INTERVIEWER 1: You're listening to *BrainsOn.*

INTERVIEWER 2: Where we're serious about being curious.

INTERVIEWER 3: *Brains On* is supported in part by a grant from the National Science Foundation.

KEN BLACKBURN: There are several secrets or real keys to making a paper airplane fly well. And really they're not secrets, because I'm going to tell you. My name is Ken Blackburn, and my job is working for the United States Air Force as an aeronautical engineer doing research on the next generation of air vehicles. But my passion is paper airplanes. I've been fortunate enough to set the Guinness Record for time in the air for paper airplanes four times.

The very first key to having a good paper airplane flight is starting with a good design. Some of the classics that we know, like the dart, are classic because they actually work.

[MUSIC PLAYING]

MOLLY BLOOM: If you've ever been on a plane, you know the drill.

ZORA WHITFIELD: Put the tray table up.

NAIROBI WHITFIELD: Make sure your seat isn't reclined.

MOLLY BLOOM: Fasten your seatbelt.

ZORA WHITFIELD: And get ready for takeoff.

NAIROBI WHITFIELD: The plane taxis down the runway, speeding up. And then--

MOLLY BLOOM: You feel the wheels leave the ground.

ZORA WHITFIELD: The plane continues to climb into the sky.

NAIROBI WHITFIELD: The cars and people and houses and trees get smaller and smaller.

MOLLY BLOOM: The captain comes on and lets you know that you've reached your cruising altitude.

ZORA WHITFIELD: This routine happens thousands of times every day.

MOLLY BLOOM: So although it's commonplace now, the idea of being able to fly a plane around the world, let alone across town, seemed like a fantasy not so long ago.

NAIROBI WHITFIELD: We're going to find out how planes work and how they were invented.

MOLLY BLOOM: And we've got some more great paper airplane tips, too.

ZORA WHITFIELD:	Keep listening.
MOLLY BLOOM:	You're listening to *Brains On* from American Public Media. I'm Molly Bloom, and joining us from Columbus, Ohio, our co-hosts Zora and Nairobi Whitfield.
ZORA WHITFIELD:	Hello.
NAIROBI WHITFIELD:	Hi.
MOLLY BLOOM:	Thank you for being here. Zara and Nairobi are here to help us answer a question that we've gotten from lots and lots of listeners.
JASON:	How does a wing on an airplane work?
AMINA:	How do airplane jets work?
TOMMY:	How do airplanes stay in the sky?
MOLLY BLOOM:	That was Jason and Simon from Bolton Landing, New York, Amina from Beirut, Lebanon, and Tommy and Lizzie from Muscat, Oman, asking those very popular questions.
ZORA WHITFIELD:	Humans have been trying to fly for a very long time.
NAIROBI WHITFIELD:	It's hard to know exactly how long, since we don't have any written records for all of human existence.
ZORA WHITFIELD:	But the first historical account happened around the year 1000.
MOLLY BLOOM:	[INAUDIBLE] strapped two pieces of wood to his arms like wings and jumped off a tall building.
NAIROBI WHITFIELD:	Needless to say, this didn't work. He died trying to soar like the birds.
ZORA WHITFIELD:	But that didn't stop others from trying pretty much the same thing.
MOLLY BLOOM:	Several people in Europe tried strapping wings to their arms.
NAIROBI WHITFIELD:	And sometimes their feet, too.
MOLLY BLOOM:	At least one was able to glide a short distance.
ZORA WHITFIELD:	But most attempts ended in injury.
	[CHIRPING]
MOLLY BLOOM:	Gloria Goldfinch, our friendly neighborhood bird, is here to explain what she has that we don't.

GLORIA GOLDFINCH: I've never spoken into a microphone before. Testing, testing. Is this on? You can hear me? Oh, good. OK. You may have noticed that we birds are designed just a bit differently than you humans. For one, our bones are hollow, which makes us much lighter. And when you add in our incredibly strong breast muscles and the design of our wings, we generate enough power to stay in flight.

And I know you've been eyeing my gorgeous feathers. And you're right, they do look good. But they serve a purpose. They help propel me through the air and steer, balance, and land. So any wings you strap to your arms are just a sad, pale imitation of what we have naturally.

MOLLY BLOOM: Thanks for taking pity on us, Gloria, and sharing your insight.

GLORIA GOLDFINCH: Absolutely any time. I love the sound of my own voice.

MOLLY BLOOM: So it takes a lot to fly. But why exactly is it so difficult?

NAIROBI WHITFIELD: That's because the ability to fly is the delicate balance of four forces.

ZORA WHITFIELD: Thrust, drag, lift, and weight.

MOLLY BLOOM: Thrust is the force pushing forward, and drag is the force pushing back.

NAIROBI WHITFIELD: Weight is the force pushing the object down, and lift is the force pulling it up.

ZORA WHITFIELD: Throughout history, there were successful attempts at getting off the ground.

MOLLY BLOOM: And staying off the ground.

NAIROBI WHITFIELD: Before the invention of airplanes--

ZORA WHITFIELD: There were hot air balloons.

MOLLY BLOOM: Which harnessed rising hot air to rise up and stay aloft.

NAIROBI WHITFIELD: And gliders.

MOLLY BLOOM: Which glide on air, but have no engine or source of power. Early gliders were difficult to control and couldn't go very far.

ZORA WHITFIELD: So what were the keys to finally getting a contraption off the ground that could be piloted and powered and controlled?

MOLLY BLOOM: Meet the Wright brothers, Orville and Wilbur.

RADIO ANNOUNCER: Ladies and gentlemen, the day was a long time in the making. But on December 17th, 1903, the Wright Brothers have done it. Their flying machine has flown.

ORVILLE AND WILBUR: Hooray!

RADIO ANNOUNCER: The Wright brothers' designed self-propelled aircraft left the ground and flew four separate times on that day, the longest of which lasted 59 seconds. Brother Orville was at the controls.

ORVILLE WRIGHT: That's me.

RADIO ANNOUNCER: The Wright Brothers have always been tinkerers, first with printing presses, then bicycles. They caught the aviation bug a few years ago and have been designing, testing, redesigning, and retesting ever since.

ORVILLE WRIGHT: We've had some setbacks along the way.

WILBUR WRIGHT: Some of our early gliders were, to put it bluntly, real duds.

ORVILLE WRIGHT: But we never got discouraged. Back to the drawing board. The wings alone were quite the undertaking.

WILBUR WRIGHT: We tested about 200 different wing designs in our wind tunnel.

RADIO ANNOUNCER: Very impressive. Leap ahead to 1904, and the Wrights have done it again. After more tweaks in design, they've flown in a complete circle this time.

WILBUR WRIGHT: 1 minute and 36 seconds.

ORVILLE WRIGHT: Huzzah!

RADIO ANNOUNCER: And then we come to 1905. Their third powered aeroplane.

ORVILLE WRIGHT: 24 and 1/2 miles in 39 minutes.

WILBUR WRIGHT: Only for us.

ORVILLE WRIGHT: To the patent office.

RADIO ANNOUNCER: Not an overnight success or a flash in the pan, Orville and Wilbur Wright, showing that working and reworking is what it takes for an idea to get off the ground.

MOLLY BLOOM: Zara and Nairobi, you know a little bit about what it takes to be an inventor. You've taken part in something called the Invention Convention. So Zora, can you tell us what that is? What is the Invention Convention?

ZORA WHITFIELD: Well, the Invention Convention is a program where kids are encouraged to invent based off of everyday problems that they observe and make an invention to solve those problems.

MOLLY BLOOM: What was your favorite invention you've done so far, Nairobi?

NAIROBI WHITFIELD: My favorite invention was Healthy Roots.

MOLLY BLOOM: What was that?

NAIROBI WHITFIELD: Well, it was a plastic pot liner that had tubes that wrapped around it. And the plastic pot liner would go inside of a pot where you kept your plants. And the tubes had holes inside of it so that when you poured water into the tube, the water would go through the tubes and come out of the holes, making sure that the entire plant got enough water.

MOLLY BLOOM: And what problem were you solving with that one?

NAIROBI WHITFIELD: Well, usually people think that either putting too much or too little water inside of the plant will help it grow. But actually, the entire plant needs to get the right amount of water, even water amounts.

MOLLY BLOOM: So how many versions of that invention did you have to do before you landed on one that you were like, OK, that works now?

NAIROBI WHITFIELD: I had to do three. The first one, when I poked the holes inside of the tubes, the holes were too small. And so hardly any water got out. And then the second one, I thought I didn't need the plastic pot liner. So I just put tubes around the pot. But I made the holes larger so that more water could get through. And the third one, I used the pot liner and made the holes larger.

MOLLY BLOOM: And so when you finally found that that worked, were you-- how'd you feel?

NAIROBI WHITFIELD: I felt really happy, because I finally got the right prototype.

MOLLY BLOOM: Nice. And Zora, what is your favorite invention you've made?

ZORA WHITFIELD: It was an invention called Pastry Perfection. And it was an aluminum pouch with a cotton grip handle that prevented you from burning your fingers on the side of the toaster.

MOLLY BLOOM: So tell me what that looks like.

ZORA WHITFIELD: It's like metal, except it's more of like foil. And it has a grip handle at the top. And it's like in a square shape so that you can put your pastry into a little pocket and then put it in the toaster.

MOLLY BLOOM: And then can you take it out with your bare hands?

ZORA WHITFIELD: You can take it up by the grip handle. And the aluminum, it does not conduct as much heat. Since it's thin aluminum. And so, you don't burn your fingers. It cools down really quickly.

MOLLY BLOOM: Like Pop Tarts? Is that what goes in there? Or what--

ZORA WHITFIELD: Yeah.

MOLLY BLOOM: Nice. Sounds--

ZORA WHITFIELD: Based off of Pop Tarts.

MOLLY BLOOM: Sounds delicious. And so which invention that you've worked on was the most frustrating, would you say?

ZORA WHITFIELD: An invention called Leave Em.

MOLLY BLOOM: What is that one?

ZORA WHITFIELD: I wanted to have an easier way to compost. So I made a biodegradable bag, which is a bag that breaks down with leaves and compost. It was supposed to go over a tree so that when the leaves fell, it could go inside of it. Except that idea didn't work because there's really tall trees.

MOLLY BLOOM: So it's hard to have a bag big enough.

ZORA WHITFIELD: Yeah. I had to put it around the base of the tree.

MOLLY BLOOM: And then so it still sounds like you brainstorm, design the model, make the model, and then test the model. And then what happens after the testing?

NAIROBI WHITFIELD: You do it again. Just try to make it better.

MOLLY BLOOM: Has there ever been a time where you've tested your first prototype and it's been perfect?

NAIROBI WHITFIELD: No.

MOLLY BLOOM: So there's always some problems to work out?

NAIROBI WHITFIELD: Yes. That would be great, but no.

MOLLY BLOOM: What advice do you have for kids who might want to try inventing something?

NAIROBI WHITFIELD: I would just say to use your imagination. And it's not that hard to look for problems in your everyday life. You just have to open up your eyes and ask people.

MOLLY BLOOM: That's excellent advice. How about you, Zora?

ZORA WHITFIELD: I would have to say that whenever you're having trouble with something and you're like, oh, I wish there was something better, don't wait for someone else to come up with a way to make it better. You just write that down and just think about ways to fix it.

AUDIO TRACK: Brains On!

MOLLY BLOOM: Before we get back to learning how planes fly, we have another challenge for you. It's time for the mystery sound.

[MYSTERY SOUND CUE]

AUDIO TRACK: Mystery Sound.

MOLLY BLOOM: Here it is.

[WHIRRING]

Any guesses?

ZORA WHITFIELD: It sounds like nature at night, with all the buzzing from the bugs.

MOLLY BLOOM: Good guess, Zora. Nairobi, do you have a guess?

NAIROBI WHITFIELD: A factory, maybe.

MOLLY BLOOM: Excellent. So we have nature and factory. I like that. So we're going to be back with the answer in just a bit.

KEN BLACKBURN: The second tip I have for a really good flying paper airplane-- make your folds really crisp, and to make all the folds very even. And one of the most common problems is that the creases were not made sharply and the wing becomes thick, and that adds drag. So symmetric, meaning that the wings are even length side. Sharp folds.

[MUSIC PLAYING]

ZORA WHITFIELD: Any questions you want to hear answered on *Brains On?*

NAIROBI WHITFIELD: A mystery sound you want to share?

MOLLY BLOOM: Or maybe you want to send us a drawing? You can send them to us at brainson.org/contact.

NAIROBI WHITFIELD: Or you can send us mail. You can find her address at our website, brainson.org.

MOLLY BLOOM: One question we really want to hear your answer to is this. What do you think it's like to travel through a wormhole? Now a wormhole is a place in the universe that connects two different spots. Maybe billions of light years away, or maybe just a few feet. They are just theoretical, which means they haven't been proven to exist yet. But we know that is no barrier for your imaginations. Send your wormhole travel fantasies to us at brainson.org/contact. That's the place where our fans share amazing questions like this one.

HILARY: What's the sourest thing in the world?

MOLLY BLOOM: We'll be back with an answer to that in our Moment of Um at the end of the show, and we'll read the most recent group of listeners to be added to the Brains Honor Roll. Keep listening.

KEN BLACKBURN: My third tip for a really good flying paper airplane-- and this is the one that most people don't know about-- are the flap settings. If you were a pilot in a real airplane and you wanted to keep your airplane from nosediving, you would pull back on the control wheel or back on the stick on the airplane. And what that does is the control surface, the flap on the very back of the airplane, it deflects up.

Every airplane behaves like a seesaw. So if you deflect the air off of the end, It's like pushing down on the back of the seesaw. And that makes the other end go up. The airplane is the same way. When you bend the back edge of your wing just a little bit, right, grab it between your fingertips and twist it at a slight angle, that deflects the air up off the tail of your airplane. And by pushing down on the tail, it lifts the nose and keeps it from nosediving.

And that's probably the single most important thing you can do to make your airplane fly really well.

MOLLY BLOOM: You're listening to *Brains On.* I'm Molly Bloom.

ZORA WHITFIELD: I'm Zora Whitfield.

NAIROBI WHITFIELD: And I'm Nairobi Whitfield.

MOLLY BLOOM: It's time to tackle that question.

ZORA WHITFIELD: How do you planes fly?

NAIROBI WHITFIELD: To start, you have to think of air as stuff.

MOLLY BLOOM: Even though it's invisible, air is made of gas molecules, and these have mass.

- Weighs about two pounds per cubic meter.

MOLLY BLOOM: Levitation engineer Casey Handmer thinks it's fun to picture that stuff being moved around by us and everything else that moves through the world.

CASEY HANDMER: And as you walk around, you don't really think about the air parting in front of you and going behind you. It may be a thing to imagine all the air moving around at all times. Like blowing in the window and going up the side of the mountain and being shoved out of the way by falling rain or flying over the wings or over the body of an airplane or around all the cars and whatever.

It will give you an appreciation for just how much the poor gas that surrounds our planet is shoved around by everyone and everything.

MOLLY BLOOM: What does an airplane have in common with shooting a basketball, wiggling your fingers, or even blinking? They all move air molecules.

ZORA WHITFIELD: Air is key to those four principles of flight we talked about earlier.

NAIROBI WHITFIELD: The rest, drag, weight, and lift.

MOLLY BLOOM: Ella Atkins, aerospace engineer from the University of Michigan, says we all know what drag feels like.

ELLA ATKINS: Whether they're in a soapbox racer or going downhill or on a bike that's just going really fast in the wind, basically that feeling, the air is pushing on you to push you back so that you can't go as fast as what you might be able to go if the air wasn't pushing on you.

ZORA WHITFIELD: The faster you go, the stronger the drag is.

NAIROBI WHITFIELD: So airplanes which are traveling very, very fast experience a lot of drag. Air is pushing against the plane.

MOLLY BLOOM: In order to overcome drag, you need thrust pushing in the opposite direction.

ZORA WHITFIELD: That thrust comes from a plane's propellers.

NAIROBI WHITFIELD: Or its jet engines.

MOLLY BLOOM: The wings of a plane, meanwhile, are what provide lift. Remember, that's the force that pulls up. Now there are a couple of concepts you need to understand in order to wrap your mind around a lift.

ZORA WHITFIELD: The first is from Sir Isaac Newton.

NAIROBI WHITFIELD: For every action, there is an equal and opposite reaction.

MOLLY BLOOM: This comes into play with the propeller and jets.

ELLA ATKINS: Well, a propeller is like a little wing that's tilted. So as it spins, it pushes the air back at a high speed, which in turn-- this is an equal and opposite reaction-- pulls the plane forward. And the faster you spin it, the more air is pushed back. So then the more that the plane is pulled forward. That's called thrust.

So a jet engine is very similar in that it's trying to push air out the back of the nozzle of the jet at as high a speed as possible. And it wants to do a large volume of air, because if you have a large velocity or speed of air and a lot of it, it has an effect of pushing you forward a lot. Again, an equal and opposite reaction overall.

ZORA WHITFIELD: And this comes into play with wings as well.

CASEY HANDMER: The propeller and the wing, they both work the same way. They take a bunch of mass-- in this case, air-- and they shove it down or backwards. And as a result, there's an opposing force produced against the wing or the propeller that moved the air out of the way.

NAIROBI WHITFIELD: The second concept key to understanding lift is from Daniel Bernoulli.

MOLLY BLOOM: The Bernoulli principle says that when the speed of a fluid increases, the pressure it exerts decreases.

ZORA WHITFIELD: Air also acts like a fluid.

NAIROBI WHITFIELD: When you narrow the path of air or water, it speeds up.

MOLLY BLOOM: So the shape of the wing narrows its path on the top, speeding it up and creating less pressure there.

ELLA ATKINS: If you look from the side view at a wing, it has a larger curved surface on top and a more flat straight surface on the bottom. That effectively, engineers figured out in wind tunnel tests over a century ago, that that gives you some lift, even if you don't tilt your wing very much into the wind. So that lift then is because the pressure on top is lower than the pressure on the bottom of the wing. And any time you have high pressure in a low pressure, it basically pushes toward the low pressure. Which again, is lifting the wing.

ZORA WHITFIELD: You need an off surface area on the wings to create enough lift.

NAIROBI WHITFIELD: That is why early flying machines were biplanes.

MOLLY BLOOM: They had two wings stacked on top of each other on each side.

ZORA WHITFIELD: Those early planes were mostly made of wood and fabric. Those materials weren't sturdy enough to support the single long wing on either side of the plane.

MOLLY BLOOM: Biplanes provided more surface area in a more stable fashion.

NAIROBI WHITFIELD: But as materials changed and lightweight metals became available, monoplanes became possible.

MOLLY BLOOM: Monoplanes are basically what we see today. One wing on either side of the plane. No more stacked wing design.

ZORA WHITFIELD: Better construction materials also allowed better and more powerful engines.

MOLLY BLOOM: Planes have evolved a lot from the slow experimental planes of the Wright brothers, to the big commercial jets we fly on today.

NAIROBI WHITFIELD: But what about the future of flight?

MOLLY BLOOM: Let's get back to the mystery sound for a clue.

[WHIRRING]

OK, so now that you know that that mystery sound is a clue about the future of flight, do you have any new guesses?

NAIROBI WHITFIELD: Maybe they're testing out a plane.

ZORA WHITFIELD: It sounds like they're opening a door while wind does rushing through it.

MOLLY BLOOM: OK. Well, we're going to find out the answer right now.

- So the sound you just heard is a sound of a new kind of flying vehicle called the cyclocopter. It's a very unique flying device. It's very different. It can hover in one place, just like a conventional helicopter. But it looks nothing like a helicopter. It looks more like a paddle wheel boat. A paddle wheel boat where you have these paddles which is rowing the boat through water.

Imagine that boat flying. So you have a number of blades, just like you have on the paddle wheel. And the key difference is it spins at much higher speeds than you would see on a boat, which will produce the required force to lift the entire aircraft up.

MOLLY BLOOM: So joining us now to talk about what the future of flight might have in store is producer Marc Sanchez. And before we go any further, who was that telling us about the cyclocopter?

MARC SANCHEZ: Hi, guys. That's Moble Benedict. He's an associate professor at Texas A&M University. And he runs something called the Advanced Vertical Flight Laboratory. If I were into making acronyms, I would call it the AVFL.

MOLLY BLOOM: So vertical flight means that he's into planes that go up and down?

MARC SANCHEZ: He's a helicopter guy. So one cool thing about helicopters is that they're really good at hovering in one place. And they can take off and land vertically. So no runway is necessary. The cyclocopter Moble was talking about can do the same thing. The one that he's been testing out is about as big as a house cat.

MOLLY BLOOM: So nobody's actually flying in cyclocopters yet, right?

MARC SANCHEZ: Not yet, no. But just like the Wright brothers, Moble is hopeful. His vision for the future includes people flying around in Personal Air Vehicles, or PAVs. Moble thinks PAVs could be the next wave in transportation.

MOBLE BENEDICT: You could park it in your garage, take it out. Fly maybe 5,000 miles you walk or wherever you're going. And compare as convenient as a car. So it's small. It can carry two or three people.

MARC SANCHEZ: And once PAVs are cruising around with one or two people, Moble thinks it won't be long until they can get bigger. So think of these PAVs like taxis and then even bigger like shuttles or buses, and possibly even a replacement for regional jets. Those are the planes that can carry around 50 people and generally fly about 500 miles.

MOLLY BLOOM: So what else does Moble see in his crystal ball of aviation?

MARC SANCHEZ: I think he feels the need--

MOLLY BLOOM: The need for speed?

MARC SANCHEZ: Molly, I will always be the Goose to your Maverick. And yes, Moble would like to see planes go faster. He wants to see supersonic planes.

MOBLE BENEDICT: By supersonic, I mean which can fly at speeds greater than the speed of sound. That's called Mach 1. So more than Mach 1.

MARC SANCHEZ: So this has already been done. And from 1976 until 2003, people could fly all over the world on these Concorde supersonic jet liners. And in their prime, Concordes flew to major cities all over the world at up to twice the speed of sound.

MOLLY BLOOM: So that would be Mach 2?

MARC SANCHEZ: Yep, Mach 2. So I could say something to you, Molly, sitting across from me. That plane would get there twice as fast as my words would travel to your ears.

MOLLY BLOOM: Whoa.

MARC SANCHEZ: That's crazy. But in order to go that fast, the Concorde needed a lot of fuel. And guess who paid for that fuel, you guys?

NAIROBI WHITFIELD: Us?

MARC SANCHEZ: Yep, passengers. An average ticket to fly across the Atlantic. So if you wanted to go, say, from New York to London or Paris, the average ticket would cost $12,000 per person.

NAIROBI WHITFIELD: Wow.

ZORA WHITFIELD: Whoa. That's a lot.

MARC SANCHEZ: But with the development of better fuel efficiency, Moble thinks that supersonic travel is going to make a comeback and be much more affordable. But by the future standards, supersonic is slow.

MOBLE BENEDICT: We have been trying to go faster and faster. And probably the fastest aircraft that ever flew is an SR-71, which can fly three times the speed of sound. But we have been trying to fly much faster than that, even like 10 or 15 Machs. Which means 10 or 15 times the speed of sound. So these are called hypersonic aircrafts.

But so far, all the hypersonic air vehicles have been very experimental. Could not fly for more than a few seconds.

MARC SANCHEZ: OK, forget supersonic. Moble things hypersonic planes are in our future. Probably not for you and I to fly across the country. They're probably better suited for the military.

MOLLY BLOOM: So Ann Curdy won't be scooting off to Las Vegas on a hypersonic flying machine.

MARC SANCHEZ: Not unless Ann Curdy is in the military. She's in the Air Force. But who knows? There are a lot of engineers and technicians trying to figure out the future of flight. NASA is actually looking into a wing that morphs like a bird. So depending on the weather condition, the wing changes shape. And right now, as we're recording this, there is a solar powered plane flying over the Atlantic Ocean. It's called the Solar Impulse 2.

MOLLY BLOOM: What does that look like?

MARC SANCHEZ: Well, it reminds me of a dragonfly. It's got this long body, really narrow. Towards the cockpit are these ginormous oversized outstretched wings, and they're covered in solar panels. It's a propeller plane, and it can only carry one person right now-- the pilot. And right now, while it's crossing the Atlantic Ocean, that trip is going to take about four days, which means that pilot, since he's the only one there, he can't go to sleep.

NAIROBI WHITFIELD: That poor person.

MARC SANCHEZ: I know, right? The best he can do is take a series of tiny naps. I imagine he'll be pretty tired when he comes back.

MOLLY BLOOM: Yeah. The future of flight sounds tiring.

MARC SANCHEZ: It does sound tiring right now, but it is still pretty exciting to think that we are here right now experiencing all these advances in flight. It's like being around the Wright brothers when they first left the ground.

MOLLY BLOOM: That is very cool. Thank you, Marc.

MARC SANCHEZ: You're welcome.

[MUSIC PLAYING]

ZORA WHITFIELD: It was a long process of trial and error.

NAIROBI WHITFIELD: Designing and testing.

ZORA WHITFIELD: For humans to be able to take flight.

MOLLY BLOOM: Everything that flies needs to balance four forces.

NAIROBI WHITFIELD: Drag and thrust.

ZORA WHITFIELD: Weight and lift.

NAIROBI WHITFIELD: And even though air is invisible, it has mass.

ZORA WHITFIELD: And can lift planes into the sky.

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

NAIROBI WHITFIELD: This episode was produced by Marc Sanchez, Sanden Totten, and Molly Bloom.

MOLLY BLOOM: Many thanks to Kesha Whitfield, Eric French, Dorothy Cochrane, Eric Wringham, Amy Hyatt, Craig Honiggs, and Stuart Bloom.

ZORA WHITFIELD: Until our next episode, keep up with us on Instagram and Twitter.

MOLLY BLOOM: We're at @brains_on.

NAIROBI WHITFIELD: And we're on Facebook, too.

MOLLY BLOOM: Now, before we go, it's time for our Moment of Um.

AUDIO TRACK: Uh. Um. Um. Um. Um.

HILARY: Hi, my name is Hilary. And my question is, what's the sourest thing in the world?

JANELLE KLEPPER: This sourest food in the world is the umeboshi plum. Other sour foods that you'll recognize are vinegar, lime juice, lemon juice. My name is Janelle Klepper. I have a Master's of Public Health in Nutrition from the University of Minnesota. We're really good at detecting things that are sour, because things that are sour might be too acidic for our bodies to do damage to our tissues, or they might be spoiled and something that we shouldn't eat that would make us sick.

Sourness is detected by acid content in food, and we can measure those on the pH scale. pH scale runs from 0 to 14, with 7 being neutral. Things that you'll recognize in food are water and bananas. They have a pH of about 7. One change in the number from 7 to 6 means that something that's 6 is 10 times more acidic than when it's at a 7.

Sour foods were registered lower numbers. And the umeboshi plum registers at 2.8 on the pH scale. Lemons and limes are also in that 2 to 3 range on the scale.

MOLLY BLOOM: It's time for the Brains Honor Roll. These are the kids who send us questions, ideas, mystery sounds, drawings, and high fives, and this is how we say thank you.

[LISTING HONOR ROLL]

AUDIO TRACK: Brains Honor Roll. High fives.

ZORA AND NAIROBI: Thanks for listening.