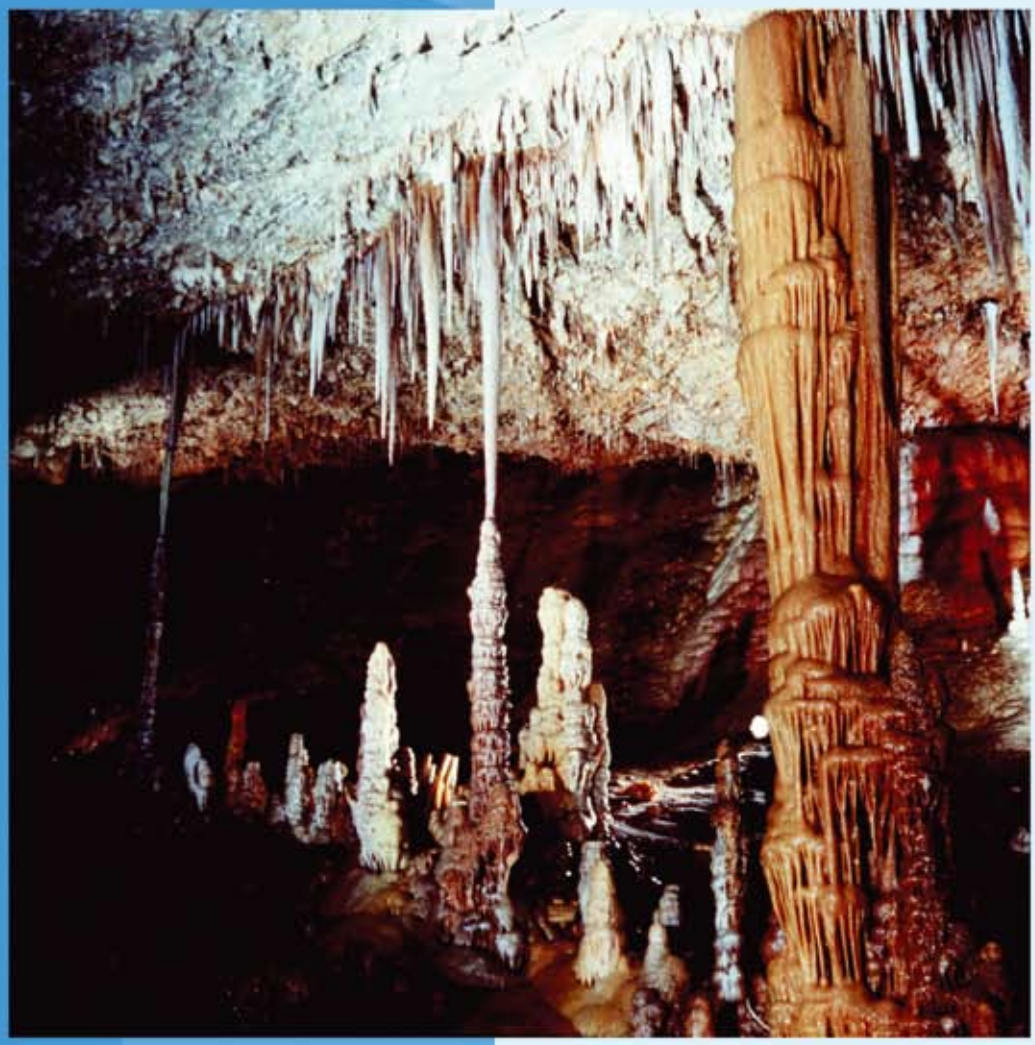
CHAPTER 2:

THE GROUNDWATER SYSTEM



A: THE WATER CYCLE ON PLANET EARTH

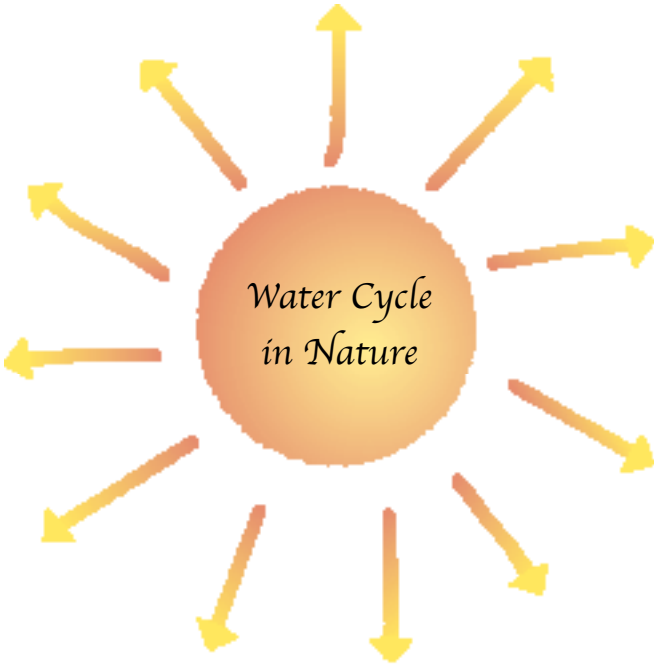
In the previous chapter, we characterized the planet Earth as a place where there were direct links between water and life. This chapter will focus on the question, "Where is water found on Earth?"

Activity 1:

What do we know about the water cycle in nature?

In this activity, try to determine what processes, and locations are important in the water cycle, and what you do not know yet.

1. For each arrow, write down a concept that is related to the water cycle in nature.



Classification

2. Sort the ideas you just recorded, into two categories:
   a. Concepts that describe locations or places where water is found in the cycle, for example, an ocean or a cloud.
   b. Concepts that describe processes that occur in the water cycle, for example, evaporation, or precipitation.

Locations	Processes through which water passes from place to place

In this activity, you defined two categories:

"Locations" - Places where water is found on planet Earth. For example, oceans, groundwater plants, clouds.

"Processes" – Physical or chemical changes that occur in water and that allows passage from one location to another. For example, evaporation is a process in which a substance changes from liquid to gas. The vapor is a gaseous substance, which was previously a liquid or a solid.

Drawing

Activity 2:

Drawing the water cycle in nature

1. Individually, try drawing a diagram on a sheet of paper, that describes the movement of water on Earth.
2. On your drawing, indicate the locations and processes that make up the water cycle on Earth.

Reminder:

Locations - places where there is water on Earth, such as oceans or plants.

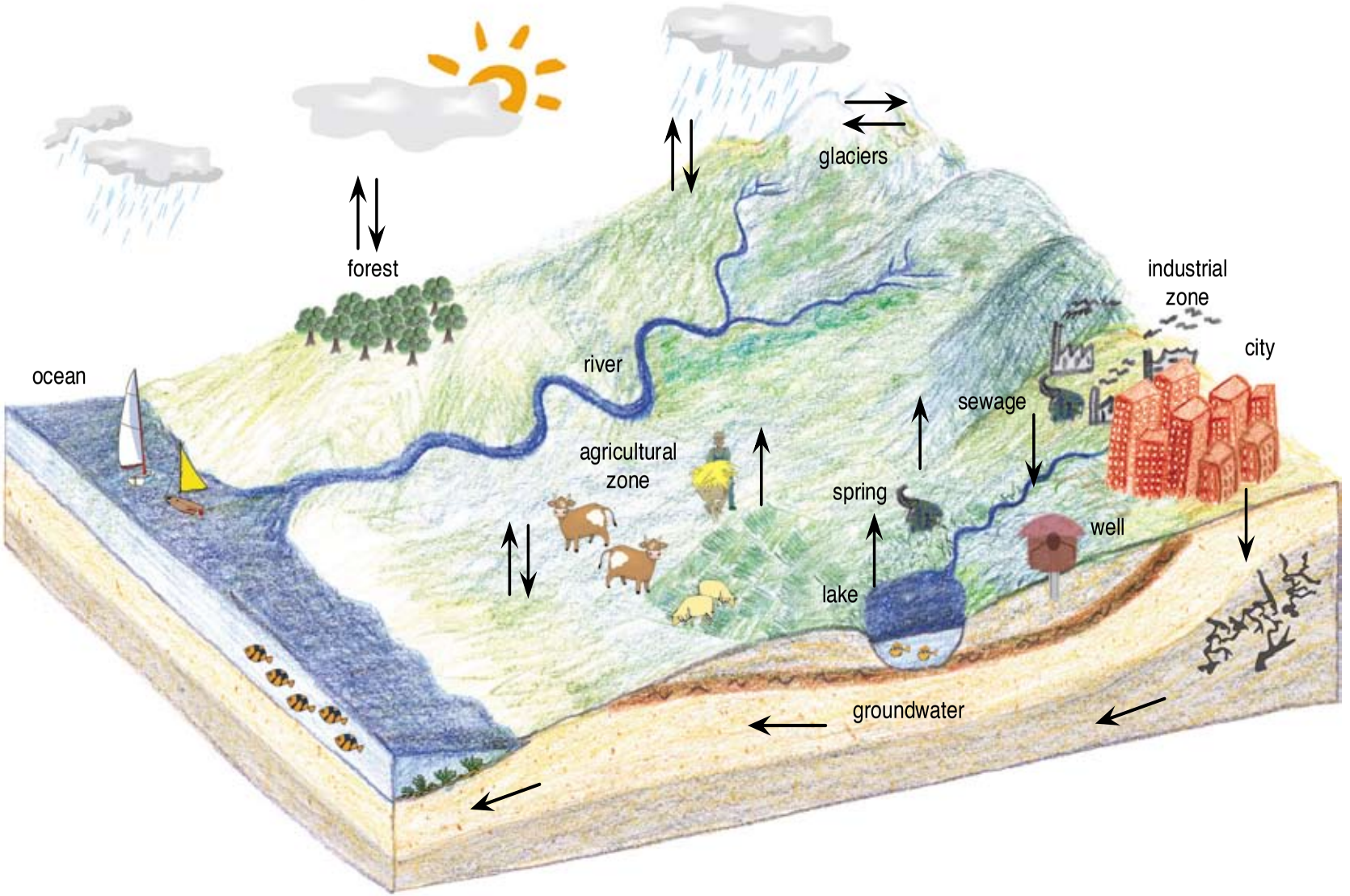
Processes - physical or chemical changes that occur in water, during its movement from one location to another, through the water cycle.

Activity 3:

The water cycle and Earth systems

1. Look at the diagram on the next page, which shows the processes occurring on Earth. Try to identify the different Earth systems: rock system (Geosphere), the system of living things (Biosphere), the air and weather system that surrounds the Earth (Atmosphere), and the water system (Hydrosphere). **[Note: not all locations and processes are labeled.]**
2. In the table below, write at least two components that make up each of the Earth systems described above:

Rock system (Geosphere)	System of living things (Biosphere)	Air and weather system (Atmosphere)	Water system (Hydrosphere)


glaciers
forest
industrial
zone
city
ocean
river
sewage
agricultural
zone
spring
well
lake
groundwater

3. Look at the diagram on the previous page, and in the table below, record how the different components of the water cycle influence each other.

Factor that has an influence	Factor that is influenced	Type of influence
Example: Snow	Rivers	The melting snow adds to the water supply of the river.

Activity 4:

Transfer of substances in the water cycle in nature

In the previous activity, you observed a diagram that showed the different Earth systems. Many of the processes occurring on Earth correspond to processes in which substances are transferred from one system to another.

For example: When we breathe, we inhale oxygen (O_2) and exhale (release) carbon dioxide (CO_2).

Therefore, breathing includes two processes:

a. Oxygen (O_2) passes from air (atmosphere) to our bodies (biosphere).

b. Carbon dioxide (CO_2) passes from the body (biosphere) to air (atmosphere).

1. Carefully read each of the statements in the table below. Complete each example to explain the transfer of substances between two systems (see the example).

Processes of transfer of substances	Substance from which system...	...into which system
Example: Humans breathe and inhale oxygen (O_2)	Atmosphere	Biosphere
1. Evaporation of water from the surface of plant leaves		
2. Groundwater absorption by plant roots		
3. Dissolution of rocks by water		
4. Evaporation of ocean water		
5. Drying soil in a garden		
6. Rainfall on the Earth's surface		
7. A tiger drinking water from a spring		

2. Take one or two photos in the area where you live, showing the interrelationships between Earth's systems.
   a. Mark the Earth systems shown on the photograph.
   b. Record the transfer of substances between Earth systems occurring in the photo. Draw an arrow and record which substances are being transferred.

THE WATER AND ROCK SYSTEMS ON EARTH

In the previous activity, we learned that water moves from one system to another. The Earth systems include the hydrosphere, biosphere, atmosphere, and geosphere. It is especially important to understand the geosphere because it is related to the groundwater system, and the quality of drinking water.

For example, in Israel, the groundwater system provides its inhabitants with more than 65% of the annual amount of water they need (1.6 - 1.8 million cubic meters). The rest of the water reaches the Sea of Galilee and reservoirs from the process of runoff.

In this chapter, we try to understand how the groundwater system affects water availability per person, and the quality of drinking water. The origin of groundwater is rain that seeps into rocks, where it is stored. Water is stored in the pores and cracks found in rocks. To understand the water quality in groundwater systems, we must understand the interrelationships between rock and water.

Note: If you have not completed the unit "The Cycling of Earth Materials", conduct the activity at the end of the book, Appendix 1 "How to characterize and identify rocks."

Activity 1:

How rocks react to water

Laboratory Equipment and Materials: samples of limestone, dolomite, sandstone, calcareous sandstone, soft limestone, and clay stone; ID cards for the samples of rocks and soils; a water dropper; a flask with 6% hydrochloric acid (HCl); a nail.

Activity Procedure:

1. Identify the samples of rocks in front of you, using the identification cards. Write their names in the table.

Observation

What is an observation? An observation is any information that we acquire through our senses. For example, if we saw that a rock cannot be scratched with a nail, it means that we use the sense of sight. Therefore, the statement "the rock is not marked with a nail" is the result of our observation. Observations are made directly, as in the example above, or through the use of instruments.

For example, if we examine the mass of a rock using a balance, the statement, "The mass of the rock is 100 grams" is considered an observation. For this, we used a tool, and not an estimate based on direct observation of the rock.

2. Place the rocks in a dish. Place 10 drops of water on each rock, and record your observations in the table below.
3. Examine the malleability of each rock after they have been soaked with water, and record your findings in the table below.

Name of the Rock	What happened when water touched the stone?	What happened to the stone when it became wet?
	infiltrated: a lot /a little /not at all / other:	it is malleable / it is not malleable
	infiltrated: a lot /a little /not at all / other:	it is malleable / it is not malleable
	infiltrated: a lot /a little /not at all / other:	it is malleable / it is not malleable
	infiltrated: a lot /a little /not at all / other:	it is malleable / it is not malleable
	infiltrated: a lot /a little /not at all / other:	it is malleable / it is not malleable
	infiltrated: a lot /a little /not at all / other:	it is malleable / it is not malleable

Conclusion

1. Based on your observations, write two conclusions about how rocks react with water on the planet Earth.

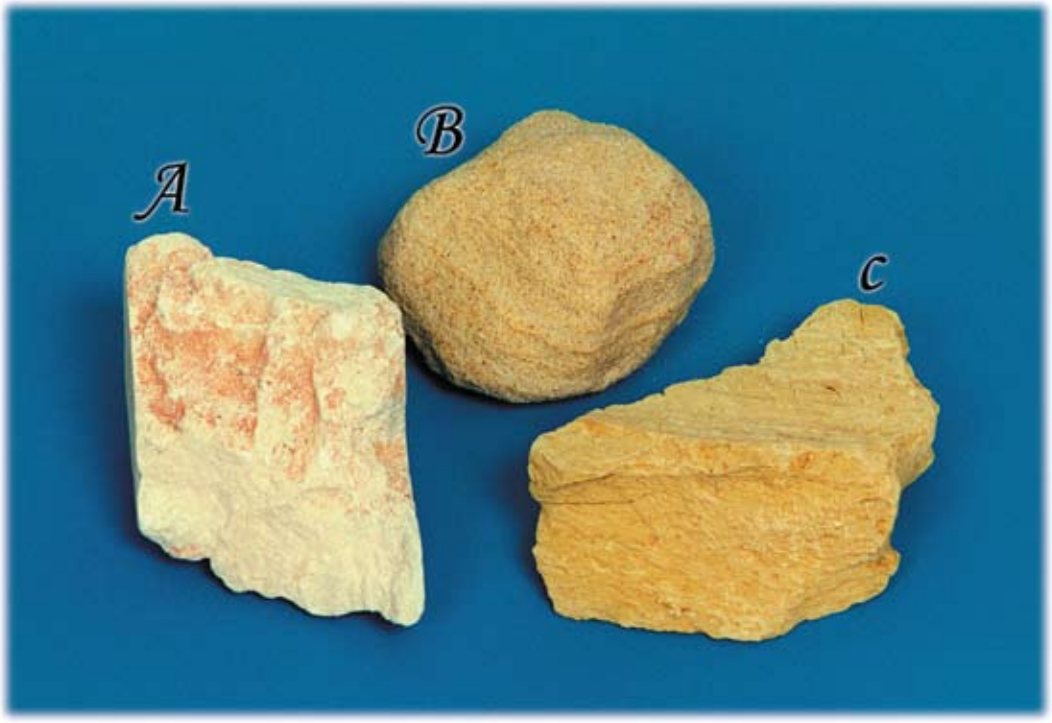
What is a conclusion?

A **conclusion** is what results from your observations. In the earlier example, if we observed that a rock is not scratched with a nail, the sentence "the stone is hard" is a conclusion that we reached as a result of our observation that "the rock was not marked with a nail." No one can see that the stone is hard! You can only see that the rock is not marked by a nail.

2. Use the table below to sort the rocks on the tray into three groups according to their response to the addition of water:

	Group 1	Group 2	Group 3
Includes the following rocks:			
The similarities of the rocks in this group:			
Hypotheses regarding the reaction to water of the rocks in this group:			

3. List two general statements that describe the connection between water and rocks on Earth.



(A) Limestone, (B) sandstone, and (C) clay stone with varying amounts of calcium carbonate.

Activity 2:

The link between rock structure and water infiltration.

In the previous activity, we observed that water reacts different to different rocks. Now, you will examine how the structure of the rock influences water infiltration.

Laboratory Equipment and Materials: a magnifying glass; polished limestone; granite; sandstone; hammer; two small glass beakers with tap water; dropper; paper towels.

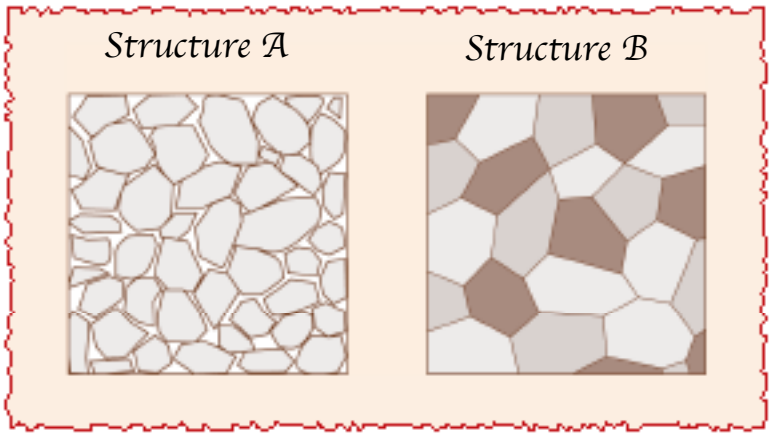
Experiment

A. Infiltration of water into sandstone

Activity procedure:

1. Rub two samples of sandstone against each other, and describe what happens.
2. Observe the sandstone sample with a magnifying glass. Which of the two illustrations below best represent the structure of the rock, Structure "A" or Structure "B"?
3. How would you describe the structure of sandstone?

Sandstone



4. Try to infer how the grain structure of the sandstone contributes to the infiltration of water in this type of rock.
5. Observe the granite sample with a magnifying glass. Which of the two illustrations above best represent the structure of the rock, Structure "A" or Structure "B"?
6. How would you describe the structure of granite?
7. Try to infer how the crystal structure of the granite influences the infiltration of water in this type of rock.
8. Fill two beaker with water, and place the sandstone into one, and granite into the other. Watch what happens, and describe your observations.
9. Does the experiment you just conducted support the hypothesis you made above? Explain.

The sandstone has a granular structure. Between the sand particles are pore spaces. In a rock with granular structure, the water penetrates into the spaces between the particles, and seeps inward. The air insde these spaces is ejected outward in the form of bubbles.

The rocks in which water seeps through their pores are known as rocks with porous structure.

B. Infiltration of water in limestone and dolomite

Observe the polished limestone sample through a microscope. Can you identify pores?

Additional Information

Any observations found or conclusions made by other people, or documented in books, movies, CDs, newspapers, or photographs is additional information. Many times, we cannot draw conclusions based on our observations if we do not have the help of additional information. For example, when the rocks were identified based on direct observations, there was additional information in the cards so that they could be identified by name.

1. The lower illustration shows a very thin piece of dolomite, as seen through a microscope. How would you describe this structure: dense crystals or granular?

The rocks do not contain pores that allow water to infiltrate. These are known as rocks that have a dense structure.

2. In the previous activity, we observed that water does not infiltrate into limestone. Also, we know that in the mountains, there are often springs that flow beneath layers of limestone.

How does water infiltrate, then, beneath the limestone?

Dolomite Stone

Interior structure of the dolomite stone, as seen through a microscope

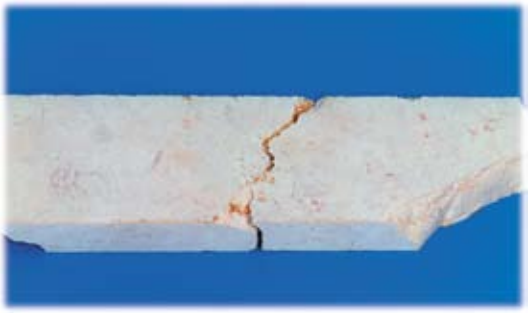
Experiment

Limestone

Activity 3:
Infiltration of water into a dense rock - Simulation Experiment

1. Place the polished limestone on a paper towel, and put a few drops of water on the center.
   - Did the water infiltrate to the paper towel?
2. With the hammer, break through the center of the polished limestone so you have two pieces. Place the two pieces on the paper towel so they are in contact with each other. Put a few drops of water in the crack.
   - This time, did water infiltrate to the paper towel?
3. What can you infer from this experiment with respect to the question: How does water infiltrate through a dense rock structure?
4. Below, you have a list of the components of the simulation, and a list of natural phenomena simulated in the experiment. Draw a line connecting the component of the experiment with the natural phenomenon it represented in the simulation.

Components of the simulation experiment		Natural phenomena
1. Polished limestone	● ●	a. Internal forces acting within the Earth
2. The water dripping on the stone	● ●	b. Time: millions of years
3. The blow from the hammer	● ●	c. The limestone on Earth
4. Does not exist in the simulation	● ●	d. The rain that falls on Earth



Polished Limestone

Additional Information

The crystal structure of limestone (or granite) is very dense. There are almost no air spaces (pores) and therefore water cannot infiltrate through it. However the internal forces acting on the Earth's crust create cracks and fissures in the rocks. These cracks allow water to move through the rocks that have dense structure.

Knowledge Organization

1. Fill in the missing words in the following text:

   In this activity, we examined two rocks: _____ and _____.

   In the experiment we conducted on the _____ rock, we found that water infiltrates easily. We infer that the _____ structure of this rock allows water _____ through. To examine our hypothesis, we conducted an experiment in which a sandstone rock was submerged in water, and we saw that the rock produced _____. We _____ that the rock has _____ particles, and that there are air spaces between them that allow _____ of water.

   In the second experiment that we conducted, we found that water cannot _____ through a limestone rock that is not cracked. We hypothesized that this is due to the _____ structure of the limestone.

   When we cracked the limestone, we observed that water had infiltrated through the _____ that were created in the rock. Given this phenomenon, we hypothesized that in nature, water seeps into the rock or limestone through _____ generated as a result of pressure exerted on the rock layers.

   This phenomenon can explain the existence of numerous _____ under the layers of limestone rocks that exist in mountains.

2. Synthesize the scientific thinking processes described in the completed text above, and fill out the following table. Use the terms observation, conclusion, and hypothesis.

Observation 1:	
Conclusion:	
Hypothesis:	

Observation 2:	
Conclusion:	
Hypothesis:	

Activity 4:

Infiltration of water into Earth's geosphere system

In the previous activity, we learned that some of the rain that reaches the Earth's surface seeps through the rocks. This activity will identify the factors that influence water infiltration into the porous structure of the geosphere system: We will examine the ability of water to move through materials of differently sized particles.

Laboratory Equipment and Materials: magnifying glass; 6 beakers (50 mL); graduated cylinder (25 mL); syringe (25 mL); 3 funnels lined with filter paper; Earth materials (3 different sized particles).

Experiment

Experimental Setup:

Place the Earth materials of different sizes into the funnels, and place the funnels into the test tubes:

Test tube 1: contains clay composed of tiny particles of about 0.065 mm (65 microns diameter). (1)

Test tube 2: contains sand composed of fine particles between 0.25 and 0.5 mm diameter.(2)

Test tube 3: contains sand composed of coarse particles larger than 1 mm diameter.

(1) The naked eye cannot distinguish particles smaller than 200 microns in diameter.

(2) Can be distinguished with the naked eye.

1. Use the graduated cylinder to measure 25 mL of water, and pour 25 mL into each of the three beakers.
2. Use the syringe to slowly pour the 25 mL of water into the funnel containing the soil to allow infiltration of the water.
3. Pour the water that accumulates in the beaker back into the graduated cylinder. Measure the amount of water that passed through each of the different types of Earth materials, and record your data in the table.

Also record in the table the difference between the initial volume of water (25 mL) and the amount of water that infiltrated into the soil.

Type of Earth Material	Amount of water (mL) before infiltration (X)	Amount of water (mL) after infiltration (Y)	Amount of water (mL) that was trapped in the soil (X-Y)
a) Gravel	25		
b) Fine sand	25		
c) Clay	25		

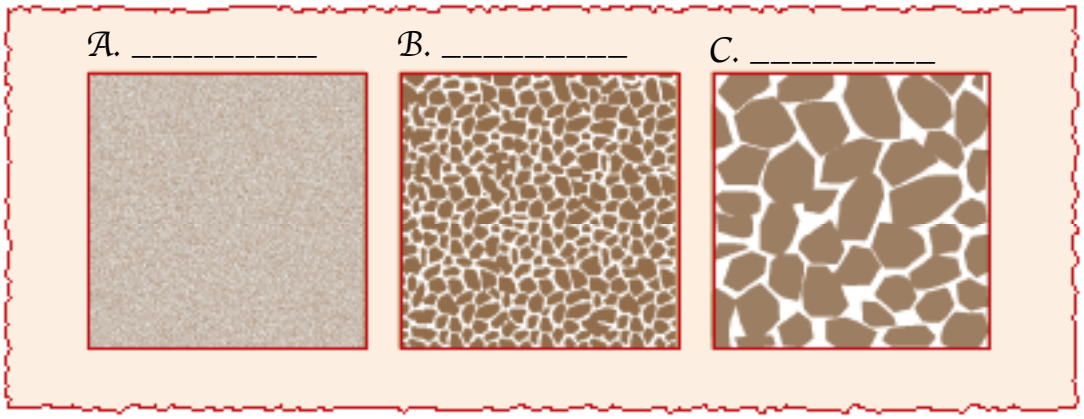
Observation

1. Which Earth material infiltrated the largest amount of water?
2. Which Earth material infiltrated the smallest amount of water?

Conclusion

1. What can you conclude from the experiment about the factors that influence the rate of water infiltration in a granular rock or loose Earth material?

2. The diagrams below show the structure of Earth materials used in the experiment.
   Match the structures below to the illustrations on the previous page by writing the appropriate name next to each picture.
3. Use the color blue to identify where the water lies between the grains in each illustration.



4. Which figure could you color most easily?
5. How do the pictures illustrate the differences in water infiltration for different types of loose Earth materials?

Thinking Scientifically

In the previous chapter, we described what makes a scientific experiment reliable:

1. Scientific research often seeks to answer a research question.
2. A scientific experiment examines how a system reacts to changes. It examines how a variable (factor) affects another.
   For example, in the experiment we conducted in the activity "The link between metabolism and water", the variable that influences (independent) is the water content in the seed, as a result of soaking them. The variable that was influenced (dependent) is the seed respiration.
3. In any scientific experiment, you want to check that the observation made was caused solely by the change in the variable you analyzed, and not due to other factors. The component of the experiment whose role is to help determine this is known as a control.
4. In any scientific experiment, you want to check that the observations were accurate, and

that your conclusions are appropriate.

Draw a line to match the statements that describe components of an experiment, with their role in the experiment.

Components of the experiment		What is the function?
1. Control.		a. Measurement accuracy - in this experient, you were asked to add 25 mL of water to each beaker.
2. Research question.		b. Because you cannot carry out the experiment without loose Earth material, each funnel serves as a control for the other two funnels.
3. Variable that influences (independent).		c. Rate of water movement in the Earth material.
4. Factors influencing the accuracy of the experiment.		d. Each group carried out the experiment, so each classroom has five to six repetitions. In this case, the average of the groups provides a reliable result.
5. Variable that is influenced (dependent).		e. Particle size of the Earth material.
6. Number of observations (repetitions of each experiment).		f. How the particle size of the Earth material influenced the movement of water.

Activity 5:

Influence of inadequate urban planning on water infiltration

1. Observation of photographs

These photographs were taken after several rain storms.

1. Examine the pictures, and record three questions you have.
2. Write a caption for the photograph to the right.

Flooded town, where the nearby agricultural crops also suffered significant damage.

2. Where you live, is it possible for rainwater to percolate down into the groundwater system?

Water runoff in streets is a well-known phenomenon during the rainy season. As a result, roads are damaged, and the wastewater system breaks down, flooding homes and causing problems for pedestrians and motorists. All of these are consequences of the urbanization process (the process of population growth in cities), especially if it is not properly planned.

These problems only appear in the media for short periods of time. However with this phenomenon, we can ask many questions: What happens to water that collectes in the streets after it rains? Is this water "lost" and no longer usable? Is it possible to avoid wasting and squandering fresh water runoff?

Surfing the Internet

To explore some of these questions, and others that you have, visit Internet sites, such as:

- Water Resources at United States Geological Survey (USGS)
  http://www.usgs.gov/water/
- Water Science for Schools (USGS)
  http://ga.water.usgs.gov/edu/

Photographing the Environment

1. Explore your neighborhood, and photograph sites that will allow infiltration of water during the rainy season, and sites that will not allow infiltration.
   Next to each photograph, write your own explanation about the possibility of water infiltration.
2. If you were contacted by a water engineer in your city, who requested your opinion on what you've found, how would you respond?
   Prepare a report with feedback and improvements that you propose for each site.

Activity 6:

Where is the water cycle found in our environment?

In the previous activity, you encountered various components of the water cycle in nature. In this activity, we will go on a journey to investigate the following sites: a cave, a spring, and a sewage treatment facility for the city.

Field Trip

Instruction sheet for the trip:

General information: (your teacher will share the missing details).

The trip will take place on (day) _____ (date) _____.

We will leave from school at (time) _____. We will return to school in the afternoon at approximately _____.

We will eat lunch during the trip (be sure to bring food with you).

The transportation from one site to another will occur by bus (the trip does not require excessive physical effort).

The drive to the spring _____ (first stop) takes about _____ hours and the activity at the spring will last about __ hours. The journey from the spring to the sewage treatment facility of the city will take about ____ minutes and the activity there will last _____ minutes. The trip from the facility to the cave is _____, and will last _____ minutes.

The activity at each location will involve two stages:

Stage 1 - Individual and team work.

Stage 2 – Group discussion on the findings and conclusions.

Items you must bring:

- Hat
- Small backpack
- Bags for collecting garbage
- Closed toed shoes for walking
- Water (at least 2 liters per student)
- Sandwiches for breakfast and lunch during the day
- On a rainy day, a coat/jacket/umbrella

Equipment and materials for the trip:

- Notebook - each student should have their own
- Pens and pencils
- A clipboard to support your writing
- Flashlight – with batteries

Synthesis

Tasks to summarize the trip

To summarize the trip, you will create a poster that represents the linkages and interrelationships among the different systems of planet Earth and how they were expressed during the trip.

The poster can be organized as a concept map, or a drawing that integrates the trip stations within the systems of planet Earth.

In order to prepare the poster well, you must first perform tasks 1, 2, and 3.

Note: Tasks 1, 2, and 3 will involve the preparation of separate posters.

Task 1:

Choose three observations made in the field, and discuss the conclusions reached as a result of these observations.

Submit your comments in text form, and accompany with photographs and sketches, as possible.

In the analysis of the observations and conclusions, differentiate between conclusions resulting directly from field observations on the trip, and findings related to laboratory observations, and geological observations made in other places and by other people.

After completing the task, write down what you consider important concepts and integrate them into the poster you will prepare.

Task 2:
Part A: Processes of dissolution and sedimentation in the cave

Surfing the Internet

http://www.nps.gov/cave/naturescience/geologicformations.htm

Visit websites about caves, stalactites and stalagmites. Read the websites carefully.
Learn how stalactites and stalagmites form. Read the explanations carefully.
Next, complete these activities:

a. Write the differences between caves, caverns, stalactites, and stalagmites.
b. Highlight the most important statements.
c. Highlight with a different color, the concepts that you know and understand from prior knowledge. Copy the information into your notebook.
d. Highlight with a different color the concepts you do not know or understand. Copy the information into your notebook.

Questions

1. What kind of rocks are common in a cave with stalactites and stalagmites?
2. How do you differentiate between the rocks limestone and dolomite?
3. Why is the concentration of carbon dioxide (CO_2) in the soil 100 times greater than its concentration in the atmosphere?
4. What is the relationship between the formation of carbonic acid (H_2CO_3) in the soil, and the formation of a cave?
5. Represent the information in the websites, using an illustration describing the chain of events that led to the creation of a cave with stalactites and stalagmites. Present the final illustration on an overhead transparency or piece of paper.

Part B: The process of dissolution and sedimentation in a laboratory

From reading the articles, we learned that these formations are the result of dissolution and sedimentation processes that take place in the cave. The dissolution process begins with the respiration of plant roots, bacteria, and fungi, which enriches the soil with carbon dioxide (CO_2). Therefore, the soil is the source of carbon dioxide (CO_2). When rainwater enters the ground, it dissolves carbon dioxide and through a chemical process, converts it to an acid called carbonic acid (H_2CO_3) which reacts with the rocks in chemical processes. This process can be represented by chemical formulas as follows:

H_2O	+	CO_2	⟶	H_2CO_3
water	+	carbon dioxide	⟶	carbonic acid

Experiment

In this activity, we will conduct an experiment that simulates the influence of living things on the characteristics of the rock.

Laboratory equipment and materials: bromothymol blue solution[3] diluted (0.01%); three test tubes; a marker; fragments of limestone, straws

[3] The bromothymol blue is a substance that reveals the presence of carbon dioxide.

Experiment:

1. You have 2 test tubes containing water with dissolved bromothymol blue (to a height of 4 cm). What color is the solution?
2. Blow slowly, using the straw, into the test tube. How did the color change?
3. How can we explain the change that occurred in the color of the solution as a result of the exhalation? (hint: $H_2O+CO_2 \rightarrow H_2CO_3$)
4. Pour half the liquid from the test tube that you did not blow into, into the empty test tube. You now have two test tubes with a solution to a height of 2 cm. Write on one tube "experiment" and the second "control".
   Into the experimental test tube, introduce a few pieces of limestone. Agitate the test tube. Wait 10 minutes.

Observation

Record the results obtained in the following table:

		Test tube (which you blew into)	Experimental test tube (with limestone)	Control test tube (without limestone)
Color	Start of the experiment			
	End of the experiment			

Conclusion

1. In your opinion, what evidence is there that the color change occurred after adding limestone fragments?

2. Try to describe the chemical reaction that took place in the experimental test tube.
   Hint 1: The limestone is composed of the mineral calcium carbonate, whose chemical formula is $CaCO_3$.

Hint 2: The reaction that took place in the experimental test tube can be described by a chemical formula:

$CaCO_3$	+	H_2CO_3	⟶	$Ca(HCO_3)_2$
Calcium carbonate	+	Carbonic acid	⟶	Calcium bicarbonate

3. Try to describe the chemical reaction that took place in the test tube in which you blew air.

Classification

Describe in a few sentences the phenomenon that takes place in a cave with stalactites and stalagmites, and the relationships between the different Earth systems.

Cave stalactites and stalagmites

Task 3:

a. Examine the observations and conclusions you recorded in your notebook from the trip, and try to identify components that represent the different Earth systems (write at least two components for each system)

Rock system (Geosphere)	Living system (Biosphere)	Air system (Atmosphere)	Water system (Hydrosphere)

b. Which pieces of evidence from the trip provide evidence of human intervention in the natural environment? Which would you like to include in your poster?

c. In the table below, put 10 examples that describe the relationships between components of Earth's systems from the trip:

Factor that influences	Factor being influenced	Type of influence
Example: rain	plants	causes germination and growth

d. On the trip, there were numerous processes representing the water cycle in nature. These are processes of material transfer from one system to another on Earth. Describe at least three examples of transfer of materials or substances (e.g., molecules of water, pollutants, fragments of rock/minerals) that are transferred in the water cycle in nature, as you saw on the trip:

The material	passes from system…	…to another system	through the following process
-->	-->	-->	
-->	-->	-->	
-->	-->	-->	

e. Write the concepts that are important to include in your poster.

Task 4:

1. As a result of tasks 1, 2, and 3, write the concepts that are important to include in your poster.
2. Prepare a poster that represents the linkages and interrelationships between the different Earth systems, as you observed on the trip.

Earth system: Rock system (Geosphere), system of living things including humans (Biosphere), air system surrounding Earth (Atmosphere), and the water system (Hydrosphere).

Drawing

Prepare a draft of the poster and show it to your teacher.

Remember: It is important to prepare the final poster only after your teacher has commented on your draft.

C: GROUNDWATER SYSTEM IN A COASTAL PLAIN

In the previous activity, we saw that some of the water that falls as precipitation on Earth infiltrates into the rocks beneath the layer of soil.

In the next activity, we will try to show what happens in those rocks.

Activity 1:

What happens down there? – Simulation Experiment

Drawing

1. Try to draw what you think the groundwater system looks like. With one color, draw the soil and rocks through which water seeps, and with a different color, draw the water.

Observation

2. In front of you is a model that represents three layers of the crust: a layer of sand, a layer of clay, and another layer of sand. Pour in a little water with food coloring into the container, and keep pace with the fluid flowing out of the outlets.

Synthesize your findings in the following table. Mark the correct column with an X.

Rock type	Rate of flow		
	No flow	Slow flow	Fast flow
Sand (top layer)			
Clay			
Sand (bottom layer)			

3. Explain the results of the experiment. Use the elements of scientific thinking: observation, hypothesis, additional information, and conclusion.

Note: After the water was poured into the container, try to identify the line that divides the area in which all the pores of the rock are saturated (full) of water **(saturated zone)**, and the area in which many of the pores are filled with air **(unsaturated zone, or zone of aeration).**

The line between the saturated zone and the unsaturated zone is called the **"water table"** or **"groundwater level".**

In the simulation, pay attention to the real water level which is a few inches below the line where the color change occurred. This is because of a phenomenon known as "wicking", which occurs when water rises through the pores of rock due to adhesion of water molecules (bipolar) to the walls of the capillaries. Dig a little below the line where the color change occurred, and find free groundwater that saturates the pores of the rock. Explore this phenomenon further.

4. Try to infer what generates the differences in the ability of water to move in different layers. Relate this ability to the rock properties in each layer.

Drawing

5. Draw the simulation container. In the drawing, show the layer of sand, clay, and another layer of sand with a single color. Add the water to the drawing with another color. Mark the water table, saturated zone, and unsaturated zone in the drawing.

Synthesis

Conceptualization and Generalization

Rock layer that carries water – The term "porosity" refers to all the spaces and cracks between the rock crystals or particles. The pores of a rock can carry water if they are connected to each other, so water has continuous flow paths, and can flow into the rock. In Latin, this layer is called the **aquifer** (*aqua* = water, *ferre* = carry).

1. What layer of rock in the experiment simulates the layer of rock that holds water (aquifer)?
   The upper sand layer / layer of clay / bottom sand layer

Rock layer that stops the water – In this case, the pores of the rock are disconnected from each other and that is why water cannot flow between them, and is retained by capillary forces. In Latin, this layer is called the **aquiclude** (*aqua* = water, *claudere* = closed, locked).

2. Which layer of rock in the experiment simulates the rock layer that stops water (aquiclude)?
   The upper sand layer / layer of clay / bottom sand layer

Groundwater level – This is the area that divides the saturated zone (where most of the pores are filled with water) from the unsaturated zone (where most of the pores are filled with air).

Classification

Summarize the process that took place in the simulation container, according to the elements of scientific thought: observations, conclusion, additional information, or hypothesis.
Below are a list of statements. For each one, record if it is describing an observation, a conclusion, additional information, or a hypothesis.

1. We saw that water came through the upper hole found in the sand layer composed of large particles.
   Observation/ conclusion/ additional information/ hypothesis.
2. No water came through the holes in the clay layer or bottom layer of sand.
   Observation/ conclusion/ additional information/ hypothesis
3. The clay is a layer that allows slow water movement.
   Observation/ conclusion/ additional information/ hypothesis
4. The movement of water in the clay layer is very minimal, and therefore acts as a layer that will slow the infiltration of water into the container.
   Observation/ conclusion/ additional information/ hypothesis.
5. The sand has a characteristic that permits water to flow easily between the particles - the sand is a layer that carries water.
   Observation/ conclusion/ additional information/ hypothesis.
6. Clay rock is composed of tiny particles with a diameter of 0.065 mm (65 microns). On the other hand, the layer of gravel is composed of particles larger than 1 mm.
   Observation/ conclusion/ additional information/ hypothesis.
7. There may be a relationship between grain size and ability of water to move through rocks.
   Observation/ conclusion/ additional information/ hypothesis.
8. The water did not reach the bottom layer of sand, and the clay layer stopped the water and prevented it from moving down.
   Observation/ conclusion/ additional information/ hypothesis.

9. Becuase there are spaces (pores) between the sand particles, the sand is a layer that permits water to move.
   Observation/ conclusion/ additional information/ hypothesis.
10. On the beach (which consists of sand), water infiltrates quickly through the sand particles.
    Observation/ conclusion/ additional information/ hypothesis.
11. The rock is made of clay minerals and has a unique structure.
    Observation/ conclusion/ additional information/ hypothesis.

Activity 2:

How do you drill a well?

In the previous activity, we concluded that the water seeps through the rocks that have a porous structure, and can be stored in the pores as well. We know that throughout human history, people have relied on the availability of water from groundwater systems.
In the next activity, we will try to understand the way in which water in the pores of rocks (which is unavailable to humans) can be made available for human use.

The Need: You're touring the desert when suddenly, the car breaks down. The nearest town is far away and would require a few days of walking. It is likely that you will become dehydrated before you reach the town. The water supply you brought is minimal. You have no way to contact anyone for help, and you have no form of communication.
The Mission: Drill a hole in the simulation container to extract water for the members of the group.
Laboratory Equipment: In one of the vehicles, you found a hose, a drill, a syringe, and a plastic container. Use them to help in your mission.

A. Preparation Phase:

1. Write down the different steps you should undertake in order to drill the well and draw water by suction.
2. Record the technical difficulties you encountered during the preparation of the operation.

B. Execution Phase:

Now, carry out the drilling and extraction of water, then answer the following questions:

1. What happens when you try to draw water with the help of the syringe only?
2. What happens when you try to draw water with the help of the hose only?
3. What characteristics should the walls of the hose have in order to allow extraction of water with good quality?

Classification

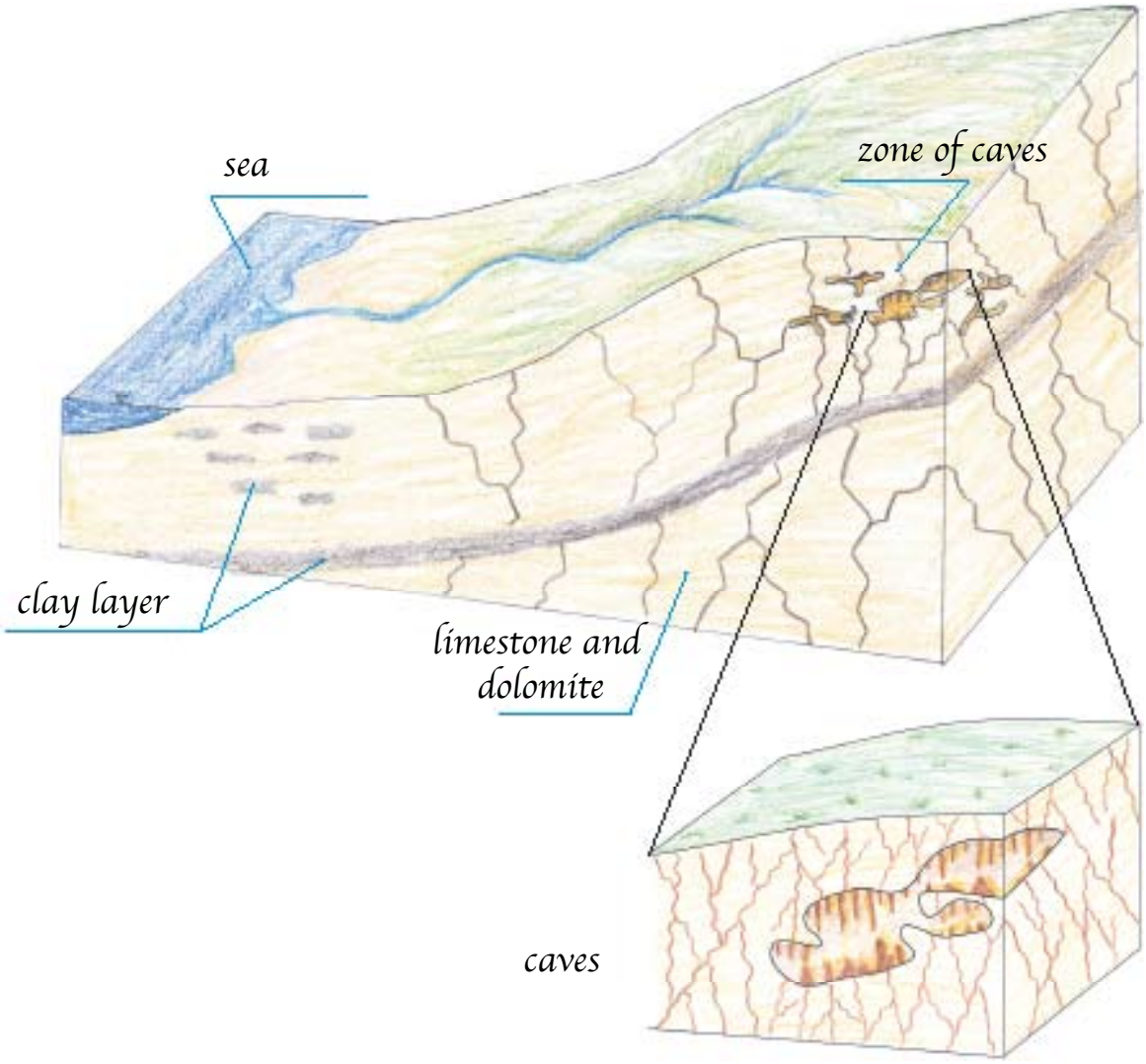
On a sheet of paper, draw the movement of water from the groundwater system until it reaches the well.

Synthesis

In this activity, you drilled a hole through which you could draw water in the desert. For example, suppose that most drinking water wells in coastal towns are supplied from a groundwater system that extends throughout a sandy coastal strip. A cross-section of rocks found in a sandy area shows that it consists of layers of porous rock (e.g., sand), as well as layers of clay and calcareous sandstone.

Drawing

On the next page is a diagram representing a cross-section from the sea to the mountains. If you had to dig a well in the illustration, where would you dig in order to reach the groundwater system? Draw the location on the picture.



Cross-section of the groundwater system of a coastal plain.

Experiment

Activity 3:

How do you build a spring in the side of a hill? - Simulation Experiment

Fill the container to the top with water, and watch the flow of water through the holes in the simulation model.

1. What is most similar to the opening from where spring water flows? Explain.

2. The illustration shows a section of rocks exposed in the hillside. Where do springs appear on the hillside when rain falls on the mountain?. Mark the route of the water droplets on the illustration.

3. In the simulation, the spring flowed through the porous rock. Are there situations in nature where a hillside spring emerges through a rock that is not porous? (Hint: The activity on page 60.) Explain.

4. A group of hikers were in the mountains of a semi-arid region when they ran out of water. An old man told them that nearby, there was a place that might have a spring. One of the hikers said that if they found a layer of a specific type of rock, and walked along the contact line between it and the rock above it, there was a chance they would find it. What specific types of rock is the hiker referring to? Explain.
5. In the tour of the spring, you saw an area where water comes from rocks of limestone and dolomite. What are the special features of these rocks that allows water to move through them?

Activity 4:

The journey of groundwater into the sea - Simulation Experiment

In the previous activity, we learned that the supply of water to the groundwater system are the rains that infiltrate into the soil and rocks, until they reach a layer with a slow rate of infiltration. Water is stored in the pores and crevices of the rocks.
The amount of rainwater that infiltrates into the groundwater reservoir each year is called "recharge."
In this activity, try to understand how water moves below the soil surface and how its movements affects the groundwater system and humans.

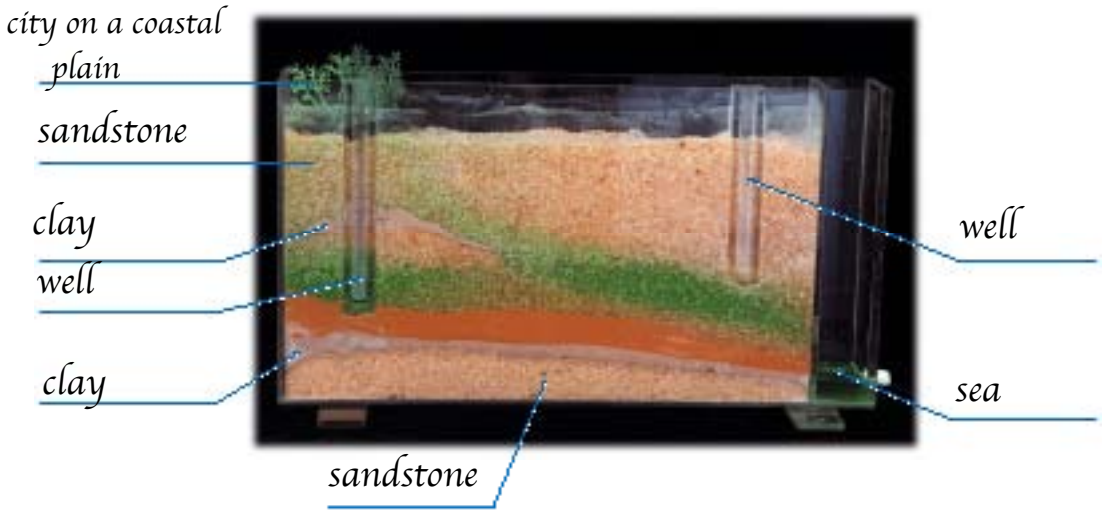
Laboratory Equipment and Materials: A simulation container showing the movement of water from the groundwater system to the sea; a 200 mL beaker; water; food coloring.

A. Journey of groundwater into the sea

Questions

Activity:

1. Identify the following components of the groundwater system in the simulator, and label them with an erasable marker: sandstone rock (rock layer that transports water), clay (layer of rock that has a slow rate of water infiltration), a well, the sea, a coastal city.



2. Pour a little water containing blue food coloring onto the surface of the simulator, far from the sea, so that it can infiltrate down. Describe what is happening.
3. Write three conclusions that result from the observation.
4. Why is the rain that falls on the sand resulting in practically no runoff (flow of water over the surface), but all the water moves immediately into the sand?
5. In one class, students claimed that in a desert area, the amount of rainfall is so small that there should be no aquifers. What is your opinion? Explain.

B. What happens to the pollutants from industry?

Hypothesis

In the center of the container is an industry that produces chemicals (pesticides). In the two wells in the simulator, hazardous pollutants were found, whose origin could have been the chemicals.

1. Is there a relationship between industry and the pollution of the wells? Explain.

Conclusion

Pour a little water with food coloring (a different color than above) in the center of the container.

Draw water from one well and see what happens.

2. Does your observation support the hypothesis from Question 1?
3. If the pesticide manufacturing industry was located on clay, would the wells have been contaminated? Explain.
4. Pour a little water with food coloring over the area where the clay layer is located, and describe what happens.
5. If this industry had been placed on layers of limestone rock, would the rate of contamination of the wells be influenced? Explain.

C. Are we able to extract all that is needed from the groundwater system?

In recent years, many freshwater wells have been closed along the coastal plain, due to increased salinity by the inflow of sea water. Because this phenomenon is worth understanding in more depth, we will make the following observation.

Observation

Close the valve on the bottom of the simulator, and pour some water with food coloring into the sea. Make at least five withdrawals from the well near the sea.

Observe closely and describe what happens.

Conclusion

1. Write down two conclusions resulting from the observation.
2. Describe what happens in a coastal plain as a result of excessive extraction of fresh water from wells near the sea.

Additional Information

In the coastal area near the sea, groundwater is located near the surface and is easily pumped. Fresh water is less dense and therefore, in coastal areas, fresh groundwater sits above the salt water (more dense). Uncontrolled extraction of water alters the balance between salt water and fresh groundwater. Excessive extraction causes a decrease in the level of groundwater. The result is that the salty sea water rises and enters the wells, making them salty.

The saline well water is unsafe, both for drinking and for irrigation. Damage can last for many years and may never be corrected. Groundwater is not a closed and disconnected system, but rather the water flows slowly through the pores of the rocks toward the sea.

In addition, each year, water is removed from the groundwater system. To keep the level of water constant, and to avoid salinization of wells near the sea, it is important to match the rate of extration of groundwater, and recharge the system through infiltration of rainfall.

Concluding Activity:

Journey of groundwater into the sea

1. After the simulation experiment, draw in your notebook the path of the water that falls as precipitation, and its movement in groundwater until it reaches the sea and returns to the atmosphere. Show the different locations where water passes, and which processes affect the properties of water as it passes from place to place.

Comment: Remember to integrate into your drawing the path of water from the polluting industry, and the wells from which water is extracted.

2. Compare the current drawing and the drawing of the water cycle that you made at the beginning of the chapter (see page 49).

Similarities	
Differences	

3. In the table, record at least three changes in the properties of water that occur when it passes from place to place. Use the list of sites and processes that you prepared in the first activity of Chapter 2.

The water changes from site...	... to site	Through the process of	The change in water properties due to the passage from one place to another is...
Example: River	Ocean	Runoff	The water is enriched with minerals and soil sediments

Activity 5:

The groundwater system and environmental quality

In an earlier activity, we saw that for rock that has a granular structure, groundwater is present within the small pores. In this activity, find out where wells are located, and where you can find a layer of rock that contains water (an aquifer).
To summarize, describe how human beings affect the groundwater system.

Divide into groups of two, three, or four students. Each student must read the information found on various websites about these topics:

a) contamination of groundwater
b) groundwater
c) artesian wells
d) aquifers

Synthesis

Ask the teacher for a copy of the relevant information, or visit websites appropriate to your chosen topic. Carry out the following activities:

a. Use a highlighter to mark the concepts you know and understand due to prior knowledge.
b. Use a different color highlighter to mark the concepts that are unknown or that you do not understand.
c. Use a different color highlighter to mark the most important concepts.

Questions

Use the information acquired from reading the articles or websites to answer the following questions:

1. What evidence is there of the interaction between man and the groundwater system?
2. How should this evidence influence the planning of the water system in your state?
3. Try to write at least three suggestions for the preservation of the groundwater system.

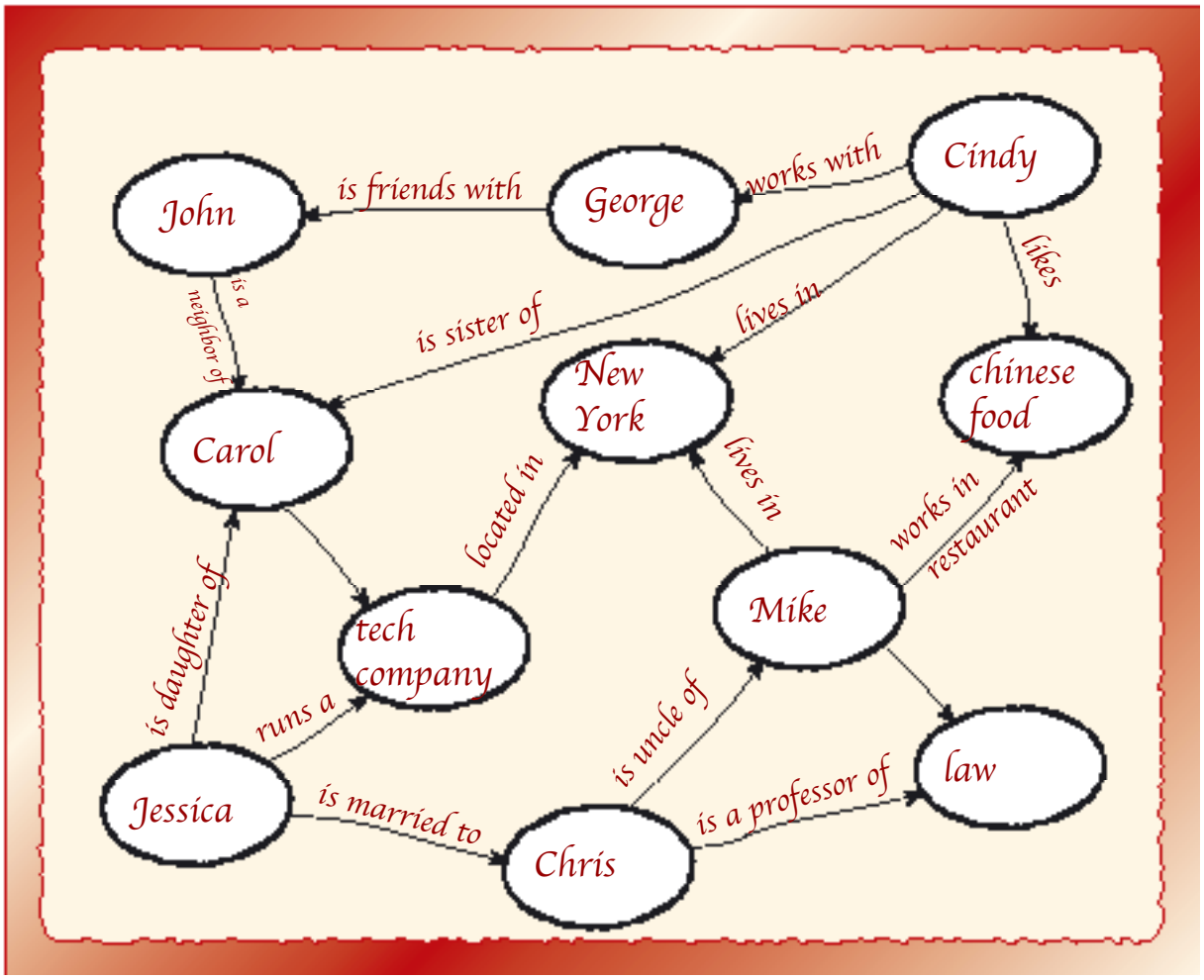
Classification

Activity 6:

Organization of knowledge into a concept map

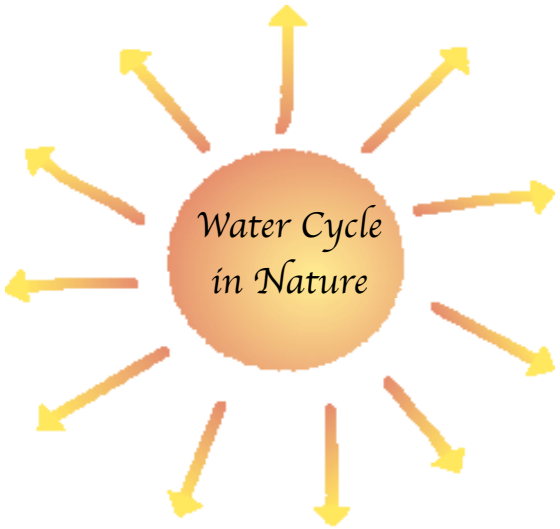
How to construct a concept map-

A concept map is a learning tool for organizing your knowledge about a particular subject. In the first phase, you will recall all the concepts related to a specific topic. Try to remember all the ideas related to your favorite TV show or a novel that you have read. Copy it into the circles. Now draw a line between the concepts that are linked in the TV show you chose, so that two ideas are connected by a relationship, and form a sentence or phrase. When creating links between different concepts related to a topic, the map you generate is an image of your knowledge about a topic (see example).



Now, try to organize your knowledge regarding the water cycle in nature.

1. At the end of each arrow, list the concepts that you think are linked to the water cycle in nature.



2. Try to generate sentences or phrases that describe the relationship between two concepts in the sun diagram. Write them down on the picture that appears on the next page: write in the two circles the concepts you want to link, and place words on the line to make a sentence (see example).

3. Try to generate a concept map that describes the different relationships between the concepts relating to the water cycle in nature.

Remember that a concept map does not have a specific order and can be started with any concept you choose. It is important to generate the greatest number of links or connections between concepts. Building a concept map is a task that has no correct or incorrect answer. You can create different concept maps with different links between concepts.

4. Was the creation of the map a pleasant or unpleasant experience for you? Explain.