CHAPTER TWELVE

RAIN

מַזְכִּירִין גְּבוּרוֹת גְּשָׁמִים בִּתְחִיַּת הַמֵּתִים, וְשׁוֹאֲלִין הַגְּשָׁמִים בְּבִרְכַּת הַשָּׁנִים.

We mention the power of the rains in [the second blessing of the *Shemoneh Esreh*, called] "Resurrection of the Dead," and we ask for the rain in [the ninth blessing of the *Shemoneh Esreh*, called the] "Blessing of the Years."

Berachos 5:2

WHERE DOES RAIN COME FROM?

We know *why* it rains in Eretz Yisrael. Unlike Egypt, for example, which predictably gets fresh water every spring when the Nile River floods, Eretz Yisrael depends on rainfall for its water supply. Since rainfall is unpredictable, and we depend on having a constant water supply, living in Eretz Yisrael helps us to pray to Hashem more sincerely and regularly than if we lived in Egypt or other countries with a predictable water supply. When rain arrives, when and how we need it, it is like Hashem is smiling upon us. When it doesn't (ח"ו), it is a sign that we need to do *teshuvah*.

In this chapter, we discuss *how* Hashem makes rain. Let's start with an experiment. Take a cold, dry icepack from the freezer and put it on the counter (Figure 12.1). Not long after it has been removed, you will begin to see tiny **crystals** of frozen water (i.e., ice) forming all over the icepack (Figure 12.2). After about an hour what do you see? The icepack is covered in water, and there might even be a puddle beneath it (Figure 12.3). Leave it there for a whole day, and both the icepack and the counter will be completely dry (Figure 12.4). Where did that water come from, and where did it go?

WATER VAPOR

Water, like most **matter**, can exist as a **solid**, a **liquid**, or a **gas**. Water as a solid is familiar to us as ice. Liquid water is, well, water! And water as a gas is called **water vapor**. Water is an amazing substance that can quickly and easily change between these three states when it is heated or cooled. When ice warms, it melts into water. If you warm it further, it will turn into water vapor. When water vapor cools, it becomes liquid water. If cooled further, it becomes ice.

The experiment with the ice pack shows how easy it is for water to go from a gas to a liquid to a solid and then back to a liquid and finally a gas again. All that was needed for the water vapor in the air to become liquid that froze to the surface of the icepack (Figure 12.2) was an icepack to cool down the air around it. The process of liquid water emerging from cooled air is called **condensation**. The more familiar process of liquid water turning to ice is called freezing. When the icepack became warmer than the **temperature** at which water freezes, the ice crystals melted back into water (Figure 12.3). Over time, the liquid water around it warmed up as well,

FIGURE 12.1. An icepack immediately after it has been removed from the freezer; it is cold and dry

FIGURE 12.2. Not long after the icepack is removed from the freezer, ice crystals begin to appear on the surface of the icepack.

FIGURE 12.3. After about an hour, all the ice crystals on the surface of the icepack have melted, and the surface of the icepack is wet. There is also a small puddle that has formed beneath the icepack, which you can see on the bottom left.

FIGURE 12.4. A day later, the icepack and the counter below it are both completely dry.

and it turned back into water vapor (Figure 12.4). The process of liquid water turning into water vapor is called **evaporation**.

The air around us is a mixture of different gases. More than 98% of it is **nitrogen** and **oxygen**. Included in the other one or two percent is some water vapor as well. Water vapor is transparent like the other gases in air, so typically you can't see it, but it is always there.

PRECIPITATION

Rain is formed from the condensation of water vapor in the **atmosphere**. There is a limit to how much water vapor air can "hold," and when that limit is reached, liquid water begins to emerge right out of the air. What affects this limit? Our ice pack experiment was a good demonstration of one of the most important factors: temperature. Hot air can hold more water vapor than cold air.

When warm air that is full of water vapor cools (which is what happens when a parcel of warm air in the atmosphere meets a parcel of cold air), the water vapor in the warm air condenses on whatever tiny specks of dust and **chemicals** happen to be floating in the air. These specks are also sometimes called "cloud seeds." A more technical name for them is condensation nuclei (singular = nucleus). They are so tiny (about 0.0001–0.0002 mm) that they float in the atmosphere. Cloud seeds are needed to make rain, because water requires a solid or liquid surface to condense easily. There are hundreds or thousands of cloud seeds in every cubic centimeter of the air around us! As these condensation nuclei float around, water vapor may continue to condense on them, causing the forming drops of water to grow until they are about 100 times their

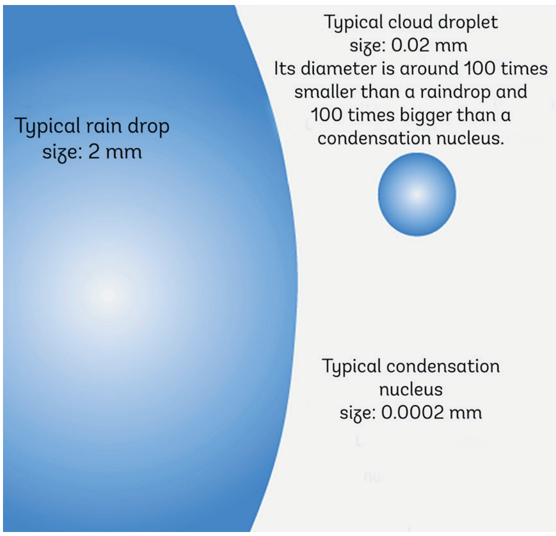

FIGURE 12.5. Comparative sizes of a cloud condensation nucleus, a cloud droplet, and a rain drop

original size (see Figure 12.5). At that point, they are called cloud droplets, and although they are much larger than the original cloud condensation nuclei, they are still tiny enough to float in the atmosphere. Unlike water vapor, which is typically invisible, you cannot see through a large **mass** of cloud droplets. We call an aggregation of cloud droplets a cloud. That's right! Clouds are just huge collections of tiny water droplets. If water vapor continues to condense and add water to the droplets, they will grow until they are too heavy to stay afloat. At that point, they will fall from the sky, and we will call them "rain drops."

Sometimes, air is cooled to below 0 degrees Celsius (32 degrees Fahrenheit). That is the highest temperature at which water vapor can freeze into ice instead of water. It usually freezes a few degrees lower than that, and then only onto cloud condensation nuclei, like rain. When water vapor condenses at these temperatures, instead of water drops, it forms tiny particles of ice that float around in an ice cloud. If additional water vapor condenses onto these ice particles, they will grow to form snowflakes, which may fall from the sky as snow. If a raindrop forms and falls, but freezes on its way down, it can reach the ground as a small ball of ice. We call these frozen balls "ice pellets" or "sleet." If ice pellets are blown up and down in thunderclouds, they can grow to form hail stones. All the various forms of water falling from the sky are collectively called **precipitation** (see Figure 12.6).

Rain

Snow

Hail

FIGURE 12.6. Different types of precipitation

Aside from temperature, another important factor that affects how much water vapor air can hold is **air pressure** (a topic that was discussed in the previous chapter about wind). High-pressure air can hold a lot more water vapor than low-pressure air.

When wind moves air up a mountain, clouds frequently form. Why does that happen? Air pressure is caused by the weight of the atmosphere pressing down on the air below it. As a mass of air moves to a higher **altitude**, there is less atmosphere above it (because some of the atmosphere is now below it). Since there is less atmosphere pressing down from above, air pressure decreases (see Figure 12.7).

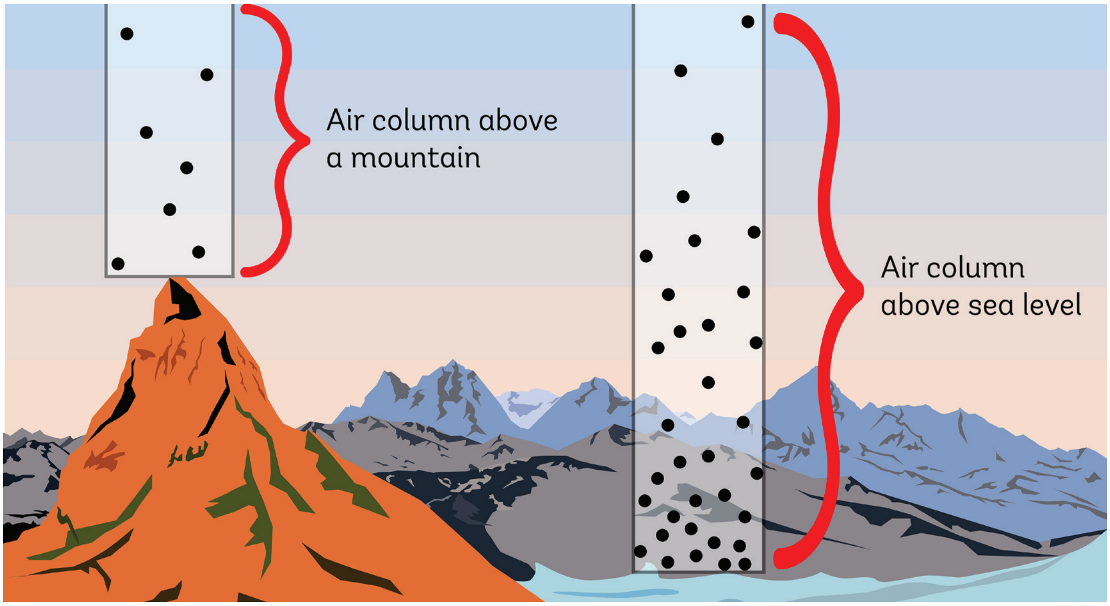

FIGURE 12.7. Why air pressure decreases with altitude. Air pressure at a given place equals the weight of all the air in the column directly above that place. Since the air column directly above a mountain contains less air than one on the surface of the Earth, the air pressure at the top of a mountain is less than the air pressure at sea level.

Since lower-pressure air can hold less water vapor, condensation occurs in much the same way that it occurs when air is cooled. There tends to be much more precipitation at higher altitudes, especially on the side of a mountain on which the wind flows up (called the "windward side"), because the air at high altitude is both cooler and has lower pressure. On the other side of the mountain, when air moves

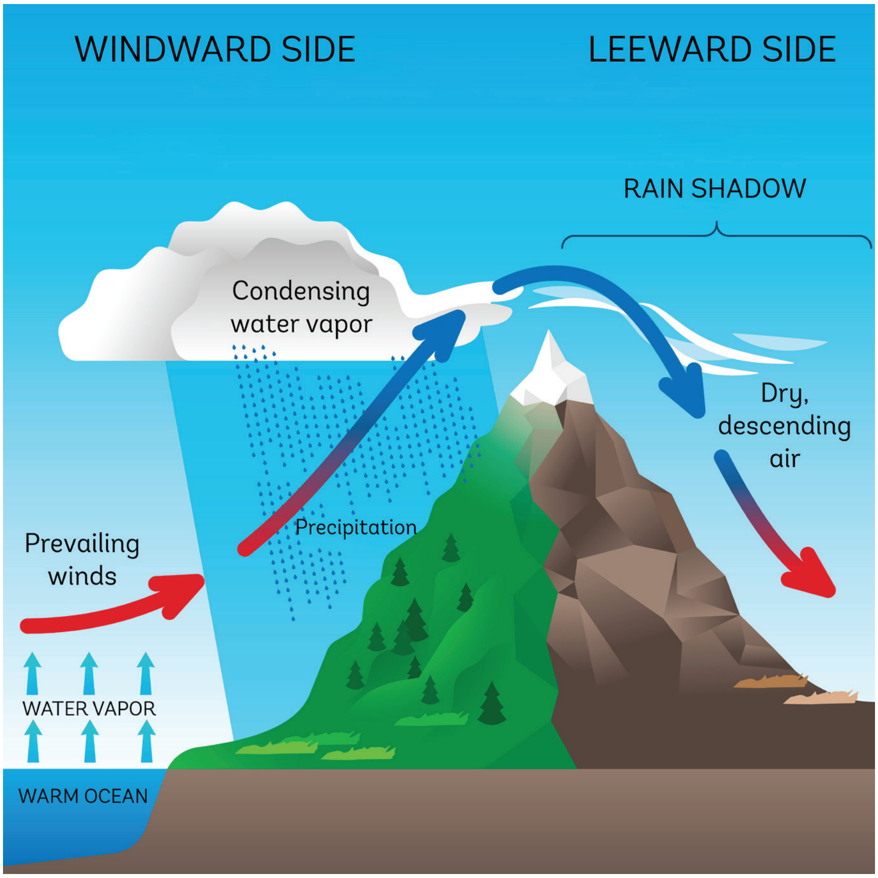

FIGURE 12.8. Winds bring rain clouds from the sea. When the clouds move up a mountain, the lower air pressure creates rain. This empties the air of most of its water vapor. When the wind blows this drier air down the other side of mountain and into a higher pressure region, there is no longer enough humidity in the air for it to form water droplets.

down the mountain, air pressure and temperature once again increase, so the air can hold more water vapor, preventing precipitation from falling on that side of the mountain. This is a way that deserts can form on one side of a range of mountains, such as the desert between Jerusalem and the Dead Sea. When this happens, the desert is said to be in the "rain shadow" of the mountain range (see Figure 12.8).

We now know that lowering the temperature or lowering the pressure of a parcel of air reduces the amount of water vapor it can hold, which might cause precipitation. However, it isn't going to rain if there is no water vapor contained in that air in the first place. Where does all that atmospheric water vapor come from? Water vapor enters the air by evaporation from oceans, seas, lakes, rivers, and plants. Yes, plants too! Water is continuously evaporating from the leaves of plants (a process called transpiration). For a large **tropical** jungle like the Amazon rainforest, this can add up to huge quantities of water vapor, which is why it tends to be so **humid** in the jungle. The closed loop of evaporation, condensation, and precipitation that never ends on our **planet** is called the "water cycle" (see Figure 12.9). Remarkably, in *Taanis* 9b, Rabbi Eliezer derives from various *pesukim* that the water in the clouds originally comes from the water in the sea!

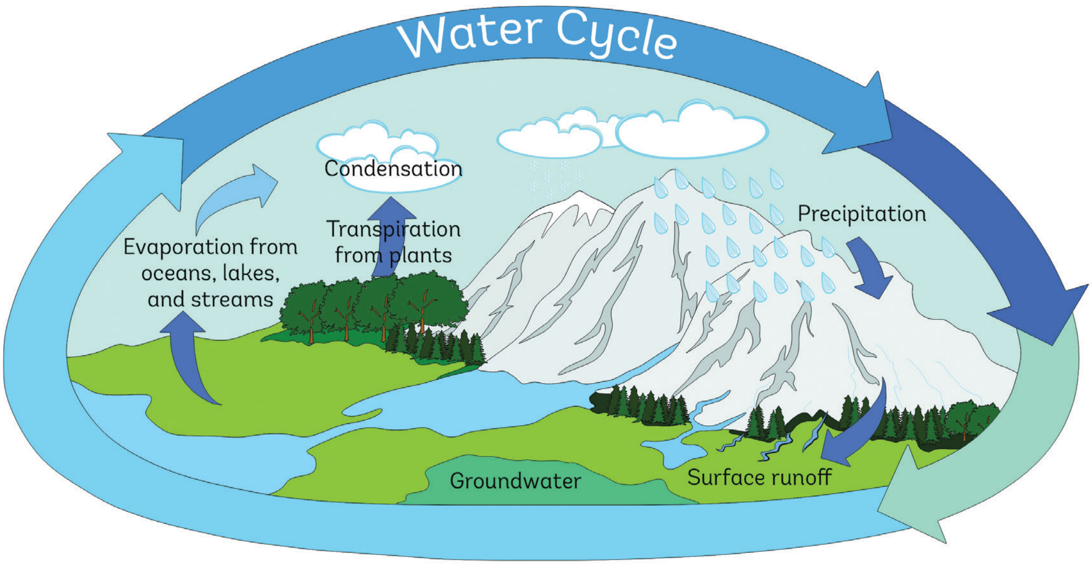

FIGURE 12.9. The Water Cycle

We have now learned enough to connect the "why" with the "how" regarding rain in Eretz Yisrael. When Hashem wants to give us rain, He may cause air full of water vapor to blow in from the over the Mediterranean Sea in the west. If this air blows up the mountains in the north and center of Israel, or if it meets a colder air mass blowing in from the north, it is likely to rain (Figure 12.10).

Alternatively, if Hashem doesn't want it to rain in Eretz Yisrael (ח"ו), then the wind will blow dry air from the deserts in the south and east, which contains insufficient water vapor for condensation to occur, even if this air is pushed up the mountains or meets cold air (see Figure 12.11).

FIGURE 12.10. A blessed, rainy day in Yerushalayim

FIGURE 12.11. This is a special prayer service in Yerushalayim like the ones that are held when not enough rain has fallen in Eretz Yisrael.