Cosmological Time Line

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Goals

- Visualize the history of the Universe with a time line.
- Understand the important processes that were necessary for the formation of life.
- Understand the adaptation of life to very varied conditions.

Activity 1: Timeline

The beginning of the Universe, the Big Bang, took place about 13.8 billion years ago (13.8 10^9 years ago).

1 metre = 10^9 years
1 mm = 1 million years

Timeline of 13.8 meters

Activity 1: Timeline

t=0 sec (13.8 10^9 years ago beginning of the Universe, the Big Bang.)

10^{-45} sec End Planck Era (N.B. Relativity Einstein)

10^{-35} sec Inflation (Exponential Expansion Universe)

10^{-6} sec Primordial Soup (Various Elementary Particles)

3 min. Primordial Nucleosynthesis of "H"

This period cannot be represented on the time line as 1 mm = 10^6 years)

Activity 1: Timeline

13.8 10^9 years Big Bang

100mm

13.7 10^9 years 1st primordial elements

100mm

13.6 10^9 years 1st water molecules

50mm

13.55 10^9 years 1st stars

420mm

13.13 10^9 years 1st galaxies

130mm

13.0 10^9 years Primitive Milky Way

Present Time

Activity 1: Timeline

13.0 10^9 years Primitive Milky Way

During the first 8.4 billion years (8.4 meters) a series of simultaneous phenomena took place.

The first stars evolved giving rise to different explosions that expelled different types of atoms and the diversity of elements of the periodic table appear. Different types of objects arise simultaneously:

- Blue giant and supergiant stars: last 10-100 million years (10-100mm). They explode as supernovae, ejecting heavy atoms such as Iron, Lead, Gold, Uranium, etc.
- Yellow stars like the Sun: last 10,000 million years (10 000 mm). They end up as planetary nebulae, ejecting medium-heavy atoms, such as Carbon, Oxygen, Nitrogen, etc.
- Red dwarf stars: Last longer than the age of the Universe.

8400mm

4.6 10^9 years The Formation of the Sun

Activity 1: Timeline

4.60 10^9 years Sun Formation

1st alcohols

30mm

4.57 10^9 years Birth of the Solar System

4mm

4.566 10^9 years Giant Planets

6mm

4.56 10^9 years Earth and Rocky Planets

20mm

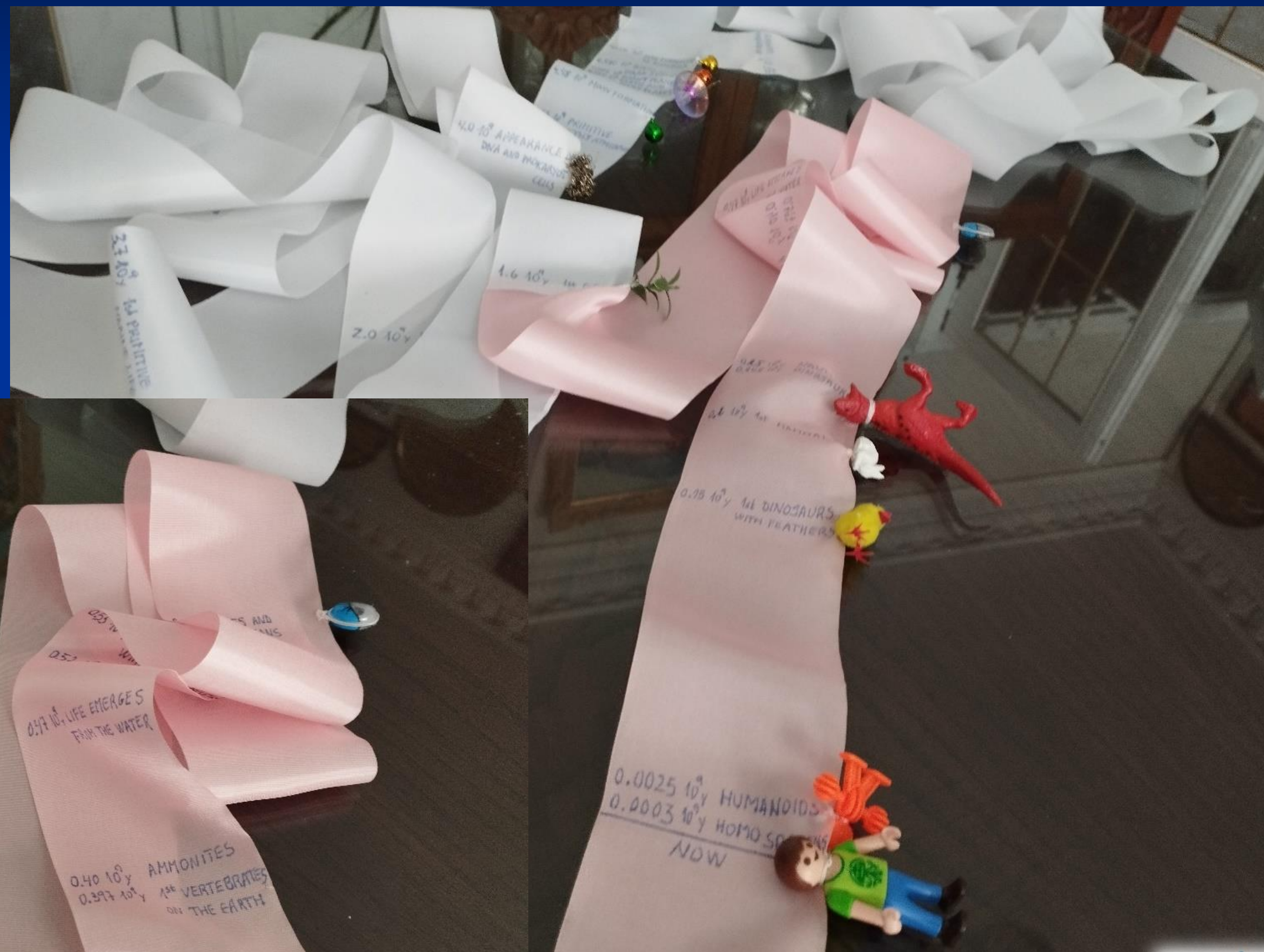
4.54 10^9 years Earth's Magnetic Field

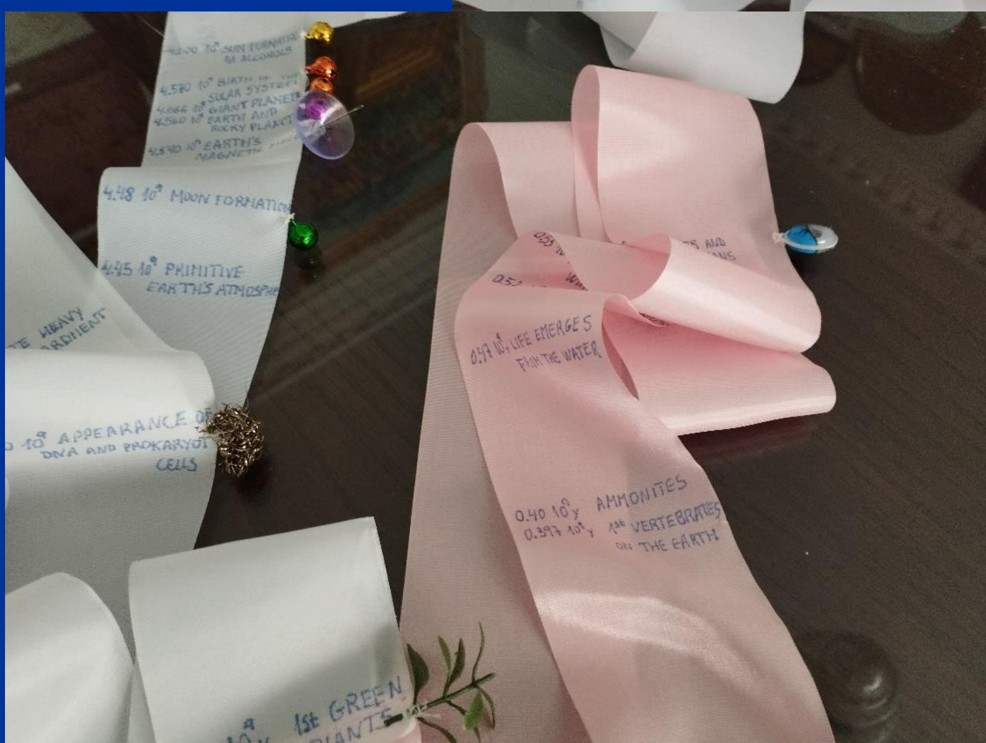
60mm

4.48 10^9 years Moon's Formation

Now

Activity 1 : Timeline





Activity 1: Timeline

4.48 10^9 years Moon's Formation

30mm

4.45 10^9 years Primitive Earth's Atmosphere

45mm

4.10 10^9 years Late Heavy Bombardment

Now

Activity 1: Timeline

4.1 10^9 years Late Heavy Bombardment

100mm

4.0 10^9 years DNA and Prokaryotic Cells

3.7 10^9 years 1st Primitive Marine Life

30mm

1700mm

2.0 10^9 years Breathable O_2

Now

Activity 1: Timeline

2.0 10^9 years Breathable Oxygen

400mm

1.6 10^9 years 1^{st} Green Plants

Now

Activity 1: Timeline

1.6 10^9 years 1st Green Plants

900mm

0.7 10^9 years 1st Tissues and Organs

Now

Activity 1: Timeline

0.70 10^9 years 1st Tissues and Organs

150mm

0.55 10^9 years Marine organisms with shells or skeletons

30mm

0.52 10^9 years Trilobites

50mm

0.47 10^9 years 1st Life emerges from the water

70mm

0.40 10^9 years Ammonites

3mm

0.397 10^9 years 1st Vertebrates on Earth

0.25 10^9 years Nautilus

147mm

Now

Activity 1: Timeline

0.25 10^9 years Nautilus

5mm

0.245 10^9 years 1st Dinosaurs

450mm

0.20 10^9 years 1st Mammals

500mm

0.15 10^9 years 1st Dinosaurs with feathers

Now

Activity 1: Timeline

0.1500 10^9 years 1st Dinosaurs with feathers

147.5mm

0.0025 10^9 years = 2 500 000 years

Humanoids

2.2mm

0.0003 10^9 years = 300 000 years

Homo Sapiens

0.3mm

Now

Activity 1: Timeline

Cannibal Galaxies

Galaxies are groups of stars bound by gravity, rotating about each other.

Groups of galaxies form the filaments of the universe. Galaxy clusters form at the junctions of cosmic filaments.

In these clusters the young galaxies compete to acquire the free gas and the older galaxies are the winners.

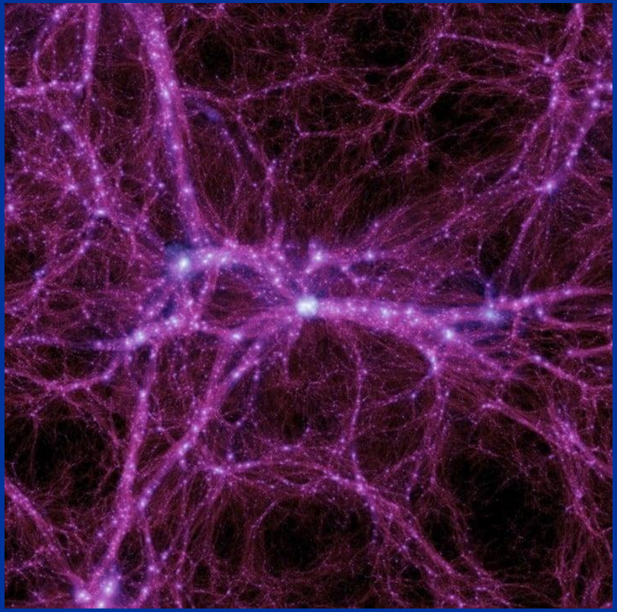
The ballet of galaxies, their encounters, their collisions and the cannibalism of the large ones over the small ones promotes star formation.

(Credit ESO)

Activity 2: Filamentary Model

The filamentary structure of the Universe can be thought of as a bubble bath where matter accumulates on top of the bubbles and especially at their intersections.

Just use soapy water and a straw or straw.



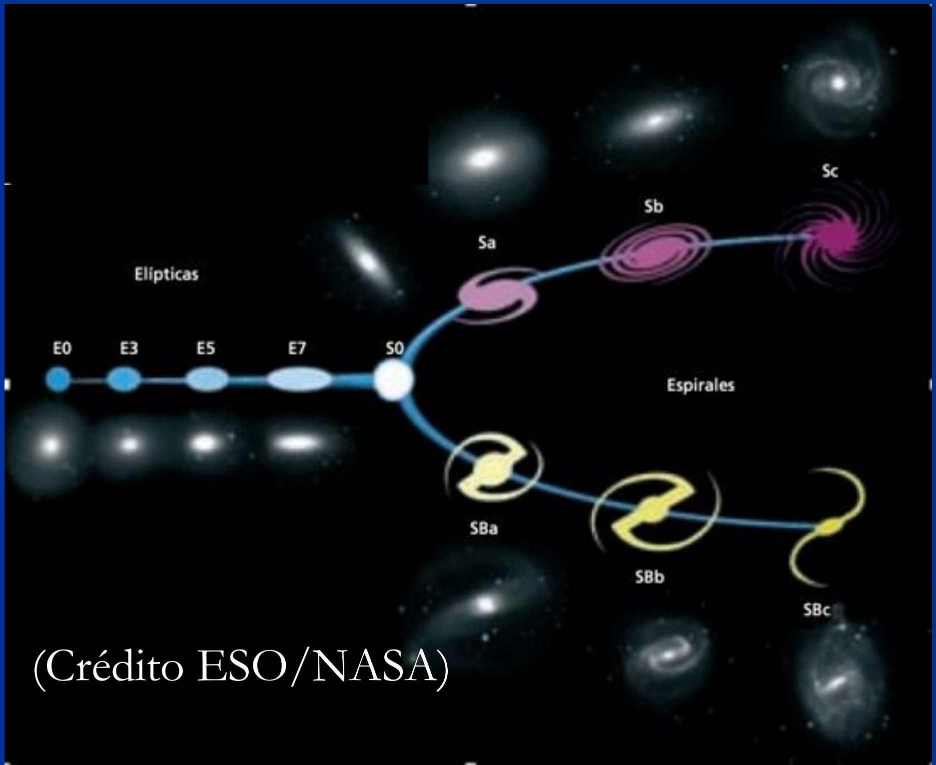
Modelling the filamentary structure of the universe (Credit: Illustris Project)

Modeling of the filamentary structure with a detergent solution

Galaxy Classification

There are spirals, barred, elliptical, irregular…

They are usually classified according to their morphology in the well-known sequence by Hubble.



(Crédito ESO/NASA)

It is now known that this is not an evolutionary sequence.

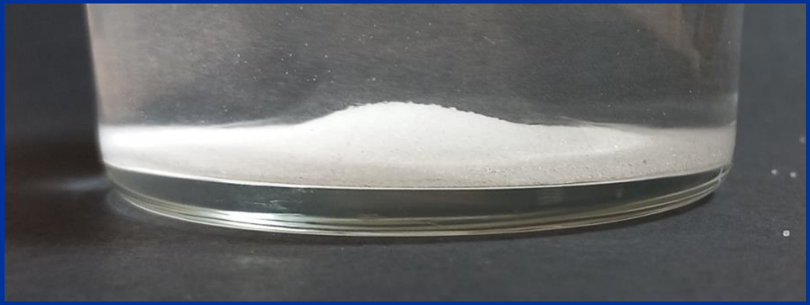
Activity 3: Simulation of Spiral Galaxy Formation

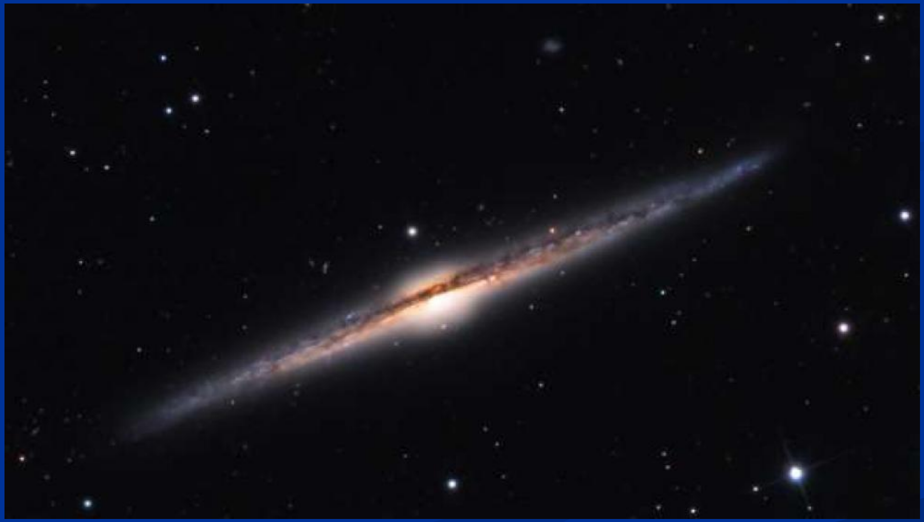
A model can be made with a glass filled with water and stirring the water with a pencil. When you stop stirring, throw in a tablespoon of bicarbonate, fine sand or common salt. Upon settling, the grains are left in shapes similar to spiral galaxies.

Spiral galaxy seen from above the plane. (Credit ESA/Hubble)

Activity 3: Simulation of Spiral Galaxy Formation

Looking at the model from the side, the central bulge of galaxies is simulated.

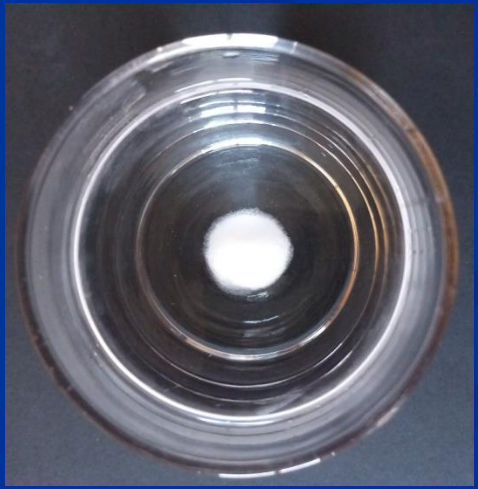


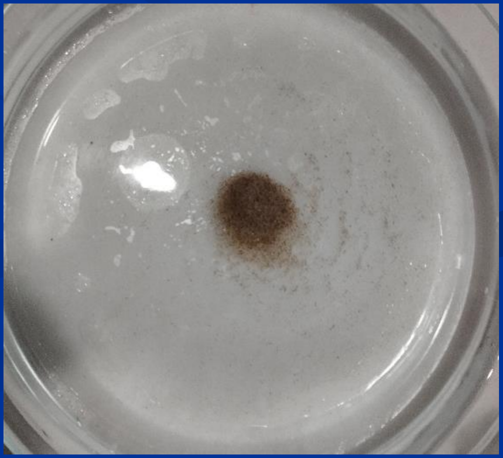


Spiral galaxy edge-on view
(Credit ESO/NASA)

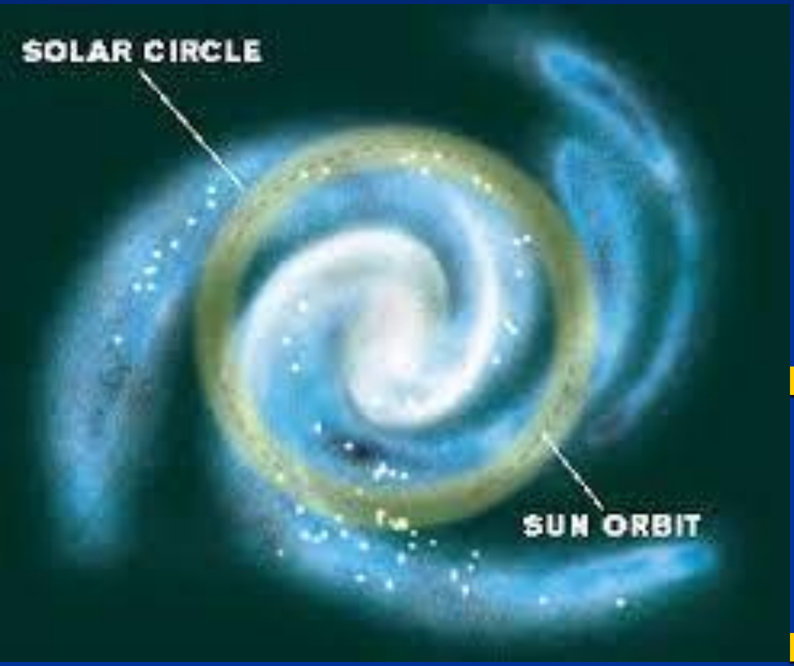
Activity 3: Simulation of Spiral Galaxy Formation

Once the galaxy is formed, if the water continues to be removed, it is possible to obtain a shape similar to elliptical galaxies.





Habitable Zone in Galaxies

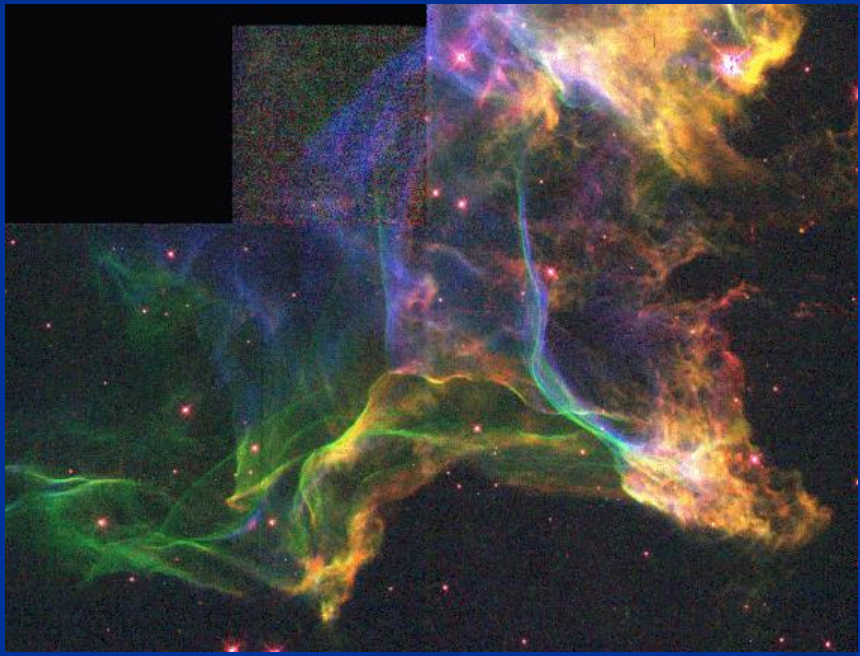


By way of example, to compare time and distance in our model of the time line, our galaxy takes 220 x 10^6 years (220 mm) to make one revolution.

- The habitable zone in galaxies is normally located at a radius of between 23 000 to 30 000 l.y. from the centre of the galaxy (the Sun is at 27 000 l.y.).
- Outside this zone, toward the edge, the atoms heavier than H and He that are necessary for life are missing.
- Outside this zone, closer to the centre, there are massive gamma-ray bursts with very energetic and violent events that make life impossible.

Plasma and Magnetic Fields

- In the intergalactic medium, in the interstellar medium and in the stars themselves, matter is usually in the plasma state.
- This plasma is made up of electrons, protons, high-energy particles and ionized gas.



Veil Nebula with filaments (Credit NASA)

Plasma and Magnetic Fields

On Earth there is matter in this state in lightning, the interior of fluorescent tubes or low consumption lamps, monitors and television screens, plasma balls and the flame of a candle.

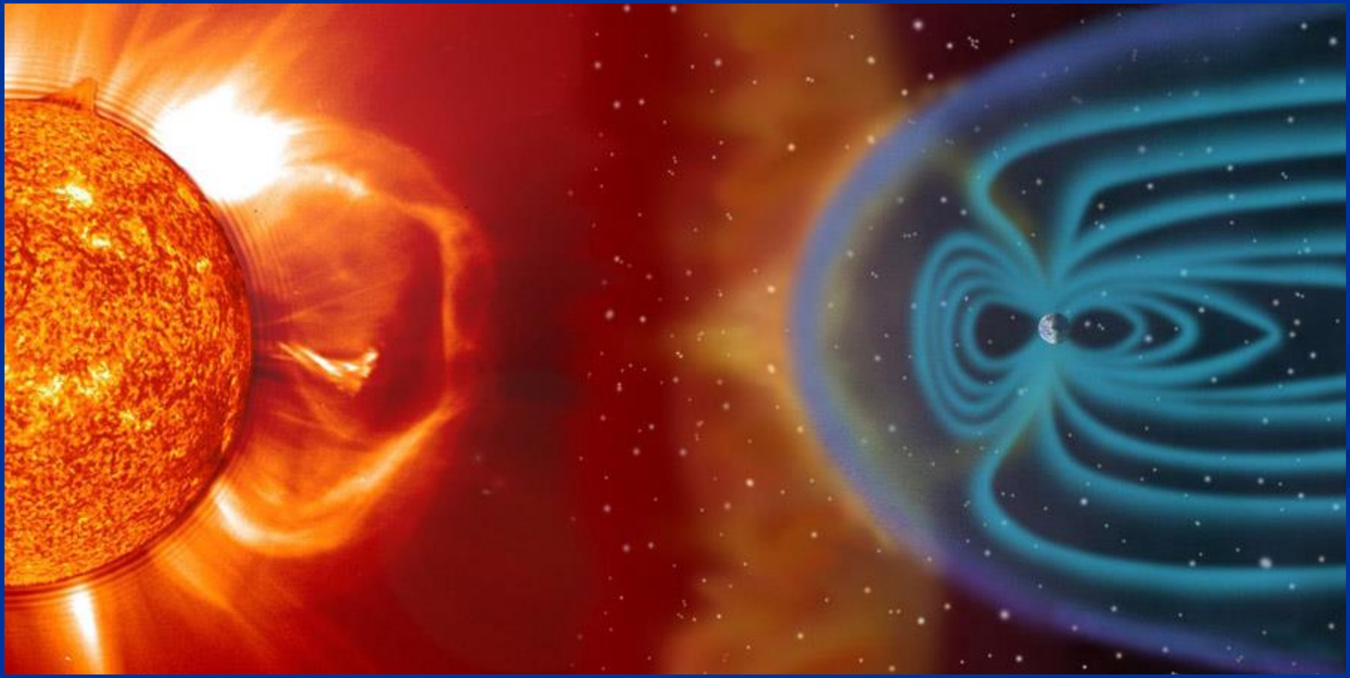
Plasma and Magnetic Fields

The solar wind is also plasma. It is a stream of charged particles released from the Sun's corona. The flow of these particles is variable and can generate geomagnetic storms, giving rise to auroras (The Northern and Southern Lights). It also deforms the plasma in the ion tails of comets.

C/2002 E3
(Credit Rykis Babianskas and Carlos Viscasillas)

Plasma and Magnetic Fields

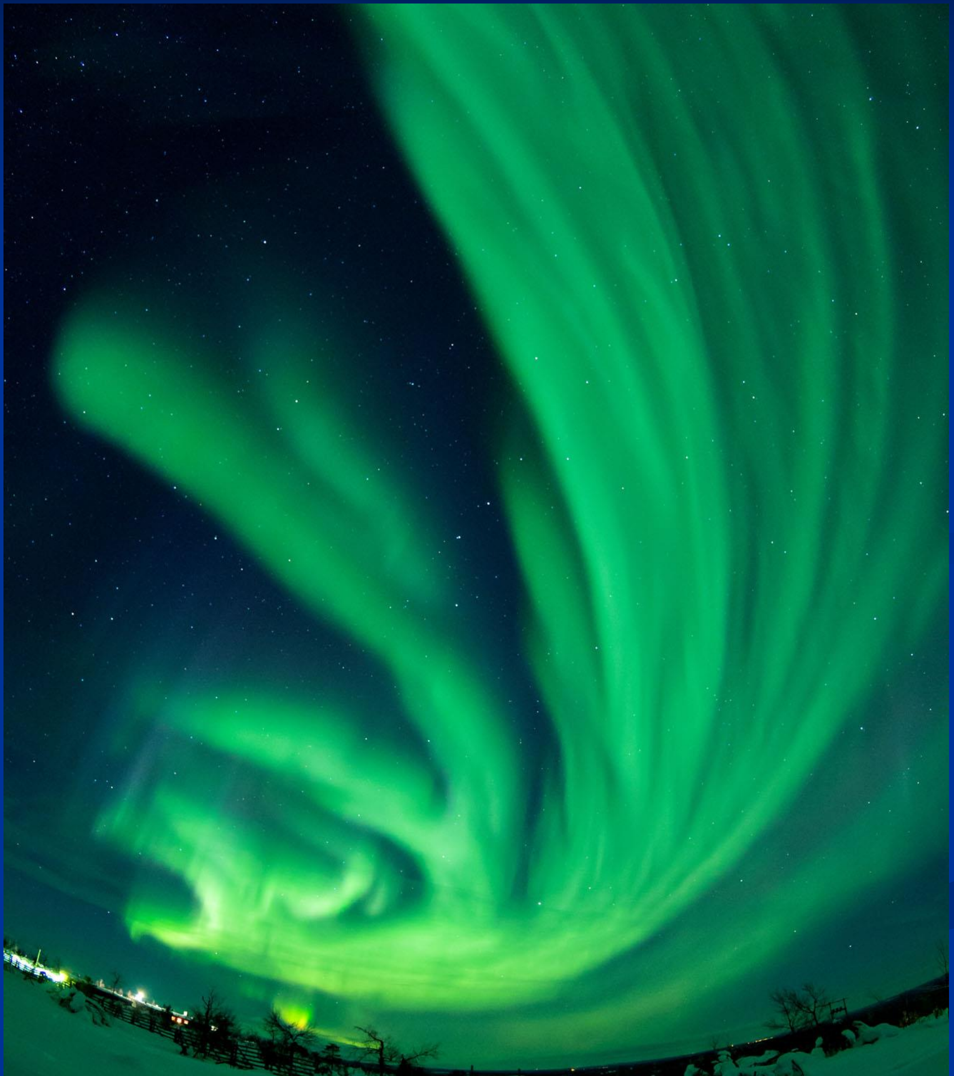
The Earth's magnetic field acts as a protective shield for life on the planet. Solar wind particles that travel at high speed and with a lot of energy have great penetrating power and would damage the DNA of cells.



Sun wind,
artist impression.
(Credit NASA)

Plasma and Magnetic Fields

The Earth's magnetic field acts like an umbrella, diverting charged particles that are dangerous to life, from reaching the Earth's surface. Their interaction with the atmosphere generates the beautiful auroras of various colours.



(Crédito Sakari Ekko)

Plasma and Magnetic Fields

The colours of the auroras depend on the energy of the molecules in the air with which they interact. In an area of:

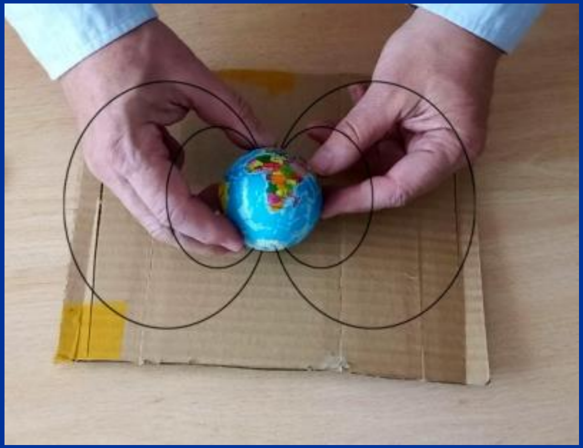
Oxygen at very high energy levels emits green/yellow light and at low levels red/purple.

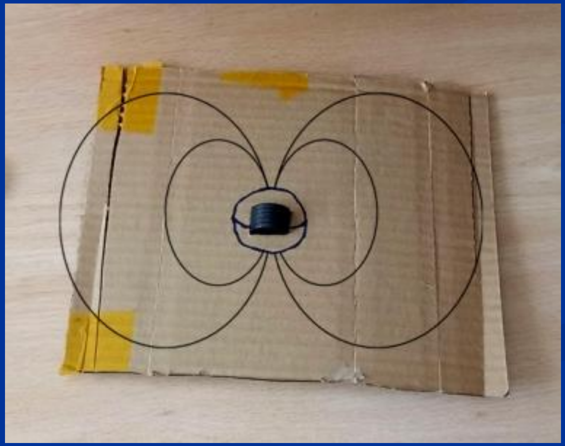
Nitrogen, if it loses electrons in its outermost layer, produces a bluish light, while it gives a red/purple colour at the lower edges of auroras.

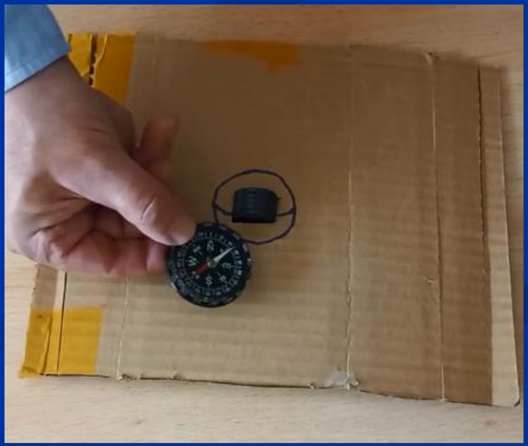
(Credit Sakari Ekko)

Activity 4: Earth's Magnetic Field

We can visualize the terrestrial magnetic field with a magnet, which represents the Earth, and a compass, with which we go through the lines of force of the field.

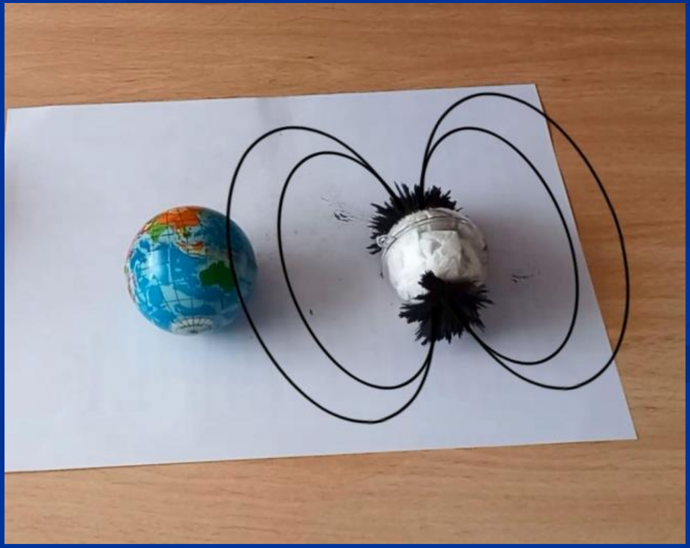






Activity 4: Earth's Magnetic Field

In a plastic sphere, we put a magnet wrapped in a paper napkin. It represents the Earth.
With iron filings near the poles, the magnetic field lines in that area, where the auroras occur, are very well visualized.



How did life arise on Earth?

The most accepted hypotheses assume that life arose on Earth from inorganic matter 4500 x 10^6 years ago.

But other scientists assume an extraterrestrial origin of life. If life did not start on Earth, it could have arrived on comets, asteroids or meteorites.

Microbes could survive embedded in rocks, protected from the extreme conditions of outer space.

No one supposes that the first living being was very complex. There must have been simpler forms of life that have served as a connection between the first organism and life today. It is possible that extremophile microorganisms reached Earth on asteroids or meteorites that impacted on its surface. In fact organic samples are found in some meteorites. It is not easy to find meteorites, but it is easy to **hunt micrometeorites**.

We will also see some areas of the Earth where extremophiles are found and which are studied by NASA and ESA.

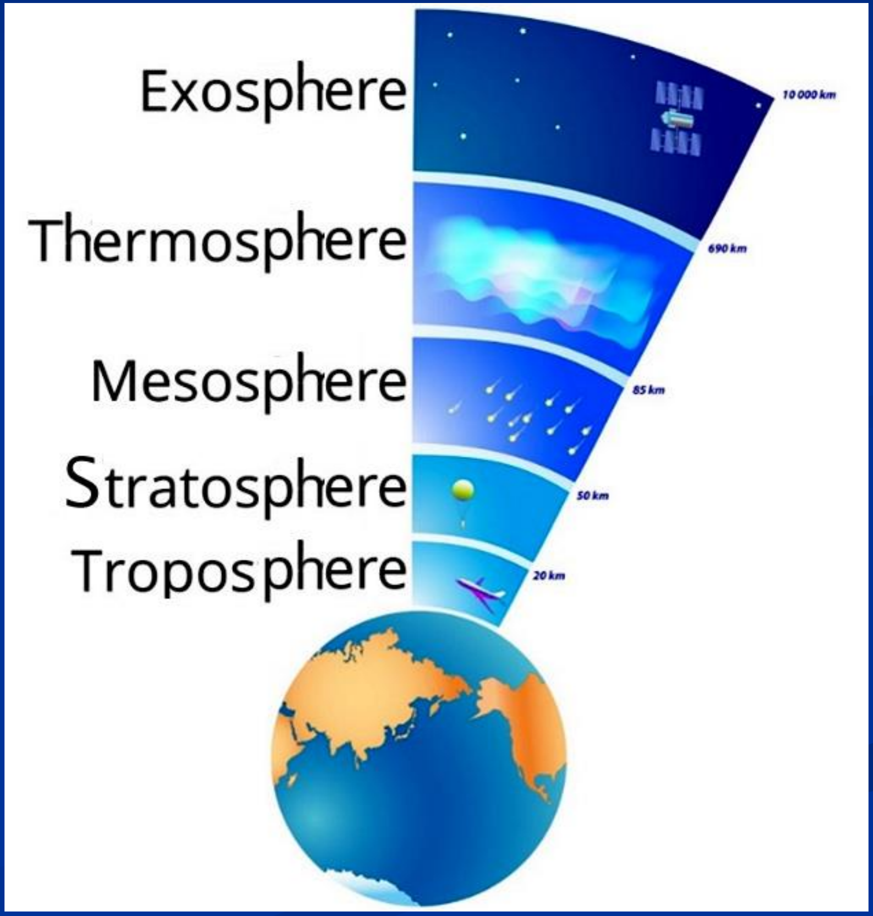
Micrometeorites

The Earth goes through the orbits of comets where it encounters traces of dust. This dust falls on the Earth's surface and gives rise to micrometeorites. Thousands of them fall every day and they normally burn up (due to friction with the atmosphere) before reaching the ground, forming shooting stars.

Those that reach the ground can be collected. They are everywhere. They are easier to find in places with little human activity or places that are difficult to access. Their rounded shapes and grooves betray their origin.

Micrometeorites

Meteors pass through the exosphere and thermosphere without much trouble because these layers are not very dense. But when they reach the mesosphere, the density is higher and the air will cause more friction and create heat. The material melts and then solidifies so that in the end it presents grooves and sometimes small bubbles, the effect of rapid solidification.



Activity 5: Simulation of Spherical Micrometeorites

Fill a tall glass with sunflower oil. Drops of water or cola are dropped from a syringe. Small spheres are formed and can be seen slowly falling down the oil column.

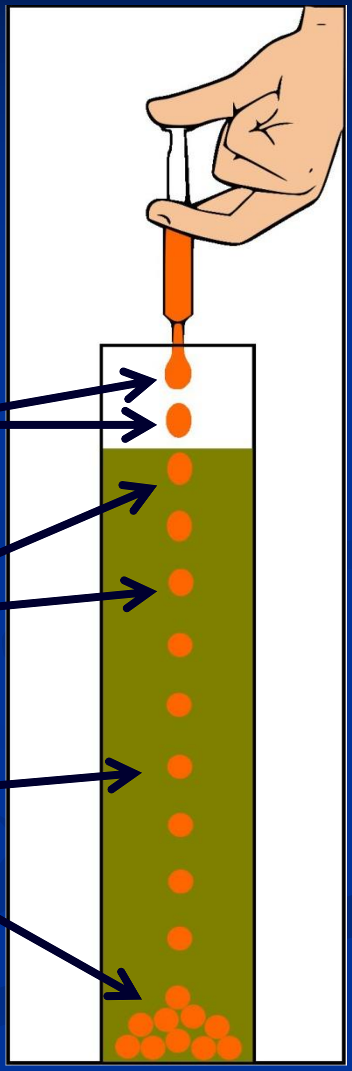
MESOSPHERE Liquid drops.

Drops still liquid, become spherical within the viscous medium.

STRATOSPHERE AND TROPOSPHERE

Spherical drops solidify and accumulate at the bottom.

CONTINENTAL CRUST AND OCEANIC FLOOR.



Activity 5: Simulation of Spherical Micrometeorites

small spheres of simulated "micro-meteorites" are formed.

real micrometeorite

Every day they fall on the Earth's surface 5 tons of alien material!

Activity 6: Look for Micrometeorites

Micrometeorites are deposited on roofs and terraces or even remain suspended in the atmosphere for a long time and then fall together with rain or snow. The best method for the recovery of this material is to look for it in gutters, which collect the material that has been deposited on the roofs, or in the gutters of the streets or highways.

These meteorites come directly from the matter that gave rise to the Solar System. They are therefore about 4500 million years old.

Activity 6: Look for Micrometeorites

Most of these meteorites have a rocky composition, but others are made of iron and nickel and can be separated from the rest with a magnet.

With a brush, sand is collected from a gutter or a ditch, and it is placed on a piece of paper. Pass a magnet under the paper to see which particles move.



Activity 6: Look for Micrometeorites

If you don't have terraces or ditches where you can look for micrometeorites, you can prepare a trap to collect them. Place cellophane paper in a tray and leave it out in the open for a week in a slightly elevated place so that animals do not approach. The process of collecting the micrometeorites is also done with a magnet.

Activity 6: Look for Micrometeorites

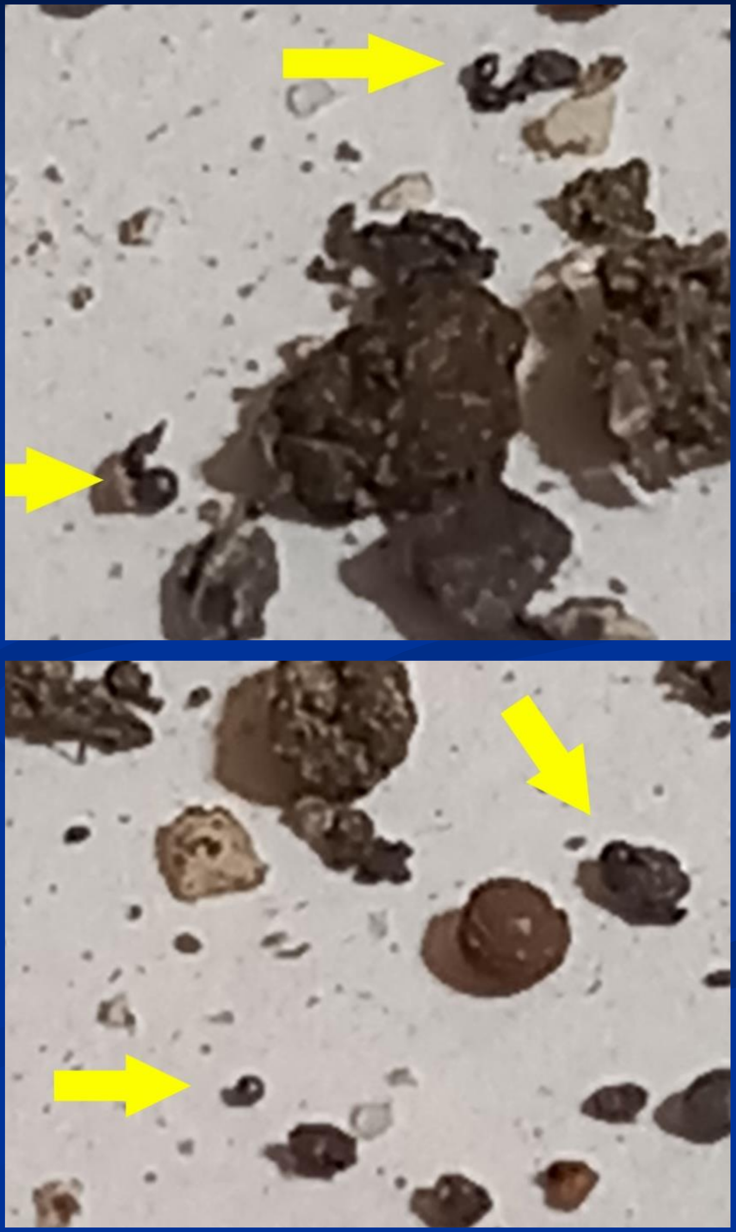
Another possibility is to prepare a trap for each student with a paper cup tied with a string and a small magnet inside the cup. Students move around the schoolyard area with the magnet cups and, when removing the magnet, if there are iron particles, they will fall on the white sheet of paper. Just look through the cameras of their mobile phones to find the micrometeorites.

Activity 6: Look for Micrometeorites

Identification of micrometeorites:

Inspect the material that has moved with the magnet, without removing it from the paper, with a cell phone or camera, using the maximum zoom.

Micrometeorites are identified by having a nearly spherical and bright shape.



Extremophile Classification

An extremophile is an organism (often a microorganism) that lives in extreme conditions (conditions that are very different from those experienced by most terrestrial life forms).

Until recently, it was thought that it was impossible for life to exist where extremophiles grow. For example, in the highly acidic and metal-containing waters of the river Rio Tinto in Spain, or in the extremely dry and heavy-metal-containing Atacama desert o en la Antártida con sus bajas temperaturas.

But it has been shown that there are organisms that live in these areas.

Extremophiles in Antarctica

In Antarctica, several groups of scientists have found life below its surface, for example:

- extremophile microbes living at 36 m with temperatures of -20ºC in salt water (not frozen due to the high concentration of salt)
- an ecosystem in total absence of light at 800 m depth

Extremophiles and Atacama Desert

Some extremophiles live in the near absence of water or are able to withstand desiccation by living with very little. Like the microbes in the soil of the Atacama Desert.

There is a very spectacular phenomenon: the flowery desert. This is the most arid desert in the world. In years when there is more precipitation than normal and a cold front appears, a large number and diversity of flowers (14 varieties) last for a few months.

Photo August 2022 after several years of dryness, the last years were 2015 and 2017.

Extremophiles and the Rio Tinto

Other extremophiles thrive in environments with high acidity and high metal concentrations (Iron, Copper, Cadmium, Arsenic, Zinc and Lead). The reactions in this river are catalysed by acidophilic bacteria, so that if the acidity is reduced, the bacteria population multiplies. This generates more oxidation of sulphides and more acidity in a process that feeds back. The inhabitants of the area know when it is going to rain because of the colour changes of the river (bacteria generate more acidity to maintain the pH during the flooding of the river).

Extremophiles & Vegetation - Rio Tinto

There are extensive groups of the shrub Erica Andevalensis or "mining heather" distributed along the riverbed.

These plants have their roots in highly acidic soils with few nutrients. Some plants even grow on the banks of the river with their roots partially submerged in acidic water and soils with high concentrations of Copper and Lead.

Activity 7: Extraction of DNA

NASA and ESA astrobiologists study on the ground (Rio Tinto Mines, Atacama Desert etc.) to understand how life evolves or adapts and how it originated.

The first step of many of the processes that are carried out to discover extremophiles consists of DNA extraction.

Activity 7: DNA extraction

The sequence DNA allows the detection of the existence of life (current or past) and this is used to search for life in space.

The DNA molecule is very long and packed with proteins (like a ball of wool) inside cells.

Solution to break the cell: Take half a glass of water,

1 teaspoon of Salt (Sodium Chloride) to remove the proteins and thus release the DNA.

3 teaspoons of Sodium Bicarbonate, to keep the pH of the solution basic and constant so that the DNA remains undegraded.

Add dishwashing liquid until the solution has the same colour, to break the membrane of the greasy cells

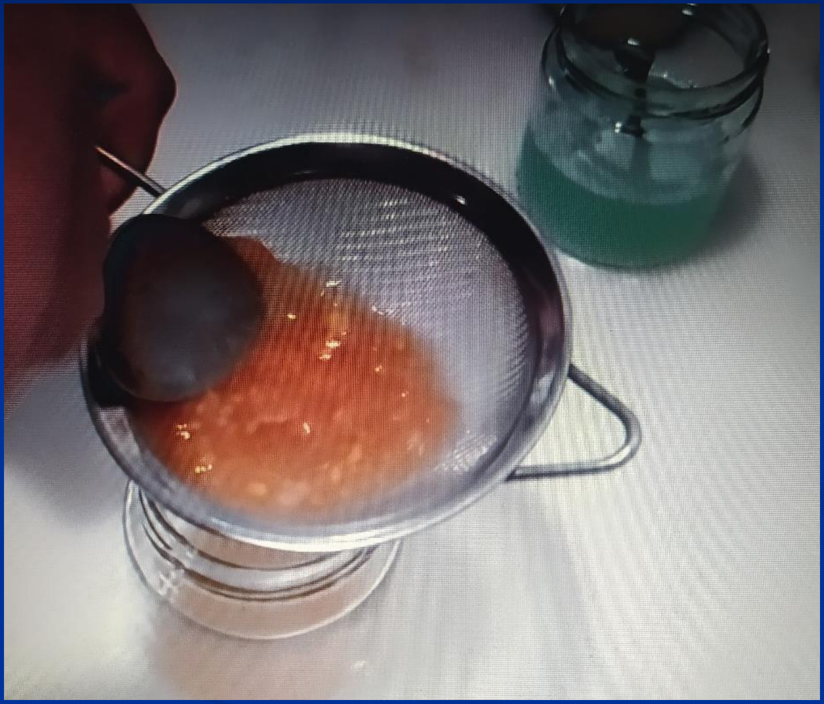
Mix without foaming to get a good view of the DNA.

Activity 7: DNA extraction

Prepare the cell juice "of tomato".

Take 2 tablespoons tomato pulp, mash it with a fork until it becomes pureed.

Add the innovative solution (the volume of the solution is double the volume of the tomato puree).



Mix carefully to break the cells, being careful not to foam. Then strain to remove the large pieces.

The content that was inside the cells is in the juice.

Activity 7: DNA extraction

Make DNA visible.

When there are many strands of DNA we see it as a white cloud (salt gives it a whitish colour, DNA is not visible to the naked eye). We slowly add alcohol, dripping it on the wall of the glass of juice, because we want the layer of alcohol to remain above the juice without mixing.

In 3 or 4 minutes a white cloud of DNA forms which agglomerates and becomes visible (rising to the top). Alcohol is added because the DNA is not soluble in alcohol and thus a cloud of DNA is formed.

Conclusions

- Understanding the long process for the appearance of life.
- Know the conditions that protect life.
- Know the extreme environments in which life can develop.
- Understand the DNA extraction process to verify the presence of life.

Thank you very much for your attention!