But Why: A Podcast for Curious Kids

How is Paper Made?

August 30, 2019

[Jane] This is “But Why: A Podcast for Curious Kids” from Vermont Public Radio. I'm Jane Lindholm. On this podcast, we take questions from curious kids all around the world just like you and it's our job to find answers. This week, we're answering questions about something we all use all the time. (paper ripped and crumpled)

[Eliza] My name is Eliza from Morgantown, West Virginia, and I’m six. My question is: where does paper come from?

[Declan] My name is Declan. I live in New Mexico.

[Wyatt] My name is Wyatt and I live in Houston, Texas.

[Niko_paper] My name is Niko. I'm six years old. I live in Southern VT.

[Max_paper] I'm Max. I'm four years old. I'm from North Carolina.

[Harlan] Hello, my name Harlan. I live in Aspen, Colorado.

[Mason] Hi my name is Mason. I’m six years old. I live in Auckland, New Zealand and my question is: how is paper made? Thank you.

[Jane] My goodness. A lot of you want to know how paper is made. All right. You got it.

Now, most of the paper, you probably see every day—newspaper, construction paper, regular white paper that you use in school, even art paper for projects at home or in art class -- is made in really big paper factories. There are big machines that crank out millions of pages of paper that all look exactly alike. And then they're packaged up and shipped out to stores so they can stack up inside your printer or be used to make a receipt at a grocery store or even turned into the toilet paper you use in the bathroom. There are lots of different kinds of paper. Different sizes, different textures, different colors and different uses.

But all paper has one thing in common. It's made from cellulose. We'll tell you more about cellulose in a few minutes. But one thing you might already be thinking is, “But wait a minute. I thought paper was made out of trees.” And you're right. Cellulose is found in wood. It's a fiber. It's a fiber in lots and lots and lots of plants. And so, paper can be made using a lot of different plant materials. But most often when we're talking about bulk paper, it's made from wood. Well, actually, a lot of paper is made from other paper, recycled paper that's been broken down and remade into new paper. That's pretty cool. But of course, that original paper was still made from trees or other fibers.

We thought about going to a big paper factory to learn more. But we figured the sound of big machinery is not really all that interesting. And besides, paper is actually something a lot of people make for themselves, sometimes with a little help. So, we thought we'd go visit an artist in New York who makes her own paper and see how she does it.

[Carol Marie] I am Carol Marie Vossler and I'm the founder and artistic director of BluSeed Studios, located in Saranac Lake, New York.

[Jane] Carol Marie has done a lot of different kinds of art, but she really loves making her own paper. And at BluSeed, she and other artists teach people, including kids, how to make all kinds of art.

[Carol Marie] Paper just makes sense to me. It's recyclable. It's environmentally friendly. You can use it for healing and art therapy projects. You can add things-- add plants or other kind of embedded objects into the paper. It can take a whole other creative way. It doesn't have to just be something that you write on.

[Jane] But, of course, you can. The paper made at BluSeed is definitely not like the white sheets of paper you might be used to. It's thicker, it's strong, it lasts a long time and it doesn't turn yellow as it gets older like, say, newspapers might. Carole Marie makes her paper from different kinds of plants, but not from big pulpwood logs like a factory might. Let's hear what you're wondering about one more time.

[Brevin] My name is Brevin. I'm six years old. I live in Austin, Texas.

[Hazel] My name is Hazel and I'm from Concord.

[Hank] My name is Hank and I'm four and I live in Richmond, Virginia

[Ian] Hi, my name is Ian. I'm five years old. I live in Vermont and my question is: how is paper made?

[Jane] Okay. Okay. Let's get started. The main ingredient you need to make paper is-- do you remember? – cellulose.

[Carol Marie] Cellulose is the plant material that makes paper and it can be from a tree or from a plant-- wild plants such as Mulberry or your flower stems. Hosta plants, abaca. All sorts of different plants.

[Jane] Cellulose is the fiber in those plants. And although leaves kind of look like paper sometimes, especially when they dry out, they don't have as much cellulose as the branches and stems or trunks of the plants do. So, you typically use the woody, thick parts of the plants to make paper. First, you have to break the plant down into really small pieces. And soak it in water, often really hot water. Sometimes you even kind of cook it, or you can use chemicals in the water. You're trying to separate the cellulose from the other elements in the wood or the plant. What you're left with is called pulp and then you can take that pulp and start to make paper. When Carol Marie makes her paper, she's not starting with the plant itself. She often gets these plant materials in a big, bulky sheet. So, a big, bulky sheet of hemp or a big, bulky sheet of another plant. But it's not really paper yet. So, she takes the different materials and she uses them to make paper.

[Carol Marie] So, this is the hemp, this is abaca, and this is flax.

Each one has a different property, like the abaca on its own gets real tight like a drum and contorts. The hemp and the flax are really nice, beautiful, strong, thin paper that you can

draw or print on. And the cotton rag, too, just cotton rag like T-shirt I'm holding here, like a blue purple kind of sheet of paper.

And it's nice and strong and thin.

[Jane] Carol Marie actually keeps recipes of the paper she's made. She writes down all the ingredients whenever she makes a new kind of paper. And if she likes the result, she uses the recipe to make that paper again.

[Carol Marie] So here, for example, this was flax, assorted flowers and stems. And I have the sorted flower and stem stapled to the paper and a sample of the paper in a clear leaf binder.

So this is the gampi here

[Jane] To start, Carol Marie is soaking a plant called gampi in a bucket.

[Carol Marie] Gampi is a wild mulberry plant. It comes all kind of stocky and dry, like dried corn husks almost, like barky a little bit. So, then I took the gampi and I had to cook it in soda ash. It cleans the plants, sterilizes a plant and neutralizes so, if there's any bugs or pesticides or any nasty things that you don't want, it'll take care of it. It also just preps the pulp.

[Jane] So, she has this pulp, the wet, loopy gampi that's been boiled with soda ash.

And when it's been boiled and rinsed, it has to go to a machine called a Hollander beater. It's a little bit hard to describe a Hollander beater without being able to show it to you. But let me try. Picture a tub, you know, kind of shaped like a bathtub, but smaller. Well, at least in this case. And sitting in the tub, but not touching the bottom is a wheel. If you've ever seen a water wheel, it kind of looks like that. And you can crank the wheel by hand or by machine to make it turn.

Now, if there's water in that tub, the water will get stirred up or beaten. And in the case of making paper, you don't just have water in the tub. You have that pulp, that cellulose fiber from whatever plant you're using, and the water. And you use the Hollander beater to stir it up and stir it and stir it and stir it and stir it and start to get those fibers loosened up and ready to come together again to become paper.

People started using Hollander beaters to help make paper more than 300 years ago.

[Carol Marie] I'm going to bring about this much—so this is like a handful of the gampi. It's just a little bit. I'm just throwing a handful in and it's going to change the texture of the hemp.

[Jane] Hemp is another fiber. It can be used to make clothes or rope or, yep, paper.

Remember how I said Carol Marie has a recipe? She uses different kinds of fibers to make different kinds of paper. So, you can use different recipes. One might make a really strong paper that's kind of thick. Another would make a thin paper that looks almost see-through or translucent. Or you can make a combination. Hemp is known for being really strong and gampi is often used in Asian style papermaking to make translucent paper. So, mixing those two materials together makes a paper that's kind of a combination of both of them.

So, Carol Marie throws a little bit of the wet gloopy gampi into the Hollander beater with the wet gloopy hemp and the Hollander beater beats the wet gloopy pulp together, mixes it all up.

[Carol Marie] This Hollander beater holds roughly a half pound of fiber or rag.

So this is a new recipe, just throwing a little of this gampi into the hemp paper and it'll change the overall character of the paper, so I'll have to make sure to make a new recipe sheet for this.

[Jane] So, the gampi and the hemp are all mixing together with the water, but it's obviously not paper yet. And if you just dried that out, it would still not turn into paper, partly because you need something that sticks all those teeny tiny little pieces together so they can stay in one solid sheet of paper.

[Carol Marie] I'm going to add, like, a tablespoon of sizing -- should be enough for a half pound of pulp. Sizing is the adhesive or glue that keeps the paper from falling apart when it gets wet.

[Jane] Sizing is also used to coat the paper so that when you write on it, the ink from your pen doesn't sink right into the paper and spread out or bleed.

[Carol Marie] You let this run for about five minutes.

[Jane] Let that all mix together and then it's time to drain the beater.

[Carol Marie] The gampi may have disappeared. Not sure because I only put in a little bit because this is sort of an experiment and a demo.

So it's a very sophisticated way to empty this. You just pull the plug. (laughs)

And so I'm pulling. The plug on the base of the Hollander beater is just like a bathtub plug.

And you pull the plug, I'm draining it into a five-gallon bucket.

[Jane] All the water drains out and you're left with that goopy mixture. But now it's solid enough that you can scoop the goop out with your hands and put it into (chuckle) another vat of water.

Making paper is kind of an involved process.

[Carol Marie] So I'm adding the pulp that I took out of the Hollander beater into a vat filled with water and it was filled, like, halfway. The vat is only about six inches deep. You have to “hog” the vat. That means—some people call it making clouds—and hogging the vat… You see how, if you look… if we look now at the vat, the cellulose pulp is just… it looks like a big fluffy cloud. And you can see how it's all separated.

It looks like cottage cheese almost in there. And there's spaces. You don't want those spaces because you'll get a lumpy sheet of paper. So, what you do is use jazz hands, like beaters.

And I'm hogging the vat. And I'm getting this all mixed up so that there's nice, even surface all the way across. And it doesn't look so much like cottage cheese anymore.

You have to do that every time in between you pull sheet. Then this is our mould and deckle.

[Jane] Mould and deckle.

[Carol Marie] The mould is a rectangular wooden frame and stretched across the wooden frame is a screen, a very tight mesh screen.

And that allows-- that screen holds the pulp and allows the water to drain out slowly. You don't want it to drain out too fast.

[Jane] So, the mould looks like a picture frame with a tight screen across it. And the deckle is like an empty picture frame that sits on top. So, you can use it to create the shape of the paper you want. Again, I know this is a little hard to picture in your head, but basically what you want to know is that you're looking for a way for all the gloopy parts to turn into a flat piece of paper and for it to be shaped exactly the way you want it, so you take your mould and deckle holding them together and you dip them down deep into the watery pulpy mixture.

[Carol Marie] You bring it into the vat, push to the bottom, come straight up.

You go to and fro, to and fro and you will see the paper form.

You'll hear the water drain.

[Jane] And you just have the pulp sitting on the top of the screen. Then you can take that frame, the deckle off and see what looks like a rectangular piece of wet paper. You're getting so close. You have to take that paper very carefully off the screen. You kind of flip it over and you let the paper sit on a piece of fabric and then you take the mould off, but you don't want wet paper that falls apart in your hands. So, the next step is to press the sheets of wet paper between sheets of fabric that will absorb some of the water. And I don't mean that you just press down with your hands. You need lots of pressure. So, if you're doing this in an art studio where artists make paper, often there might be a machine that can help you press your paper really hard.

[Carol Marie] You're putting it under like 20 thousand tons of pressure and you're slowly lowering the pressure and it's squeezing all the water out and you do it like three times, like, slowly.

And that third time you let it stand 30 minutes to—some people do it overnight, but we were typically leaving it in maybe 30 minutes to an hour. And the paper came out, super flat, beautifully pressed. And then from that, we would either hang it on, like with clothes pins on a clothesline and let it air dry. Or here at Bluseed, we have a dry box.

[Jane] In a dry box, you get to use a fan to help blow the paper dry and flat. And there you have it. Paper! Paper you can draw or paint on. Paper you can write a letter on. Paper you can look at because maybe you've pressed flowers or leaves into it to make it look pretty.

So it's just paper that's a piece of artwork by itself with no writing on it. Or paper that you fold up and turn into a paper airplane. Hey, I'm not judging. You made it. You get to do what you want with it.

What do you think? Sounds a little bit complicated, right? But at its most basic, you're breaking down the fibers of a plant into small pieces and then putting them back together in a smooth, thin, flat piece of paper. And you know, the invention of paper has allowed humans to do some amazing things. Imagine if we had never found a way to write things down beyond scratching or painting onto rocks. We definitely wouldn't all be reading the great books we love, would we? Coming up, we'll learn more about why paper is such an important technological advancement in the evolution of human society.

[Jane] This is “But Why: A Podcast for Curious Kids” I'm Jane Lindholm. Today, we're answering a question a surprising number of you have sent us.

[Sam] Hi, I'm Sam. I'm five years old. And I live in Duxbury, Vermont. I want to know how paper is made.

[Diya] My name is Diya. I'm five years old. I live in Phoenix. And I want to ask how is paper made?

[Jane] So far, we've learned about how artists make paper out of interesting materials like hemp and cotton and flax. But when it comes to most of the paper you probably use, it's made from one specific type of original plant material.

[Landon] How is paper made from trees?

[Ahmar] How do people turn wood into paper?

[Amelia] How do you make paper out of trees?

[Noah] How does paper come from trees?

[Autumn] How do trees get from trees to actual paper.

[Jane] that was Landon from Kansas City, Missouri, Ahmar, from Milton, Ontario, Canada, Amelia from Virginia, Noah from Palo Alto, California and Autumn from Pennsylvania.

Newsprint, copy paper--you know, the kind that you might use in a computer printer--construction paper, even toilet paper and paper towels all come from trees. That's because trees have a lot of cellulose, the substance that makes up plant cell walls and vegetable fibers. And trees are big and we use a lot of paper, so we need a lot of big trees to make it. To get cellulose out of trees, the process is kind of similar to what we were just learning about earlier, but it's scaled up to a factory level, so that tons of paper can be made very quickly. Wood from trees is first cut up into small pieces called wood chips. You've probably seen wood chips before. Well, those wood chips are turned into a pulp. And the way they're turned into a pulp is different depending on the kind of paper. For a weaker paper like newsprint that doesn't need to be super strong, the wood chips might just be ground to a pulp using saw blades in lots of water. But for white sheets of paper that are a little bit stronger and need to be bright white so you can write on them, the wood chips are

turned into a pulp using water and chemicals that break down the wood into cellulose. Then the pulp is often bleached with more chemicals to make it bright white.

When it comes to getting the water out of the pulp instead of using a mould and deckle and doing it by hand, piece by piece, big machines will spray the pulp onto a moving conveyor belt, and then other machines press and dry and heat it to make a big, long roll of paper, which can then be cut and colored to make all kinds of paper products.

[Kate] Hi, my name is Kate. I'm nine years old. I live in Essex Junction, Vermont. And my question is, what kind of trees give paper and why?

[Jane] Paper is mostly made from softwood trees like pines and fir these days because their cellulose fibers are long and thin, although sometimes hardwood trees are used in the mix. But as we heard from Carol Marie, all kinds of materials can be used to make paper, and that includes a lot of different kinds of trees. But actually, remember I said a lot of the paper we use in our daily lives was already paper before. It gets recycled and turned back into that pulp and it goes through the process again to be a new sheet of paper for you.

[Blake] Hi, my name is Blake. I'm six years old and I live in Vermilion, Alberta. My question is why does paper fall apart when it gets wet?

[Lucy] Hi, my name is Lucy, I'm 7 years old and I live in Salt Lake City, Utah. And my question is why, when you put paper in water, it gets all soggy and it is easier to rip up.

[Jane] we gave that question to our paper maker, Carol Marie Vossler.

[Carol Marie] The reason that paper falls apart, it's lacking the sizing. The paper I have here in front of you, this is a hemp sheet of paper made out of hemp. It's really strong and if I dipped it in water, it would not fall apart. It's because sizing was added and sizing is an adhesive finishing that keeps the paper glued together when it becomes saturated. And it's another cost, you know, cost way too much to size all the paper in just regular notebook paper or especially toilet paper. You don't want that to have sizing and you need it to dissolve and go away fast.

[Jane] The way I kind of think of it is that when you put paper in water, you're sort of reversing the process of how it got made in the first place. I mean, it's only paper because it's been squeezed together and dried out. If you soak it in water, it's going to eventually turn back into that soggy, pulpy mess. But that sizing that Carol Marie is talking about, the glue? One of its other jobs is to make the paper resistant to water so it doesn't absorb liquid as much. And as she said, some paper is designed to absorb water like a paper towel or toilet paper. But other paper is designed so that when you use a pen or a marker, the liquid in your ink sits on top of the paper and dries on the surface rather than sinking in. So, if you're left-handed like me and you find yourself smudging your writing all the time, you might need to find a paper that absorbs the ink or water a little bit more.

Here's a question from Andrew and his mom.

[Andrew] Child: My name is Andrew and I am three…

[Mother] why does the sun take the color away from construction paper?

[Jane] Andrew, the sun is very powerful, so when it shines directly on construction paper, it actually causes a chemical reaction in the dyes or pigments, the colors used to make the construction paper red or blue or green. That chemical reaction can cause the colors to reflect the sunlight differently and they look faded. But you know, you can do kind of a fun little experiment or art project by using the sun's power. Take some construction paper and place it outside in direct sunlight. So, make sure the sun is shining right down on it. And then use different shaped objects to cover parts of your sheet of paper. Like maybe use magnetic letters to spell out a word or put leaves and flowers on top of the paper in an interesting pattern. Leave it there. Come back in a few hours. Take the objects off your paper and see how much the sunlight faded the color where you didn't have the objects in just a couple of hours.

Our last question comes from Grant.

[Grant] I'm eight years old and I'm from Aurora, Illinois. My question is: who invented paper?

[Jane] Papermaking started in China well over 2000 years ago, and Cai Lun is the man who often gets credit for the invention. He was a servant in the imperial court. Other historians say there's evidence of other people making paper before that. But Cai Lun is credited with starting paper on its path to mass production. Now, it's important to note that people were writing long before we had paper. People wrote or painted on stone. They used bark to mark things down or dried animal skins. They used silk fabric to write on. But paper is hugely important as an invention because it's lighter, cheaper or more durable than a lot of the other materials that had been used before. And it could be mass produced. It could be made in bulk so that lots of people could have access to paper and lots of people could then write things down. Other cultures learned papermaking techniques from the Chinese, but for a long time, people still had to write each letter or speech or proclamation out by hand. Imagine if every book had to be written out by hand, word for word. Well, it just wouldn't be possible. So, the invention of paper inspired the invention of ways to mass produce writing, things like printing presses so you could use one printing press and make 75 or 75,000 books that look exactly the same. And that has had a huge impact on how humans live and communicate. Following paper's path around the world is like following world history. But what do you think the future of reading and writing and paper is? Do you think we'll even need paper in the future, or will everyone just use tablets to read and write and communicate?

Something to think about for sure.

So I'm going to leave you to contemplate that and end today's episode here. Thanks so much to Carol Marie Vossler at BluSeed Studio.

As always, if you have a question for "But why" about anything, have an adult help you record it. It's easy to do on a smartphone.

Then you can have your adult send the file to Questions@ButWhyKids.org. We'll do our best to get an answer for you. "But Why" is produced by Melody Bodette and me, Jane Lindholm, at Vermont Public Radio.

Our theme music is by Luke Reynolds. We'll be back in two weeks with an all new episode. Until then, stay curious.