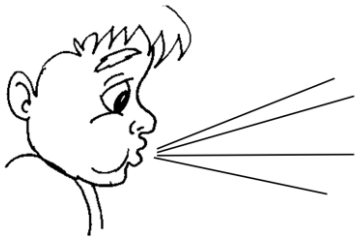
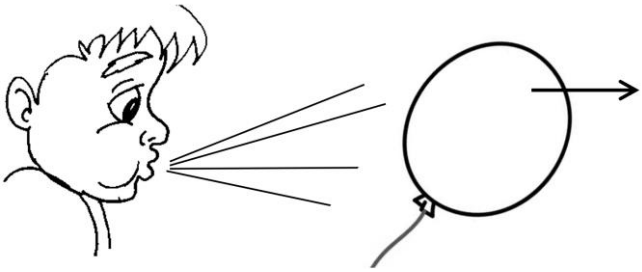
1. Air is “something”

Air is funny. It might seem like it is nothing: we cannot see it, we cannot grab it. And still, we know it is there, (it exists), it is something. To show that air is something, let’s make air move by blowing against it:

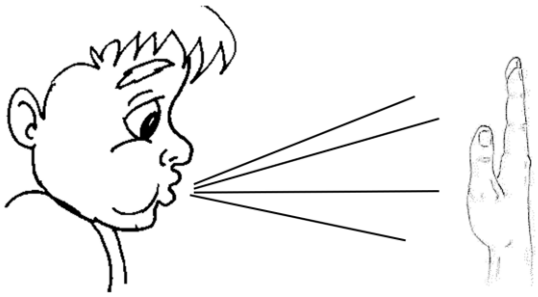


Did you see anything? Me neither! We cannot see the moving air, but we can make it visible with the help of a balloon. Did you see that?

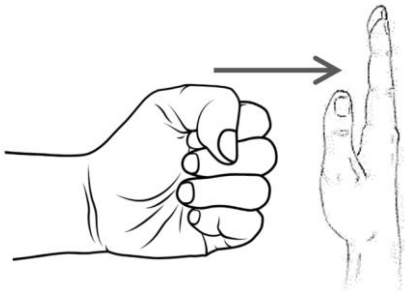


So, what happened here? When we blow, we move the air which then bumps into the balloon and makes the balloon move. When you are outside with a balloon and there is wind, the balloons move as well. In fact, that’s exactly what wind is: just moving air.

Now, if we blow against our hand,



the moving air bumps into our hand and we feel the air much like I can feel my fist bumping into my hand

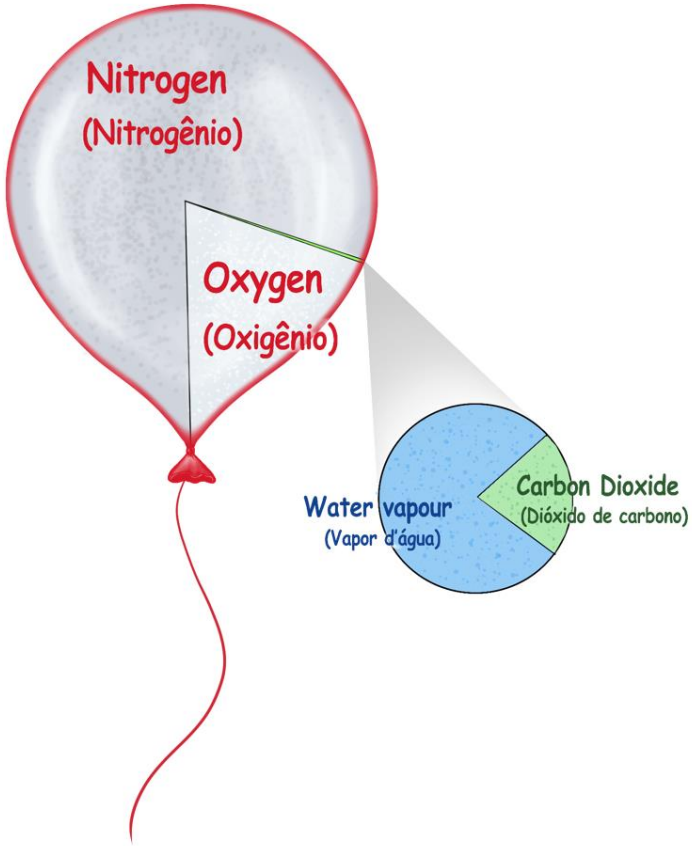


Just like my fist is something, so is air.

OK, let's stop and think about what we've learned so far. We've learned two things: The first is that air is something: The second is that wind is just moving air.

But if air is something, what is it made of? Well, air is made of a things called molecules. Molecules are the building blocks of everything around us. So, let's see which type of molecules are in air.

Here we have a drawing of a balloon and the air molecules that are in it:



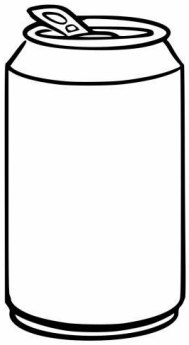
- Most of the air is Nitrogen that is not used for much
- Almost everything else is Oxygen that we use to breathe.
- Then there is only a very, very small part of the balloon left, that is so small that I cannot draw what is in it. So, I made it a little bigger and we see that in that very small section there is:
    - Carbon dioxide that plants "breathe" from the air with their leaves to grow more leaves and fruits and
    - Water in the form of water vapor, which we cannot see, but when it turns to liquid water it can form clouds!

What have we learned in this video?: We learned that air is "something" it is full of molecules like nitrogen, oxygen, carbon dioxide and water. And air can move, which is what we call wind!

2. Air is heavy

We have learned that air is "something" even though we cannot see it. And there is a lot of air surrounding the earth. All this air together, we call the atmosphere. The atmosphere is about 100km (!!!) high, and it pushes down on our shoulders. You are very strong to carry all that weight. In this experiment we will show how heavy the atmosphere really is with the help of this can.

This can is made from very thin, flexible aluminum:



(Show can, crackle the can)

Why doesn't the 100km high atmosphere crush this soft can?

It is because the air outside the can isn't the only thing pushing on the can….

(Show hands pointing inward)

, there is air inside the can as well, and it pushes outward.

(Show hands and outward)

They both push equally hard, so the can stays exactly the way it is.

But what if we had a way to suddenly remove all the air on the inside of the can? That would mean that then the air only pushes the can from the outside. Think about that, what do think will happen? With this experiment we can do just that, remove all the air from the inside of the can. We will first show the experiment and then explain how it works.

Take a big aluminum can and fill it with a tiny bit of water, not too much. Then we heat up the can. Don't do the experiment by yourself! It is dangerous. I will put on my safety goggles

After a while we see steam coming from the can, this means that all the air is now pushed out.

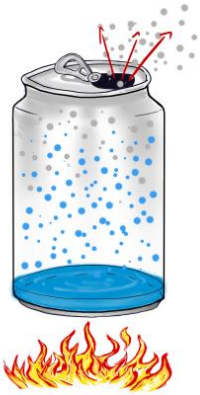
Now we carefully take the can from the fire and put it into a tank of cool water with the can opening facing downward.

WOW! The atmosphere crushed our can! Let’s see what happened here

1

We started with a can with just a little bit of water in it at the bottom and air above it

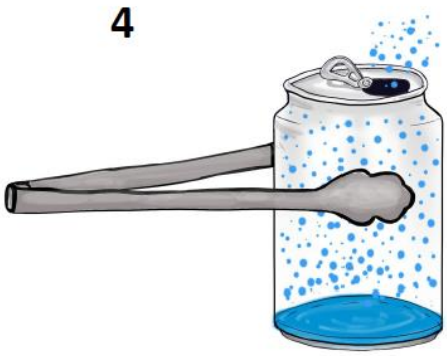
2



We then started to heat up the can which evaporates the water to water vapor that pushes the air out of the can.

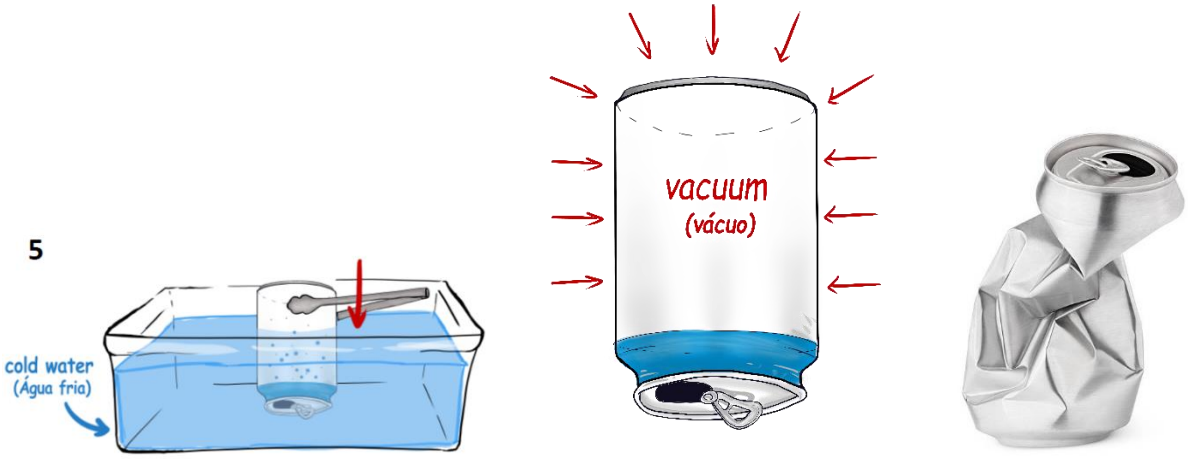
3

When the can is completely filled with water vapor, we could see steam coming out of the can.



This was the time to take the can to the water tank and put it upside down in the water

Now things went really fast: because of the cool water, the water vapor immediately changed back to liquid water and because the opening of the can was under water no air could get into it. We now had removed all the air from the can, which is what we call a vacuum, and the atmosphere was now pushing inward on the can without pushing outward at the same time. The result: a crushed can (hold crushed can in hand).



What have we learned? We have learned that:

- All the air that makes up the atmosphere is heavy! (You are very strong to carry all that weight on your shoulders all the time!)
- But also that this air is pushing in all directions (inside and out), so as long there is air both on the inside and on the outside of the can, the can will not get crushed.

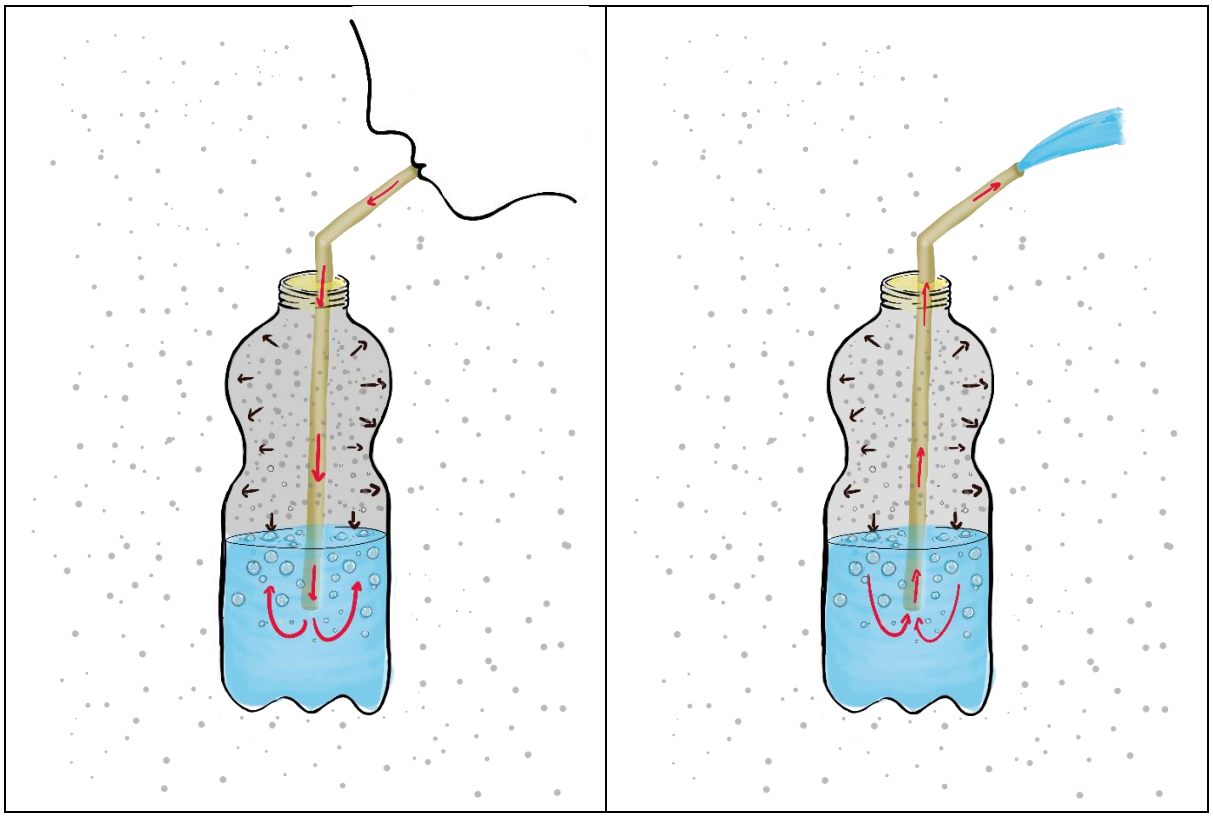
3. Air moves

3a. More air moves water

We know now that air is something. In fact, it is so heavy that it can crush a can, if there is more air outside the can than inside the can. Let's now create the opposite situation: Let's put more air inside a water bottle than outside the bottle.

We take a water bottle and fill it halfway with water. So right now, the bottom half of the bottle is filled with water, and the top half is filled with air. We stick in a straw, and cover the top with clay, so no air can get into or out of the bottle, except through the straw.

When I now blow hard on the straw, we get a water fountain! What happened?



(Left drawing)
Well, by blowing on the straw, I'm adding air to the bottle – you can see this in the air bubbles moving through the water. That means that now there is a lot of air in the bottle, pushing on the walls of the bottle, and on the water in the bottle.

(Right drawing)
When I stop blowing on the straw, this extra air will push the water back up through the straw, which gives you a water fountain. Having more air in one place than in another can make water *move* from the place with more air to the place with less air.

So air can move water. Let's now see if air differences can move something else too.

3b. Less air moves air

In the previous experiment we learned that water and air start to move if we create an area with more air. Now we will look at what happens if we create an area with less air.

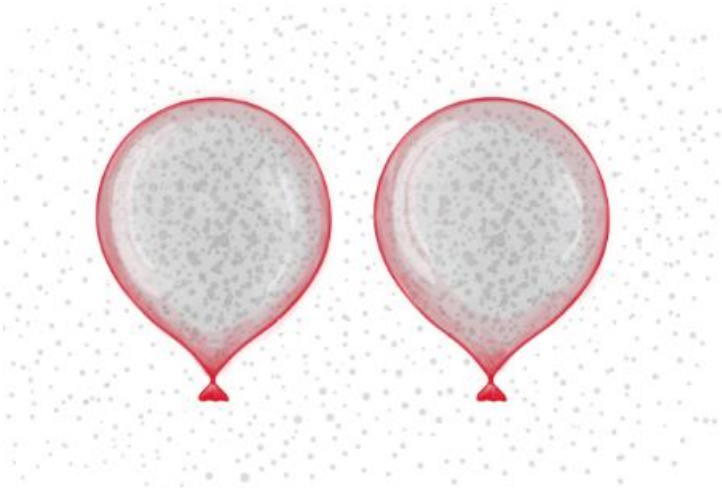
Here we have a balloon. If I blow against it, it will move because air is something and the moving balloon shows that.

Now we take two balloons and place them close together. What will happen if I blow between the two balloons? Think about it (short pause).

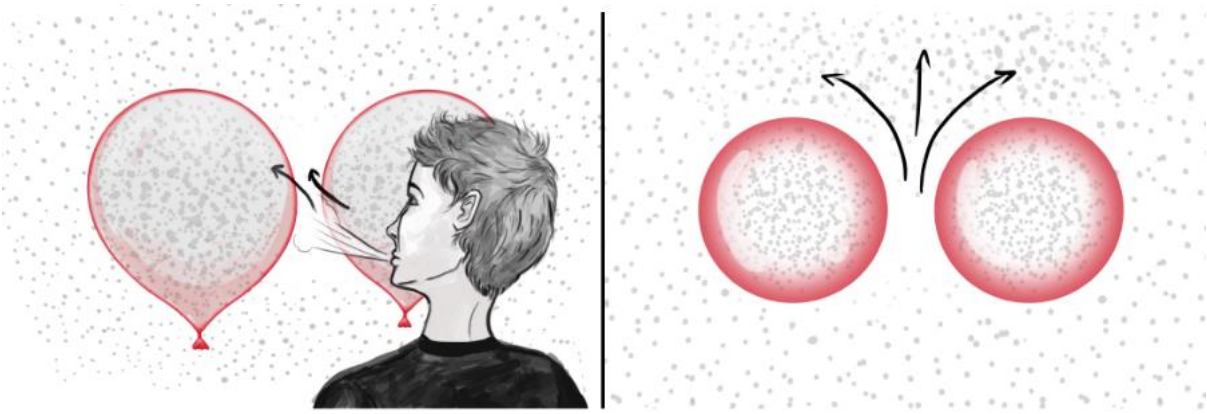
OK let's see what happens (blow between balloons, balloons move together).

They move together! Did you expect that? Maybe you thought they would move apart?

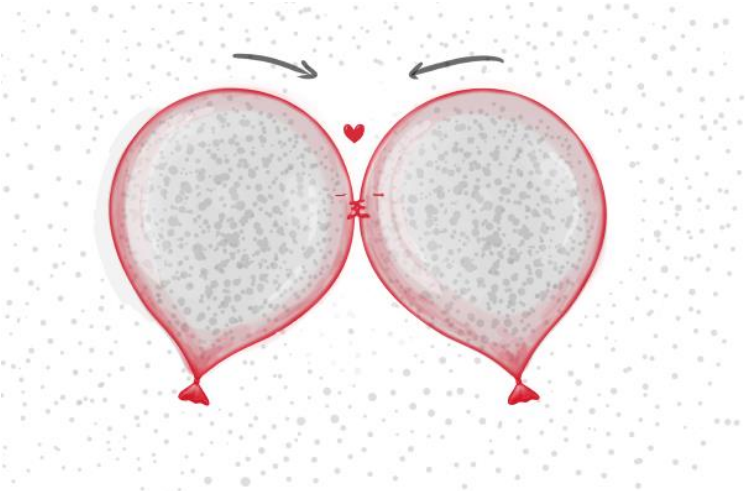
Let's see why they moved together:



We started like this, two balloons filled with lots of air. The air around it was all the same



Then I started to blow between the two balloons, making the air there move away creating an area with less air between the balloons.



This in turn made the balloons move; they moved from areas with more air to the area with less air until the two balloons kissed each other.

In the atmosphere differences in the amount of air make the air move as well, in other words it creates wind, which together with things like Temperature and Rainfall are important ingredients that make up our weather.

4. Air goes upward

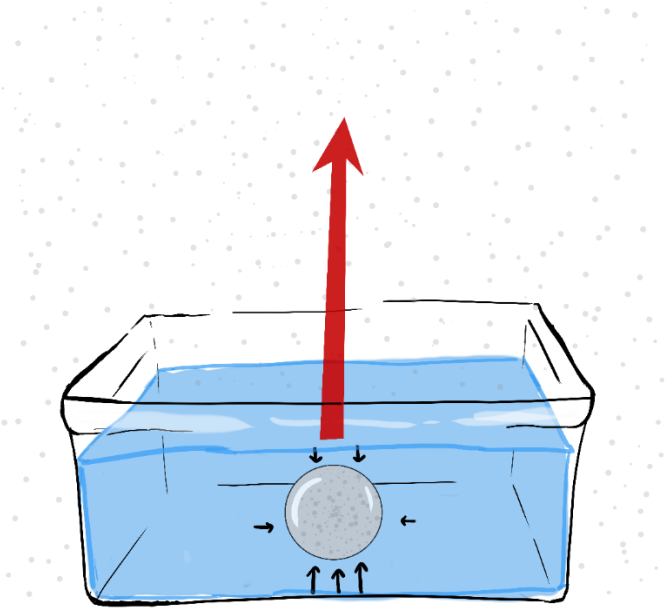
So far, we have thought a lot about how air can move water and air. Let's now see if we can understand how moving air can lead to the clouds we see in the sky every day!

First, we have to know what a cloud is. A cloud is still just air – just like the rest of the atmosphere. The difference is, that the air in a cloud has a lot of water in it. And in the rainforest, there is a lot of water! Water in the ground, water in rivers, and, most importantly, water in trees. But all of this water is near the surface, while the clouds are about 1 km up in the sky. So to form clouds, we need to take this water from the surface, put it in the air, and move that wet air up in the atmosphere, by about 1 km.

(In lab)
So the question we have to ask ourselves, is how can we make air go upwards? The secret, which we will explore in this video, is to make the air *light*.

How can air be light? To understand this well, let's first take a step back from thinking about clouds, but let's think of our balloon (show balloon). This balloon has air in it, and this air is not lighter than the air around it, because it will just fall down.

However, let's now put it in a bucket of water. You can see it floating on the water, like a little boat. So compared to this water, the air in the balloon *is* light. And so if I now push the balloon into the water, I can feel the water pushing back against the balloon. And if I let go of the balloon, it comes flying back out of the bucket!

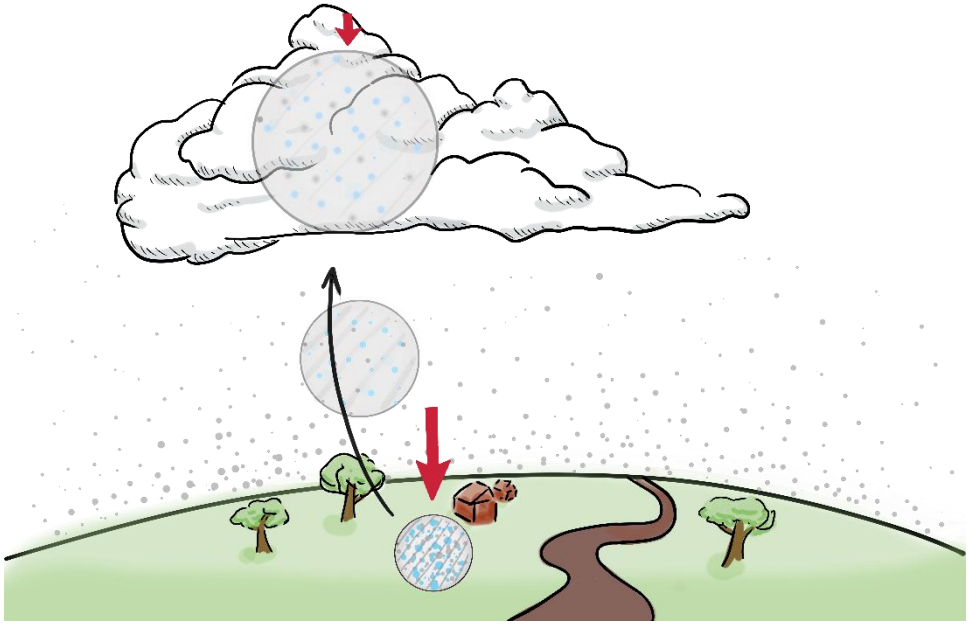


(In studio)
Let's look at a drawing of what happens. The air in the balloon is exactly the same air as the air around the bucket of water. However, this air is *lighter* than the water in the bucket, about 1000x lighter in fact. So the heavy water in the bucket is pushing on our light balloon of air. The more water we push out of the way with the balloon, the more the water pushes back. The result is that the balloon shoots upwards.

(Show balloon again)
Okay, we are getting somewhere. Light air in a balloon can go upwards, if it is surrounded by something heavier, like water. But in the real world, we never see balloons of air shooting out of the water around us, do we? No, to make the air around us in the atmosphere light, we have to do something else: We have to heat it up.

(Do this experiment)
So let's heat up some air! We put a pan of water on the gas burner, and make it boil. If you look carefully, you can see steam coming out of the pan, and you can see it's going upwards. The steam is just water in the air, and this air is very warm, since it's coming from the pan. So here we have it: This warm, wet air is light, and it goes upward.

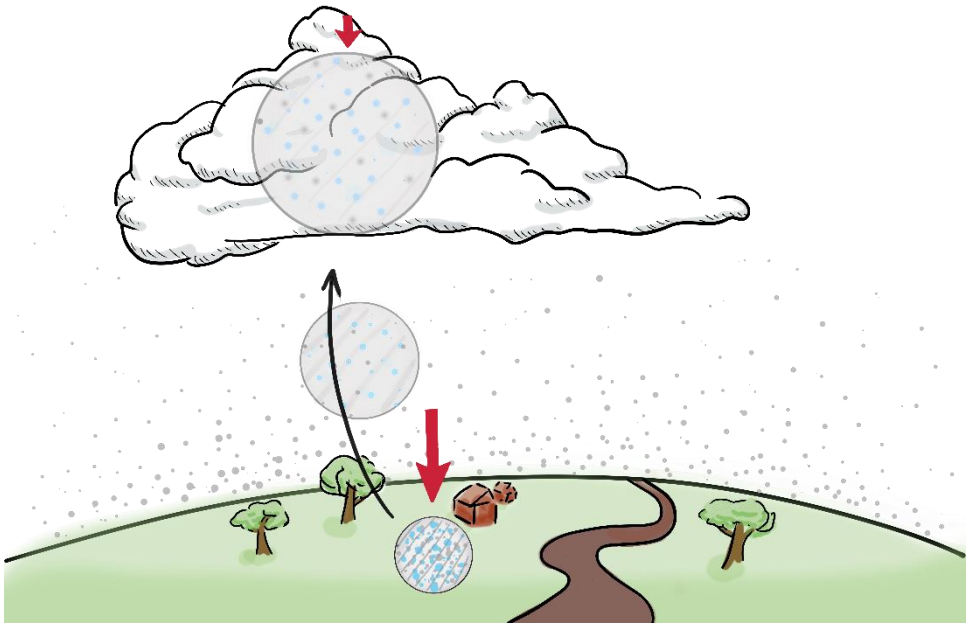
To imagine how this might lead to clouds, let's put a plastic bag over the heater – be careful not to burn it. You can see the bag blowing up as it fills with light, warm air full of water, that wants to go up. In fact, if I let the bag go, it flies up and away!



So what does all of this have to do with clouds? Well, in the real world, the surface is warmed by the sun, which creates little bubbles of warm air everywhere around us, full of water from the river, ground and from the trees. And because these little bubbles are warm, they are light, just like the air in our plastic bag. This makes these warm bubbles shoot upwards, like invisible hot air balloons! It's some of these balloons of hot, humid air that end up forming clouds.

To see how that works exactly, watch the next video!

5. Air forms clouds



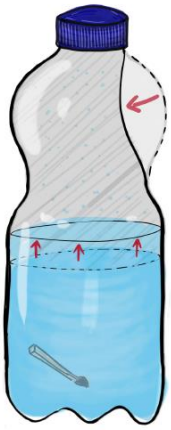
In the last video, we said that clouds are like invisible balls of light air with water, that shoot up around us. But clouds aren't invisible! Why not? Let's investigate with a final experiment.

(Demonstration)
We take an empty water bottle and fill it about halfway with water. Let's now shake the bottle, so the air in the bottle is full of water. Now we light a match, throw it in the bottle and quickly close it. We do this to add little bits of smoke to the air in the bottle. These "smoke particles" will help us make a cloud. If I now push hard on the bottle, the air has less room, and pushes hard on the bottle – just like when we made the water fountain. Look at how hard I'm pressing! But now, when we let go, we get a cloud in the bottle! I can make the cloud go away again by pressing on the bottle again, but every time I let go, the cloud comes back!

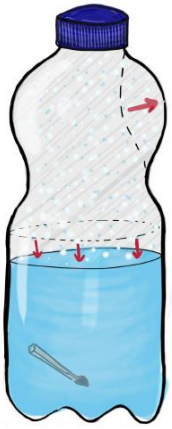
Why did we get a cloud? Well, let's go over what we did again.

First, we filled the air in the bottle with water, by shaking the bottle. This air is now full of water, but we didn't get a cloud yet.

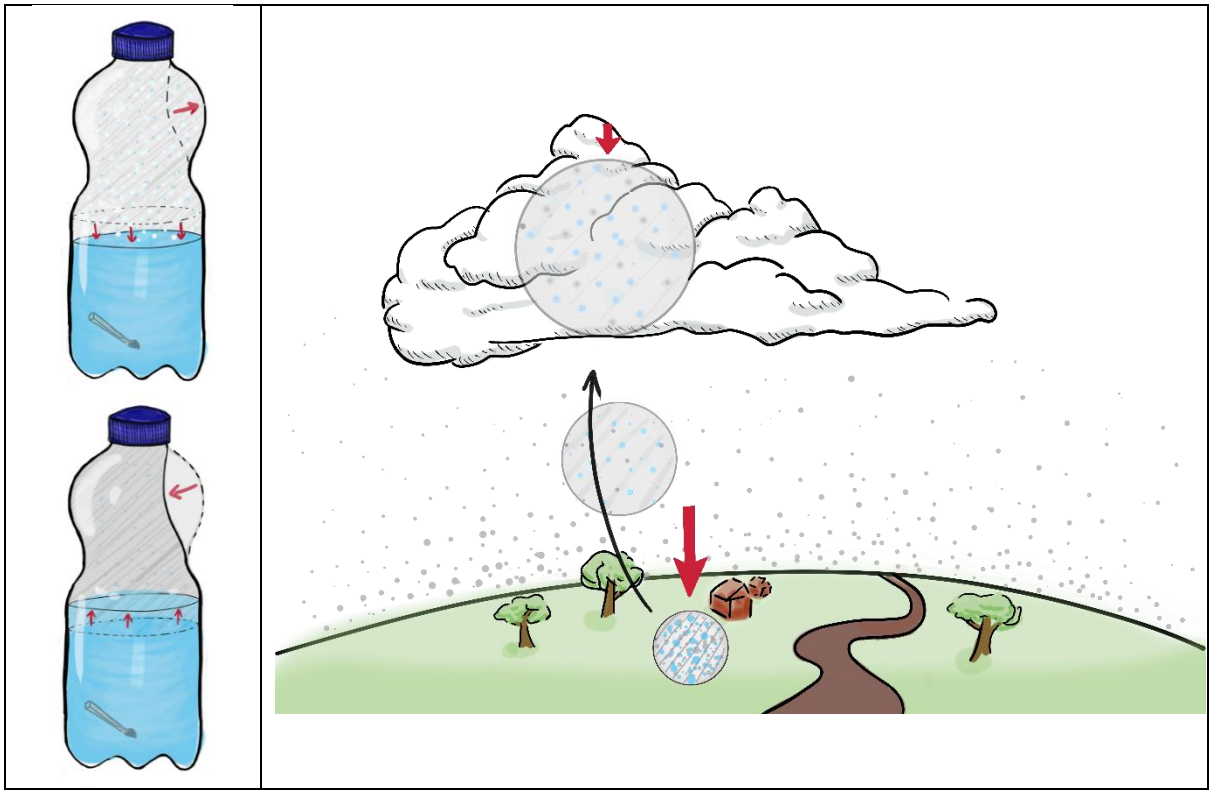
Then, we added the pieces of smoke, by throwing a match in the bottle. You can see the smoke drawn in the grey haze. But we still didn't get a cloud.



What we needed to do to make the cloud, was to press on the bottle. Now air cannot escape from this bottle, so now the same amount of air has a lot less room. And it's pushing hard on the bottle, just like in the water fountain experiment.



When I let the bottle go, that air quickly can fill the whole bottle again! When the air takes up more room like this, it will cool down. And when it cools down, then the water in the air in the bottle, forms little liquid droplets, on top of the smoke particles we put in there before. All these droplets taken together, give us a cloud!



So what does all this have to do with the hot, light, rising air balloons from the last video? Remember from the crushed can experiment that the atmosphere is like a 100 km thick layer of heavy air, that pushes down on top of us. Well, as those balloons go higher and higher through the atmosphere, there is less heavy air left on top of them. This makes the balloons take up more space, just like what you saw when I let go of the bottle. And, when a ball is moved up around one kilometer, the air has taken up enough space that the water in it forms droplets on small pieces of smoke or trees, exactly like we saw in the bottle. This is how you get the clouds you see around you in the sky every day: They are just hot bubbles or warm air shooting upwards, full of water and particles that make little liquid droplets, once the air takes up more space.

Epilogue

So what have we learned? We have learned that air is something, even when we cannot see it. And because air is something, it can influence things around it. For example, it is really heavy – heavy enough to crush a can when you remove all the air in it. We also saw that air can move things: If you have more air in one place than in another, this can move water out of a bottle, or make balloons move towards each other. Air moves things: from the place with more air, to the place with less air. It is this movement of air that we experience as winds in the atmosphere. Finally, we saw how we could make bubbles of humid air near the surface shoot up by making them warm and light; when this air takes up more space, the water in the air can form clouds, even thunderstorms and rain. All of this shapes the weather around us, and it's all because of air!