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Music

Host – Sarah Crespi
Welcome to the *Science* Podcast for March 9th, 2012. I'm Sarah Crespi.

Host – Kerry Klein
And I'm Kerry Klein. This week: magnetism on the Moon, understanding nuclear reactor accidents, and deep-sea optical adaptations; plus, a few stories from our online daily news site.

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Host – Sarah Crespi
Magnetic anomalies on the Moon—or, strong magnetic fields with no correlation to geologic structures—have been puzzling researchers since the first Moon missions. Mark Wieczorek and colleagues calculated that swaths of native Moon rocks 100 kilometers deep would be needed to account for the strength of these anomalous fields—but that exceeds the thickness of the lunar crust. I spoke with Wieczorek about how these magnetic materials might have been delivered by a giant projectile and about the history of magnetism on the Moon.

Interviewee - Mark Wieczorek
Since the Apollo missions starting in 1969, it's been known that the Moon has been strongly magnetized in places. And it's been kind of difficult to understand these magnetic anomalies because, first of all, lunar rocks aren't very magnetic, and secondly because these magnetic anomalies don't really appear to correlate with any geologic structures or processes. So in this study, what we did here is we tried to show that the force of magnetization on the Moon is actually not due to rocks from the Moon that are magnetized but rather that they're due to rocks from asteroids that collided with the surface of the Moon, in particular, with a giant asteroidal impact event that formed the largest impact crater on the Moon.

Interviewer - Sarah Crespi
So you said that the Moon was weakly magnetic. Well how does the magnetic field compare with what we have here on Earth?

Interviewee - Mark Wieczorek
In comparing the magnetic fields of the two bodies, there's two things you need to take into consideration. The first is that on the Earth, the strongest portion of the magnetic field is due to a magnetic field that's generated in the core of the Earth by a dynamo process, and this generates a global dipolar magnetic field. Now, the Moon probably had a dipolar magnetic field in its past, but it doesn't have one today. The second source of magnetization on both objects is that portions of the crust are magnetized. In essence, what happens is when you have a, like a volcanic eruption, the lavas will cool in the presence of a magnetic field and become magnetized, and then these will generate a secondary and weaker magnetic anomaly. And this is what we see on the Moon today.

Interviewer - Sarah Crespi
And so what about these strong magnetic anomalies that you studied – what was known about them going into this?

Interviewee - Mark Wieczorek
Nothing was known of lunar magnetism before the Apollo missions in 1969. Starting with Apollo 12, they brought magnetometers, and they found out that there were strong magnetic fields on the surface of the Moon. Most recently, in 1998, there was a mission called Lunar Prospector, which is a NASA Discovery-class mission where they made the first global magnetic field map of the Moon showing that there were strong magnetic anomalies kind of just randomly dispersed across the lunar surface.

Interviewer - Sarah Crespi
So what were some of the hypotheses that attempted to explain these anomalies – these random distribution of these magnetic anomalies?

Interviewee - Mark Wieczorek
Well the reason I became interested in this study is because there weren't very many good hypotheses to explain these magnetic anomalies. And the biggest problem is that there were very few correlations between these magnetic anomalies and lunar geology or geologic processes. So, for example, if you just take the largest magnetic anomaly on the near side of the Moon – a place called Reiner Gamma – and if you look at a lunar geologic map or if you look at lunar topography or anything you don't really see anything there. As a geophysicist, I would have never guessed that there would have been a magnetic anomaly in these regions. So most of the hypotheses that have been put forth have relied on somewhat, I would say, exotic mechanisms. They involve things like comets with their comas colliding with the Moon and generating transient magnetic fields. People suggested that when you formed giant impact craters that you could generate transient magnetic fields as well. And perhaps even with the largest impacts you could generate magnetic fields on the antipode of the planet – that's 180 degrees away on the opposite side of the planet. Now, while these mechanisms might account for some of the magnetic anomalies, they certainly don't account for all of them. And in this study, what we noted is that there is actually one correlation between lunar magnetism and geology, and that is that the largest grouping of magnetic anomalies on the Moon are located next to the largest impact basin on the Moon. This is a basin that's about 2,000

kilometers in diameter on the far side of the Moon. It's called the South Pole-Aitken basin, so it's roughly half the size of the U.S. And it's been suggested based on some geologic mapping that this basin is somewhat elliptical. So it is suggestive to some people that it was due to what's called an oblique impact event, where an asteroid collides with a surface kind of at an angle. And what we suggested is that if you had an oblique impact event that this would deposit materials from the asteroid on the downrange rim of the basin. And what's interesting for us is that the meteorite materials from these asteroids are very strongly magnetic because they contain lots of iron, so they're roughly 100 times magnetic than lunar rocks.

Interviewer - Sarah Crespi
So what you did was you used computer simulations to determine if an object hitting the Moon could have created magnetic fields. And what did you have to take into account when you were looking at these models?

Interviewee - Mark Wieczorek
So in terms of the computer simulations, this is the work of the coauthor on the study, Sarah Stewart, at Harvard University. And in essence, what we did here is we just used the shock physics simulations and you try to simulate what happens when you collide two objects with each other at very, very high velocities. So the velocities we're talking about here are about 15 kilometers per second, which is, you know, roughly about a thousand times faster than you drive in your car on an average day. And in terms of the things that we need to take into account, one is like the impact velocity, because this determines how much of the materials vaporize and how much of it is melted. We also need to take into account the impact angle, because that determines where the projectile materials end – whether they end up in the center of the crater or whether they end up in exterior to the crater.

Interviewer - Sarah Crespi
So you compared the results of these simulations to what was actually observed at the basin, and you found that one model fit what you see the best.

Interviewee - Mark Wieczorek
In terms of the best parameters we needed, the first thing is that in order to best match the lunar magnetic anomalies, we found that roughly a 45-degree impact angle was the best match to the observations. And this is good because 45 degrees is the average impact angle that you expect for objects colliding with the Moon. And also in terms of the impact velocity, we found that the best match was roughly about 15 kilometers per second, which again this is the average impact velocity of objects with the Moon today.

Interviewer - Sarah Crespi
So what you found is that it wasn't an impact that magnetized materials that already existed on the Moon but that the impactor actually brought the magnetic material with it.

Interviewee - Mark Wieczorek

Yeah. So in this study, we start with the assumption that the Moon had a global magnetic field when this impact occurred. We show how to get the magnetic materials to the surface of the Moon. And then once those materials are in place during this giant impact event, they're relatively hot, and if they cool in the presence of the global magnetic fields then this would generate a magnetic anomaly that could be present today.

Interviewer - Sarah Crespi
So this has been a really long-standing question going back to the Apollo missions. Why has it been such a tough problem to solve?

Interviewee - Mark Wieczorek
Well first I should say that we're not claiming that we solved everything in lunar magnetism. So there's still lots of work to be done. I think what we partially solved in this work is that we showed how to get highly magnetic materials on the surface of the Moon. Now what we didn't address at all was the origin of the magnetic fields that magnetized these rocks. And the current hypothesis is that this is probably due to a global dipolar magnetic field similar to that what the Earth has today. But there's been very few simulations that have tried to model this in the past, and I would probably say that most of these simulations aren't exactly successful because it's very hard to generate a very strong magnetic field on the Moon because it's kind of a small object which loses its heat very rapidly. And it's just that predicted magnetic field strengths are much weaker than what's predicted by the paleomagnetic studies.

Interviewer - Sarah Crespi
So if there wasn't ever a dynamo on the Moon, then how would this material have gotten magnetized?

Interviewee - Mark Wieczorek
Well that makes this a little bit more difficult. So in order to make these magnetic anomalies, you need to have some kind of magnetic field present at the time in order to magnetize the rocks. And the easiest way to do this is if you have a core-generated dynamo, which is around for long periods of time. So the Earth has been around for roughly four billion years or maybe even more. For the Moon, we think based on the number of studies that it probably did have a global dipolar magnetic field in its past – this is based on paleomagnetic studies where they date rocks and they determine what the strength of their magnetization is. It's also based on a few magnetic anomalies that we find in impact craters, which suggests that they cooled in the presence of a global magnetic field. But there are some alternative hypotheses, and that is that some impact basins could generate transient magnetic fields. And these transient magnetic fields could last perhaps on the order of roughly one day or so. So if there wasn't a dipolar magnetic field generated from the Moon's core, it is possible that you could generate transient magnetic fields that could magnetize these rocks. But I think that this hypothesis isn't as strong as the other hypothesis.

Interviewer - Sarah Crespi

You do mention in your paper that the information that is deposited on the Moon by a large impactor like this would be useful for studying maybe the origins of the solar system or the origin of these large objects. Could you talk about that a little bit?

Interviewee - Mark Wieczorek
Yeah, sure. The idea here is that when our solar system formed, the planets started out by a process called accretion. And this is where you start out with dust-size particles, they stick together and form even bigger-sized objects, and these bigger-sized objects smash into each other forming larger and larger objects until you end up with four big planets in the inner solar system. Now it's possible that this object, which smashed into the Moon perhaps 4.5 billion years ago just after the Earth/Moon system formed, that this material here, this asteroid, could be representative of the composition of these planetesimals in the inner solar system when our planets were forming. So if we could obtain a sample of this, this would be really, really interesting because it would tell us what were the building blocks of the planets when they formed 4.5 billion years ago.

Interviewer - Sarah Crespi
Wow. Well, Mark Wieczorek, thank you so much.

Interviewee - Mark Wieczorek
Thank you.

Host – Sarah Crespi
Mark Wieczorek and colleagues write about the moon's magnetic anomalies in a research article this week.

Music

Host – Kerry Klein
It's been a year since a devastating tsunami touched off the accident at Japan's Fukushima nuclear power station. But, in fact, accidents at nuclear reactors are extremely rare -- and that scarceness of data makes it difficult to predict the interaction of damaged nuclear fuel with its environment. A Review published this week presents what is known about the chemical and physical consequences of nuclear accidents, and discusses how to better prepare for such occurrences. Lead author Peter Burns spoke with me about the paper, and began by describing how nuclear fuel is processed in a normally functioning reactor.

Interviewee - Peter Burns
Fresh fuel – before it goes into a reactor – is almost always uranium dioxide. It's an enriched fuel – 3 to 5% of the uranium is uranium-235, the fissile isotope; and the remainder is uranium-238, which is not fissile. And basically fresh fuel is simply that – it's not really very radioactive because uranium is only an alpha emitter, and the half-lives of those two isotopes are very long; 238 is 4.5 billion years, and 235 is about 700 million. So basically it's not radioactive for all intents and purposes, so it's easy to handle and transport and so on. In the reactor though, the whole purpose of the fuel is to produce energy, and that is created or released by the fissioning of the uranium isotopes.

Most of it comes from uranium-235 initially, at least. When the uranium-235 isotope is split, it gives fission products or lighter elements, as well as the release of energy and radioactivity. And it's the energy, of course, that we're after. The fission products pretty much cover the periodic table. So over the course of time, the chemistry – the composition of the fuel – literally changes; it becomes much more radioactive, becomes more much chemically complex as the reactor continues to function. And by the time one would normally take a fuel out of a reactor, it's about 3 to 4% fission products.

Interviewer - Kerry Klein
So the spent fuel is actually much, much more radioactive than the fresh fuel you start with.

Interviewee - Peter Burns
Yeah, on the order of a millions times more radioactive.

Interviewer - Kerry Klein
Wow.

Interviewee - Peter Burns
You can handle uranium dioxide fuel when it's fresh without posing any real risk to yourself. But if you approach an actual spent fuel assembly, you'll get a lethal dose in about a minute. And that's assuming that it's only been out of the reactor for a relatively short time.

Interviewer - Kerry Klein
So now, let's move onto what we would consider a meltdown or what you refer to as a nuclear core-melt accident. So what exactly happens in those cases? What happens within the reactor?

Interviewee - Peter Burns
Yeah, a reactor running normally, of course, is producing a lot of heat, and that's mostly from the fissioning of the uranium and that's, of course, why we do it. The cooling system removes that heat from the reactor, takes it elsewhere to run turbines and generate electricity. Now what a lot of people don't realize about the reactor is that even if you shut it down, even if you stop the fission reaction by insertion of the control rods, the heat generation does not stop. And that is because during reactor operation you've created all of these fission products that have very short, many of them have very short half-lives. So they decay rapidly, and they release a tremendous amount of heat. And that has to be cooled. So most of these have happened in reactors that have been shut down. You have a loss of coolant event. If the cooling system fails, the heat will overheat and basically a whole series of events happens as the different containment devices and structural materials and fuel cladding and so on start to melt and deform and react with whatever is in the vicinity. If there's water present or steam, the steam will react with the zirconium alloy cladding and release hydrogen, which leads to explosions, and so on. But the meltdown itself is where the core of the reactor – the fuel and the structural components and the cladding – ends up literally melting and flowing downwards due to gravity and

accumulating in the bottom of the reactor vessel – at least one would hope it accumulates there. In a severe enough accident, it could even perhaps move all the way through the bottom of the reactor vessel.

Interviewer - Kerry Klein
Now how often are these accidents?

Interviewee - Peter Burns
Well fortunately, they're rare. But they're not as rare as a lot of people would think. There's been around 20 core-melt accidents in the world to date that we know of, although not all of them have resulted in really some significant radioactivity or injury to humans.

Interviewer - Kerry Klein
So we know a lot about, well we clearly know a lot about spent fuel because we must design proper containers for them so they don't leak into the environment. But what, how much do we know about the damaged fuel during these core-melt accidents?

Interviewee - Peter Burns
In terms of the damaged fuel, there's been really very limited studies. Basically several groups have studied fuel that actually has been melted in a controlled environment and its reconfiguration from a kind of physical point of view and the release of gaseous fission products from it. But what has not really been studied is the longer-term fate of that material. So after the fuel has melted and it's mixed with various containment devices and so on – everything has been melted into a big blob – we know very little about what that blob looks like from a chemistry and heterogeneity point of view and material science point of view, and we know very little about how water or even just the air will interact with that over time. And that, of course, other than the gaseous fission products, which are basically released upon meltdown, everything else is presumably still more or less in that big unknown blob. And it's the interaction of the water and the air with that that is going to control the release of radioactivity to the environment.

Interviewer - Kerry Klein
So there's sort of a "big three" that most people think of when we think of nuclear accidents, you know: Three Mile Island; Chernobyl; and then, of course, the most recent Fukushima Daiichi accident. So can you just sort of compare what actually happened during those accidents and how much was actually released into the environment?

Interviewee - Peter Burns
Sure. Three Mile Island – in 1979, there was a partial meltdown of a single pressurized water reactor. And some of the fuel and cladding and so on did melt and flowed to the bottom of the reactor vessel. It was caused by a loss in coolant, as most reactor accidents are of this sort. And there was release of the gaseous fission products that were contained in the fuel from primary containment, but almost all of that was captured in secondary containment. So there was a very modest release of radioactivity to the environment, although it's still I guess somewhat controversial just how much. It wasn't much. In the

case of Chernobyl though, things were totally different. There were massive fires and explosions, and the entire containment systems were destroyed. All of the gaseous fission products essentially that would have been in the fuel were released to the environment. And the explosions also blew around six tons of fuel into the atmosphere, which fell back, of course, in the vicinity. There was a huge amount of melting that took place – melting of core materials, as well as associated structural materials – and there were actual lavas that formed that flowed around into the lower parts of the reactor buildings and then solidified. In Fukushima, the meltdowns were somewhere in the range of partial to complete depending on the reactor. Hydrogen explosions did cause breaches in containment. Volatile fission products, the gaseous things, probably were largely released early in the accident. But what's different about Fukushima relative to the earlier events is the vast quantities of water that were pumped into the reactor cores and into the storage pools in order to try to cool them. And that created a whole new release pathway for radionuclides out of the reactors into the environment. We don't know how much radioactivity was released through the water flow, and we don't know very much about how the water interacted with the fuel and other structure materials.

Interviewer - Kerry Klein
So in fact these accidents were actually quite different, and their long-term impacts are all quite different.

Interviewee - Peter Burns
Oh, I think that's absolutely fair to say.

Interviewer - Kerry Klein
So what is our best pathway forward that you determined from this study for being prepared for these sorts of accidents in the future?

Interviewee - Peter Burns
Well, I think, on the one hand, we're going to see continuous improvement in our understanding of the impact of really low probability events on reactor performance. And we're going to probably learn to design reactors better over time, and we're also going to get a better understanding of the actual low probability events that are going to occur. Because these are the ones that get you – in the end, it's the things that are really unlikely, but if you have enough reactors operating in the world, sooner or later some of these things will happen. And the number of reactors operating now is about 440, but that's going to steadily increase, and one could imagine it being perhaps a thousand or more in not too many years. So I think we need to take very seriously the development of knowledge about how damaged and destroyed and melted nuclear fuel moves in a reactor containment vessel and then how it interacts with the environment, especially water that we might use in an emergency to cool it. Studies that have been done to date really haven't looked at the longer-term interactions of water and the atmosphere with these damaged materials. They've focused mostly on the very short-term release of the gaseous and different volatile fission products. Those ones pose a lot of short-term risk, but the risk is relatively short term because those fission products typically have very short half-lives in the minutes to days kind of range; some are years. But the fuel itself –

as it interacts with water or whatever over time – has a potential to release radionuclides that have much longer half-lives and they pose a much longer environmental threat.

Interviewer - Kerry Klein
Well, Peter Burns, thank you so much for speaking with me.

Interviewee - Peter Burns
My pleasure.

Host – Kerry Klein
You can read more from Peter Burns and colleagues in a Review entitled "Nuclear Fuel After a Reactor Accident" – in this week's *Science*. A News Focus in the same issue looks at the nuclear power situation in Japan one year after the Fukushima disaster.

Music

Host – Sarah Crespi
Deep in the ocean, sea creatures lure prey, scare off predators and camouflage themselves, all by playing with light. Some change their appearance based on the availability of light, while others have eyes tuned to UV-light to discern edible sources of bioluminescence. I spoke with *Science*'s Elizabeth Pennisi about some of these novel adaptations and how they might be used to improve terrestrial or even extra-terrestrial optics.

Interviewee - Elizabeth Pennisi
Went I went to a meeting I was struck by two talks about how the deep sea fish makes and uses green florescent light and another talk about how giant clams channel light into their tissue to help supply the algae that live with them with light. And I got to thinking about how undersea organisms make, use, and manipulate light, and that's what this story is about. We talk about the history of how researchers became aware of the existence of all this utilization of light and some examples of how organisms are challenged by this dark world.

Interviewer - Sarah Crespi
So, as you mentioned, sea creatures have a unique lighting situation. The amount of light that they get to see changes as they get deeper. Can you describe some of those changes?

Interviewee - Elizabeth Pennisi
Yeah. As you go deeper, the light gets bluer as other wavelengths are filtered out. And then, in the open ocean, the light dims about 10% every 75 meters, so that by a thousand meters down, there's no light left. And in this world, the organisms have to figure out how to hide from their predators, and it's very difficult because there's no place to hide in the ocean. So they play optical tricks to disappear.

Interviewer - Sarah Crespi

And so it's not just the basic spectrum of light that these organisms are playing with, as well. One of the most amazing examples in the story is a fish that can camouflage itself with polarized light. Can you tell us about that?

Interviewee - Elizabeth Pennisi
So there are some fish that have silvery sides, and the idea behind that is they reflect the light in such a way that they basically disappear in the water. Now one problem is that if a predator can see polarized light, that the polarized light should be reflecting off the fish and still make them visible even though they have "disappeared". But when researchers actually tested this, they found that actually these silvery fish don't reflect polarized light or at least are less conspicuous than they expected. So they did some modeling of guanine plates that the fish use to make themselves into biological mirrors. And they found that these plates – if they're thick enough – reflect polarized light the same way as incoming light, so basically they make themselves disappear even in polarized light.

Interviewer - Sarah Crespi
These are like invisibility cloaks.

Interviewee - Elizabeth Pennisi
Yeah.

Interviewer - Sarah Crespi
And so you also mentioned some organisms that detect UV light down in the bottom of the ocean.

Interviewee - Elizabeth Pennisi
Right. This is something that researchers studying deep sea creatures discovered in some crustaceans is that even though there's technically no UV light down in the bottom of the ocean, these organisms had UV receptors in their eyes so that they could detect UV light. And what the researchers figured out is that these UV receptors help the organisms discriminate between the bioluminescence of organisms such as sea pens and corals that live on the bottom and aren't very edible from bioluminescence of the zooplankton and other organisms that are edible.

Interviewer - Sarah Crespi
But not all of these interesting responses to light have to do with the predator-prey relationship. As you mentioned, there's also these clams that have a symbiotic relationship.

Interviewee - Elizabeth Pennisi
Right. So giant clams have algae in their tissue. The algae produce food, and the giant clams give them a place to live and also provide them with nitrogen. Now giant clams also can be iridescent, and researchers were curious to see if there's any connection between the iridescent cells and the algae. So they looked at the structure of the iridescent cells in the algae with electron microscopy. And after they did that, they then built a computer model of this structure showing that the algae exists in long columns in a

plate of iridescent cells. Then, in a simulation, they had incoming photons hit the iridescent cells and figured out what happened to those photons. And it turns out that light that would be deleterious to the algae because it's too strong would be filtered out and reflected, whereas light that would be good for the algae is channeled down deeper into the columns so that algae that normally wouldn't have access to light had access to light.

Interviewer - Sarah Crespi
Wow. So as the light changes, so do the adaptations. We see different things closer to the surface and different things deeper down. And at the very bottom, I'd expect there to be little or no light. But that's not what scientists have found. There's actually organisms emitting a bunch of light. So how did they first find out about that?

Interviewee - Elizabeth Pennisi
So people have known about bioluminescence in the sea for as long as they've been going out in boats. But they had no idea what was below the surface. And then, in the 1950s, scientists were trying to figure out how far does light get down into the water. And when they lowered these photomultipliers off the side of the ship, what they realized is they got a lot of bioluminescence in the water, and they were just shocked at how much light there was. Nowadays they have these ultrasensitive cameras that use red light as their light source, and they put them down at the bottom of the ocean with lures, and they just watch what happens, and they see many fish, squid, octopus, all sorts of creatures that have light organs that produce their own light.

Interviewer - Sarah Crespi
So one theme I've noticed is that these marine organisms' eyes seem to be more sensitive or more finely tuned than land dwellers. Is that something that we can use for technological applications?

Interviewee - Elizabeth Pennisi
So yes, so we can learn a lot from how organisms process light and from there apply that to our own optics. One program that's underway is called Shrimp in Space. And this is a researcher who has been studying mantis shrimp, which have these stalked eyes that are extremely sophisticated, and they scan their environment line by line to develop a whole picture. And he thinks that satellites could benefit by using some of the approaches that the stomatopods use in how they process light.

Interviewer - Sarah Crespi
Really interesting. Okay. Well, thanks for talking with me today.

Interviewee - Elizabeth Pennisi
Well, thank you.

Host – Sarah Crespi
Elizabeth Pennisi is the author of a News Focus this week on light in the deep ocean.

Music

Interviewer - Kerry Klein
Finally today, I'm here with *Science* contributor Meghna Sachdev, filling in for David Grimm, who is here to give us a rundown of some of the recent news from our daily news site, news.sciencemag.org. So first, Meghna, a story that might help me prepare for that trip to Antarctica that I've always been meaning to take.

Interviewee - Meghna Sachdev
Well, yes. So, as we know, Antarctica is very cold and it's very far away, so it's one of the most pristine environments on Earth. But scientists now, well one of the things that they've been worried about is plant stowaways, which are basically non-native plant species that visitors bring in accidentally and could end up actually growing there.

Interviewer - Kerry Klein
So plant stowaways. Is there really a large enough people visiting Antarctica for this to be a danger?

Interviewee - Meghna Sachdev
Well, the number of people visiting is increasing, and with climate change, Antarctica is also just going to get more hospitable. So this is actually a little bit of a concern.

Interviewer - Kerry Klein
All right. So I'm looking at my shoe right now, and I don't really see any seeds on there. Is this how much is this phenomenon actually happening?

Interviewee - Meghna Sachdev
Well, so for the first time, researchers actually did a continent wide study of about 2% of the visitors who were visiting Antarctica. And they vacuumed their gear, and they, you know, checked their pockets and things, and they got about 2,700 seeds. And from that, they kind of figured out that that's probably about 71,000 seeds just in one field season. So scientists, actually, it turns out, are worse than tourists at bringing in seeds. About 20% of tourists were unwitting seed smugglers, and about 40% of scientists and their teams had them. And the average person who had these plant hitchhikers actually had about nine seeds on them. So it does seem to be a bit of a problem.

Interviewer - Kerry Klein
So what kinds of species are we talking about here?

Interviewee - Meghna Sachdev
Well what's a bit of a concern is that about 50 or 60% of the seeds seemed to come from cold climates. So they looked at the types of seeds, and they looked at visitors' travel habits, and it seemed like a significant percentage of the seeds might have a chance of taking hold. Apart from that, with climate change, Antarctica does seem like it might become a little bit more hospitable. And, by about 2100, scientists think the risk will increase pretty dramatically. So there's a lot that goes into whether or not a non-native

species will actually take hold, but at least we know now that Antarctica is not completely immune to something like that happening.

Interviewer - Kerry Klein
So is there anything that can be done to prevent this? You know, as a traveler to Antarctica, what can I do to keep myself from smuggling in seeds?

Interviewee - Meghna Sachdev
Well it's actually not that hard. Visitors basically just need to clean their equipment, empty pockets, and mostly just vacuum everything you bring in. And they also say that scientists should watch where they store their gear. And as long as everything gets a good vacuuming, things should probably be okay.

Interviewer - Kerry Klein
All right. And onto a story about everyone's favorite ingredient in wine – the yeast.

Interviewee - Meghna Sachdev
Yes. So in Sicily, a lot of wine makers still follow the old ways. They might not be stomping around on the grapes with their feet, but they're still using old stone troughs and things like that. And so researchers thought they'd sort of see what was going on with the local wine yeast.

Interviewer - Kerry Klein
And what is going on with the local wine yeast?

Interviewee - Meghna Sachdev
Well, actually what they found is that the local yeast, a lot of the strains, they're actually as good as – or sometimes even better – than commercially available, widely sold yeast.

Interviewer - Kerry Klein
So when we talk about local local wine yeast, what exactly does that mean? If it's not coming in a jar from a supermarket, how are they finding it, how are they using it?

Interviewee - Meghna Sachdev
Well, one of the ways in which, you know, you can get sort of wild strains of yeast is they just sort of grow. So modern wineries are pretty serious about keeping things clean – there's a lot of scrubbing. And, you know, part of following the old ways sort of means there isn't quite as much cleaning going on so. So, you know, grubby fingernails or poorly scrubbed tubs also mean that there's a little more wild yeast action going on.

Interviewer - Kerry Klein
Wow. And so you said that they actually do stack up to widely sold yeasts. How did scientists figure that one out?

Interviewee - Meghna Sachdev
Well, scientists used two of the local strains to ferment local grapes. So they studied them, and the alcohol content looked good, and they also seemed to be churning out esters, which is what a lot of people want in their wine because it makes it smell good. But, you know, esters and alcohol content is not necessarily what we're looking for. So they also did a taste test. And it turned out that, sure enough, Sicilian wine experts preferred the wine made by the local yeast.

Interviewer - Kerry Klein
No kidding. So if I am in a winery, a commercial winery, should I start to think about moving towards some wild strain of yeast?

Interviewee - Meghna Sachdev
Well, I think what this means basically is that microbial diversity is a good thing – it's good to have lots of different kinds of yeast available, and it's good to have lots of different strains.

Interviewer - Kerry Klein
So is this part of Sicily the only place where we can find these wild strains of yeast?

Interviewee - Meghna Sachdev
Well, no, actually, scientists so far have described less than 1% of the estimated 700,000 strains of wine yeast worldwide. So there's definitely lots of other yeast to discover.

Interviewer - Kerry Klein
And a lot of potential for really delicious wine.

Interviewee - Meghna Sachdev
Exactly.

Interviewer - Kerry Klein
Okay. And for our last story today, we are digging up more dirt on the iceman.

Interviewee - Meghna Sachdev
Yes, so Ötzi the iceman, he was a naturally preserved mummy that they found melting out of a Alpine glacier in '91, and they've been poking and prodding at him and finding out all sorts of things, trying to figure out what he last ate. But what they just did is they sequenced his genome. And we actually ended up finding out a lot of cool stuff.

Interviewer - Kerry Klein
So what kind of "stuff" did we find out?

Interviewee - Meghna Sachdev
Well, we knew that Ötzi had severe arteriosclerosis, but what we were surprised to find out – or what scientists were surprised to find out – was that he had a genetic

predisposition to it. And, well, that's surprising because he didn't have any of the risk factors that we…

Interviewer - Kerry Klein
Well we don't know – he could have smoked; he could have been an alcoholic.

Interviewee - Meghna Sachdev
Well, probably not. He wasn't overweight; we definitely think he was getting enough exercise; and he probably wasn't smoking or drinking. So unfortunately what this means is that we might be less able to prevent arteriosclerosis than we had thought.

Interviewer - Kerry Klein
Wow. How interesting. So what else did his genome tell us?

Interviewee - Meghna Sachdev
Well Ötzi was also the first known carrier of Lyme disease, so now we know that Lyme disease has really plagued humans for thousands of years, and we also found out where Ötzi came from. So his mitochondrial DNA has been sequenced before, but that really just gave us information about the female line. Now after scientists sequenced the Y chromosome, we know that Ötzi is related to populations in Sardinia and Corsica, as well as some places in Georgia and Russia. And interestingly, we also know now what he looked like.

Interviewer - Kerry Klein
Oh, really.

Interviewee - Meghna Sachdev
Yeah. So we know he had brown eyes, brown hair, and type O blood, and we also know that he was lactose intolerant like most Neolithic Europeans.

Interviewer - Kerry Klein
Wow. So this is a lot of new information. Have we learned all that we can from him?

Interviewee - Meghna Sachdev
No, we haven't. Scientists are trying to compare Ötzi's Lyme disease pathogen with more modern versions and trying to figure out how Lyme disease evolves. And as the research that scientists are doing evolves, there's still a lot more that Ötzi could end up telling us.

Interviewer - Kerry Klein
Great. Well, I can't wait to hear more about it. And what else have we had on the site this week?

Interviewee - Meghna Sachdev
Well, on *Science*NOW you can read about the sequencing of the gorilla genome and how we're more related than we thought. And there's also new information about the elusive

Higgs boson. On Insider, we have a story about the biosecurity debate about labs who work with engineered bird flu viruses, as well as one about a diesel lung cancer study that has finally been published after a 20-year dispute. And this week's *Science*Live, our weekly chat on the hottest topics in science, is the science of tiny critters where we discuss the science of miniaturization in vertebrates. And don't forget, you can follow us on Facebook and on Twitter at *Science*NOW.

Interviewer - Kerry Klein
Great. Thanks, Meghna.

Interviewee - Meghna Sachdev
Thank you.

Interviewer - Kerry Klein
Meghna Sachdev is a *Science* contributor. You can check out all of our news at news.sciencemag.org, including daily stories from *Science*NOW and science policy from *Science*Insider. While you're there, be sure to check out *Science*Live, a live chat on the hottest science topics every Thursday at 3 p.m. U.S. Eastern time.

Music

Host – Sarah Crespi
And that concludes the March 9th, 2012 edition of the *Science* Podcast.

Host – Kerry Klein
If you have any comments or suggestions for the show, please write us at sciencepodcast@aaas.org.

Host – Sarah Crespi
The show is a production of *Science* Magazine. Jeffrey Cook composed the music. I'm Sarah Crespi.

Host – Kerry Klein
And I'm Kerry Klein. On behalf of *Science* Magazine and its publisher, AAAS, thanks for joining us.

Music ends