ALICE LOWE: You are listening to Brains On.

BEATRIX LOWE: Where we're serious about being curious.

MOLLY BLOOM: Baking can seem kind of magical.

ALICE LOWE: You take a bunch of ingredients.

BEATRIX LOWE: Mix them together.

MOLLY BLOOM: Put them in the oven.

ALICE LOWE: And then a little time passes.

BEATRIX LOWE: And you have cake.

MOLLY BLOOM: Or cookies.

ALICE LOWE: Or bread.

BEATRIX LOWE: But there's no magic wand involved in the process.

ALICE LOWE: It's chemistry.

MOLLY BLOOM: Today we're going to learn all about the science of baking.

BEATRIX LOWE: Keep listening.

ALICE LOWE: Keep listening.

MOLLY BLOOM: You're listening to Brains On from NPR News and Southern California Public Radio. I'm Molly Bloom. I'm here with my two co-hosts today, sisters Beatrix and Alice from Minneapolis. Hello. Thanks for being here.

BEATRIX LOWE: Hello.

ALICE LOWE: Hello.

MOLLY BLOOM: Now, you both have been around baking your whole lives. Your mom is a professional baker. Can you tell me what is the first thing you remember baking?

BEATRIX LOWE: Cookies, I think.

MOLLY BLOOM: And what is your favorite thing to bake now?

ALICE LOWE: I really like baking cookies. I think it's really fun.

MOLLY BLOOM: And Alice, what is your favorite part of the baking process?

ALICE LOWE: My favorite part is cracking the eggs and beating them together.

MOLLY BLOOM: Why?

ALICE LOWE: Because it's fun to crack the eggs, and it's kind of fun of a challenge when you try not to get the egg, the outside in.

MOLLY BLOOM: Like, don't want to drop the shell into the batter? Yeah.

BEATRIX LOWE: You need to be careful of how much ingredients you put in there and what ingredients you put in there. Like if you want your cake or cookies to be crunchy with egg shells in them, that's fine, just I don't think I'd want that.

[LAUGHTER]

MOLLY BLOOM: That would probably not taste delicious.

BEATRIX LOWE: No.

MOLLY BLOOM: And Alice, what do you think is the hardest part of baking?

ALICE LOWE: I think the hardest part about baking is when you cook it because you don't want to cook it too high of a temperature or too low of a temperature, because if it was too low of a temperature, it would be all sticky and gooey, and if it was too high of a temperature, it'd kind of be burnt.

MOLLY BLOOM: So you have to take it out at the right time.

ALICE LOWE: Yeah.

MOLLY BLOOM: And what part of baking do you think is the most magical or that you have the most questions about?

BEATRIX LOWE: I think the most magical part of it is when it's halfway done baking, and it just smells really awesome.

MOLLY BLOOM: And it's hard not to open the oven.

BEATRIX LOWE: Yes.

MOLLY BLOOM: Well, I love baking too. But I have to admit, I didn't know anything about the science behind it before we started making this episode. And we were inspired to look into it by this baking question sent to us from Bloomington, Indiana.

ESME: Hi, I'm Esme, and I'm 6 years old. My question is, how do ingredients cook together?

BEATRIX LOWE: To find the answer, we spoke to Dave Dominguez.

ALICE LOWE: He's a food scientist at General Mills.

MOLLY BLOOM: He explained to us that all the different ingredients play important parts.

DAVE DOMINGUEZ: There's flour, there's shortening oftentimes, there's sugar, there's water, there's eggs, and each of those ingredients has a specific function in the baking cycle. And it's all about taking these raw materials and then transforming them into something else.

ALICE LOWE: First, you have flour.

MOLLY BLOOM: Flour is made by grinding up wheat, which is a plant.

BEATRIX LOWE: Flour provides starch and protein in your batter and dough.

DAVE DOMINGUEZ: So starch is basically sugar molecules that are all hooked together in a long chain. And the plant does that in order to store them away in these little granules called starch granules. The protein part, that's kind of like LEGOs that form structure in the bread and hold it together.

ALICE LOWE: Then you have shortening or fat.

DAVE DOMINGUEZ: It could be butter, it could be lard, it could be hydrogenated vegetable shortening, and it gives it a very short texture. That's why we call it shortening, because they crumble and come apart. And that, as the name implies, it helps shorten the texture because it interacts with the proteins and coats them and prevents them from getting too tangled.

I think of the proteins like knitting yarn-- my mother used to like to knit-- and how it all kind of mixes together and gets all tangled up. Well, those what the proteins do in the bread.

BEATRIX LOWE: Don't forget the egg.

DAVE DOMINGUEZ: So the egg's interesting because there's two components of eggs. You ever crack an egg? You get the egg white, and you have the egg yolk. And the egg whites have proteins, which are good for structuring and adding texture to your baked product. The egg yolk has a lot of interesting ingredients within it. It has a lot of fat, adds color, adds flavor.

But it also has a group of compounds. We call it emulsifiers. It's kind of a fancy word for the ability of these particular compounds to dissolve in water and fat. And so it helps mix things together very well.

MOLLY BLOOM: And you have perhaps the most important ingredient of all.

BEATRIX LOWE: The leavener.

ALICE LOWE: That's baking soda, baking powder, or yeast.

MOLLY BLOOM: We'll talk more about how they do this in a minute, but the basic function of leaveners is to create gas in the batter or dough.

BEATRIX LOWE: These gas bubbles are key.

MOLLY BLOOM: But they can't do their job without another very important ingredient.

ALICE LOWE: Heat.

DAVE DOMINGUEZ: Those bubbles, as they get hot, start to expand. So when they expand, you can see the bread start to rise. And actually, the word "leavening" comes from the word "levar," like "levitate," all those other words. It just means to rise or to lift and to raise. And so what happens with the heat, gases expand when they get hot, and so by adding heat, you're expanding the gases.

MOLLY BLOOM: Some recipes don't use baking soda, baking powder, or yeast to introduce gas. You can also simply whip your batter.

BEATRIX LOWE: That's when you stir together your ingredients in a way that adds bubbles of air.

ALICE LOWE: Which is basically more gas that expands when it heats up.

DAVE DOMINGUEZ: The early part of the baking cycle is just heating. We call that oven spring. And so then it's just the gas expanding in that batter or dough system. Then you run into a process where there's a whole class of active little molecules in all of us called enzymes. And these enzymes are very interesting because they perform all sorts of interesting functions.

And there are these enzymes that are in the dough that start to take the long starch molecules, which are all the sugars hooked up together, and they start clipping them apart. And that in turn affects what we call the viscosity or how runny or how thick the batter is, and it makes it a little less so that it can start expanding a little more.

BEATRIX LOWE: The starch goes through a transformation too.

DAVE DOMINGUEZ: What happens is that as you start heating it up, they're kind of damaged, and they start to absorb water, and they go through a transformation, a change called gelatinization. They get kind of jelly-like. And when the starch gelatinizes, the structure can't expand anymore. It just stops. And then the structure is set.

And then what happens as it gets warmer is that the proteins that are in there actually denature. And when the proteins denature, the little films around those bubbles become rigid, and then the gas expands, but it can't expand anymore, and they actually rupture. And that's when you form your crumb.

And then what happens, then you get to the point of the baking cycle where the crust starts to dehydrate and you start browning.

ALICE LOWE: Browning tells you when your baking is almost done.

BEATRIX LOWE: And it's another cool reaction where the dough actually changes color and creates new pigment.

DAVE DOMINGUEZ: Well, there's a whole series of reactions. So when the sugars start to react with one another, it goes to this long, complicated process in which they form all these intermediate compounds. And at the very end, they form pigments called melanoidins. Kind of like melanoidin pigments in your skin. Same kind of class of compounds.

And depending on the nature of the sugar, the type of melanoidin formed has a different color. And it happens at different temperatures because the different sugars have different melt points and reactivities.

MOLLY BLOOM: Now, did you guys realize that when you're baking, you're becoming chemists?

ALICE LOWE: No.

MOLLY BLOOM: Before we learn about leavening, we have an important task to take care of. It's time for the mystery sound.

[ELECTRONIC STINGER]

SPEAKER: (WHISPERING) Mystery sound.

MOLLY BLOOM: We're actually going to have two mystery sounds this episode. Here's the first one.

[WHOOSHING, THUMPING]

Any guesses?

ALICE LOWE: I think it's a waterfall.

MOLLY BLOOM: A waterfall. How about you, Beatrix?

BEATRIX LOWE: I have no idea.

[LAUGHTER]

MOLLY BLOOM: Well, it's something having to do with baking. Do you want to hear it one more time since it was kind of short?

[WHOOSHING, THUMPING]

OK, Beatrix, any other guesses?

BEATRIX LOWE: The sound of a mixer, maybe?

ALICE LOWE: I think it's actually of the thing that can grind it up really fast. Something that you can use to make some ingredients soft.

MOLLY BLOOM: That's a good guess. Here is the answer.

KELSEY MCCREIGHT: That was the sound of the oven steam. Hi, I'm Kelsey McCreight, and I'm a baker here at Rustica Bakery. It is used in order to prevent the crust from forming on the bread too quickly so that the air bubbles can expand and the loaf reaches its full potential.

By providing moisture on the outside of the loaf, it doesn't dry as quickly and solidify. And that way, the gas has the chance to fully expand. Otherwise, sometimes the loaf will blow up or split right down the middle.

MOLLY BLOOM: So that was the sound of steam coming out of the oven. So they have a little device where steam fills the oven to prevent the crust from forming too soon. Stay tuned for our second mystery sound and another chance for guessing in just a bit.

BEATRIX LOWE: Do you have a question you want to hear answered on Brains On?

ALICE LOWE: A mystery sound to share?

MOLLY BLOOM: Or maybe you just want to send us a high five or a drawing.

ALICE LOWE: Email us.

MOLLY BLOOM: We're at brainson@M, as in Minnesota, PR.org.

ALICE LOWE: By the way, have you signed up for our newsletter?

BEATRIX LOWE: That's where we talk about new episodes, live events, and cool science stuff to check out.

MOLLY BLOOM: Also, real soon we're going to have contests there where you can win stuff like your very own Brains On whoopee cushion.

[WHOOPEE CUSHION FARTS]

[LAUGHTER]

I have one in my hands right now. It's silly and fun and could be yours. We'll have details on entry in the contest in our newsletter, but first, you need to sign up at brainson.org.

Now's the time in every episode where we highlight the awesome kids who keep this show going with their curious questions.

ALICE LOWE: Magical mystery sounds.

BEATRIX LOWE: And hearty high fives.

MOLLY BLOOM: Here's the most recent group to be added to the Brains Honor Roll.

[LISTING HONOR ROLL]

[THEME MUSIC] Brains On [INAUDIBLE].

ALICE LOWE: You are listening to Brains On.

BEATRIX LOWE: From NPR News and Southern California Public Radio.

ALICE LOWE: I'm Alice Lowe.

BEATRIX LOWE: And I'm Beatrix Lowe.

MOLLY BLOOM: And I'm Molly Bloom. Today we're exploring the science of baking.

BEATRIX LOWE: To find out more about how yeast works, we're going to go right to the source.

CATHY: Welcome back to Cooking with Cathy. Our next guest is someone who knows me very well. Almost as well as she knows her baking. Please give a warm oven welcome to my sister, Belinda.

[APPLAUSE]

BELINDA: Thanks, Cath. What a pleasure to be here to share my baking expertise with your lovely audience.

CATHY: [LAUGHS] Great. No one calls me Cath anymore. Well, let's get this over with. I mean, let's get this show on the road.

BELINDA: Now as you can see on the counter, I have sliced up a loaf of bread. You guys want to try some?

[APPLAUSE]

You can do better than that. Now, do you guys want to try some of this delicious bread?

[APPLAUSE]

You get a slice, and you get a slice, and you get a slice.

CATHY: Yes, Belinda. Everybody loves bread.

BELINDA: Did you know that this bread started out as a tiny ball of dough?

[GASPING]

It's true. And today, one of my oldest pals has agreed to join us and tell us what it takes to turn that dough into bread.

CATHY: Jill, you let Belinda book her own guest?

JILL: [MUMBLING]

CATHY: We'll talk about this later, Jill.

BELINDA: What do you think? Should I bring them out?

[APPLAUSE]

OK, then. Give it up for my dear old pal Yancey Yeast.

YANCEY YEAST: Hey, there, Belinda. Nice to see youse again. Cathy, long time.

CATHY: Oh, hello, Yancey.

BELINDA: I met Yancey when I baked my very first loaf of bread.

YANCEY YEAST: That's right. You were what, 10 or something?

BELINDA: Actually eight.

YANCEY YEAST: Eight years old. Whoa. We've been working together a long time. But you want to know something there, Belinda? I keep coming back because you feed me so well. I mean, where else is a little fungus like me going to get so much to eat?

BELINDA: Why, I don't know what you're talking about. Seriously, you guys, all I do is give Yancey a little flour and water, sometimes a little sugar.

YANCEY YEAST: Flour, water, and sugar. Get a load of that. She's only talking about my all-time favorite meal. And then warm me up a bit, and I'm set.

CATHY: Isn't Belinda the best?

YANCEY YEAST: Oh, you better believe it, Cath. Once I get going, I chow down on the sugars and naturally produce some byproducts along the way, the most important being good old CO2.

CATHY: Carbon dioxide.

BELINDA: What a gas.

YANCEY YEAST: And the flour and water make a perfect sticky wall that traps those gas bubbles. In the oven, the gas bubbles expand, causing that dough to rise even more.

CATHY: Well, we appreciate you being here, Yancey. But that's not the only way to get doughs or batters to rise. That's why I've invited my special guests, Baking Soda and Baking Powder.

[APPLAUSE]

BS and BP, thanks for being here. BS and BP, thanks for being here.

YANCEY YEAST: Cath, I don't think you're going to get much in the way of conversing from the likes of them two.

CATHY: Excuse me?

BELINDA: Unlike our pal Yancey here, those two aren't alive.

CATHY: Oh, dear.

YANCEY YEAST: I'm a microorganism, baby. Those two, well, they're just chemical compounds. Sorry, toots.

CATHY: Oh. Just when I was finally about to figure out what the difference is between those two.

BELINDA: Well, I can help you with that. Baking soda is sodium bicarbonate.

YANCEY YEAST: Yeah. Salt and CO2 stuck together.

BELINDA: Baking powder is a sodium bicarbonate combined with an acid added to it, which causes a reaction.

YANCEY YEAST: So baking soda needs other ingredients to react. But baking powder is a one-man show.

BELINDA: When they react, they release CO2 bubbles into the batter.

YANCEY YEAST: Just like me and my fellas. Yeast in the house.

BELINDA: But they're not alive.

YANCEY YEAST: Indubitably. And far less interesting conversationalists, I might add.

CATHY: Well, thank you so much for being here today, Belinda and Yancey. We've all learned so very much.

YANCEY YEAST: Any time, Cath.

BELINDA: After the break, I'll show you how to make Cath's favorite cookie-- chocolate crinkles.

CATHY: That's your favorite cookie, Bel. I like snickerdoodles.

BELINDA: Stay tuned for more Baking with Belinda.

CATHY: Cooking with Cathy.

[APPLAUSE]

BELINDA: Who wants more bread?

MOLLY BLOOM: So are you guys ready for that second mystery sound?

[ELECTRONIC STINGER]

SPEAKER: (WHISPERING) Mystery sound.

MOLLY BLOOM: Here it is.

[RUSTLING, SQUEAKING]

Any guesses?

BEATRIX LOWE: I think the ending, I think those clanging of pots and pans, maybe.

MOLLY BLOOM: OK, so you think you heard some pots and pans in there.

BEATRIX LOWE: Yeah, and I have no idea what in the world that squeaky sound was.

MOLLY BLOOM: Alice, do you have any guesses about the squeaking?

ALICE LOWE: Uh-huh. I think the squeaking was either a whoopee cushion or a balloon.

MOLLY BLOOM: OK, a balloon or a whoopee cushion and some pots and pans. You guys ready for the answer?

ALICE LOWE: Mm-hmm.

MOLLY BLOOM: Here it is.

NATE HOUGE: That's the sound of bread degassing. So it's come out of the first rising, the first fermentation, and the gluten structure has captured air. And when you form the bread into a loaf, you're squishing it down, forming it, and that's the air escaping through the gluten. So it's like popping little balloons. I'm Nate Houge, and I'm a baker at Brake Bread.

MOLLY BLOOM: So you were not that far off when you thought about balloons squeaking, because it's basically little balloons of gas. So I think you were pretty close on that one. Now when most of us bake with yeast, we add it to our dough from little packets or jars usually.

BEATRIX LOWE: But wild yeast is actually everywhere.

ALICE LOWE: And you can bake with that too.

MOLLY BLOOM: It's that wild yeast that likely led to the discovery of baking tens of thousands of years ago. Ken Albala, director of food studies at the University of the Pacific, is here to tell us about how humans stumbled upon the coolness that is baking.

KEN ALBALA: People have been using fire and cooking grain in it long before wheat was domesticated. Probably a good 10,000 or 20,000 years before people gathered wild grains and ground them.

So if you just add water to that and leave it around for a while, yeast will naturally attack the dough, and so will lactobacillus bacteria. And that will cause it to get a little sour and to rise. And if you put that on a hot surface, you have a nice flat bread.

If you go to some of the really early sites in the Middle East like Catalhoyuk in Turkey or Jericho or places like that, there are pretty rudimentary ovens that are built into each house. So in the corner you'd have a little mud oven with a hole leading outside for the smoke to go outside.

You could start a fire in there, take out the ashes, put in a bread or something, and just close up the door on the thing, and you're basically baking. So we have pretty complete ovens and grinding stones in the same place, and usually a storage area where you keep wheat. So it's clear that that's like a little household bakery. That's like 10,000 years ago, so around 8,000 BC.

Flatbreads probably come before because you don't need any technology to do that at all. You can literally put up a rock on a set of hot coals and just cook right on top of that. And I think by the time you have clay technology, people will generally be able to store much more grain, and not just collect it, but also save some and plant it nearby so you don't have to wander off and gather it. The moment you have stored grains, you can grind them. That means you've got flour. And once you have flour, you can bake very easily.

There's probably no inventor of risen bread. There are a lot of theories. People think maybe they were making a porridge and left it out and it became sour. And it does actually happen spontaneously. It's not even like it's really a human process. Humans help a little in the whole thing, but it's nature that does the fermentation. It's the lactobacillus and the yeast that really do the whole thing. So probably bread is an accident.

ALICE LOWE: Baking is all about chemistry.

BEATRIX LOWE: You mix a bunch of ingredients, add heat, and let the reactions do the work.

MOLLY BLOOM: Turning your batter or dough into delicious baked goods.

ALICE LOWE: Gas bubbles in the batter expand when they get hot.

BEATRIX LOWE: Causing it to rise.

MOLLY BLOOM: The bubbles are trapped by the other ingredients, which create a structure to hold in the gas.

ALICE LOWE: And deliciousness.

MOLLY BLOOM: That's it for this tasty episode of Brains On.

BEATRIX LOWE: This episode was produced by Marc Sanchez, Sanden Totten, and Molly Bloom.

MOLLY BLOOM: Many thanks to Mike [INAUDIBLE], Holly Nolan, Stuart Bloom, Anna [? Weigel Reed, ?] Micah Taylor, and Dave Dominguez.

BEATRIX LOWE: To listen to past episodes, head to our website, brainson.org, or listen in your favorite podcast app.

MOLLY BLOOM: And if you're a fan of Brains On, consider leaving a review in iTunes.

ALICE LOWE: It really helps other kids and parents find the show.

BEATRIX LOWE: You can also keep up with us on Instagram or Twitter.

MOLLY BLOOM: We're at brains_on.

ALICE LOWE: And we're on Facebook too.

MOLLY BLOOM: We'll be back soon with more answers to your questions. (ALL) Thanks for listening.