the seasons come about and why it is cold in winter and hot in summer.

Material:

- inflatable globe
- sheet of paper
- torch
- 2 Playmobil figures
- UHU-Patafix

Participatory activities: Working with models

Keywords: Radiation, radiation intensity, angle of incidence

Step 1: When is it hotter and when is it colder outside?

min

Learning arrangement: Children sitting in a semi-circle around the teacher

Teacher: ***"In some months of the year, such as January and February, we feel more cold. It is winter. In others - like July and August - it's hot. Why is that? Let's find out with our Playmobil figures Anna and Peter."***

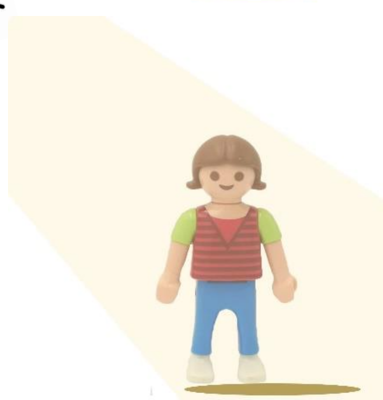
The teacher places the Playmobil figure Anna on a white sheet of paper and illuminates her vertically from above with the torch.

Teacher: ***"Look at Anna. The torch represents the sun. When Anna is directly illuminated from above, she gets hot! Her shadow under her feet is small! In summer, the sun is high in the sky!"***

"Now we tilt the torch (the sun)."

The teacher tilts the torch and illuminates Anna from one side:

„If the torch (the sun) is at an angle in the sky, the light becomes weaker and spreads over a larger area of the ground. Anna is rather cold! And her shadow is long. In winter, the sun is lower in the sky."



Step 2: How does the Earth rotate in space?

min

Learning arrangement: Children sitting in a semi-circle around the teacher

The teacher showing the inflatable globe: ***„And now let's take a look at the earth. The Earth does <u>not</u> rotate straight on its axis*** (bottom left image)***. After the formation of the moon, it began to rotate at an angle and more slowly. The upper tip of the Earth's axis always points to the Pole Star in the sky."***

Wrong: Straight earth axis

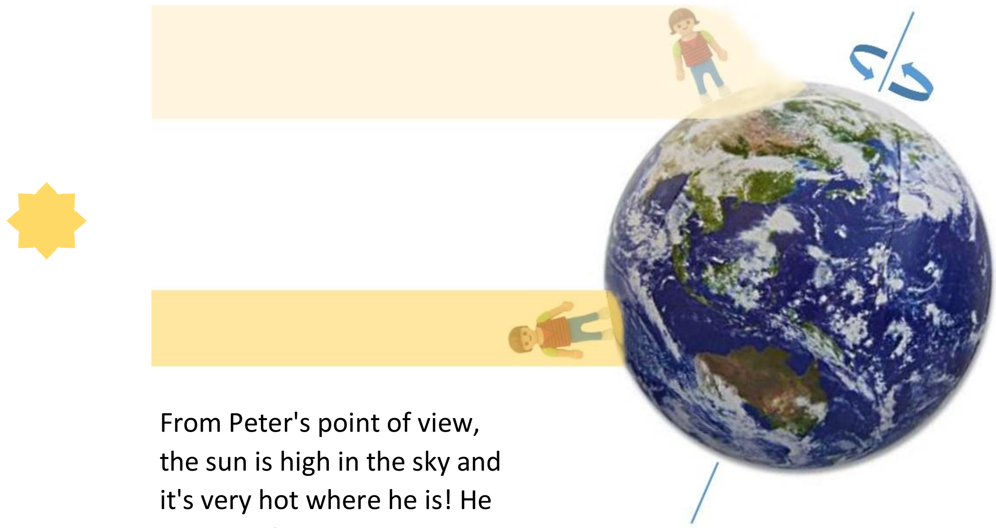
Correct: **tilted** earth axis

Step 3: Understanding the seasons

min

Learning arrangement: Children sitting in a semi-circle around the teacher

To help the children understand what causes the seasons, we look at the sun's rays in the picture below with two Playmobil figures (let's call them Anna and Peter), both standing on the day side of the earth (attach with the help of Patafix).



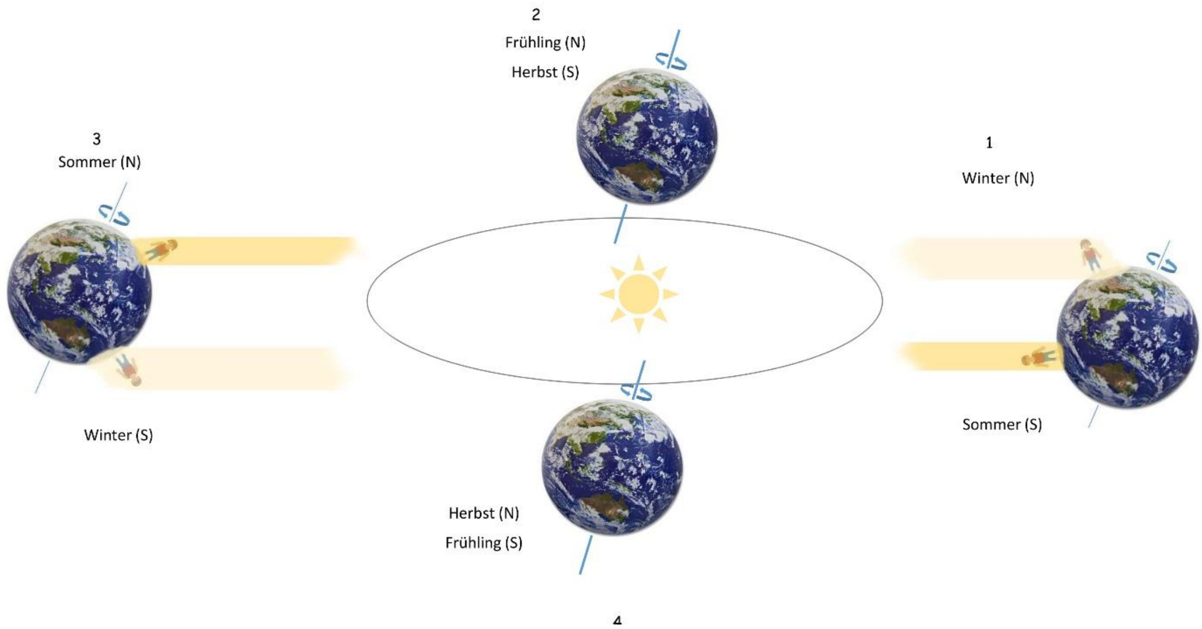
From Anna's point of view, the sun is low on the horizon and it's cold. She's going out sledging!

From Peter's point of view, the sun is high in the sky and it's very hot where he is! He goes out for ice cream!

Anna is in Finland (northern hemisphere). There, a beam of sunlight hits the ground **at an angle and is distributed over a large area**. Peter is in Chile (southern hemisphere). The sun's radiation hits him **almost vertically, in other words from 'above' and is distributed over a much smaller area**. In the north it is winter, in the south it is summer (see picture number (1) below).

Teacher: ***"It is these different angles of incidence of the sun's rays that cause a noticeable difference in temperature during winter and summer!"***

"And now tell me in position 1 of the earth: Which child goes skiing and which child eats ice cream? And in position 2, which child goes skiing and which child eats ice cream?"



Step 4: Reflexion

min

The children work in groups of 4 children.

The teacher places the inflatable globe with the two children's figures in the centre of the classroom. One of the positions shown in the picture above is displayed.

The children indicate for which child it is summer and for which child it is winter and explain the reason to each other.

Activity 2.2.3: The very young earth

Total Duration:

Goal: The children realise that the early Earth was very different from today. They realise that it took a long time for the earth to become the beautiful, life-friendly place we know today.

Material:

- moon model (10cm)
- Inflatable globe
- poster 26 (early earth landscape)
- volcano model (clay, vinegar, baking powder, plaster powder, food colouring)

Participatory activities: Experiment

Keywords: atmosphere, gas, oxygen, volcano

Step 1: Formation of the earth's atmosphere

min

Learning arrangement: Children sitting in a semi-circle around the teacher

Activating prior knowledge

"Remember the astronauts on the moon. Why do they have to wear spacesuits? Why can we breathe on Earth and not on the moon?"

Wait for the children's answers

The teacher showing the inflatable globe and the model of the moon: ***"The Earth is heavy enough that its gravity is sufficient to hold a layer of gas around its surface. This layer of gas is called the atmosphere. The moon is too small and can therefore not hold an atmosphere. The gases simply escape into space."***

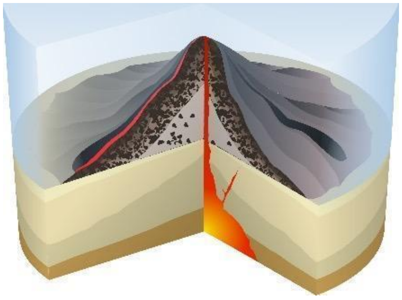
The teacher showing poster 26 of the early earth: ***"In the beginning, the Earth's atmosphere consisted of the gas that the Earth had collected from the huge disc of dust and gas from which all the planets were formed. We could not have breathed or lived in this atmosphere. Back then, the Earth was still very hot and its surface was covered in volcanoes that spewed out lava and gases."***

Step 2: Reconstructing the early earth landscape

min

Learning arrangement: Children sitting/ standing around a desk

Realisation: A small volcano can be recreated using vinegar and baking powder. Detailed instructions can be found on the Internet, e.g. at *https://www.youtube.com/watch?v=WpSfuMIjQtU*



Left: Volcano (Credits From © Sémhur / Wikimedia Commons); right: self-made volcano model (Geolino extra)

Step 3: Reflexion

min

The children draw a picture of the early Earth landscape in their Pale Blue Dot booklet.

The pictures can then be looked at together as a class.

Activity 2.2.4: Origin and significance of water on earth

Total Duration:

Goal: Children learn how water came to earth and its importance for the development of the earth.

Material:

- inflatable globe
- Model of the early earth
- Model of the dry earth
- Craft material for asteroids (see document ‘Templates’)
- poster 27 (asteroids bring water) and poster 28 (rain)
- model of the Earth formed from modelling clay from activity 2.1.1
- modelling clay blue
- empty jam jar
- plate
- water
- kettle
- ice cubes
- cards with evolutionary stages of the earth (see document ‘Templates’)

Participatory activities: Experiment

Keywords: asteroid, water vapour, clouds, evaporation, condensation, water cycle

Step 1: How did the water come to earth?

min

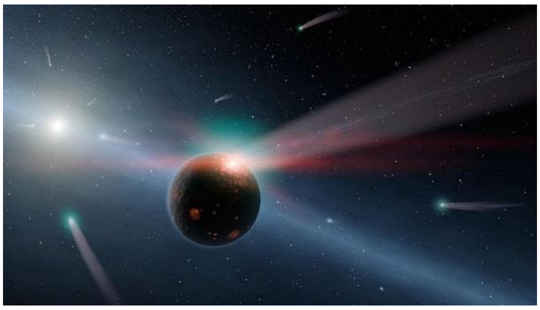
Learning arrangement: Children work at their tables; children then stand at one side of the room to let the asteroids fly

The teacher showing the inflatable globe: ***„When we look at the Earth today, we realise that 71% of its surface is covered by water. But we have just heard that the Earth was a glowing sphere at the very beginning.***
Shows the model of the early earth.
Then all its water would have to evaporate. When the earth slowly cooled down, it was actually completely dry. Shows the model of the dry earth.
So where did all the water on the earth come from?”

The teacher showing poster 27 with asteroids: ***”There are several indications that most of today's water was brought here by asteroids. They are porous and contain water in their rocky material, which is protected from evaporation. During a time when the orbits of Jupiter and Saturn became unstable, tens of thousands of asteroids were catapulted into the interior of the solar system and hit the Earth on their way to the sun. Because the Earth's surface was still hot at the time, our planet collected water in water vapour (gaseous) form. This vapour mixed with the gases in the atmosphere.“***

Realisation: Build your own asteroids out of paper and crepe paper with the children. You can find the detailed instructions in the document ‘Templates’.

The children can then try to make their asteroids collide with the inflatable globe!

Asteroids brought water to the young Earth (source: NASA/JPL-Caltech); asteroid models for children (source: Scorza)

Step 2: It rained for a very long time

min

Learning arrangement: Children sitting in a semi-circle around the teacher

The teacher showing poster 28 with rain: ***"In the beginning, water only existed as water vapour around the hot earth. As soon as the earth's surface cooled, water condensed and began to fall as rain. Geologists estimate that it rained for 80,000 years! After so much rain, the oceans and seas formed."***

Step 3: The water cycle - making rain

min

Learning arrangement: Children sitting /standing around a table

Realisation: In this activity we will demonstrate the water cycle.

Boil the water and fill about 1/3 of the glass jar with it. Place the plate on the jar so that it is sealed and no water vapour can escape. Leave the plate to sit on the glass for a few minutes. Then put a few ice cubes on the plate and ask the children to watch carefully what happens.

The water vapour condenses on the underside of the plate and the water starts to drip down the inside of the glass. It starts to rain!

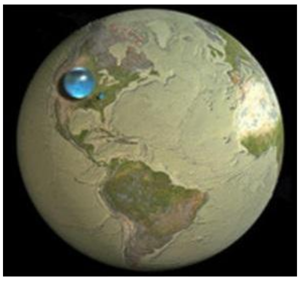
Step 4: Visualise the amount of water on earth

min

Learning arrangement: Children work at their tables

Teacher: ***„You have just heard that 71% of the earth's surface is covered by water. If you took all the water from the earth and put it into a sphere, how big would it be?"***
Let the children guess.

Realisation: To visualise the amount of water on the Earth compared to its volume, the model of the Earth made from modelling clay from activity 2.1.2 is used again. The total amount of water on the Earth is now represented by a second modelling clay ball with a tenth of the Earth's diameter. The mini-earth and the water model can be kept by the children as a reminder of how the earth was formed. (see right picture; Credits: usgs.gov)



Step 5: Reflexion

min

Realisation: Each child receives a sheet of paper with the pictures of the evolutionary stages of the young earth. (See document 'Templates'). The children cut out the pictures and then put them in the correct order. Starting with the glowing earth, the formation of the moon, the asteroids that bring the water, the rain and finally the earth as it looks today.

The children then compare their results with the person sitting next to them.

2.3 The emergence and development of life

Description: The children recognise how many seemingly random things had to come together in order for the first living creatures to emerge and understand how long it took for more complex life forms to develop. They get a feeling for the long periods of time that passed before the first animals and finally humans emerged. This makes the children realise the preciousness of each individual life.

Activity 2.3.1: The origin of life in water

Total Duration:

Goal: The children recognise the great importance of water for the formation of the first life forms.

Material:

- poster 30 (white smoker and first cells) and poster 31 (cyanobacteria)
- cards with developmental stages of life on earth
- felt tape
- craft materials for Earth calendars (see document 'Templates')

Participatory activities: Organising images into a sequence

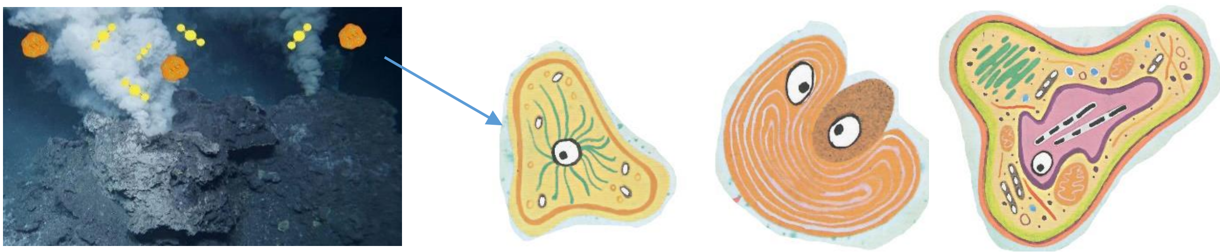
Keywords: UV light, cell, white smoker, photosynthesis

Step 1: The first living creatures emerge - story

min

Learning arrangement: Children sitting in a semi-circle around the teacher

The teacher showing poster 30 of a white smoker: ***„The first life originated in water. Near white smokers (water volcanoes), something incredible happened: small, tiny particles began to stick together, forming the first tiny creatures encased in a bubble (a cell)!***



The first cells had many forms. Some began to swallow other cells. Others formed clumps and lived close together or formed long chains. For billions of years, only these small cells lived in the water! Much later, the first aquatic animals and plants formed out of them."

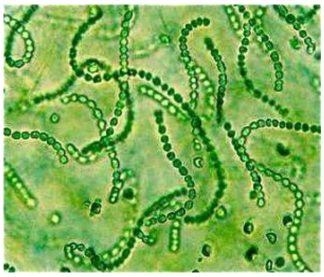


Figure: Top left image: White smokers, University of Bremen; right: cells (book 'Where we humans come from' Barr&Williams), and green cyanobacteria (Wikipedia).

Step 2: Visualising the development of life

min

Learning arrangement: Children sitting / standing around a table

Realisation: The children take the cards with the evolutionary stages of the young earth and organise them along a felt tape that represents time.

Starting with the young solar system, with the glowing earth and the collision of Theia with the earth on the orange part of the felt tape,

the dry Earth and the asteroids that bring water on the brown section,

then the first cells and aquatic animals, on the blue section of the felt tape

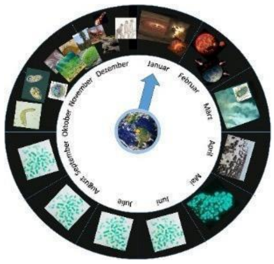
and finally the dinosaurs, mammals, etc. up to man on the green part.

Step 3: The earth history calendar

min

Learning arrangement: Children work at their tables

Realisation: Let the children create their own 'Earth calendar'. The incredibly long 4.5 billion years of the earth's history are shown in twelve equal time intervals, representing the months of a year in a calendar. The movable window makes it possible to focus on one evolutionary event at a time. Make the children aware that animals and humans only emerge in the last of the twelve sections. Homo sapiens does not even appear until the last hour of the last day of the year!



The earth calendar (credits: Scorza)

Step 4: Reflexion

min

The children answer the following questions in their Pale Blue Dot booklet:

Where did the first living creatures appear?

What forms did the first living creatures have?

Did it take a long time for the first large animals and plants to emerge?

When did the first humans appear?

Activity 2.3.2: How do we study the past?

**Total Duration**:

Goal: By estimating the age of trees, the children gain an insight into scientific methods and realise how we can know so much about the past.

Material:

- poster 32 (tree stumps)
- wooden discs with age rings

Participatory activities: Experiment

Keywords: tree ring

Step 1: Determining the age of trees

min

Learning arrangement: Children sitting in a semi-circle around the teacher

Activating prior knowledge

"Have you ever seen a tree stump?
What did it look like? Was it the same colour everywhere? What did you notice?"
Wait for the children's answers.

Teacher: ***" Trees can live for hundreds - and sometimes even thousands - of years! If you've ever seen a tree stump, you've probably noticed that the top of a stump has a series of rings. These rings can tell us how old the tree is! Trees grow more slowly in winter than in spring or summer. The wood therefore has a slightly different colour. The number of dark rings therefore tells us how old a tree is."***

Step 2: Determine the age of trees yourself

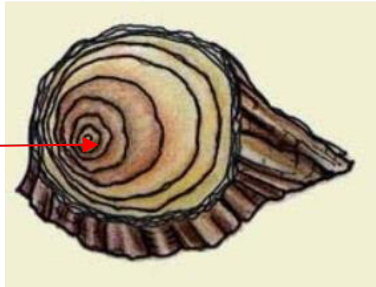
min

Learning arrangement: Children work in small groups or with their partner

Realisation: Let the children count the rings on the wooden discs and on the pictures of the tree stumps to find out how old the trees are.

Age: Age: Age:

1



Tree stumps (credits: NASA)

Step 3: Reflexion

min

The children draw a picture of a tree stump with age rings in their Pale Blue Dot booklet and write the age of the tree next to it.

The pictures can then be looked at together as a class.

Activity 2.3.3: The life-friendly earth

 **Total Duration**:

Goal: The children realise once again what a special and wonderful place our earth is and how many events were necessary to make life on it possible. As a result, the children realise the need to protect our earth, as well as all life on it.

Material:

- Felt model of the earth made up of individual components (water, land, atmosphere, sun...)

Participatory activities: Thought experiment

Step 1: What would the earth be like without ... ?

min

Learning arrangement: Children sitting in a semi-circle around the teacher

'What would the earth be like without... Water?' provides a starting point for thinking about the very special place the Earth is. By looking at the life-friendly Earth as an evolutionary product, we can begin to explore the connections between the components of the Earth with children.

Realisation: Show the children the individual components of the felt model of the earth (land, water, atmosphere, sun, plants...). Let the children name the components and put the model together.

Then invite the children to think together about what would happen to the earth and life on it if one of the components were missing.

What would the earth be like without...

- the sun (without sun: frozen water, no plants, no energy)
- the moon (no stable axis of rotation, no tides)
- air (Important for climate, breathing, water cycle)
- planets (no oxygen for breathing, important for nutrition)
- ground (essential for most plants)
- animals (in combination with plants: e.g. for hummus)
- bacteria (the human body consists of more bacterial cells than human cells)

The Earth (credits: NASA)

Step 2: Reflexion

min

The children discuss the following questions with a partner or in small groups:

Why can we live on Earth but not on the moon or another planet?

What makes the Earth so special?

3. Glossary:

Key:
Words in blue are Keywords.
Words in green are for further explanation for teachers.

Apollo mission: The Apollo missions were a US space programme with the aim of bringing people to the **moon** and safely back to Earth. The eleventh mission (Apollo 11) was the space mission in which the first humans landed on the moon. The astronauts took many pictures, carried out measurements and also brought **moon rocks** back to Earth.

asteroid: Asteroids are small objects (compared to a **planet**), ranging in size from a few metres to hundreds of kilometres, which are under the **gravitational** influence of the **sun**. Most of them are located in the **asteroid belt** between Mars and Jupiter and are also influenced by the gravitational pull of the largest planet in our **solar system** (Jupiter). The presence of Jupiter protects us from the impact of many asteroids. Asteroids are not round in shape and scientists estimate that there are hundreds of thousands of asteroids orbiting the sun in our solar system. We also believe that the Earth was hit by many asteroids in its early life: One of them gave birth to the **moon** (the event is called a giant impact) and many others brought water to our marvellous planet. As they are mostly made of ice particles, they melted as they hit the Earth, releasing water on the planet. An asteroid that enters the Earth's **atmosphere** is called a meteor if it burns up in the atmosphere (also known as a shooting star) and a **meteorite** if it is so large that it does not burn up completely in the atmosphere but hits the Earth.

asteroid belt: An asteroid belt is a ring-shaped area in which a large number of **asteroids** are located. In our **solar system** there are two asteroid belts with the **sun** at the centre. One is located between Mars and Jupiter and the other outside Neptune.

atmosphere: The layer of air that surrounds a planet is called atmosphere. Not every **planet** or rocky body is capable of forming an atmosphere. The **moon**, for example, has no atmosphere because it is not heavy enough to hold it. The atmosphere of a planet can consist of different **gases**. On Earth, the most important gases in the atmosphere are nitrogen and **oxygen**. The presence of an atmosphere on Earth is very important as it protects us from **asteroid** impacts and from the **sun**'s UV radiation.

atom: Everything around us is made up of atoms. The air, water, earth and stones, plants, animals and us humans. An atom has a nucleus consisting of protons and neutrons. Electrons move in the shell around this atomic nucleus. The atoms of different elements (hydrogen, **oxygen**, carbon, etc.) differ in the number of protons and neutrons in their nucleus. The number of protons determines what kind of element it is. Hydrogen atoms, for example, have only one proton in their nucleus, helium atoms have two and oxygen atoms have eight. The number of neutrons for a particular element, on the other hand, can vary slightly.

tree rings: Tree rings or annual rings are circular patterns in the cross-section of a tree. They are formed because trees grow at different rates depending on the season and the newly formed wood has different strengths. The number of tree rings thus indicates how old the tree is.

deuterium: A deuterium **atom** is a **hydrogen** atom with an additional **neutron** in its nucleus. The atomic nucleus therefore consists of a **proton** and a neutron. Deuterium is therefore also known as heavy hydrogen.

electrons: Electrons are elementary particles. This means that they cannot be broken down any further and are among the smallest components of which everything else is made up.
They have a negative electrical charge. Electrons travelling through a cable, for example, generate an electric current.

earth's magnetic field: Our earth is surrounded by a strong magnetic field. The rising and sinking of iron in the liquid interior of the earth creates an electric current that generates this magnetic field. The Earth's magnetic field protects the Earth from the **solar wind** and **cosmic radiation**, making life on the Earth's surface possible.

fusion: Fusion or nuclear fusion is the process when two **atom**ic nuclei fuse and form a new, heavier nucleus. This releases a lot of energy, but the process is only possible at extremely high temperatures and high pressure. **Stars** in which such extreme conditions can be found generate the energy that makes them glow through fusion.

galaxy: A galaxy is a collection of several hundred billion **stars** with their **planets** as well as many **clouds of gas and dust**. There are different types of galaxies. Spiral and barred spiral galaxies are flat discs in which stars, planets and **gas** rotate around a centre in which there is usually a **black hole**. Elliptical galaxies are usually even larger and do not form a disc, but an ellipsoid.
The galaxy in which our **solar system** and the Earth are located is called the **Milky Way** and is a barred spiral galaxy.

gas: Any substance for example water can assume a solid (such as ice), liquid (such as water) and gaseous state (**water vapour**). A substance that is in a gaseous state is referred to as a gas. In this state, the individual particles (**atoms**) that make up the substance move more strongly and are therefore no longer as strongly bound together as in the liquid or solid state. For this reason, gases are less dense than liquids or solids.

gas planet: Planets that are much larger than the Earth and consist of a huge amount of **gas** are gas planets. Planets such as Jupiter and Saturn are known as gas giants. They consist of a solid core surrounded by a very extensive gaseous envelope. Uranus and Neptune are also known as ice giants because, unlike Jupiter and Saturn, they have an icy inner core within the gaseous envelope. Their gas composition also differs from that of the **rocky planets**: They consist mainly of **hydrogen** and helium.

gas and dust cloud: A cloud of dust and **gas** (mainly **hydrogen**). If a somewhat denser core forms in the centre, this can attract the outer layers through its **gravitational** force. This results in the formation of an increasingly heavier and larger ball of gas. Over time, this ball of gas not only becomes denser but also hotter until it finally forms a **star**. The remaining gas and dust around the newly born star can flatten out into a **dust disc**, from which **planets** can then form.

rocky planet: A rocky planet is a **planet** similar to our Earth. It has a solid surface that can be covered by both oceans and land. Depending on the size (and mass) of the planet, rocky planets can have an **atmosphere**. Earth, Venus and Mars have a thin atmosphere, while Mercury has none at all.

gravity: Gravity is a force that attracts lighter objects to heavier ones. The heavier an object is, the stronger its gravitational pull but the further away you are from this object, the weaker it becomes. The earth, for example, is significantly heavier than a human being. Every person is therefore pulled back to the earth when they jump into the air. When astronauts in a **spaceship** move away from the Earth, however, the Earth's gravitational pull becomes weaker and weaker so that the astronauts float in the spaceship.
Gravity also ensures that objects such as **stars**, **planets** or **moons** do not fall apart and many of them have assumed an almost round shape. To understand this, you can imagine a planet as a collection of

rocks. If this cluster of rocks becomes heavy enough, the gravitational pull felt by the outermost rocks is so great that they move as close as possible to the centre of the cluster. The whole accumulation thus becomes a **sphere**.

habitable zone: The habitable zone is a ring-shaped area around a star that is just far enough away from the **star** for water to occur there in liquid form. Closer to the star it is so warm that the water evaporates, further away it is so cold that it freezes. The location of the habitable zone depends primarily on the mass of the star (heavier stars are hotter than lighter ones) but also on the pressure at the surface of the **planet**.
In our solar system, Earth is the only planet in the habitable zone. Mars and Venus lie on its edges.

comet: Comets are comparatively small celestial bodies with a diameter of usually a few kilometres. They consist of rock, dust, water ice, dry ice (frozen CO_2) and other frozen hydrogen and carbon compounds. Comets form at the outer edge of the **solar system**. When they approach the **sun**, they develop a tail. This is formed when frozen particles are vaporised by the heat of the sun and then pushed away from the comet (by the radiation pressure of the sun).

condensation: When a **gas**eous substance such as **water vapour** cools down and changes into its liquid form (e.g. water), this process is called condensation. The individual water molecules lose energy in the process. They therefore move more slowly and are closer together. In the liquid state, the substance is therefore denser than in the gaseous state.

cosmic radiation: Cosmic radiation refers to very high-energy particles that come from **outer space**. These are mainly **protons** and various **atomic** nuclei that fly towards the earth at great speed. They come from the **sun**, other **stars** or even from other **galaxies**. Because of their high energies, these particles are dangerous for us and other living beings on Earth. Fortunately, a large proportion of the radiation is shielded by the **Earth's magnetic field**. The particles that come from the sun are also known as **solar wind**.

light year: The light year is a unit used to measure distances in astronomy. A light year is the distance that light will cover when travelling for one year. A light year is 9 460 730 472 580 800 metres, or approximately 9.46 trillion kilometres.

scaled model: A scaled **model** is a replica of one or more actual objects. This replica is significantly larger or smaller than the original, depending on what is being modelled. However, the proportions and distances are exactly the same as those of the real object.

meteorite: An **asteroid** that enters the earth's atmosphere and hits the earth is called a meteorite. An asteroid that does not hit the earth but burns up in the **atmosphere** is called a meteor or shooting star.

Milky Way: The Milky Way is our home **galaxy**. It is a barred spiral galaxy with a **black hole** at its centre that is about 4 million times heavier than our **sun**. Our **solar system** lies on the edge of the Milky Way in a quiet region between two spiral arms.

moon: A moon is an object that orbits a **planet** and is also called a **satellite**. Moons orbit a planet as they move around the **star** together with the planet. The Earth has only one satellite, the moon (also called the Earth's moon), while other planets can have several. Jupiter, for example, has around 80 moons.

moons: See **moon**

moon rock: Rocks from the surface of the **moon** are called moon rocks. The astronauts of the **Apollo missions** who landed on the moon brought moon rocks back from there for examination.

moon phases: The phases of the moon describe the different shapes of the **moon** that we see on earth as the moon moves around our **planet** and the **sun**. It is important to understand that the Earth and Moon (as well as all other planets) do not shine on their own, but only **reflect** the light coming from the Sun. At night, we can see the moon in different phases. This is because the side of the moon that is visible to us is sometimes fully illuminated and sometimes only partially illuminated, depending on its position. Thus, the part of the illuminated surface of the moon that is visible on Earth can vary from 0 % (at new moon) to 100 % (at full moon). The phases of the moon change gradually over a period of around 29 days.

neutrons: Neutrons are small particles that are found in **atomic** nuclei and have no electrical charge. They are similar in weight to **protons** and therefore significantly heavier than **electrons**. In **fusion** processes, neutrons can be converted into protons or protons into neutrons.

orbit: The path along which an astronomical object moves through **space** is called an orbit. This orbit can be closed, for example in the case of **planets** or **asteroids** orbiting a **star** on an elliptical path or **moons** moving around a planet. However, there are also objects that come to us from outside the **solar system**, are deflected by the **sun** so that they fly a curve and then disappear back into space without returning. Such orbits are called open orbits.

outer space: See **universe**

photosynthesis: Photosynthesis is the process by which plants produce important substances they need to live, such as sugar. To do this, they have to absorb $CO_2$from the air and also need water. With the help of sunlight, they can then convert water and CO_2 into the substances they need. This also produces **oxygen**, which the plant releases into the air.

planet: A planet is a round body that orbits around a **star**. There are 8 planets in our **solar system** that move around the **sun**. The first four planets are **rocky planets**, while the outer four planets are categorised as **gas planets**. A planet must have a round shape and its orbit must be clear of other objects. Since 1995, more than 7000 planets have been discovered orbiting stars other than our sun. They are known as exoplanets.

proton: Protons are small particles with a positive electrical charge. They are similar in weight to **neutrons** and almost 2,000 times heavier than an **electron**. The number of protons in an **atomic** nucleus determines what kind of element it is. **Hydrogen** atoms, for example, have only one proton in their nucleus, helium atoms have two protons and oxygen atoms have eight protons.

protoplanet: A planet shortly after its formation from dust and rock that is still in the process of fully developing is called a protoplanet. Protoplanets are usually very hot, as they still carry the heat from the formation process. This was also the case with the early Earth, which had a completely molten surface. Protoplanets can have a primary a**tmosphere** consisting of **hydrogen** and helium, the most common **gases** found around forming planets.

rocket: A rocket is a long, cylindrical object that is launched into the air. Rockets can be catapulted to great heights or long distances by burning material and are typically used as fireworks or signals. They are also used to launch **spacecraft**, **space probes** or **satellites** into their **orbit** and allow them to escape the Earth's **gravity**.

spaceship: A spaceship is a vehicle in which **astronauts** can travel through space. It consists of an air-filled room with the same pressure as on earth, so that the astronauts do not have to wear a spacesuit during the flight. It also has a drive and control elements and is usually equipped with various measuring **instruments** with which the astronauts explore the **universe**.

space probe: A space probe is an unmanned spacecraft that is controlled from Earth. It is equipped with various measuring **instruments** to explore our **solar system** in more detail and send the measured data back to Earth.

rotation: When an object spins around itself, this is called rotation. Almost all celestial bodies such as the **planets**, **moons** and the **sun** rotate around themselves. The planets and moons additionally move around a central body, i.e. the planets orbit the sun and moons orbit a planet.

rotation axis: The axis of rotation is a straight line around which a body **rotates**. For example, the Earth rotates around the line that runs from the North Pole straight through the Earth's centre to the South Pole. An axis of rotation does not necessarily have to pass through the object but can also be further away from it.

satellite: A satellite is an object that orbits a celestial body. Human-made satellites are devices that orbit the Earth or another **planet** to collect data or take measurements. Unlike a **spaceship** or a **space probe**, they remain in a fixed **orbit** around a celestial body instead of moving between them. The **moon** is a natural satellite of the Earth.

oxygen: Oxygen (O_2) is the component of air that is vital for us. We breathe in oxygen and breathe out carbon dioxide (CO_2). Plants, on the other hand, do exactly the opposite. They absorb $CO_2$from the air and produce oxygen from it again (see **photosynthesis**). Oxygen makes up approx. 20.95% of the air around the earth.

space: See **universe**

black hole: A black hole is an object in which the entire mass is concentrated in a very small space. It is therefore extremely dense. From a certain distance from the black hole on, not even light can escape it.

sun: The sun is the **star** at the centre of our **solar system** around which the earth and the other **planets** orbit. Like other stars, it also produces energy through the **fusion** of hydrogen into helium. This means that two **hydrogen atom**ic nuclei fuse and form a heavier helium nucleus. During this process, which is only possible at very high temperatures and high pressure, energy is released.
The sun has a diameter of around 1.39 million kilometres, which is about 109 times the width of the Earth. With an age of around 4.5 billion years, the sun is only about halfway through its life.

solar system: The solar system is one of many planetary systems in the **Milky Way**. A planetary system consists of one or more **stars** and some **planets** orbiting the star(s). It also includes all other smaller objects that are under the **gravitational** pull of the central star, such as **asteroids**, **comets**, **moons** and **dwarf planets**.

solar wind: The solar wind is part of the **cosmic radiation**. When the very high-energy particles hit the **Earth's magnetic field**, they are deflected from their path. This also causes the auroras.

dust disc: A dust disk is a flat disk of dust particles that **rotate** around the centre of the disk. Such a disc can occur when a new star forms from a **cloud of gas and dust**. The remaining gas and dust rotate around the newly born **star**. This eventually flattens the cloud into a disc. In such a disc, the dust particles can slowly grow and form larger flakes which then become small grains. Over time, these can stick together and collect more dust, growing larger and larger until they eventually become large chunks and ultimately **planets**.

star: A star is a **spherica**l object that consists of hot **gas**. They are much larger and heavier than **planets** and have such a high temperature and pressure inside that nuclear **fusion** can take place there. This means that two **hydrogen** nuclei fuse to form a helium nucleus. In very heavy stars (at least eight times heavier than our sun), the helium nuclei can also continue to fuse and form even heavier elements, which can then also fuse again until iron is finally formed in the innermost part of the star. Energy is released during all these processes, which is why stars shine. The closest star to us is the **sun**.

supernova: **Stars** that are more than eight times heavier than our sun explode at the end of their lives in a supernova explosion. In the process, they eject their shell, which consists of a mixture of different elements. These elements are formed during the lifetime of the star by nuclear **fusion** in its interior (see **star**). In this way, stars can enrich their surroundings with heavier elements (heavier than **hydrogen**).

lurching: An object that **rotates** around itself has an **axis of rotation**. If this axis is not stable, but wobbles back and forth, for example, the movement of the object is called lurching.

telescope: A telescope is an astronomical **instrument** that can be used to observe distant objects such as **planets**, **stars** or **galaxies**. It consists of lenses and curved mirrors to magnify the light of a distant object. It was invented in the 17th century in the Netherlands but was first used to observe celestial objects by Galileo Galilei. Today there are many telescopes, both on the ground and in **orbits** around the earth.

universe: The universe, **cosmos** or **outer space** is the vast space in which everything else is located. All **galaxies**, **stars**, **planets** and **moons** are part of the same universe.

UV light: Sunlight consists of different components. When it falls on water droplets in the air or on a glass prism, the light is split into its different components and we see a rainbow. However, in addition to this coloured light, there are also components that we cannot see, e.g. infrared light (heat radiation) and ultraviolet light (UV light). UV light has more energy than the coloured light that we can see and is therefore more dangerous for us. If we have been in the sun for too long and have therefore been exposed to too much UV light, we get sunburnt. In addition, large amounts of UV radiation can increase the risk of skin cancer.

vacuum: Vacuum describes a space or area without any matter (also without air). The space between the **planets** and **galaxies**, for example, is very empty. There is an almost perfect vacuum there. To create a vacuum in a container on Earth, the air must be pumped out of the container. In most cases, it is not possible to completely empty the container and create a perfect vacuum, but even with an almost empty space, experiments can be carried out to explain, for example, how our body or other objects would behave in **space**.

evaporation: Any substance such as water can assume a solid (e.g. ice), liquid (e.g. water) and **gas**eous state (**water vapour**). In the solid state, the individual particles that make up the substance are closest together and move the least. When the substance is heated sufficiently, the particles start to move more and are therefore no longer so close together. When a substance changes from a liquid to a gaseous state, this is called evaporation or vaporisation.

volcano: A volcano is an opening in the earth's crust through which lava, volcanic ash and **gases** can escape from an underground magma chamber. Volcanoes can occur both as cracks in the earth's crust and as mountainous cones. Such cones are formed from solidified lava that erupts from the volcano itself. Volcanic activity is also possible under water, where a large amount of ash is produced through contact with water. Volcanoes are usually located where two tectonic plates collide (such as the Ring of Fire in Japan), but can also occur near hotspots (such as the Hawaiian archipelago). There are also volcanoes on other **planets** in our **solar system**: Olympus Mons on Mars is the highest volcano in the solar system with a height of 25 kilometres, while Jupiter's moon Io is the most volcanically active body in the solar system.

water vapour: On earth, water occurs in all three different states of aggregation (solid, liquid and **gaseous**). Depending on the temperature and pressure, water can **evaporate** from the liquid phase and change into the gaseous phase. At normal surface pressure, this transition takes place at 100 °C. Water vapour forms **clouds** that can store and transport large quantities of **water** in this gaseous form before it **condenses** and falls back to earth as rain. Due to climate change, our atmosphere is getting warmer and can therefore store more water vapour than before. For this reason, it is expected that clouds will form more frequently and extreme weather events will become more likely.

water cycle: Water **evaporates** in large quantities from the Earth's oceans and is then distributed over land mainly by precipitation (rain, hail and snow). Glaciers on mountain peaks or in high mountain regions can store iced water for centuries before it melts and is transported back into the oceans via rivers. At lower latitudes, rivers are fed by precipitation and water can be stored in groundwater reserves. Water plays a crucial role in the habitability of our planet. Vegetation needs water to survive, as do animals. The ongoing warming of the Earth's **atmosphere** is changing the precipitation patterns on our **planet**, altering the complex and diverse ecosystems of the Earth.

hydrogen: Hydrogen is the most common element in the **universe**. **Stars** consist largely of hydrogen, as do the huge **gas clouds** in **galaxies** and the **atmospheres** of **gaseous planets**. It is also the simplest **atom** and consists of only one **proton** in the nucleus and one **electron** in its shell.

white smoker: Hydrothermal vents are places near cracks in the seabed where **gas** escapes directly from the earth's mantle. They are usually located near volcanically active areas and can form so-called black or white smokers. These smokers emit nutrient-rich gases that come directly from the Earth's interior. This allows some life forms (such as chemosynthetic bacteria) to develop and thrive even under the extreme conditions on the seabed (absence of light, high pressure and low temperatures).

white dwarf: Stars that are about the size of our **sun** eject their shells at the end of their lives. The remaining core of the star then collapses and forms a so-called white dwarf. Such a stellar corpse is very small, with a diameter about one to two times the diameter of the Earth, but much heavier than a **planet**. They are therefore very dense and initially very hot. Over time, they cool down further and further and shine less and less brightly.

cloud: When **water vapour condenses** in the sky, it forms clouds. Clouds consist of water droplets and/or ice crystals floating in the **atmosphere**. They come in different shapes and heights and are usually white in colour. When the water droplets start to grow and merge, they eventually become so heavy that **gravity** pulls them down and they fall to earth as rain or snow. When a storm is approaching, the clouds take on different colours as the composition of the clouds and their visual characteristics change.

cell: Cells are the building blocks of every life form and they are the smallest units that go through the cycle of birth, nutrition and reproduction that defines life. Cells can vary in complexity and there are many differences between, for example, a plant cell and an animal cell. Cells can reproduce by different mechanisms and they contain the genetic material of the individual life form.

dwarf planet: A dwarf planet is a rocky object that orbits the **sun** just like a **planet**. It is heavy enough that it has acquired an approximately round shape (see **gravity**). Unlike a planet, however, a dwarf planet has not cleared its **orbit** of smaller rocks (called planetesimals). Pluto is a dwarf planet.

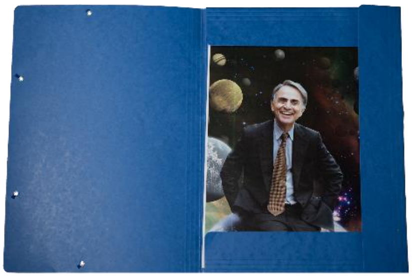
4. Literature for module 2:

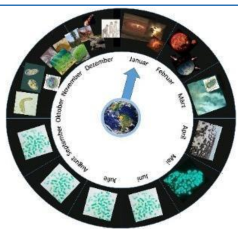
Anna Claybourne: Amazing evolution für Kinder

Lisa W. Peters: Our family tree: An evolution story

Butterfield and Lynas, Nosy Crow.: Welcome to or world

5. List of materials for module 2

	Blue folder for handbooks	
	Blue folder (Din A3) with poster for storytelling	
	Model of the Milky Way (see document 'Templates')	Activity 2.1.1
	Small boxes for dust flakes	Activity 2.1.2
	hot earth (polystyrene ball with 12 cm diameter, painted orange red)	Activity 2.2.1 and 2.2.3
	Theia (polystyrene ball with 10 cm diameter, painted orange red)	Activity 2.2.1
	hot moon (polystyrene ball with 4 cm diameter, painted orange red)	Activity 2.2.1
	Inflatable globe	Activity 2.2.2, 2.2.3 and 2.2.4
	small torch	Activity 2.2.2
	Large moon (polystyrene ball with a diameter of 10 cm, painted grey)	Activity 2.2.3

	medium globe (11 cm diameter)	Activity 2.2.4
	dry earth (polystyrene ball with 10 cm diameter, painted grey an brown)	Activity 2.2.4
	Asteroid (see document 'Templates')	Activity 2.2.4
	Cards showing the formation of the earth (see document 'Templates')	Activity 2.2.4
	Felt tape	Activity 2.3.1
	Cards showing the development of life	Activity 2.3.1
	Earth calendar (see document 'Templates')	Activity 2.3.1
	Wooden discs with tree rings	Activity 2.3.2
	Felt model of the earth made from different components	Activity 2.3.3