B1 Water cycle

Subexperiment B1.1 The Earth's water cycle
Subexperiment B1.2 Water transport in plants

1 Main question

The following questions underlie the subexperiments and guide the activities:

- What happens to the water on Earth?
- What is the water cycle and how does it work?
- How can plants live and grow?

2 Background

2.1 Relevance to the curriculum

Water is important for people in many ways, which makes the discussion of the topic very multifaceted. The students will learn about the characteristic properties of water and establish the connection to their surroundings.
In addition to the properties of water, the global water cycle plays a key role.
This cycle highlights the importance of water for the environment and people. The individual components that make the water cycle a "cycle" are central in working through the topic.
Plant life on Earth is emphasized in this cycle. Students will become familiar with typical characteristics and basic behavior of plants. These topics will be addressed based on the example of water transport in plants.

Topics and terms

Biotope, ecosystem, water cycle, water transport

2.2 Skills

The students will ...

- understand the concept of the Earth's water cycle.
- become familiar with the different components of the water cycle and be able to designate their role in the water cycle.
- learn that water can occur in different states of aggregation.
- comprehend the water transport principle in plants and become aware of the complex system of capillary action.

3 Additional information on the experiment

You will find additional media for preparing or for further study of this experiment on the media portal of the Siemens Stiftung:
https://medienportal.siemens-stiftung.org

4 Conducting the experiments

Note: The required apparatus and materials that are not supplied as well as those that are supplied in the kit are designed for experimentation by **one** group of a maximum of **five** students. In total, the material is sufficient for **ten** groups of students.

4.1 B1.1 The Earth's water cycle

4.1.1 Apparatus and materials

Required materials that are not supplied

Materials	Quantity
small plant with roots	1
soil	3 handfuls
stones or other small objects from nature	as desired
transparent plastic container*	1
water**	200 ml

* The plastic container must be taller than the plant so that the plant can be in the container without touching the cover.
** If necessary, provide it in a small watering can. The amount of 200 ml was calculated based on the size of the plant and the container shown in the photos of materials in the student instructions.

Supplied

Materials	Quantity	Box no.
plastic wrap	50 cm	loose in the kit

4.1.2 Organizational aspects

Facilities	At a simple table in the classroom
Time required	▪ Subexperiment setup: approx. 45 minutes ▪ Conducting and observation: a few weeks ▪ Analyzing and documenting the results at the end of a complete week of observation: approx. 30 – 45 minutes
Safety information	See the "Safety information on the topic of the environment" guide book binder
Cleanup	The soil and the plants in the plastic containers can be transferred to flower pots and placed in the classroom.

4.1.3 Explaining the subexperiment in the teaching context

The students will create a biotope in an airtight container and observe the changes that occur.

Technical background

All water reservoirs (including lakes, oceans, rivers, and groundwater) on the Earth, sunlight, and the various meteorological events constitute the driving forces of the water cycle.

- When it rains, water falls from the clouds to the Earth.
- This rainwater forms puddles and ends up in the ground, lakes, oceans, and rivers through trickling down and surface runoff.
- When the surface of the various water reservoirs is heated by the sun's rays, the water evaporates and rises to the atmosphere.
- In the upper layers of the atmosphere, the temperature is cooler and the water particles condense (water changes from the gas state to the liquid state again) to form clouds.
- When a sufficient volume of water droplets has collected in the upper layers of air, the water falls back to the Earth in the form of rain, snow, or hail.
- The rainwater trickles away into the ground and collects in the groundwater, which appears again at various sources.

The water cycle then starts again from the beginning.

About 97.5 percent of the Earth's total water is found in the oceans. The remaining 2.5 percent of global water resources are freshwater in the form of ice, groundwater, soil moisture, surface water (lakes and rivers), and rainwater. By building their own small biotopes in this subexperiment, the students can easily understand the Earth's water cycle. In biology, the habitat of organisms is referred to as a biotope. Biotopes are the smallest units of the habitat Earth (biosphere). In this context, the students will gain insight into the various manifestations of water (here, liquid and gaseous forms).

4.1.4 Ask about the students' prior knowledge and ideas

The students are often unfamiliar with the fact that substances can take on other manifestations ("states of aggregation"). They may not yet have grasped the fact that substances can undergo transitions from the solid to the liquid state and from the liquid to the gaseous state. Therefore, in preparation for this topic, we recommend starting with an example from everyday life that illustrates the transition of water between states of matter.

- For instance, using the example of a melting ice cube in one's own hand, each student can experience the transition of ice into liquid water through the heat in his or her hands.
- Another short experiment would be to have the students breathe on a windowpane or a mirror, since a change in the state of aggregation (invisible steam becomes small water droplets) can also be observed here.

These short experiments provide the students with initial insight into the principle of transformation of substances and help them recognize the connection to the water cycle.

4.1.5 The research cycle

Important aspects and information on the individual process steps of the research cycle during the student experiment:

The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ What is a water cycle? Another option is to allow the students to come up with their own research questions with the help of a story to get them thinking about the topic.
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ "Water is always moving and is transported in various forms." ▪ "The water cycle works only if it is raining or snowing. It is interrupted when the weather is nice." **Related to the experiment:** ▪ "The water cycle can't work if you don't add any water (from the outside)." ▪ "The plant will dry out and wilt if you don't water it." ▪ "The plant needs air. It can't grow without air and will die." Segue from the guesses to the experiment.
Experimenting 	**Experiment setup:** The students may also bring the small plants and plastic containers from home. **Conducting the experiment:** When the students conduct the experiment, remind them to be patient and to wait before drawing conclusions. The results will not become apparent until after a few days, depending on the indoor climate.
Observing and documenting 	The students will experience that … ▪ the droplets that have formed on the inside of the plastic-wrap cover "fall" to the soil again. ▪ the plant does not dry out, even though nobody waters it. **Most important observations:** ▪ Water is always present without being added from outside the biotope. ▪ Water can appear in different forms, that is, states of aggregation.
Analyzing and reflecting 	During the evaluation and reflection, it is especially important to make sure that the students rely on their documentation, since the experiment is to be observed over a period of at least one week. **Results to be expected:** ▪ Water condenses on the plastic wrap. ▪ Water transpires from the plants.

4.1.6 Other information

In the student instructions

Doing further research 	The assignment to do further research in the student instructions serves to establish a transfer of knowledge from the biotope in the plastic container to the global water cycle. The knowledge can be transferred very well in a class discussion based on the graphic in the student instructions. The students will encounter the water cycle many times in their further education.

Miscellaneous notes

To add another teaching unit on the topics of “saving water” and “conserving resources”, the teacher or students can make small holes in the biotope’s plastic wrap. The students should continue to observe the biotope and see what happens to the plant when water is “removed” from the cycle: The plant begins to wilt. In transferring knowledge from the biotope to the global water cycle, the students will recognize the consequences that water removal can have.

4.2 Subexperiment B1.2 Water transport in plants

4.2.1 Apparatus and materials

Required materials that are not supplied

Materials	Quantity
clear drinking glasses of the same size	2
water	1 glassful

Supplied

Materials	Quantity	Box no.
ink	5 drops	13
paper napkin	1	loose in the kit
pipette	1	12

4.2.2 Organizational aspects

Facilities	At a simple table in the classroom
Time required	Setup, conducting, and analysis: approx. 45 minutes.
Experimental variations	▪ Different groups can use glasses of different sizes. When the experiment is analyzed, any differences that occur can be discussed and explained. ▪ Another possibility is to vary the thickness of the paper napkins. However, paper napkins with other thicknesses must be obtained in advance. ▪ Instead of drinking glasses, the 500 ml plastic cups from the kit can be used. However, they can tip over more easily than glasses.
Safety information	See the “Safety information on the topic of the environment” guide book binder
Cleanup	The pipettes should be thoroughly cleaned to remove all ink residue before they are placed back in the box. To do so, rinse them several times with clear water.

4.2.3 Explaining the subexperiment in the teaching context

The students will become acquainted with water transport in plants. They will gain initial insight into how a capillary system works.

Technical background

The paper napkin absorbs water until it is saturated; the water rises and eventually reaches the highest point. The students will recognize that water does not necessarily flow only downward, but rather can also move upward in certain systems.
The subexperiment shows the principle of a capillary system in simplified form.
A capillary is a very thin vessel. A liquid can rise or fall in a capillary due to its surface tension. Whether a liquid rises or falls depends on whether it is a wetting liquid like water or a non-wetting liquid like mercury. Wetting by water occurs when the attractive forces between the capillary walls

and the water molecules (adhesive forces) are greater than the forces keeping the water molecules together (cohesive forces). In narrow gaps or tubes, the adhesive forces act upon the liquid from all sides (= capillary forces) and draw the liquid inside.
The capillary system of plants starts at the plants' roots and ends in the tips of the uppermost leaves. The water is absorbed by the roots and evaporates from the leaves. The water absorbed by plants' roots is transported all the way to the tips of the leaves in capillary bundles – called vascular tissue – with a capillary diameter of 0.001 – 1 mm. The water rises due to the combination of osmosis (forces due to different salt and sugar concentrations), capillary forces, and transpiration (evaporation of the water from the leaves). This results in suction, which allows the water – and thus the nutrients dissolved in the water – to rise up to 120 meters. The cohesive forces hold the thin water threads together in the process. Because of this, the plant is ensured a continual supply of water. A capillary system is therefore nothing more than a thin network of pipes that ensure the supply of water to, for example, the smallest parts of plant leaves, even if the water has to flow "uphill" to do so.

Note: In the experiment, the gaps between the napkin's cellulose fibers act as capillaries.

4.2.4 Ask about the students' prior knowledge and ideas

The students will assume that plants live on rain because when it doesn't rain, plants dry up. We also water flowers close to the stems and intentionally moisten the soil around the stems so that the roots receive a lot of water from above. The water supply thus runs downward, or so the students think. The fact that water can also flow upward is something the students do not know from their typical everyday world.

4.2.5 The research cycle

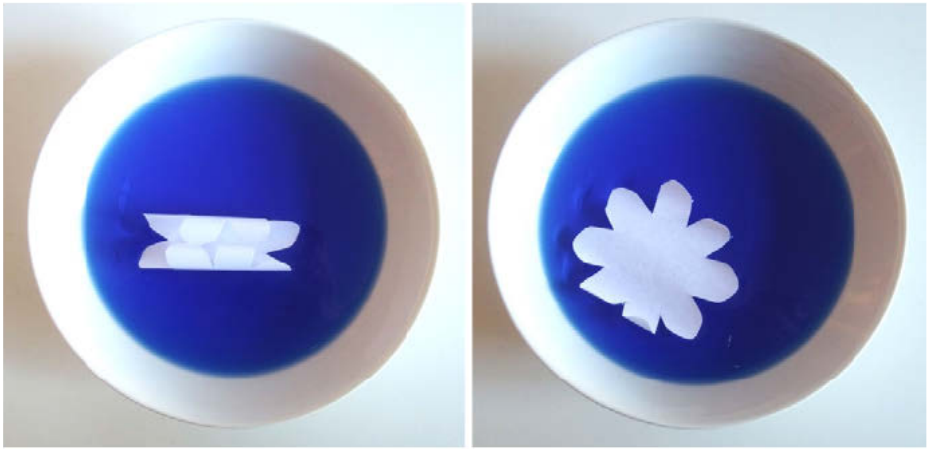
Important aspects and information on the individual process steps of the research cycle during the student experiment:

The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ How do plants absorb water? ▪ How does rainwater get to the treetops?
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ "The plants absorb water through their leaves." ▪ "The plants draw the water from the soil." **Related to the experiment:** ▪ "Nothing happens." ▪ "The napkin becomes wet up to the water line." Segue from the guesses to the experiment.

Experimenting 	**Experiment setup:** If the school does not have enough glasses, you can ask the students to bring two glasses of the same size to class. **Conducting the experiment:** When conducting the experiment, the students should make sure that the two ends of the napkin reach far inside both glasses. To do so, they can bend the napkin inside and hold it down at first.  Fig. 1: Experiment setup
Observing and documenting 	The experiment will allow the students to see how the water moves upward through the napkin and then travels from one glass to the other.
Analyzing and reflecting 	Through this hands-on experiment, the students will learn how water transport can also flow upward and gain initial experience based on the model. They will see how the napkin gradually absorbs the water from the full glass until it is saturated. When the capacity to absorb water has been exhausted, the system then reverses, meaning that the water in the napkin is released into the second glass. **Results to be expected:** 1. The water level in the full glass falls, and the initially empty glass fills up a bit. 2. The plants absorb water from the soil and transport it to all parts of the plants. **Reference to the story to get the students thinking about the topic:** In the scene described in the story to get the students thinking about the topic, no capillary forces are at work.

4.2.6 Other information

In the student instructions

Doing further research	To show the capillary force of water in a different way, the students can use the blue colored water for another experimental variation. If they cut out a flower from white paper and place it on the blue water, the paper absorbs the water with the aid of capillary forces. The flower turns blue and the points bend upward. In this way the students recognize that water is being transported upward.  Fig. 2: Paper flower with turned-up points.

Miscellaneous notes

Twist a white napkin into a flower (twist a stem, and fan the napkin out at the top to form a flower) and place it into a glass of water with some ink. After a short time, the paper will become saturated with “ink water” and the napkin flower will turn blue.
Alternatively, cut the stem of a napkin flower lengthwise from the bottom to about the middle. Place one half of the stem in a glass with, for example, blue ink and the other half in a glass with red ink. After a while, the flower will turn red and blue; in the border area the colors may mix (purple).