00:00 Sarah Crespi: This week's episode is brought to you in part by The Sounds of Science Podcast. Eureka! It's the sound of discovery, but what does it take to get there? From the Charles River Eureka Blog comes a new monthly podcast called Sounds of Science. Each episode features a scientist looking for their elusive eureka moment. Sounds of Science explores the process leading up to the latest breakthroughs and the challenges that still remain. Subscribe to Sounds of Science on Apple Podcast, Stitcher, or wherever you get your podcast. This week's episode is also brought to you in part by the American Dental Association. Teeth tell a story. We know what ancient civilizations ate, drank, even where they lived all from looking at their teeth. What story will your teeth tell about you? Your ADA dentist can help you find out and give you the tools to keep your teeth healthy for years to come. Use the American Dental Association's find a dentist tool to find the right dentist for you. Go to ada.org/sciencemag today.

01:07 SC: Welcome to the Science Podcast for November 30th 2018, I'm Sarah Crespi. In this week's show, I talk with a staff writer, Liz Pennisi, about the evolution of plasticity. What does it mean that some animals, some organisms have a little wiggle room in their genomes. Meagan Cantwell talks with Marco Ajello about a new method used to determine the history of star formation in the universe. And for this month's book segment, Jen Golbeck talks with Christine Du Bois about her book, The Story of Soy.

01:58 SC: I've got Elizabeth Pennisi here with me, she's a staff writer for Science, and this week, she wrote a feature on how plastic traits get fixed in animals and I guess, more than animals, in genomes. I'm Sarah Crespi. Hi Liz.

01:58 Elizabeth Pennisi: Hi.

01:58 SC: So, this is kind of a complicated topic, but you have a couple really good examples in your story. Let's talk about this side-blotched lizard that can be different kinds of colors. Can you set that up for us?

02:13 EP: Okay, so side-blotched lizards are these lizards that live in the Southwest, mostly in desert environments. They can change their color to match their environment.

02:25 SC: And do they change it right away, like a chameleon?

02:28 EP: Not quite, it can take a couple of weeks to completely change over, depending on how much contrast there is between where they were and where they are now are. Mostly, their color ranges from sandy tan to maybe a brownish color of the rocks. But in the Mojave Desert, there's this black lava flow that some lizards have decided to live on. And what researches have shown is that the lizards living on the black lava are blacker, get blacker than the lizards that live on the sand most of the time.

03:04 SC: Mm-hmm. There's a trait that they have in their genes that is somewhat flexible. It's
influenced by the environment while the animal's alive, they can be lighter, they can be darker. But then, sometimes, that flexibility gets eliminated and they go to like dark lizard or light lizard, right?

03:21 EP: In this case, the flexibility wasn't eliminated, it just shifted a little bit. So, what the researchers found is that the lizards that live on the lava, when you stick them back on a light surface, they get light, but they don't get as light as the lizards that live on the light surface. And when they stick those lizards on the lava, they get darker than the lizards that live on the light surfaces can get. And so what you've seen is a genetic shift in the color range of these lizards.

03:54 SC: So, they're flexible, but that flexibility is being changed over time?

04:00 EP: Correct.

04:00 SC: Very cool. So, let's talk about Lamarck for one second. It's introduced in your story, and people always bring it up when they talk about adaptation of living organisms. So, Jean-Baptiste Lamarck was a French naturalist with his own ideas about how evolution worked, the things that happened in the lifespan of the parents were passed down to the offspring, but that's not what's happening here.

04:22 EP: So, Lamarck's idea was that you could acquire a characteristic, so, say a giraffe could get a longer neck because he was reaching for leaves during his lifetime, and that longer neck would be passed down to the offspring. And, of course, now we know that that's not how evolution really works. On the surface, when you think about what happened to these lizards, you can think, "Well, maybe it is how evolution works." But it's not. In this case, the "acquired trait" is really just a plastic trait, and the plasticity of being able to be dark or be light is built into the genes.

05:02 SC: And that's driven by adaptation. So, there are dark, dark lizards and darkish lizards, and the dark, dark ones survive, the ones that can reach that darkness peak, and so, they're selected for, right?

05:14 EP: Right, right. The darker the better.

05:16 SC: Now, let's go really small. So, researchers were able to observe this kind of thing in real time by using fast breeding organisms like yeast. Can you describe those experiments and what they showed?

05:28 EP: Sure, so these researches do what's called experimental evolution in single-cell organisms, in this case, yeast, and they change the conditions under which they're growing the yeast to see the effect on their evolution. So, in this particular experiment, the researchers exposed yeast to paraquat, which is a toxin that causes the cells to make excess oxygen-free radicals which damage DNA and just generally hurt the cell. When they exposed the yeast to this toxin, the yeast grew much slower, but over time, the yeast began to recover their normal growth rate. This adaptation they decided was a plastic adaptation, in other words an example of plasticity, because when they took the paraquat away for a while and then re-exposed the yeast to paraquat, the yeast were still in trouble.
06:27 SC: Right. So, they could respond to this insult and change something about themselves, but that went away when the insult was removed.

06:35 EP: Correct.

06:36 SC: And there probably wasn't enough time for a mutation that was somewhere randomly in that population to take over, save these organisms, and then go away.


06:47 SC: Okay. In your story, you mentioned a few cases where this has been seen in the wild and also this laboratory example, but how common overall is this phenomenon?

06:58 EP: Well, for one, I think we probably have more options than we realize. As people studied climate change and the effects of climate change on plants and animals, they realized that plants can adjust, and that adjustment is part of their plasticity, at least to some degree they can adjust. So, what the plants are doing are responding to their environment, and everybody has built into their genes some ability to respond to the environment. Now, if the environment changes in some permanent way, then the organisms that have the greatest ability to adapt to that environment will do best. They will produce more young, and eventually, there could be a genetic change to sort of solidify or fix that particular form of the trait in that organism. Now, you ask, "Why doesn't that happen all the time?" It probably is happening all the time and we don't realize it.

07:56 SC: What are the trade-offs between having a lot of plasticity in your genome, carrying a lot of options around with you, and not having that? Like, why wouldn't we just have a ton of options in all our genes?

08:10 EP: There is a cost to being plastic. Basically, if you can adapt to a lot of different environments, you're probably not really great at any one.

08:19 SC: Right. So, you lose specialization at the cost of being this flexible.

08:23 EP: Right.

08:24 SC: This is a very similar process, but it's much faster than say, a mutation arising.

08:28 EP: Random mutations occur pretty slowly. So, if you have an environment that's changing really fast, you can't evolve, i.e., mutate really fast enough to keep up with the changes. But if you have plasticity, then you can basically depend on that plastic response to make it so that you can survive, at least somewhat in the environment, long enough for a mutation to occur.

08:56 SC: I brought up Lamarck before because I think that this idea, some people might think this is adapting Lamarckian evolution, but is it a controversial idea if you make this distinction between what he said and what people are saying here?
09:09 EP: It's been somewhat controversial, mainly because I think people don't really understand exactly how plasticity can work to help facilitate evolution, but I think there are more and more examples that researches are finding. And the other thing that's helpful too, is they're finding the genes that are underlying the changes that they see in the organisms. So, there is a genetic explanation.

09:39 SC: All right, Liz Pennisi, thank you so much for talking with me.

09:41 EP: Hey, well, thank you. Have a nice day.

09:43 SC: Elizabeth Pennisi is a staff writer for Science. You can read her story at sciencemag.org/news. Stay tuned for Meagan Cantwell's interview with Marco Ajello about the history of star formation.

10:00 SC: This week's episode is also brought to you by OpsGenie by Atlassian. Incidents happen and they require complex coordination. Between operations and software development teams we're putting out fires every day. That's why getting alerts immediately is critical. Thankfully, there's OpsGenie by Atlassian. OpsGenie empowers Dev and Ops teams to plan for service disruptions and stay in control during incidents, it also gives teams the power to respond quickly and efficiently to unplanned issues and helps to notify all the right people through a smart combination of scheduling and escalation paths that account for things like time zones and holidays. Better yet OpsGenie allows for deep flexibility how, when and where alerts are deployed. With over 200 integrations like Jira, Amazon CloudWatch, Datadog, New Relic and more. Plus it tracks all activity and provides useful insights to improve future incident responses. With OpsGenie your next incident doesn't stand a chance. Visit opsgenie.com to sign up to get a free company account and add up to five team members. That's opsgenie.com, O-P-S-G-E-N-I-E.com. Never miss a critical alert again with OpsGenie.

11:18 Meagan Cantwell: I'm Meagan Cantwell and I'm with Marco Ajello to talk about a new approach to determining the history of star formation all the way since the big bank. Hi, Marco.


11:29 MC: What is the importance of understanding star formation history?

11:33 MA: Well star formation history is one of those incredibly useful and incredibly important quantities. Everything depends on stars at the end, all the light that we see. In the UV optical infrared is, emitted by stars and all the basic elements other than helium and hydrogen are being basically synthesized in stars. So understanding stellar evolution across the history of the universe is one of those fundamental problems.

12:00 MC: This isn't the first determination of the universe's star formation history right? How many other models have there been?
There have been quite a few of them because it's something very important, but all the other methods of measuring this formation rate of the universe rely on just one way to do that, which is basically detecting galaxies in very deep observations for example by the Hubble Space Telescope.

How were these reconstructions limited?

They are limited to the fact that anything that has not been detected in those deep fields can not be accounted for. So galaxies that are just too faint to be detected even by Hubble, we know those exist, they cannot be accounted for. And also, there is star formation that happens really far away from the galaxy centers and that's too faint to be detected in galaxy surveys.

Which brings us to your team's approach which estimated the star formation history by observing over 700 blazars. Could you explain what a blazar is and how observing them helped you reconstruct the history of star formation?

Blazars are super massive black holes at the center of massive typically elliptical galaxies and these black holes are creating some gases, so they are being fed some gas and they are able, somehow, to accelerate particles to near the speed of light. These particles emit all kinds of light in particular emit a lot of gamma rays. We used these objects as probes of the extra galactic background light. So our goal in this project was actually to measure the entire output of the universe emitted by stars.

Every star that's ever existed leaves an imprint on the galaxy, which is what this extra galactic back light, you mentioned is. So, how did you measure this back-light?

This kind of light, the star light acts as a fog for gamma rays that are traveling through space. So, there is a process known to particle physicists, which is the pair creation process. In this process, you can have two photons. So two particles of light interacting with each other, and disappearing creating an electron-positron pair. In our case, we have one of the gamma ray emitted by the blazars while traveling through space has a non-negligible chance to interact with one of those photons from stars and being absorbed. We see how many of these photons from lasers have been absorbed to quantify how thick is this fog of starlight photons. The thicker it is the more photons from lasers have been absorbed.

How does determining the thickness of the fog allow you to model the star formation rate?

We are able using blazar some 703 blazars across, basically a large fraction of these are in the universe, we can actually reconstruct how much light there was at any point in time. They sorted the universe in three frequencies, three different wave bands. The optical, the ultraviolet, and then your infrared. And we can convert this relatively easily with standard knowledge to the activity star formation activity as a function of age in the universe. If you have UV light, the ultraviolet light is emitted by massive stars. These are extremely short lived stars so whenever you see this light this means there has been recent star formation. Once you observe this UV light this can be transformed
into star formation rate rather quickly accounting for all the stars that are not seen, simply because they are less massive and less luminous. And also accounting for the absorption of light by dust, which is a process that happens.

15:25 MC: All possible because of the Fermi Gamma-ray telescope. What about this telescope is so unique that allows this approach?

15:32 MA: It is the only gamma-ray telescope in space. There are no other instruments that survey the same energy band. And there are some gamma-ray telescopes on the ground. The thing is that you need to be in space if you want to be able to detect photons of the right gamma-ray energy, which is around between 10 giga-electron volts and 100 giga-electron volts. So this means roughly 10 to 100 times the energy of visible light because those are the ones that interact with the UV photons from stars, which is extremely important to measure star formation rate across the history of the Universe.

16:07 MC: Yeah, and what were the advantages of this approach to determining star formation history as opposed to past approaches?

16:13 MA: It is a more comprehensive approach. So we measure all the light that ever existed. All the light that was ever emitted. And this means that if there are galaxies that Hubble for example has not detected yet because they are too faint, the light still exists, it's still in the extragalactic background light. It's still in this common starlight. So we are sensitive to all the things that other instruments and other approaches have not seen.

16:39 MC: So how has the rate of star formation changed since the Big Bang?

16:44 MA: In the first billion years of the Universe, the universe already was able to form stars and then it started forming stars at much larger rate. So it became a lot more efficient doing that. It turns out that it reached a peaked efficiency in forming stars roughly five billion years after the Big Bang or eight billion years ago. This is the point in time when the universe was forming stars at a very large rate. From the point on the star formation rate of the universe has declined, and this is due to many things. One of them is the fact that a lot of all the available gas in galaxy has been transforming to stars and short-lived stars like our sun or even less massive than our sun are fairly long lived. So they lock the gas in stars.

17:31 MC: Ultimately, your reconstruction was pretty similar to past ones, correct?

17:35 MA: It is. It is very similar, and it is in very good agreement.

17:39 MC: So what is the next step with your research? Does your team plan on using the Fermi telescope to explore another aspect of the universe?

17:46 MA: I think at this point we have exploited as much as possible, the Fermi telescopes in order to construct the extragalactic background light but there is... There is a limitation. The fact that if you want to go construct the extragalactic background light to longer wave lengths, which
means more towards the infrared, those photons not detected by the larger telescope mode of Fermi anymore. But those photons are detected by telescopes on the ground and these are the, these are called Air Cherenkov telescopes. So our next goal is basically to use data from those telescopes and continue to measure up the star light particular extending the measurement in the infrared region that is very important for the process of dust absorption for example.

18:29 MC: Alright, thank you so much, Marco. Marco Ajello is an assistant professor of Physics and Astronomy at Clemson University. You can find a link to his research at sciencemag.org/podcasts.


18:50 Jen Golbeck: Hi everyone, and welcome to this month's book segment of the podcast. If you're a vegetarian like me, you'll be noshing on the delicious soy-based turkey substitute for your big feast this month. And that's why we're reading Dr. Christine M. Du Bois's new book, The Story of Soy. I'm joined by Christine Du Bois and I'd like to start by saying that I have a sort of intimate personal relationship with soy. I eat a lot of it as a vegetarian, but I also grew up in rural Illinois, surrounded by soybeans. That said, I didn't know a lot about its history or the tremendous scope of its global impact, until I read your book. Can you start by giving us an overview of the breadth of what you covered?

19:29 Christine Du Bois: So my book, The Story of Soy, you might consider it a biography of soy. If soy were a person like me, you'll be noshing on the delicious soy-based turkey substitute for your big feast this month. And that's why we're reading Dr. Christine M. Du Bois's new book, The Story of Soy. I'm joined by Christine Du Bois and I'd like to start by saying that I have a sort of intimate personal relationship with soy. I eat a lot of it as a vegetarian, but I also grew up in rural Illinois, surrounded by soybeans. That said, I didn't know a lot about its history or the tremendous scope of its global impact, until I read your book. Can you start by giving us an overview of the breadth of what you covered?

20:10 JG: In the book, you take deep dives into different parts of soy's history and the role it played in wars, societal development, politics and the environment. If we go into any of those though, I think we'll lose the big picture. So can you summarize just how important this little bean is on a global scale?

20:24 CB: Soybeans are one of the most traded crops around the world. Most people have no idea how incredibly important this plant is because it is fed primarily to chickens and pigs on large factory farms with relatively few employees. So most people, especially people, who live in cities are not aware of how in agricultural areas, particularly in North and South America, this crop is huge. It's hugely profitable and it is hugely shaping our world. It was the first commercially really successful genetically engineered crop and because it was so commercially successful it has spurred the development of other genetically-engineered crops. It is used in countless products both industrial products and many, many food products, although in very small quantities. So it's everywhere in our environment, and it has everything to do with cutting edge science and it is massively important to economies and trade disputes.
21:36 JG: Let me pick up on that trade dispute item, because a few weeks ago The Washington Post had a really interesting piece on how North Dakota soy farmers were being especially hard hit by the tariffs implemented as part of this ongoing US-China trade war, because they sell the vast majority of their crop to China. Do you see that that loss of access to US markets, whether it's temporary or long term is going to have a worldwide impact? Like will other countries start growing more soy, and what would that mean?

22:04 CB: The way soy is being handled as a crop worldwide, especially in South America right now, and it's really a looming problem for Africa as well, is often quite environmentally destructive. The only reason I've not mentioned North America here is that we already destroyed the North American prairies a long time ago, even before soy was planted there. So it's a done deal, here in North America, but in South America, there's a lot of land that was still virgin wilderness that is being deforested or de-savannahed in order to grow soy because it is such a lucrative crop. And it's really a very, very serious problem particularly in places like Paraguay, which have much less strict environmental regulation and places like Brazil, which has increasingly strict environmental regulation to protect the Amazon, but which has very difficult problems of enforcement.

23:03 CB: Cargill and the Nature Conservancy have worked together to try to improve some of the systems for protecting the Amazon. But there's such a long way to go and some of the things that are being done to assist the soy farmers of Brazil, in particular the completion of a highway that cuts right through the Amazon... Which is a national highway... Is really leading to deforestation along its borders. Within 50 miles of any major road you get a lot of people coming in, building all the things that would service the truck drivers and then towns spring up, and then when towns spring up, you have to have schools and hardware stores and churches and so forth, and more and more gets built up along the highway.

23:49 CB: So there's a very deep concern and of course, the concern relates to how is all of this going to affect global warming, and right now with what's going on with the United States trade war with China, we have slapped a 25% tariff on to our soy being exported to China, which is our largest buyer. And so right now the Chinese don't have a lot of options for making up that soy, but in the long run, they're going to want to look for other suppliers that are not gonna be slapping that tariff on them. And so they are investing as they already have been, but they're probably going to accelerate it now, investing in more virgin lands in Africa and South America, but they're really doing a lot in Africa, that are probably gonna start being planted in soy and so more wildernesses that are going to be destroyed and this is a very grave concern for climate change.

24:47 JG: Christine Du Bois her new book is The Story of Soy and it's out this month. We'd love to hear your comments on the Science Magazine books blog, Books, Et Al. Have a happy holiday, however much soy it may contain, and we'll be back in December with more books.

25:02 SC: And that concludes this edition of the Science Podcast. If you many comments or suggestions for the show, write to us at Science Podcast at aaas.org. You can subscribe to the show anywhere you get your podcast or you can listen on the science website at sciencemag.org/podcast. To place an ad on the Science Podcast, contact midroll.com. This show was produced by Sarah Crespi and Meagan Cantwell, and edited by Podigy. Geoffrey Cook composed the music on behalf of science magazine and it's publisher, AAAS, thanks for joining us.
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