NEIL DEGRASSE TYSON (Astrophysicist, American Museum of Natural History): Hi, I'm Neil deGrasse Tyson, your host of NOVA scienceNOW, where this season we're asking six big questions. On this episode: Where did we come from?

The Sun; the planets; our home, the Earth: what triggered their creation?

I went on the hunt for rare evidence...

Where are we?

...that's been dropping from the sky.

He's got something!

RUBEN GARCIA (Meteorite Hunter): It sounds really big!

NEIL DEGRASSE TYSON: And it's pointing to a cosmic birth, more violent than we ever imagined.

Also, life: it's been around for billions of years, but how did it begin?

JOHN SUTHERLAND (University of Manchester, England): You know what you want to make, but you don't have a recipe.

NEIL DEGRASSE TYSON: For decades, we've been trying to cook up the building blocks of life, in the lab, and recreate the origins of it all, but the parts didn't seem to fit together, until now.

JOHN SUTHERLAND: We were the guys who stood back, and looked at it in a different way.

NEIL DEGRASSE TYSON: One team may have retraced a key step in the birth of life, itself. How did they do it?

And what about us and our origins? They say some of the hairiest questions in human evolution could be solved by these guys. Head lice! Ew!

MARK STONEKING (Max Planck Institute): Lice have been with us and evolving with us for as long as we have existed.

KATIE SHEPHERD (Lice Solutions): Now, see, right there? Now come straight out.

ZIYA TONG (Correspondent): Oh, my goodness. Oh, my goodness!

KATIE SHEPHERD: If you want to hit the red alarm button at school, all you have to say is the word "lice."

NEIL DEGRASSE TYSON: These tiny bloodsuckers are rewriting human history.

JEAN-JACQUES HUBLIN (Max Planck Institute): We cannot neglect the lice.

NEIL DEGRASSE TYSON: Also, where does your identity come from? Your memory, of course.

ANDRE FENTON (SUNY Downstate): My memories define me.

NEIL DEGRASSE TYSON: This brain researcher made a major discovery about how memories are formed and even how they can be erased.
ANDRE FENTON: You can wipe out who you are, and that’s an alarming thing.

NEIL DEGRASSE TYSON: All that and more on this episode of NOVA scienceNOW!

Where did we come from? How did we get here? Our history, in the cosmos and on planet Earth, was shaped by countless events, some obviously epic, some seemingly trivial, yet all vital in getting us to this point, here and now, the people we are today.

One of the reasons we’re here, that we exist at all, is that Earth, cosmically speaking, is in a relatively peaceful place: orbiting our Sun in a near perfect circle. Our cosmic neighborhood has granted life billions of years to evolve, mostly undisturbed. But where did this stable piece of real estate come from?

We know that stars and planets, once upon a time, all started out like this, with enormous clouds of gas and dust. How we got from here to here, we haven’t exactly figured out yet. But lately, we’ve found some intriguing new evidence that tells us our peaceful solar system might have started with a violent event.

If we want to unlock the secret behind the origin of our sun and its planets, it would be helpful to find some remnants from the birth itself, an event that took place about four-and-a-half-billion years ago. Luckily, there are some rocks left over from our earliest days, asteroids formed during our solar system’s birth. Occasionally, some of them drop in on Earth, and when they do, they’re called meteorites.

I’ve come to the deserts of Arizona to try to track down some rare space rocks.

Where are we?

LAURENCE GARVIE (Arizona State University): Perfect place for hunting for meteorites: southern Arizona. Look at this. You couldn’t ask for a better place. It’s open desert. It’s an old lakebed, and so the sand has been blown away, like right now, and it’s exposing the rocks that are on the ground. And you’re just looking for something that looks a little bit different. And you’ll know it when you see it.

NEIL DEGRASSE TYSON: Well, I’m from the city. So all this looks different. I’ll be hauling everything back for you.

So how do you spot a meteorite? Well, sometimes, the signs are hard to miss. Some leave deep impacts in Earth, like one that blasted Arizona’s Barringer Crater, 50,000 years ago. But most leave less obvious traces. They can be as small as dice, reduced to a rocky cinder. Then they have to be distinguished from Earth’s rocks.

One trait stands out in nearly all meteorites: metal; they’ve got it. So, the best way to find a meteorite is to hear it first.

No question about that one.

RUBEN GARCIA: And we can pick that up, this far out.

NEIL DEGRASSE TYSON: Ruben Garcia brought along some samples and showed me why a metal detector is the meteorite hunter’s best friend.

RUBEN GARCIA: It’s what meteorite hunters call “a halo.” You don’t have to swing over the meteorite. You get in that halo area and you hear the sound going up.

NEIL DEGRASSE TYSON: You get in the zone.

RUBEN GARCIA: We like that.

This is very typical as meteorites go.
This is called an ordinary chondrite. And about 82 percent of all meteorites that fall are going to be of that variety.

**NEIL DEGRASSE TYSON:** Chondrites are rocky meteorites that haven't melted completely. That's what we want to find.

**RUBEN GARCIA:** There's more. We've actually got what we call meteorite canes, and this is what I was talking about.

**NEIL DEGRASSE TYSON:** These are golf clubs. I know. This is a golf...

**RUBEN GARCIA:** This is a golf club with a very strong, in this case, two very strong magnets attached.

Go ahead and test it...

**NEIL DEGRASSE TYSON:** I'm going to test it. Mmm hmm.

**RUBEN GARCIA:** ...with the cane and see what you got.

**NEIL DEGRASSE TYSON:** Yes!

**RUBEN GARCIA:** There you go. Music to my ears!

**NEIL DEGRASSE TYSON:** I have found a meteorite.

**RUBEN GARCIA:** You certainly have.

**NEIL DEGRASSE TYSON:** I keep this one.

You guys ready to find some meteorites?

**LAURENCE GARVIE:** Let's go find some.

**RUBEN GARCIA:** Let's go do it.

**NEIL DEGRASSE TYSON:** Hunting for meteorites is like trying to find a pebble on miles of beach.

**LAURENCE GARVIE:** One of the graduate students has found something.

Watch the cactus.

**NEIL DEGRASSE TYSON:** Oh, thank you.

**RUBEN GARCIA:** It sounds really big.

**NEIL DEGRASSE TYSON:** All right.

Oh!

**GRADUATE STUDENT:** There it is!

**NEIL DEGRASSE TYSON:** A piece of farm equipment?

**RUBEN GARCIA:** That is your first "meteor-wrong." Congratulations!
NEIL DEGRASSE TYSON: "Meteor-wrong?"

RUBEN GARCIA: "Meteor-wrong."

NEIL DEGRASSE TYSON: But I want a "meteor-right."

LAURENCE GARVIE: So all we do is fan out now and just...

NEIL DEGRASSE TYSON: We just fan out. This is a whole area here.

LAURENCE GARVIE: It could be anywhere here.

NEIL DEGRASSE TYSON: Got something.

LAURENCE GARVIE: This has no characteristics of a meteorite.

NEIL DEGRASSE TYSON: Hmmm. This meteorite hunting is a lot harder than it looks, and some days, you don't find any.

So they told me this was the remains of a meteorite hunter that came out unprepared.

This is one of those days.

No telling what you'll find out here.

Luckily, over the years, hunters have turned up more than 30 thousands specimens. The largest—at around 60 tons—landed in Africa 80,000 years ago. Some of the rarest are pieces of the moon, blasted here after impacts there.

But one of the coolest things about meteorites is that most were formed four-and-a-half-billion years ago, during the birth of our solar system, when, for reasons not yet known, a cloud of gas and dust was transformed into a sun with circling planets. So, can these space rocks tell us what triggered the event?

Here at Arizona State's Center for Meteorite Studies, its director, Mini Wadhwa, ...

MEENAKSHI "MINI" WADHWAA (Arizona State University): Come on in.

NEIL DEGRASSE TYSON: ...is trying to decipher our cosmic past.

MINI WADHWAA: Here, you will gown up, to go into the clean lab.

NEIL DEGRASSE TYSON: Protective clothing prevents contamination from foreign particles.

Inside, Wadhwa breaks down meteorites in search of their chemical birth certificate. After crushing and dissolving them in acid, she can identify the atoms and molecules inside. The results? This 4.5-billion-year-old meteorite is laced with a special kind of atom called nickel 60.

MINI WADHWAA: Nickel 60 is interesting for us, because it is the decay product, the daughter, of iron 60. And iron 60 is created when another atom, iron 60, decays through radioactivity. That number, 60, tells you how many protons and neutrons are in an atom’s nucleus, so when this rock formed, four-and-a-half billion years ago, it was originally infused with iron 60. And iron 60 is created in only one place: a supernova.
A supernova is the violent, destructive explosion that marks the death of a massive star. So that means when these meteorites were forming from a gas cloud during the birth of our solar system, the gas cloud had been sprinkled with iron 60 from an exploding supernova.

MINI WADHWA: We’re interested in iron 60 because it may be ejected by a supernova nearby...

NEIL DEGRASSE TYSON: Right before we were all born.

MINI WADHWA: ...right before the solar system was born.

NEIL DEGRASSE TYSON: But wait a minute. A supernova is one of the most powerful explosions in the universe. It's so luminous, it can be seen across billions of light years. It releases as much energy in an instant as our sun will produce over its 10-billion-year lifetime. So how could a baby solar system survive such a violent, destructive event?

Well, turns out, some researchers think the reason we survived is that the supernova explosion was actually the trigger that created our solar system in the first place.

ALAN BOSS (Carnegie Institution of Washington): The one question we're trying to understand now is: "Could such a supernova actually have been involved in the formation of our own solar system?"

NEIL DEGRASSE TYSON: Alan Boss is one astrophysicist convinced that we owe our existence to a supernova. He thinks it happened like this: like everything else in the universe, we started out as a cloud of gas and dust; then a distant massive star died and went supernova, sending a shockwave toward us; when the wave of pressure hit the cloud, it collapsed and condensed, starting a chain of events that led to the formation of our Sun.

You can think of it kind of like a snowplow.

You can create mounds of snow or destroy them.

ERIK WILSON (Labrador Mountain Ski Resort): We can do either/or.

NEIL DEGRASSE TYSON: So, you are the supernova of the ski slope.

ERIK WILSON: That's for sure.

NEIL DEGRASSE TYSON: As the plow pushes through a parking lot of light fluffy snow, the snow clumps together in bigger and bigger chunks. Out in space, pressure hitting a gas cloud has a similar effect, except, instead of snowballs, you get stars!

Once you've got the makings of a star, gravity draws leftover gas and dust into a giant swirling disk. The dust continues to stick together, clumping into rocky asteroids, which eventually become orbiting rocky planets. And voila: a solar system!

So is this where we came from?

Well, not everybody is buying the "supernova-as-a-creator" theory.

STEVE DESCH (Arizona State University): What remains a little bit controversial about that idea is that you can't have that fluffy cloud near the supernova. When that shockwave is coming out of the supernova explosion, it's superstrong.

NEIL DEGRASSE TYSON: For Steve Desch, a supernova hitting a gas cloud is more likely to do this. Like a snowplow in overdrive, a supernova shockwave might sweep away any gas clouds in its path.
Desch thinks something gentler triggered the collapse: a shock driven by radiation from a massive star, but Alan Boss has crunched the numbers and insists that at the right distance, a supernova shockwave would be transformed from a destroyer, into a creator.

ALAN BOSS: We believe that our own solar system was a cloud, sitting there in space, more or less minding its own business, when a supernova shockwave struck the cloud and had it collapse down and form a new star system.

NEIL DEGRASSE TYSON: We still don't know for sure what the trigger was, but since we've discovered meteorites with supernova dust, we do know that a violent explosion rocked our cosmic neighborhood at the time of our birth, and it's quite possible that without it, our stable, stately solar system would never exist at all.

Once upon a time...

Our solar system had hundreds of Moon-sized planets...

Over many, many years they smashed together to make fewer, bigger planets.

And those smashed together to form fewer, even bigger planets.

Until one day, only a few really big ones remained...

The planets of our solar system.

NEIL DEGRASSE TYSON: One of the most significant events in our distant past is still perhaps the greatest mystery: the origins of life itself. How did it all get started?

If you look down the evolutionary tree of life, you'll see that we mammals branched from reptiles, which branched from fish, and so on and so on, all the way down to the base of the tree, a common ancestor, some single-celled organism, billions of years ago. But what came before that? And where did the very first living thing come from?

Correspondent Chad Cohen digs down deep into the roots of the tree and uncovers some groundbreaking research into how life first began.

CHAD COHEN (Correspondent): Everything on Earth that has ever lived came from an ancient ancestor billions of years ago, perhaps a simple single-celled organism like this. But from where did it come? From where did the first life emerge?

JACK SZOSTAK (Massachusetts General Hospital): Life emerged from chemistry, and then it's... after that it's just details, right?

CHAD COHEN: So, at the root of the tree of life, it appears, is chemistry: simple elements like carbon, hydrogen, oxygen and nitrogen. But how did they get cooked together into the complex molecules of life?

JOHN SUTHERLAND: We're here on the planet, and we must be here as a result of organic chemistry.

CHAD COHEN: John Sutherland, from the University of Manchester, England, along with co-authors Matt Powner and Béatrice Gérland...


CHAD COHEN: Gérland.

BÉATRICE GÉRLAND: Okay.

CHAD COHEN: He and his team took on the task of looking for the Holy Grail of life.
JOHN SUTHERLAND: You know what you want to make but you don't have a recipe.

CHAD COHEN: We can all imagine what this is like. In the kitchen, we bring together different ingredients all the time to make all kinds of different things. It's the recipe, though, that makes it all work. Take for example: the cream puff.

BÉATRICE GÉRLAND: Oh, yeah, pâte à choux.

CHAD COHEN: Okay, pâte à choux, as it's known in French. In this case, I know the ingredients: flour, eggs, milk, water, butter. What I don't know is the recipe. So I might just try mixing all these things together and baking them.

I could try different orders, different combinations, different amounts, but what you get is not pâte à choux.

Too brittle. Too hard. Too...well, I have no idea.

Attempts to find the recipe for early life were unsuccessful, too, even though researchers knew the basic ingredients.

JACK SZOSTAK: Yeah, exactly.

CHAD COHEN: Nobel laureate Jack Szostak and his team at Massachusetts General Hospital say that early life needed two things:...

JACK SZOSTAK: You need the cell membrane...

CHAD COHEN: ...a container, something to live in and keep other things out.

JACK SZOSTAK: And you need some genetic material, something that can allow the inheritance of information.

CHAD COHEN: Every modern creature uses D.N.A. to do that. It's an organism's instruction manual, genetic code, spelled out in chemicals inside this twisty double helix. D.N.A. has long been hailed as the fundamental molecule of life. We also have R.N.A., as well, usually described as D.N.A.'s helper. But now, it turns out, R.N.A. has a starring role.

JACK SZOSTAK: Years ago R.N.A. was kind of a bit player in the cell. Now our picture's completely inverted, and we think R.N.A.'s really the important thing.

CHAD COHEN: R.N.A. has a genetic code also written with chemicals: A, C, G and U. They're used to help build the proteins that make up the cells in our bodies: skin, hair, brain cells, the heart. R.N.A. helps make them all.

So what's the recipe for R.N.A.? It's made from three parts: a sugar, a phosphate and a single letter of the genetic code, a base. Each of these parts is made up of simple chemicals that existed on the early Earth, but nobody has been able to put them together, that is, until John Sutherland came along.

JOHN SUTHERLAND: We were the guys who stood back and looked at it in a different way.

CHAD COHEN: It's one thing to make chemicals in the lab, but there were no labs on the early Earth. So Sutherland tried to replicate the conditions; in some way, simulate what that Earth would have been like,...

JOHN SUTHERLAND: Simulate the actual chemistry that took place.

CHAD COHEN: ...starting with their version of what Charles Darwin suggested as the perfect spot for the source of life, a warm little pond.

JOHN SUTHERLAND: The pond itself is actually the little round-bottom flask.
CHAD COHEN: And because it was a warm little pond...

JOHN SUTHERLAND: It's around about the temperature of a cup of English tea.

CHAD COHEN: Sounds nice.

And so they tackled the problem at hand: trying to make R.N.A. Knowing what chemicals it would take, the question was how to cook them together.

People have known the ingredients for some time now, but the recipe has not been really working out.

JOHN SUTHERLAND: You actually have to be the person that writes the recipe book.

CHAD COHEN: So that means we have to go back to the kitchen and try to combine our ingredients for pâte à choux in a new way. Remember the ingredients: eggs, milk, flour, water and butter. We combined them before, with no luck. But now we have a real chef to help us.

RICHARD COPPEDGE (Culinary Institute of America): Well, you had the right ingredients, but you forgot one very important step. It's that intermediate step.

CHAD COHEN: Chef Richard Coppedge, of the Culinary Institute of America, explains that I was missing an all-important intermediate step.

RICHARD COPPEDGE: You didn’t precook the mixture.

CHAD COHEN: I can’t just mix these things together and bake it?

RICHARD COPPEDGE: No, because that’s why you have this.

CHAD COHEN: So precook? What does it mean to precook something?

Some of the ingredients need to be cooked together first.

This is the intermediate step that...

RICHARD COPPEDGE: ...that you didn’t do earlier.

CHAD COHEN: I first cook the water, milk, butter and flour together. No eggs! Then...

RICHARD COPPEDGE: Take it to the mixer. Now you can add the eggs.

CHAD COHEN: Okay, now, finally...okay.

And you get just the right mixture...

RICHARD COPPEDGE: Alright. That’s ready to be baked.

CHAD COHEN: The result?

RICHARD COPPEDGE: Wow. They look perfect.

Without that intermediate step of precooking, you really don’t have pâte à choux. It’s not much of anything without that intermediate precooking step.
CHAD COHEN: And apparently that was the problem scientists were having with R.N.A.: trying to combine all the parts together. And that's not the way to do it.

JOHN SUTHERLAND: No, it's not.

CHAD COHEN: So Sutherland's team took their own intermediate step. First, they created a hybrid made of a sugar and only half of the base, the part that holds the genetic code. This intermediate substance came together in the flask through the simple process of evaporation.

JOHN SUTHERLAND: It looks like a smear or a smudge on the inside of the flask.

CHAD COHEN: On the early Earth, the intermediate would have formed through evaporation, made its way up into the atmosphere and then fallen from the sky...

JOHN SUTHERLAND: So this would come down in rain. Or, if the temperature was cold, it would precipitate out as solid particles and fall to the ground, almost like a kind of organic snow.

CHAD COHEN: ...and, as in the lab, meeting up with the remaining chemicals in perhaps another warm little pond and attaching together in the final step. And it worked! For the first time, scientists created a building block of R.N.A., what's called a ribonucleotide, containing the base C. In hindsight, pretty simple.

JACK SZOSTAK: It never occurred to me to try putting them together in a different order, so it was not obvious.

CHAD COHEN: It was, in fact, an amazing accomplishment.

JOHN SUTHERLAND: 'Cause if you take the right mix of ingredients, in the right order, with the right set of conditions, you can cook a nice piece of pastry. I can make a ribonucleotide.

CHAD COHEN: And it came together in simple steps that could have taken place on their own on the early Earth.

JOHN SUTHERLAND: My team and I have recreated an early Earth scenario and let it run. And the chemistry just does it on its own.

CHAD COHEN: But that wasn’t all. They took their piece of R.N.A. and subjected it to something else easy to come by on the early Earth.

BÉATRICE GÉRLAND: Light!

CHAD COHEN: Yes, sunlight.

JOHN SUTHERLAND: So, if you hit the switch, you’ll see what happens when the sun shines.

CHAD COHEN: Something amazing happens. The light shining upon their sample turns some of the C-bases, the bit that makes up the genetic code, into "U"s.

JOHN SUTHERLAND: So, two for the price of one, just by having the Sun shine.

CHAD COHEN: They had discovered a natural pathway to two of the four letters of R.N.A., letters that code for the proteins that build all living things.

JOHN SUTHERLAND: We were pretty happy, actually.

CHAD COHEN: Understatement?

BÉATRICE GÉRLAND: No, they were happy. I would never say the contrary, but in their English way...
JOHN SUTHERLAND: We might have had a trip to a local pub.

CHAD COHEN: And so, while we're a long way from figuring out exactly how life got started...

JACK SZOSTAK: They've really, I think, solved one of the central hard questions in prebiotic chemistry.

CHAD COHEN: ...they've filled in a piece of that mysterious underside to the tree of life, because, as we trace our origins by looking down, chemists like Sutherland are seeing things in a different way.

JOHN SUTHERLAND: What you see looking down from biology is what we see looking up from chemistry, and we can actually establish a link between the two.

CHAD COHEN: A pathway from simple to more complex chemicals, until chemistry becomes biology. They've given us a glimpse of where we come from...

John Sutherland's recipe for life required sunlight.

Here's a possible recipe for the molecules of life that requires NO sunlight ...

Mix metals and minerals with volcanic gases.

Pressurize to 14,700 pounds per square inch.

Cook at 212-320°F

Where in the world do you find a kitchen like that?

Volcanic vents, thousands of feet below the surface, right here on Earth...

And just maybe on places like Jupiter's moon, Europa.

NEIL DEGRASSE TYSON: Life existed on Earth for nearly four billion years before anything remotely resembling a human being showed up. And even then, when we started to branch off from other apes about 10,000,000 years ago, our ancestors looked pretty different.

For one thing, they were a lot hairier. Then, at some point, hair mostly disappeared from parts of our bodies and remained in a few others, including the head. Without body fur we had to figure out how to make clothes to keep us warm.

Since hair and clothes don't turn up much in the fossil record, figuring out when and why all this happened has stumped paleontologists, but, recently, we discovered a witness to our hairy history.

Correspondent Ziya Tong combed through the evidence to find the stealthy, diminutive creature who's now revealing some new clues to our origins and defining key steps on our path to being human.

ZIYA TONG: These little creatures might not be pretty, but scientists are just now discovering how much lice can reveal about our past.

MARK STONEKING: Presumably, lice have been with us and evolving with us and adapting with us, for as long as we have existed as a separate species and even before the origins of humans.

ZIYA TONG: Most parents are horrified to hear that their child might have head lice, but when evolutionary biologist Mark Stoneking, got the news, he was just curious.
MARK STONEKING: My son came home from school with a note from the teacher saying a child from his class had come to the class with lice, and in the pamphlet there were facts about lice.

ZIYA TONG: Two facts caught his eye: head lice only live on the human scalp, and they cannot go more than a day without drinking our blood.

MARK STONEKING: But then, when I actually started to look into this in more detail, I discovered that it was potentially even more interesting.

ZIYA TONG: Stoneking discovered that the story of lice contains clues about our ancient history, dating all the way back to the dawn of humanity itself.

Most of what we know about human evolution comes from these: the fossilized bones of our ancestors. With their help, we've traced our evolution from small furry creatures to the big-brained beings we've become today. But bones can't tell us everything.

One mystery that's stumped the fossil hunters is when we started wearing clothes. We're not talking about these kinds of clothes, but something more basic.

JEAN-JACQUES HUBLIN: We don't have any direct evidence to answer the question when the first clothing developed, and it's a very important question.

ZIYA TONG: Important because it will help us get a handle on when we left Africa, our ancestral home, and spread out into colder regions.

The earliest clues are bone sewing needles dating as far back as 40,000 years ago, but we know early humans were world travelers long before that. Their fossil remains have been found across the globe.

JEAN-JACQUES HUBLIN: They were tropical creatures, and they had to adapt to this new environment, and it really is some kind of puzzling question to figure out how they were able to cope with this kind of environment.

ZIYA TONG: At some point our ancestors figured out how to bundle up, but when?

Lice may hold the answer.

DAVID REED (Florida Museum of Natural History): It's really fascinating to me that we can use these parasites to study so many aspects of human evolutionary history. Ziya, you are not going to believe...

ZIYA TONG: David Reed is now the world's foremost expert on the evolution of lice. He thinks the pests can solve all kinds of mysteries about our past, like when we started wearing clothes.

He is bringing me to a local strip mall, in Florida, to see if I've got what it takes to be a professional nitpicker.

DAVID REED: Ziya, this is Katie from Lice Solutions.

ZIYA TONG: Good to meet you.

KATIE SHEPHERD: Nice to meet you, too.

ZIYA TONG: And what is your name?

KYLEE (Lice Solutions Client): Kylee.

ZIYA TONG: Hello, Kylee.
So, what are we going to be looking for today?

KATIE SHEPHERD: We are going to see if Kylee has head lice.

ZIYA TONG: Katie is going to teach me to remove lice the age-old way, by hand.

KATIE SHEPHERD: Initially, I like to part the hair here.

See? Right there, right there.

ZIYA TONG: Okay. I just go straight, like that?

KATIE SHEPHERD: Now just come straight out, all the way out.

ZIYA TONG: Oh, my goodness. Oh, my goodness!

So, I got you some samples. So, what are we going to do with these guys?

DAVID REED: Well, we're going to take them back to the lab, and we are going to study their D.N.A.

ZIYA TONG: Back in the lab, Reed studies the D.N.A. of, not only the head louse, but also of this little guy: pediculus humanus humanus, the body or clothing louse.

To the naked eye it looks identical to the head louse, but there are a few key differences: it lives and lays its eggs only in clothes and bedding, and, unlike the head louse, the clothing louse can kill you.

DAVID REED: ...that it carries three deadly diseases that have killed millions of humans over recent history. There are epidemic typhus, trench fever and relapsing fever. Because of these diseases they carry, they were partly responsible for decimating Napoleon's Grand Army, through its famous winter march.

ZIYA TONG: As dangerous as they might be, for Reed, clothing lice are fascinating, because they must have evolved from head lice, and they could only do that after we started wearing clothes.

DAVID REED: Clothing lice wouldn't have had a niche to live in until humans started wearing clothing. So, if we can learn when they first started to emerge from head lice populations, we can learn when humans began to start wearing clothing for the first time.

ZIYA TONG: Reed set out to determine when the head louse and the clothing louse split into two separate species. To do that, he used a genetic dating technique called the molecular clock.

Here's how it works: D.N.A. is made out of a sequence of four chemicals known by their initials a, c, g and t. A D.N.A. sequence mutates, or changes, randomly, but at a known rate.

MARK STONEKING: D.N.A. sequences change by mutations, and the idea behind the molecular clock is that those changes occur at, more or less, a constant rate, over time.

ZIYA TONG: When Reed compared the D.N.A. from modern clothing lice to human head lice, he discovered that the two species split over 170,000 years ago, and this, Reed says, is when we started to wear clothes.

DAVID REED: A hundred and seventy thousand years is important, because that tells us that modern humans had the technology to use clothing while they were still in Africa. And that, then, allowed them to successfully colonize other parts of the world.

ZIYA TONG: Scientists believe that the invention of clothing in Africa was a key factor in allowing our ancestors to migrate into colder climates and to spread across the globe.
The invention of clothing is just one of the mysteries that lice are helping to solve. They also hold crucial clues to the big event that made clothing necessary in the first place: the loss of our fur.

MARK STONEKING: The loss of body hair is interesting to anthropologists, because it is a feature that distinguishes us from our nearest living relatives, chimpanzees. They have body hair, we don’t.

ZIYA TONG: The problem is that no one has been able to determine when our ancestors took this big evolutionary step. It turns out that the answer may lie with another kind of lice, even less welcome than head lice. The crab, or pubic louse, lives only in the human pubic region and has large claws designed to grab on to the thicker hair.

We know pubic lice didn’t evolve from head lice. They’re a completely different species, so different, we must have caught them from another animal.

MARK STONEKING: Human pubic lice are more closely related to gorilla lice than they are to other human lice.

ZIYA TONG: Actually, scientists don’t know exactly how lice jumped from gorillas to our human ancestors. They speculate that we may have eaten them or perhaps slept in their nests. But they do know that, in order for crab lice to survive on our bodies, something had to give.

MARK STONEKING: We lost our body hair and that basically created a geographical barrier between the pubic region and the head region that the lice could not cross.

ZIYA TONG: So both head lice and crab lice were able to thrive on our bodies, thanks to this no-lice-land: the expanse of skin on our torso.

So if we can figure out when crab lice appeared as a separate species, that should tell us when we started showing all that skin.

To find the answer, David Reed compared the D.N.A. of gorilla lice and human crab lice. He found that the two species split about 3,000,000 years ago. And that’s when David Reed believes we lost our body hair, when we were still small chimp-like creatures, with few of the qualities we consider human.

DAVID REED: Most estimates don’t go beyond a million years and suggest that we lost our hair around that time. These lice are telling us a very different story, that we might have lost our body hair as long as 3,000,000 years ago.

ZIYA TONG: And that’s a milestone in human evolution, because losing their fur enabled our ancestors to regulate their body heat by sweating more efficiently. Eventually, they could run long distances and hunt wild animals. The protein this provided was essential to the development of a big brain, the hallmark of becoming human.

Piecing together the details of our human journey is a challenging task. It’s ironic that some of the most mysterious gaps are being filled in by a creature we’ve never really liked.

JEAN-JACQUES HUBLIN: We cannot neglect any piece of evidence. And if the lice teach us something, it is very important. So we cannot neglect the lice.

Here’s a timeline of early human’s greatest achievements...

Clothes: 170,000
Dwellings: 500,000
Fire: 800,000

Oh, yeah, then there’s toolmaking...
Tools: 33 million years ago

Yeah, us and tools...

We go way back.

NEIL DEGRASSE TYSON: All humans, all living creatures, have common origins, but what about our individual origins, our own personal history? Where does that come from?

Who you are, where you’ve been and what you’ve done is all up here, captured and preserved in your memories. If you lost that—the story of your own origins—you’d lose your identity, your sense of self.

In this episode’s profile we meet a researcher whose fascination with how memory and identity work led him to discover a chemical that has the power to erase memories and make our sense of where we come from disappear.

As a new father, Andre Fenton loves capturing memories of his baby daughter Zora and wife Lisa.

ANDRE FENTON: That's Zora's first Halloween.

NEIL DEGRASSE TYSON: Andre thinks of all his memories as living in a dynamic set of file cabinets in his mind, where they're stored and add up to a life.

ANDRE FENTON: Memory defines a person. My memories, in many ways, define me.

NEIL DEGRASSE TYSON: As a neurobiologist at SUNY Downstate in Brooklyn, Andre has become famous as the guy who, with a simple injection, can wipe away a memory forever.

TODD SACKTOR (SUNY Downstate): Scientists had thought it was impossible to erase a memory, so that was, like, a shock to the whole community.

ANDRE FENTON: You can wipe out who you are, and that's an alarming thing.

NEIL DEGRASSE TYSON: Andre's cutting-edge ideas tap into our deepest hopes and fears, something we've seen in the movies.

ANDRE FENTON: There's Eternal Sunshine of the Spotless Mind that deliberately investigates what would happen if you could erase painful amorous memories.

JIM CARREY (As Joel Barrish in Eternal Sunshine of the Spotless Mind/Film Clip): I'm erasing you, and I'm happy.

ANDRE FENTON: The conclusion is it's not good.

NEIL DEGRASSE TYSON: Except what Andre’s doing is real. His fascination with the inner workings of the mind date back to his childhood. Born in Guyana, Andre had to adapt into a strange, new world at a young age.

ANDRE FENTON: When I was six or seven, I moved to Toronto, Canada, what was essentially a new culture. So I learned to skate, immediately.

NEIL DEGRASSE TYSON: And at home, Andre had to cope with the tumultuous relationship between his mother and stepfather.

ANDRE FENTON: They must have separated, I don’t know, 10 times or so, during the course of their, their marriage. They were divorced twice. I have painful memories, and if you had asked me right after my stepfather had packed his suitcases, "Would you like to get rid of this memory?" The answer might, probably have been, "Yes."
When I was in high school, I became deeply interested in understanding, "Who are you in this world? What is the nature of my experience?"

NEIL DEGRASSE TYSON: At Montreal's McGill University, Andre searched for answers. He tried meditation and philosophy. Then a movie suggested that the key piece of this puzzle might lie inside his own head.

ANDRE FENTON: I had seen Altered States, where a psychologist goes into a sensory deprivation tank, and he has experiences that come from his brain, and he's seduced by this.

WILLIAM HURT (As Eddie Jessup in Altered States/Film Clip): Beautiful!

NEIL DEGRASSE TYSON: So, Andre tracked down a sensory deprivation tank to try himself.

ANDRE FENTON: And it was like instant meditation. And the thing that fascinated me was that my mind would construct images. I could move rather fast, at times, like, warp-speed fast, and at other times, very, very slowly. And there was nothing I was really experiencing that was outside of me.

NEIL DEGRASSE TYSON: His time in the tank convinced Andre that to understand his experiences, he must first learn how the brain works. That's when he turned to neuroscience. One of the first challenges in the lab was to create a device that would force a rat to acquire a specific memory, a kind of memory-making machine.

So Andre ran an electric current that would send a harmless shock whenever the rat entered the invisible triangle. In the future, the rat should remember to avoid this area. The device was called "the place avoidance task."

But, because Andre was only interested in spatial memory, he needed to make sure the rat was not cheating by using sight, sound or smell to navigate the arena surface.

To outsmart the rat, Andre began obsessively looking for a solution.

LISA ROBINSON (Andre Fenton's Wife): Well, Andre is an incredible multi-tasker. You know, I think a typical moment with Andre is that he's walking the dog, carrying Zora in her BABYBJÖRN®, talking on his cell phone on a conference call, and taking money out of the bank, kind of, all at the same time.

NEIL DEGRASSE TYSON: But many of his best ideas surface in one unusual place.

ANDRE FENTON: I spend a lot of time in the shower, thinking about things, which my family is very unhappy about, because we only have one shower.

LISA ROBINSON: It’s like pieces of a puzzle that he needs to fit together, and he, kind of, works on it and works on it, until it clicks.

NEIL DEGRASSE TYSON: That's when he had a breakthrough with his memory-making machine.

ANDRE FENTON: I let the rat step up onto my hands, which I kept just above the arena surface, and Benedetto physically turned the disk. And I let the rat crawl off my hand, and we watched to see where the rat avoided.

NEIL DEGRASSE TYSON: By constantly rotating the floor, Andre had taken away all the clues for the finding the shock zone.

ANDRE FENTON: And that's how the rotating arena developed.

NEIL DEGRASSE TYSON: Now, Andre had a machine that could quickly create long-term spatial memory, but what to do with it? Enter Todd Sacktor, a fellow neuroscientist whose lab, coincidentally, was just one story up from Andre's at SUNY Downstate.
Todd was one of many researchers struggling to discover the mechanisms the brain used to lock in some memories for a lifetime, while others faded away.

Neuroscientists believed that a long-term memory occurred when a specific pattern of connections between a group of neurons were strengthened and maintained over time. After two decades of research, Todd suspected that many of those connections were maintained by a single enzyme in the brain called "PKMzeta."

TODD SACKTOR: In a sense, I love PKMzeta.

NEIL DEGRASSE TYSON: The clearest way to demonstrate its power would be to block PKMzeta and see if a long-term memory would be erased.

TODD SACKTOR: So, I walked down one flight into Andre's office.

ANDRE FENTON: And he said, "I think we're ready to find out if PKMzeta is actually the mechanism for maintaining memory."

TODD SACKTOR: And I said, "Andre, what's the best task to test the hypothesis that PKMzeta is important for maintaining long-term memory."

NEIL DEGRASSE TYSON: Todd suggested several memory experiments to use with PKMzeta, but Andre saw flaws in all of them.

ANDRE FENTON: Then he suggested another apparatus, and I said, "Nope, I see this problem with that." He eventually said, "What would you use?" I said, "Well, I would use the place avoidance task."

NEIL DEGRASSE TYSON: The experiment was simple. They placed a rat in the rotating arena and let it learn to avoid the shock zone.

ANDRE FENTON: A nice thing about the place avoidance task is that where the rat goes gives you a pattern that looks like a scribble. When the rat is avoiding, it's a scribble that avoids a triangle.

NEIL DEGRASSE TYSON: Once the rat consistently avoided the triangle, the memory had been learned. Then they injected a chemical which would stop PKMzeta from working in the brain.

ANDRE FENTON: If you were to inhibit PKMzeta, then you should be able to erase a memory.

Todd was sure it would work. I was certain it would not work. But once we injected the inhibitor, you could see that the rats went everywhere. The scribble just went all over the arena, like when the animal's put there for the first time.

NEIL DEGRASSE TYSON: The rat's memory of the shock zone was gone. With PKMzeta disabled, the strength of the connections among the brain cells that formed the memory seemed to weaken.

ANDRE FENTON: We came to the very simple conclusion: PKMzeta is crucial for maintaining long-term memories, the kind that last forever, the kind that make you who you are.

Todd came down with some sort of bubbly thing. We sort of poured it around, and we cheered to that.

NEIL DEGRASSE TYSON: Andre realized he was just scratching the surface of how PKMzeta and long-term memory work, but the press swarmed over the story of memory-erasing scientists in Brooklyn.

LISA ROBINSON: Seeing Andre's face on the front page of the New York Times was a surprise to all of us.
NEIL DEGRASSE TYSON: While Andre's experiment only applied to rats, his research touched on a darker current in the public psyche.

ANDRE FENTON: I received emails from a variety of people who were interested in having their memories erased:

"I'm seeing therapists and psychiatrists, two years now, but to no avail."

"If I could get a three-year amnesia somehow, I would do it in a minute."

"I would happily trade in all of my memories, even the good ones, if it would erase this."

"I'm living in hell and would try anything to alleviate..."

"Please, please, please keep me in mind if any clinical trials in that area ..."

"I'm sorry if I inconvenienced you in any way. I really did have a lot of accomplishments in life and had a lot of future potential."

I really hope I never get to make the decision of whether we reboot a mind or not. I'm convinced that it's a bad idea. Imagine, you're an adult person, and you've spent a lot of time accumulating an identity. You might not like that identity, but the very notion that you could literally remove all of it, I don't know what you would be. I'm not sure you'd be human. And I wouldn't know how to put it back.

London cabbies are required to memorize the location of 25,000 city streets!

Neuroscientists wondered how that might affect a part of the brain called...

The Hippocampus

The Hippocampus was long believed to be where memories of locations were stored.

So they scanned cabbies' brains...

And found something very interesting...

Their Hippocampi were larger!

NEIL DEGRASSE TYSON: And now for some final thoughts on where we came from. We only recently figured out the origin of our own moon. And we have some idea of how the Sun and Earth formed, but that's only because modern telescopes empower us to see other stars and planets freshly hatched within gas clouds across the galaxy. As for the origin of life itself, the transition from inanimate molecules to what any of us would call life remains one of the great frontiers of biology. Since life on Earth is, so far, the only known example of life in the universe, our dilemma may simply be that we have no other examples to compare us with. If we did, then the life/non-life transition might look downright simple to us. No doubt, the most challenging class of questions in science is the origin of things. So much of what we understand comes from knowing what something is and what that something used to be, which allows us to figure out, or at least imagine, what happened in between. Okay. So where did it all come from?

We're quite happy with our Big Bang description of cosmic origins. But actually, the Big Bang accounts for what happened only after the beginning. The beginning itself, and especially what happened before, remains the biggest mystery of all. Why? Because our universe is the only known example of a universe in the universe. And that is the Cosmic Perspective.