[THEME SONG]

MOLLY BLOOM: You're listening to *Brains On* from American Public Media. We're serious about being curious. And we've been hearing a lot of curiosity from our listeners about this.

[LOUD THUNDER RUMBLES]

MAISIE: I'm Maisie and I'm 5 years old. And my question is what makes thunder?

KINCADE: Hello, my name is Kincade and I'm seven years old. How does lightning form in a cloud?

MOLLY BLOOM: Thunder and lightning are linked like smoke and fire, chickens and eggs, cause and effect. So we need to start with Kincade's question-- how does lightning form in a cloud? We may call these kinds of storms thunderstorms but it's really lightning that is the star of the show.

So how do these storms get started? That cute fluffy white cloud out your window isn't going to turn into a thundercloud just like that. There are some basic ingredients that are needed. First, you need warm moist air near the ground. Then you need that air to be lifted up. That could be caused by the warm air being blown up the sides of mountains or pushed up by ocean breezes on the coast.

In the middle of the country, it will be a cool front of air moving in that does the trick. This creates instability. Kenny Blumenfeld, Climatologist with the Minnesota Department of Natural Resources, says that instability is another needed ingredient.

KENNY BLUMENFELD: So you need warm air, often more moist air, near the surface of the Earth. And then above it, you need air that cools somewhat rapidly with height. That sets up an imbalance in how dense the air is.

You have the less dense air, which is that warm and moist air near the surface, trapped beneath air that it's actually lighter than. And so that's unstable just like if you were to push a buoy down under the surface of the water. And so that unstable environment is very good for getting upward motion.

MOLLY BLOOM: This upward motion of the air makes a thunderstorm cloud very tall, and this leads to lightning.

KENNY BLUMENFELD: A really big thunderstorm cloud might be 40 or even 50,000 feet tall. And way up there, the temperatures are often 25 to 40, maybe even 50 degrees below 0 Fahrenheit.

MOLLY BLOOM: Up there at the top of the cloud where it's very cold, ice crystals start to form.

KENNY BLUMENFELD: When that happens, the charge between the water and the ice crystals start to separate. These form the charge difference that results in the lightning. Charge builds up between the cloud and the ground and then can get released through the static discharge.

MOLLY BLOOM: That's the same kind of static discharge that you feel when you drag your sock-wearing feet across the carpet and then touch something metal, ouch, just on a much bigger scale. And there are lots of different ways that lightning can strike-- from the cloud to the ground, from the ground to the cloud, within a cloud, or between different clouds. But how does lightning make thunder? Well, it's basically an air explosion.

[LOUD THUNDER RUMBLES]

KENNY BLUMENFELD: Lightning gets extremely hot, up to 50,000 degrees Fahrenheit. And even though it's really infinitesimally small, it takes up almost no physical space, but that heated channel causes the air molecules to expand so rapidly because they are still gas molecules, and so when they get warm, they expand.

Imagine this little innocent air molecule going from, say, 75 degrees up to 50,000 degrees or even 30,000 degrees in almost no time at all. So the expansion is so rapid it's essentially like an explosion. And the explosion of these air molecules creates a shockwave, and then the shockwave moves outward from that heated lightning channel.

And this is essentially the thunder that you hear, is the sound of that initial blast working away from the lightning. You need the lightning to make the thunder. And it's always telling you, hey, the air just exploded.

MOLLY BLOOM: So depending on how close you are to the lightning strike, the thunder will sound different. If you're far away, it sounds rumbly and rolling, that's the sound making its way to you. If you're very nearby the lightning, it sounds like a cannon blast. And you can use the gap between the lightning and the thunder to tell you how far away that lightning strike is.

Every five seconds between the two equals one mile. So if you see lightning and then count until you hear thunder-- 1, 2, 3.

[LOUD THUNDER RUMBLES]

You can tell how far away it is. Less than five means less than a mile away. Thunderstorms are amazing but they're best to be enjoyed indoors. Lightning can be dangerous if you're outside. If you hear thunder or see lightning, go inside.

KENNY BLUMENFELD: If You can't get inside a building, then get inside a closed car, not because of the tires but because of the enclosed metal around you are relatively safe. You need something to protect you, build a little cage around you. That's what a hardbody car does. And if you don't have one of those, then you start trying to get as low as you can away from really tall objects.

So thunderstorms are really beautiful. They're easy to appreciate. And the safest way to appreciate a thunderstorm is to get inside an enclosed building. And one thing I did when I was a kid was if it was-- especially at night. We would just turn off the lights. And we could sit in the middle of the room and let the lightning just light up the whole room.

And then once you do that, you can just appreciate their power. If you're interested in thunderstorms and you're good at looking around, just pay attention to the different colors-- yellow, red, white, blue. It's phenomenal. And if you're really lucky and you've got a really fast eye and the storm is far enough away, you could see the discharges that happen way above the clouds in space.

And they call these sprites, blue jets, and dwarves. And this is a whole sort of magical side of thunderstorms that we often don't see because it happens very quickly and it's very hard to see.

MOLLY BLOOM: We'll have more in a minute to find out how thunderstorms can turn into tornadoes, but first, it's time for the Mystery Sound.

[MYSTERY SOUND AUDIO CUE]

SPEAKER: Mystery sound.

MOLLY BLOOM: Here it is.

[MYSTERY SOUND]

Any guesses? The answer will be revealed later in the show. If you could live on Mars, would you do it? We're doing an episode all about the Red Planet, and we want to hear your thoughts. Tell us why you would or wouldn't want to leave Earth and live on Mars. And if you do want to go, what would you do there? Email us at hello@BrainsOn.org.

We love hearing from our listeners. In fact, you all are the backbone of this show. Every episode, we choose one or more of your questions to answer. And in doing so, we end up in some pretty cool places. So if you have a question for the show, send it to hello@BrainsOn.org just like Violet did.

VIOLET: My question is how do zippers work?

MOLLY BLOOM: Listen for the answer to that question during our Moment of Um at the end of the show. Plus we'll welcome the latest group to be added to the Brain's Honor roll. That's how we thank everyone who keeps the show going with their energy and ideas. Stay tuned.

MINDY THOMAS: Hi, I'm Mindy Thomas, Co-host of NPR's Wow in the World, NPR's first podcast for kids. Every week, my buddy, Guy Raz and I, take wild adventures into the coolest new scientific discoveries. And we want to invite you to come along for the ride. Find Wow in the World on Apple Podcasts or wherever you listen to podcasts.

MOLLY BLOOM: Ready to go back to that mystery sound? Here it is again.

[MYSTERY SOUND]

Any other thoughts? Well, here with the answer is Noah and his sister, Emily, from Brookline, Massachusetts.

NOAH AND EMILY: That was the sound of hail falling down from the sky and the porch and the deck and the sky and our car and our windows.

MOLLY BLOOM: So that was the sound of hailstones. Remember those ice crystals we talked about earlier in the show? Hailstones form in a similar way. Here's Kenny Blumenfeld again.

KENNY BLUMENFELD: And then what happens is you get these little hailstones that form and they're light. And so the air that's moving upward can still carry them higher into the cloud, where they collect more water and freeze more and get bigger. And it's only when they become big enough that that upward-moving air can't hold it anymore that they fall out. And then if they're really big, you hear them bonking things.

MOLLY BLOOM: Another side effect of thunderstorms can be tornadoes. So we want to answer this question.

LUCA: My name is Luca and I'm eight years old. My question is how do tornadoes start?

MOLLY BLOOM: To find out how they form, we spoke to Eyad Atallah from McGill University. He's been interested in tornadoes for a long time.

EYAD ATALLAH: I grew up near Chicago. And we were driving from Chicago to Detroit. I was probably like second grade. I saw a tornado form west of our car and I was pretty excited. Once I got to school and realized that this was something I could actually do for a living, it was pretty much a done deal after that.

And then I started-- just as a hobby, started chasing tornadoes. And then it got to the point where now I occasionally take classes from McGill University out to the field and teach them how to forecast and how to chase tornadoes while trying to be safe.

MOLLY BLOOM: The same ingredients that make thunderstorms also make tornadoes.

EYAD ATALLAH: Winds at different levels in the atmosphere move in different directions and at different speeds. If you think of a paddlewheel that's attached to a stream, the water in the stream is flowing and that's pushing the paddle on the bottom of it, which basically causes the paddle wheel to spin.

So we can get that same thing in the atmosphere, except in the atmosphere, it's usually not the bottom of the paddle wheel that's fast. It's the top. So basically, since the winds are blowing much more quickly higher up in the atmosphere, we're basically creating this rotor or this rotation in the air.

MOLLY BLOOM: The stronger the difference in temperature between these air masses, the stronger the rotation. But at this point, the rotating plume is laying on its side. How does it become a tornado?

EYAD ATALLAH: What happens is this plume of warm air actually takes the paddlewheel and it tips it over on one side. If you imagine a tube, like let's say a tube from a paper towel tube, you're holding it in your hand and you imagine that it's rotating. And then you start to tip one side of it up. That's basically the warm air rising, is tipping this tube up.

MOLLY BLOOM: That takes this rotating plume of air from on its side to standing straight up and down. And while thunderstorms are very common, tornadoes are definitely not. Less than 1% of thunderstorms will create a tornado. So tornadoes are very rare but if a tornado warning is issued, there are things you can do to protect yourself.

EYAD ATALLAH: If you have a basement, go into the basement. If you don't have a basement, then you go into the area of your house that is most interior, preferably a room that is relatively small so that the walls are close together. And maybe put something over yourself like a mattress or a foam pad or something just in case there's any debris.

MOLLY BLOOM: Meanwhile, Eyad and his students will drive 10,000 miles over two weeks tracking and chasing tornadoes. He teaches them how to predict where tornadoes form using tools and their own powers of observation.

EYAD ATALLAH: You can teach people to visually cue in on how the cloud formations are evolving so that you can actually tell where the tornado is likely to form.

[MUSIC PLAYING]

MOLLY BLOOM: Thunderstorms are caused by warm, humid air rising through cooler air. Tornadoes can form when that rising air rotates. Lightning is a spark of electricity that happens between clouds, the air, and the ground. And lightning causes thunder, which is basically air molecules exploding. Keep your eyes on the sky and remember, there are lots of ways to observe these amazing storms safely. Now before we go, it's time for our moment of Um.

[MOMENT OF UM AUDIO CUE]

VIOLET: My name is Violet from Calgary, Alberta. My question is how do zippers work?

BRYON ROBINSON: I've been asked that question probably hundreds of times. My name is Bryon Robinson. I work for YKK. I'm in sales engineering. YKK is known worldwide for zippers. Basically, if you look at a zipper in its simplest form, you have three parts.

You have the textile tape, which is the material, and that's the material that is sewn into like a jacket. You have elements, which are the metal parts that are attached to this base tape. And you have what we call a slaughter. The slaughter is the actual part that you hold and you move the zipper up and down. And that's what connects the elements and that's what takes the elements apart.

If you take your knuckles, left and right hand, and you put one finger on top of the other-- on top of the other, you can see how your knuckles, if you pull a little pressure and pull apart, you can't pull your hands apart. That's how a zipper works. So if the left element connect to the right element, they both hold each other together.

The slider is made up of three basic parts. You have the diamond, which is the top of the slider. You have the opening at the bottom, which is called the mouth. And we have on the sides, which are called rails. As the elements go through and they go past the diamond if they're closing, it aligns each element on the right and left-hand side up so that one can fit in between the other.

And then the rails actually push it closed. And the mouth makes sure everything is closed up. You can do with your bare hands, but a zipper has what they call a zipping angle, the angle of which the elements have to be to fit in between each other. And it's very difficult to get your fingers to position the elements at that certain angle. The slider itself is designed so that it positions the elements at that angle, allowing one to fit into the other.

MOLLY BLOOM: I'm going to zip right through this list of names. It's the most recent group of *Brains'* Honor Rollees.

[LISTING HONOR ROLL]

That's it for this episode of *Brains On. Brains On* Is supported in part by a grant from the National Science Foundation. Keep up with us on Instagram and Twitter, we're at Brains_On, and we're on Facebook too. And you can send us your questions, mystery sounds, drawings, and high fives anytime. Our email is hello@BrainsOn.org. We'll be back soon with more answers to your questions. Thanks for listening.

[MUSIC PLAYING]