RORY: You're listening to *Brains On,* where we're serious about being curious.

KELLY BARNHILL: In the beginning, there was only bog and bog and bog and bog. There were no people, there were no fish, there were no birds or beasts or mountains or forest or sky. The bog was everything. And everything was the bog. But the bog was lonely. It wanted eyes, with which to see the world. It wanted a strong back, with which to carry itself from place to place, to place. It wanted legs to walk and hands to touch and a mouth that could sing.

And so the bog created a body, a great beast that walked out of the bog on its own strong boggy legs. And the Beast was the bog and the bog was the beast and the beast loved the bog and the bog loved the beast, just as a person loves the image of himself in a quiet pond of water and looks upon it with tenderness.

MOLLY BLOOM: That's an excerpt from the book, *The Girl Who Drank the Moon,* read by author, Kelly Barnhill. Rory, how did that passage make you feel?

RORY: I could definitely picture in my mind what she was saying.

[MUSIC PLAYING]

MOLLY BLOOM: It's amazing how something can go from one person's imagination to words on a page, back into another person's imagination and still stay so vivid. That's the magic of a book. We'll be exploring that today.

RORY: What happens in your mind when you're reading words on a page?

MOLLY BLOOM: They're all written by another person.

RORY: And how is this thing we call a book even made?

MOLLY BLOOM: You're listening to *Brains On* from American Public Media. I'm Molly Bloom, and with me today is 11-year-old Rory House from Charlotte, North Carolina. Hi, Rory.

RORY: Hi, Molly.

MOLLY BLOOM: So what have you read that sticks with you, like a particular book or a scene or a character?

RORY: When I was little, I loved *Charlie and the Chocolate Factory.* That was my favorite book. And it still probably is one of my favorite books today.

MOLLY BLOOM: What do you think about that book was so sticky in your brain?

RORY: Probably just the whole concept of it. It seems so whimsical and so fun.

MOLLY BLOOM: And have you ever thought about whether, if you and a friend are reading that same book, if you see it differently in your head?

RORY: Yeah, so me and my friend are reading the same series. So I've always wondered, "hey is she thinking about this book differently than I am?"

MOLLY BLOOM: And are you guys seeing it differently?

RORY: We're mostly seeing it the same, but mostly where our character likes and dislikes are becoming different.

MOLLY BLOOM: Interesting. And have you written fiction yourself ever?

RORY: Yeah. So when I was little, I wrote a book-- not a book, but a story about how a turtle was born without a shell and it went on an adventure to try to find its shell.

MOLLY BLOOM: I love that.

RORY: The turtles name was Charlie.

MOLLY BLOOM: Did the turtle find its shell?

RORY: I didn't get to that part actually.

MOLLY BLOOM: Still a mystery.

RORY: Still a mystery.

MOLLY BLOOM: So it's a little strange when you think about it that a book, those ideas and characters, even worlds exist on these flimsy, thin sheets of paper. So how exactly is this miraculous thing made anyway? We've got a lot of questions about this.

LAURA TREND: My name is Laura [? Trend, ?] I am 10 years old and I live in Dallas, Texas. My question is, how do people make books? I really like reading and learning about new things.

MARK SANCHEZ: Excellent question.

MOLLY BLOOM: Agreed. *Brains On* producer, Mark Sanchez, joins us now to flip through the pages of book making.

MARK SANCHEZ: Yeah, and to help out, I made a History of Books Mixtape. Let's fire it up.

[MUSIC PLAYING]

(SINGING) Let's turn the pages of books from the ages from cover to cover, it's time to discover.

In the first century, the Chinese discovered how to make paper. They took bark from Mulberry trees, pounded it flat and soaked it in water until its fibers began to loosen. Then they took those fibers, or pulp, and laid them out onto a piece of fishing net or old cloth. They pressed the water out. And as they did that, the fibers stuck together in a sheet. A little more drying and, paper. The same basic concept for making paper holds true to this day.

[MUSIC PLAYING]

Moving forward about 500 years, people in India and Indonesia made books from slender palm leaves. These were used to document things like math, art and the stars. Picture a bunch of thin rulers, stacked one on top of the other and bound together with string.

(SINGING) We're planting trees and other natural resources. Many cultures made books about their lives before us.

[MUSIC PLAYING]

So we still don't have a modern book, but the Romans brought us one step closer. They used skins of sheep and lambs for their pages. These sheets were cured and stretched and scraped. So they ended up smooth and thin and excellent surface for writing on. Now take one of these skins, fold it in half, then fold it in half again, then fold it in half one more time. You end up with 16 folded pages, front and back. A folded group of pages like this is known as a signature. The Romans found that they could bind multiple signatures together with cords to make longer books. And guess what? This process is still being used today, props to you, Romans!

[MUSIC PLAYING]

(SINGING) Oh, the pages make a signature. Books are growing up. Yeah, they're getting mature. Books.

One thing to keep in mind is that all of the books you've heard about so far were written out by hand. Books were scarce and expensive and only about 5% of the population even had access to a book in the Middle Ages. Personal libraries were considered huge, even if they only had five books in them, which makes sense because back then, it took years to handwrite just one single copy of a book.

[MUSIC PLAYING]

(SINGING) My hand is cramped from writing all day. I do love books, but there has to be a better way.

A better way was on the way, thanks to Johann Gutenberg. It was the mid 1400s in Germany and Gutenberg wanted a faster way to make books. He perfected something called the printing press. This wooden machine pressed paper down onto metal letters covered in ink. This put words on paper much more quickly than handwriting then. And this process was, wait for it, repeatable. Wave goodbye to handwriting pages and pages. And while your hands up there, why not give Gutenberg a high five?

[MUSIC PLAYING]

In the 50 years leading up to the printing press, they were able to handwrite only about 20,000 books across Europe. Over the next 50 years after Gutenberg's invention, 12 million books were printed. All of a sudden, almost everybody had access to books, which meant they had access to knowledge and each other's big ideas. This boom of books changed the world. It brought people from the Middle Ages into modern times.

[MUSIC PLAYING]

(SINGING) Let's turn the pages of books from the ages from cover to cover, it's time to discover. Books.

MOLLY BLOOM: Whoa. I feel like I just stepped out of a time machine.

RORY: Well, there's still one more page to turn on this trip.

MOLLY BLOOM: Come with us now as we take a little field trip to a modern day printer.

JEFF BAKER: My name is Jeff Baker. I work for the Avery Group at [INAUDIBLE] Printing. And we make books. Designers usually come to us with an idea. They take content, which could be essays, images, diagrams. That design is proofed and edited numerous times before it is finally blessed to go into Print production. Once we have approval to proceed to press, we make something called "plates".

This is a metamaterial roughly the size of a kitchen table that is wrapped around cylinders on a press. There's a series of cylinders and rollers and a press. And the first set of rollers, which are maybe a little bit smaller, a little bit more the size of a baseball bat, will take ink out of a ink fountain, or a container of ink and allow that ink to travel down from roller to roller. Those rollers would then ink up that plate that we wrapped around that large cylinder.

That cylinder and that plate will then transfer to what we call a blanket, which is a softer material, not like the blanket on your bed, but almost more like a rubber mat. And it's got a little bit of softness to it so that it can take an impression from the cylinder. That blanket then would transfer the ink and the image onto a piece of paper. And this isn't an 8 and 1/2 by 11 piece of paper that you put through your printer at home, this is a large, 3 foot by 4 foot piece of paper.

The image that's being transferred from plate to blanket to paper is the words, the images, all of the content that designer designed to now create this book. So we've printed the sheet, both sides. It sat and it dried. And now we're ready to start into post-production. Like I said, we have this very large sheet, the size of your kitchen table. But your book is much smaller. It's something that you can hold in your hands. So we need to fold that sheet.

If you would take just any sheet of paper and fold it in half once. In half again. And in half a third time. You now, by folding three times, have taken that large sheet of paper into a signature. And although there's folds on top and the side of that folded sheet or folded signature, if you would trim the top off and the face off, you would now be able to flip through and see 16 pages.

MOLLY BLOOM: OK, Rory. I want us to try to make a signature now.

RORY: OK.

MOLLY BLOOM: So let's fold our piece of paper in half.

[PAPER CRACKLE]

Now fold it in half again.

[PAPER CRACKLE]

OK. Now we're going to fold it in half one more time. So now, you hold it up. How would you describe it, Rory?

RORY: It's basically just mini book.

MOLLY BLOOM: Yeah, so if you hold it so that basically the spine of the book is on the left hand side, you can open it. And it's like a little book and you can notice that on the top, there are folds. And on the right hand side, there are also folds. And if you cut those off, then you will have magically a 16 page mini book. You can write your story about your turtle who's missing its shell.

[CHUCKLE]

OK. Let's get back to Jeff at the printing press.

JEFF BAKER: The pages are placed out of order on the big sheet because once that sheet has folded down, those pages will all of a sudden, be placed in the correct order. And we use a piece of equipment called a folder that actually has another series of rollers and plates that allows the sheet to travel through and fold exactly where we want it to. Now most books aren't just 16 pages. You might have 10 forms of 16 pages, or 10 sets of 16 page signatures. The next step is to bind those together to make the book.

RORY: Sometimes this is done with glue. That's called perfect bound.

MOLLY BLOOM: And sometimes it's done with needle and thread. This is called smyth sewn.

JEFF BAKER: Take a bird's eye view of the top of the book. If you see trimmed pages, no faults, and a lot of glue, that book is perfect bound. If you see all the folded edges of the spine of each signature and less glue, it's probably smyth sewn. If you want to double check it's smyth sewn, page through the signatures. See if you can find the center sig. If you find that center sig where it lays the most flat, you'll notice that there is actually about an inch long pieces of thread that are sewn through the book.

[MUSIC PLAYING]

MOLLY BLOOM: Let's put a bookmark in our episode for a minute. It's time for the Mystery Sound.

SPEAKER 1: (WHISPER) Mystery sound.

MOLLY BLOOM: Here it is.

[UNINTELLIGIBLE ROBOT VOICE]

256 novels.

Any guesses?

RORY: I have no idea.

MOLLY BLOOM: Let's hear it one more time.

[UNINTELLIGIBLE ROBOT VOICE]

256 novels.

RORY: Is that a typewriter?

MOLLY BLOOM: Excellent guess. We will be back with the answer in just a bit.

[MUSIC PLAYING]

Do you have ideas you want to share with us? You can send those to us at brainsOn.org/contact.

RORY: Your ideas and energy make this show possible.

MOLLY BLOOM: And in order to thank all of you, we started the Brain's Honor Roll.

RORY: That's where we list the kids who've sent us mystery sounds, drawings, high fives, and questions, like this one.

KYLE: Hi, I am Kyle from Tennessee. My question is why do turtles walk so slow?

RORY: That's a good question.

MOLLY BLOOM: It is a good question, right? We'll answer that question during our moment of "um".

RORY: And give a shout out to the latest group of inductees to the Honor Roll.

MOLLY BLOOM: That's all at the end of the show. Stay tuned.

[UPLIFTING MUSIC PLAYING]

RORY: You're listening to *Brains On.* I'm Rory [? Howes. ?]

MOLLY BLOOM: And I'm Molly Bloom. Today, we're getting a read on books. And in order to read books, we need to use our brains. And our brains are really complex computers. They're constantly sorting out the zeros and ones of life, which brings us to this question sent in by Noraina from Mount Laurel, New Jersey.

NORAINA: My question is, what goes on through our brain when we're reading?

BEN BERGIN: Gosh, a whole lot.

RORY: Ben Bergin heads up at the language and cognition lab at UC San Diego. His research includes looking at how we give meaning to words while we read. So we invited him here to be with us today. Hi, Ben.

BEN BERGIN: Hi, there.

RORY: What happens in your brain when you're reading?

BEN BERGIN: Well, we know at least what you have to do is you have to recognize the letters first. And there are parts of the brain that are responsible for that. And after we've recognized the letters, we start to match them to sounds and we start to match them to words. And then finally, you've got to figure out what those words mean. So you've recognized a word, another word, a third word, but you've got to put them together in some way so that they make sense to you so that you can figure out what the person who is writing actually meant. And that's the hard problem of meaning.

RORY: What area of the brain do we use while reading?

BEN BERGIN: Almost all of them. We use parts of the vision system. That's at the back of the brain in the occipital lobe mostly to just see the letters and recognize which letters they are. We use parts of the temporal lobe, which is the lower side of the brain, kind of by your ear, to identify what sounds those letters correspond to and what words they play a part of. We use the emotional centers of the brain. The amygdala, for example, to create the emotional experiences so that we can figure out, oh, that person felt disgusted and this is what it felt like. We use the motor parts of our brain in the frontal lobe to create the experience of what it would be like to do the things that people are described as doing. So if you read about someone who's chasing through a forest, trying to get away from a big cat or a predator or something like that, you may imagine what it's like to feel the experience of running.

RORY: When you're reading, why do you sometimes visualize what's happening in your story?

BEN BERGIN: Well, in part because you can't help but do it. Part of figuring out what the words mean is-- and maybe not intentionally, but certainly quickly and fluidly activating images of what those things that are described would look like, what the things described would feel like, what they taste like, what they'd sound like. That's just part of the process. Now we don't know exactly why we do it. It could be that it's useful for certain things. So if I want to figure out how the cat escaped from the mail chute and there's a bunch of language describing it, it might not make sense to me until I sort of figure out, well, let's see. The front paws could have gone over the lip of the mailbox like so. And then it could have pushed with its little back feet quickly just enough to edge itself over the top. If I imagine that in my mind's eye, it might be easier to get a feel for exactly how that worked.

RORY: Do certain words in grammar have different effects on your brain than others?

BEN BERGIN: Oh, most definitely. When you read words that are very emotional words, very positive words or negative words that make you angry or frustrated or happy, those words affect your brain quite differently. They release a series of responses where your brain recreates an experience that's like what you would have experienced in the first place. So if you really don't like sewage and you think sewage is a really gross thing, when you read the word sewage, the parts of your brain that create an experience of disgust start firing. And you obviously, don't have the same reaction in your brain when you read a word like, unicorn, unless for some reason, you really don't like unicorns.

[LAUGHTER]

MOLLY BLOOM: I like unicorns.

RORY: Who doesn't?

MOLLY BLOOM: So when you're talking about painting a picture when you're reading, how exactly are you doing that in your brain?

BEN BERGIN: Well, you start at the bottom and you start at the top. At the bottom is the words that you're reading. So there is a word like "cat" and a word like "mailshoot", and you have associations with those words. You've lived a life of experiences where you've seen cats. And the same with mailshoots. So you use those experiences and the words also from the bottom up, tell you how to put them together. So the grammar of a sentence will say something like, "the cat jumped into the mailshoot", or "the cat climbed out of the mailshoot". Those little grammatical words, "into", and "out of", they tell you about how to put things together in a new way. And this is where you use, not the bottom up, but the top down. You know lots of things that are reasonable for cats to do and things that are unreasonable for cats to do.

So you know things about cats that you've brought from all of your experiences and you use that top down knowledge to say, what's the most likely thing that it could mean for a cat to climb out of a mailshoot? Well, probably it crawled out head first. And probably it used its front paws to pull itself out. And that wasn't in the sentence. That wasn't in the words. That was in what you know about the world. So you're combining the words with what you know about the world to construct a new scene that you think is your best guess of what the language is trying to tell you.

RORY: That's interesting. Thanks for being here.

BEN BERGIN: It's my pleasure. So much fun.

MOLLY BLOOM: So Rory, what's going on in your head when you're reading a good book and you're trying to imagine what's happening with a particular character?

RORY: I'm trying to put myself into that character's point of view and say, "hey, why are they doing this?" OK, if I were this character, this is why I'd be doing this, but I'm not sure if this is why this character is doing this.

MOLLY BLOOM: Yeah, it is tough to predict what happens next. And there is so much to think about on every page. We caught up with some kids at Wild Rumpus Books in Minneapolis and asked what goes through their heads too.

HENRY: I feel like I'm basically reading the book, I feel like I'm inside it.

JULIANNE: I usually hear just like the voices of the characters, I try to picture what their voice might sound like.

VIRGINIA: I see the characters face emotions and them getting surprised and scared at different parts of the story.

ODEN: And pretty much imagining what it would be like to see it from a third person view.

HAILEY: Usually in the person, I see what they look like, what their eye color is, their hair, where they are, like a school, I imagine what the school looks like. Is it a big building? A new building? An old building?

CHINO: I see like the characters and things coming alive, like making a movie.

HAILEY: I feel kind of like I'm a spectator in the stuff going on in the book.

MOLLY BLOOM: Thanks to Henry, Julianne, Virginia, Oden, Hailey and Chino for letting us in on what they're thinking when they read. OK, Rory. Let's get back to the sound you've been trying to guess. Are you ready for the reveal?

RORY: Yes.

MOLLY BLOOM: Let's give it one more listen.

[UNINTELLIGIBLE ROBOT VOICE]

256 novels.

RORY: I was thinking it's a typewriter, but now I'm thinking it's, like, an audio book?

MOLLY BLOOM: Oh, excellent guess. Here is the answer.

DAVID GEORGE SANDOVAL: OK. My name is David George Sandoval. That sound you just heard was me typing on a Braille Note, or a Braille Note Touch. So this is one of the ways I would use Braille to type.

MOLLY BLOOM: So you were very close. Do you-- Rory, do you know what Braille is?

RORY: Isn't it, like, when you're blind, you have those bumps that help you read?

MOLLY BLOOM: Yes. Exactly. Braille is a written code for visually impaired people. It's a series of tiny pencil tip sized bumps laid out on a surface in specific patterns. Those patterns represent different letters, numbers are even words. And instead of reading letters typed on a page, people like David, who can't see, feel out these tiny bumps with their fingers to read what's written.

DAVID GEORGE SANDOVAL: I'm going to type in here, for example,

[UNINTELLIGIBLE ROBOT VOICE]

MOLLY BLOOM: Obviously, it would be hard to write in Braille. Just imagine trying to poke hundreds of tiny dots yourself. So David uses the Braille Note Touch.

DAVID GEORGE SANDOVAL: When I type, you will basically hear it speak all the characters that I typed.

MOLLY BLOOM: It's a small computer about the size of a hardcover book. It has eight keys and a space bar for typing and a strip of tiny plastic dots at the bottom that go up and down to make Braille sentences.

[UNINTELLIGIBLE ROBOT VOICE]

For David, hearing those sounds as he types on his Braille note is sort of like me seeing the words as I type on a computer. He can also play back what he's written to check it or he can use the strip of plastic dots to call up a sentence he wrote and read it back in Braille. He says he likes reading and even wants to write a book one day. He uses the Braille Note to practice.

DAVID GEORGE SANDOVAL: I write about stuff that goes on at school, or at home, or I usually will write about my feelings sometimes. So Braille, basically, allows me to write my journals, as mentioned. It also helps me with homework. It also helps me look at menus in restaurants because, of course, some restaurants will accommodate the visually impaired, like the Cheesecake Factory, for example. It also will allow me to look at articles that people sent me. So in a way, Braille can help me do a lot of things.

[UNINTELLIGIBLE ROBOT VOICE]

MOLLY BLOOM: We've been looking at books through the eyes of a reader. What we see, what we touch, what we feel and experience when we pick up a book.

RORY: But in order to read words, someone has to write them.

MOLLY BLOOM: Someone like author, Kelly Barnhill, who you heard at the very beginning of the show.

RORY: Kelly's latest novel, *The Girl Who Drank the Moon,* just won the 2017 Newbery Award.

MOLLY BLOOM: That's like the Oscar for books. A big deal.

RORY: She thinks about her words a lot. She writes and rewrites and rewrites again. And there's a lot going on in her brain that she's trying to help our brain understand.

KELLY BARNHILL: I have to do a lot of thinking about a book before I can start it. So for me, what that means is that all of my books start with a box, like an actual box. And I will just throw things in the box as I think about them. So I just have to be just quietly thinking and not really doing very much writing, and really, for about two years that I think about a book. And I think about the characters. I think about who they are. I think about what motivates them. I think about the texture of the language that I want to use, how I want a book to sound. And how I want a book to feel when you're saying it out loud because all of my books are designed to be read out loud.

Reading is an act of radical empathy that we see as another person sees, we hear as they hear, we feel as they feel, we think as they think. And it's a reminder that my own point of view is not the only one. And that is a totally radical idea, you know? And this is part of what we have to do as human beings. We have to be able to be another person so that we can stop being such selfish jerks. You know?

[CHUCKLE]

[UPLIFTING MUSIC PLAYING]

MOLLY BLOOM: People have been writing and recording their thoughts for thousands of years.

RORY: Johann Gutenberg's printing press made it possible for books to spread far and wide.

MOLLY BLOOM: As with books from the Roman era, books today are printed using folded sheets of paper called, signatures.

RORY: Our brains read those pages and learn how to put words and sentences together.

MOLLY BLOOM: We build off this to form meaning and stories.

RORY: And reading helps us see the world from different perspectives.

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

RORY: *Brains On* is produced by Marc Sanchez, Sanden Totten, and Molly Bloom.

MOLLY BLOOM: We had engineering help with this episode from Eric Stromset and Veronica Rodriguez. Special thanks goes out to Mark Barber, Debbie Ferguson, Mari Abrams, at the Braille Institute of America, Jana Pulliam, Don Leeper, Matt Howes,

RORY: 5A in St. Gabriel Catholic School in Charlotte, North Carolina.

MOLLY BLOOM: Jeff Jones, Lauren D., Collette Morgan at Wild Rumpus, Toki Wright.

RORY: And Sullivan and Connor [? Howes ?] from Charlotte, North Carolina.

MOLLY BLOOM: Now before we get to the Honor Roll, let's stop and take a moment of "um".

(IN UNISON) Um. Um. Um. Um. Um. Um.

Today's moment of "um" is brought to you by Kyle, who asked us, "why do turtles move so slowly?"

NICOLE: I would argue that they actually don't move so slow.

[MUSIC PLAYING]

Hi, my name is Nicole [? Musokova. ?] And I am studying how turtles move. If you just look at their speed in terms of meters per second or miles per hour, they're fairly slow. But if you look at it in their body length per second, on sand, they managed to run up to three body lengths per second, which is fairly fast. Now some of the things that are restricted them from going faster is their entire spine is fused into the shell. So they have no movement on the spine. All the propulsive forces come only from the legs.

They do try to make sure they don't flip. And they do try to do that by throttling their speed a little bit in order to not flip. So they do have a way of writing themselves, even though not all turtles are able to do that in the end. Although, it has been shown that sometimes their mates will help them to flip over again, or if they manage to get against a log, they can push themselves over.

But sometimes, when they end up on their back, that's their death sentence because they will never make it over. So to balance their large body, which is basically just a box with legs, they cannot get too imbalanced. So there is an upper limit on their speed, but they're not that slow to begin with.

[UPLIFTING MUSIC]

SPEAKER 2: Um.

SPEAKER 3: Um.

SPEAKER 4: Um.

MOLLY BLOOM: I'm going to move fast like a turtle as I read the most recent group to be added to the brain's honor roll.

[LISTING HONOR ROLL]

[MUSIC PLAYING]

We'll be back soon with more answers to your questions.

RORY: Thanks for listening!

(SINGING IN UNISON) Buh, buh, buh, buh buh, buh, buh, buh, buh, buh, Brains On!