Science AAAS

Science Magazine Podcast

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Music

Host – Kerry Klein
Welcome to the *Science* Podcast for June 14th, 2013. I'm Kerry Klein.

Host – Sarah Crespi
And I'm Sarah Crespi. This week: the geophysical history of North America [21:56], detecting the Earth's water from space [12:25], and investigating an ancient strain of leprosy… [00:59]

Interviewee – Stewart Cole
Leprosy is one of the very few infectious diseases which causes the human skeleton to become deformed and these deformities are visible to archeologists as they excavate.

Host – Kerry Klein
Plus, a few stories from our online daily news site [32:10].

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Music ends

[00:59]
Host – Sarah Crespi
Nowadays, *Mycobacterium leprae* infection or leprosy can be treated with antibiotics, but in medieval Europe the disease went from endemic to extinct without the aid of such treatments. I spoke with Stewart Cole about his group's work untangling the history of the disease by comparing the genomes of modern bacteria with those found in the bones of people that lived up to a thousand years ago. He starts off with what we know about the geographic spread of leprosy.

Interviewee – Stewart Cole
From the phylogenetic comparisons of different strains of *Mycobacterium leprae*, we suspect that the disease originated either in Eastern Africa or somewhere in the Middle East, and that it disseminated from these sites as humans migrated around the world. There's very clear evidence from the genome sequences of *Mycobacterium leprae* that the disease was introduced into certain continents. So for instance, in North America, leprosy was introduced by the Europeans who settled in the country, and in Central and

South America, the same thing happened except that we also have very clear evidence for import, if you like, of leprosy from Africa.

Interviewer – Sarah Crespi
So do any of these similarities in strains make a difference, or do any of these strain differences matter to how the disease is treated?

Interviewee – Stewart Cole
No. All strains of *Mycobacterium leprae* respond to the same treatment. There's no evidence for there being any form of drug resistance. And this, of course, is extremely good news, because it means that we can control leprosy by means of what's called multi-drug therapy.

Interviewer – Sarah Crespi
And so why did you choose to target medieval Europe in your study?

Interviewee – Stewart Cole
Well, we targeted medieval Europe for a number of reasons. First of all, in the 12th and 13th centuries, leprosy was endemic in Europe. The incidence of the disease could have been somewhere in the region of between 0.1 and 1%. So you know, this is a truly staggering number of cases. Another reason is because these days, most cases of leprosy are found in the developing world, particularly in parts of Asia, also in Brazil, for instance. And in order to understand how the disease spread around the world, it's important to sample as many countries as possible. Now, I'd like to remind you that leprosy is one of the very few infectious diseases which causes the human skeleton to become deformed, and these deformities are visible to archeologists as they excavate sites. Often, skeletons are uncovered, for instance when roadwork takes place, when new highways are built, and you can clearly see if an individual had been affected by leprosy.

Interviewer – Sarah Crespi
You actually took advantage of that fact that you could see the bacterial effects on the bones to then go further and use samples from those bones.

Interviewee – Stewart Cole
Exactly. So we would target those sites, make a bone extract, and then isolate the DNA from that extract and subject it to whole genome sequencing using high-throughput technologies.

Interviewer – Sarah Crespi
And can you talk about the different samples that you used in your study?

Interviewee – Stewart Cole
So in our study, we used several bone samples, and we also used samples from the pulp of teeth. And in fact, one of these samples was spectacularly successful, because it contained a huge amount of DNA from *Mycobacterium leprae*. And it was this sample which enabled us to perform the de novo whole genome sequence in the family.

Interviewer – Sarah Crespi
There was a lot of bacterial DNA, and it was better preserved than the human DNA that was side by side with it in the bone. Why was there this difference?

Interviewee – Stewart Cole
We know that *Mycobacterium leprae* has an extremely thick, what's known as waxy coat around it – a material which protects the cell from drying out and also from ultraviolet light or other insults from the environment. And so in a way, it's almost as if, if you think of the DNA as being the wick in the candle, it's completely covered by wax and so protected from degradation in that way.

Interviewer – Sarah Crespi
And you point out that this resistance to degradation could be helpful in future research. Can you talk about that a little bit?

Interviewee – Stewart Cole
Yes, absolutely. I think this will allow us to go back in time, because the quality of the DNA, which was isolated from these specimens which were a thousand years ago, was really quite outstanding. And so this encourages us to go on and look at even older skeletons. So for instance, we have access to some remains from Egypt, from mummies which are over 5,000 years old, and these show signs of leprosy. So if we can repeat the same procedure with them, that will allow us to go back another 4,000 years in time.

Interviewer – Sarah Crespi
And so more broadly, what does that mean? Does that tell us more about leprosy, or does it also include other information?

Interviewee – Stewart Cole
This will tell us more about the types of the strains of *Mycobacterium leprae*, which were around at that particular time. It will also enable us to calculate mutation rates more exactly, because we're in a very good position here. Unlike most people who work on the microbial evolution, because we can actually date the sample using radio carbon dating of the skeleton, that gives us a precise point in time.

Interviewer – Sarah Crespi
Let's talk a little bit more in detail about your results from the current study. What did your comparison of all these different sequences show?

Interviewee – Stewart Cole
So the comparison of the sequences brought up two, what I think are really exciting findings with respect to understanding how this infectious disease, leprosy, was transferred around the world. So first of all, from the medieval samples, we were able to find that there were actually two distinct genotypes present in medieval Europe. One of these genotypes was what we call the European genotype, and this we have seen elsewhere in a few European countries and in many settings where Europeans migrated.

For instance, in North America in the rare cases of leprosy which are now recorded, we find exactly the strain which was once present in medieval Europe. The second strain which we detected in the medieval European samples is nowadays most commonly found in the Middle East. We've recorded examples of this in Turkey and Iran, and so this points to a link between medieval Europe and that part of the world.

Interviewer – Sarah Crespi
So you can follow the disease and see the spread of people.

Interviewee – Stewart Cole
Exactly. And I think that's really fascinating.

Interviewer – Sarah Crespi
Can you talk a bit more about what's unique about the genome of leprosy?

Interviewee – Stewart Cole
So the genome of *Mycobacterium leprae* is really very unusual by bacterial standards, because about 50% of it is made up of pseudogenes, dead genes which have accumulated mutations that prevent them from encoding functional proteins, for instance. And this is pretty unusual. Most bacteria will have some pseudogenes in their genome, maybe, you know, in *Mycobacterium tuberculosis*, for instance a close relative, there are 4,000 genes present and perhaps 20 pseudogenes. In *Mycobacterium leprae*, there are 1,600 real genes and as many pseudogenes. For me, this has always been puzzling, because bacteria generally tend to, once a function has been lost, the corresponding genes are usually eliminated and we see the genome shrinking. This hasn't happened in *Mycobacterium leprae*, because there's still such a huge number of pseudogenes present. And that makes me think that maybe *Mycobacterium leprae* emerged in this form only very recently and that there hasn't therefore been sufficient time for these pseudogenes to be lost. However, this is clearly speculation, and it needs to be tested by further experiment. For instance, looking at older samples might be helpful because the analysis described in the recent *Science* paper shows that there are more, a few more pseudogenes present in modern strains of *Mycobacterium leprae* than there were in medieval European strains. So if we could go back a few thousand years more, we might find that actually there were a couple more functional genes at that particular point.

Interviewer – Sarah Crespi
Now is there any evidence that the successive number of pseudogenes contributes to either its slow growth or its resistance to growing in the lab or its just kind of long standing plague on humanity?

Interviewee – Stewart Cole
Yes, I think while there's no experimental evidence to prove that the pseudogenes are responsible for the slow growth, I think it's highly likely that they do contribute because lots of very essential functions have been lost, and this means that *M. leprae*, for instance, has difficulty in acquiring iron because it's lost the genes required for iron uptake. And I think as there are a number of similar examples of important metabolic functions, which

have been lost like that, accumulation of these losses has resulted in the bacterium becoming handicapped and very slow growing.

Interviewer – Sarah Crespi
Okay. Stewart Cole, thank you so much for talking with me.

Interviewee – Stewart Cole
You're most welcome.

Host – Sarah Crespi
Stewart Cole and colleagues write about chasing ancient infectious disease in this week's *Science*.

Music

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Host – Sarah Crespi
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Host – Kerry Klein
And, if you're looking for any ideas, I'm going to go back to fiction and recommend *Stranger in a Strange Land*, an oldie but a goodie by Robert Heinlein. It's about a martian who finds himself on Earth and has to adjust to life on our blue planet.

Host – Sarah Crespi
Interesting, Kerry. So, check out that book and more from Audible, and don't forget—you can get a free download just for signing up at audiblepodcast.com/sciencemag.

Music ends

[12:25]
Host – Kerry Klein
Remote sensing by detectors mounted on satellites has revolutionized how we understand the Earth, and without it, we wouldn't have technologies like global positioning systems and Google Maps. Back in 2002, a team of scientists launched a satellite that aimed to map a different kind of feature: the Earth's water. And that satellite is the focus of a Perspective this week. Lead author James Famiglietti spoke with me about how this satellite works and what it means for water management.

Interviewee – James Famiglietti
Our paper really highlights the difficulties of water management today, in particular, under a changing climate and the pressures of population growth, but it also underscores the role that the NASA satellite gravity mission has been playing in helping us monitor

things like ground water depletion and locations of flooding and drought. And the third thing that I think will probably end up maybe being the most lasting contribution of the paper is that it presents a map of changing water availability in the United States, and it's a map that we derived using the GRACE satellite mission. And it shows places all across the U.S. over the last decade that have either been gaining or losing water, and I think it really highlights the need for urgent coordinated action in the United States.

Interviewer – Kerry Klein
Okay. So you mentioned the GRACE Mission. What exactly is GRACE?

Interviewee – James Famiglietti
GRACE stands for Gravity Recovery and Climate Experiment. It's a NASA mission that was launched in 2002 to map changes in Earth's gravity field, really, with unprecedented accuracy. One of the very nice outcomes of this mission is that it has allowed us to map changes in water storage all over the world.

Interviewer – Kerry Klein
And how exactly do you get from gravity signatures to water flow?

Interviewee – James Famiglietti
GRACE really functions like a scale in the sky, and when we think about a, say, a bathroom scale we push down on some spring-loaded weights and that would be converted into a mass change. With GRACE, we have these two spring-loaded weights that are not very big. Each is about the size of a squashed minivan, and they orbit at about 400 kilometers. And what happens is that the change in mass on the surface, say, because of a big flood or a big load of snow on the mountains, actually pulls those spring-loaded weights towards Earth's surface. So it's got this, basically, mobile scale that's orbiting around the Earth and mapping out places that are changing and losing water weight.

Interviewer – Kerry Klein
And how exactly do you isolate the signature of water? You know, how can you be sure that it's not the movement of people or really large objects?

Interviewee – James Famiglietti
Right. Yes, we get lots of interesting questions like that, like, what about the mass migrations of the wildebeest but also more, very good questions like what about erosion? What about oil exploration and oil extraction? So it turns out that water is ubiquitous and also extremely heavy. So when we compare the mass changes of water to just about everything else, water dominates so it's most the time the dominant thing. Sometimes, if there's a huge earthquake like the Sumatra earthquake back in, I think it was 2004, really, really big earthquakes will show up, and if we want to focus on water, we have to do the correction for the earthquake.

Interviewer – Kerry Klein

And GRACE has been in orbit since 2002. How frequently are you able to take these measurements? What sorts of time scales are you looking at?

Interviewee – James Famiglietti
It takes about a month to map Earth's gravity field, and really what we're looking at is the change in the gravity field, or the change in mass, which as we just talked about is mostly the change in water mass. So it takes a month to map a gravity field, say we make a map this month in June and we can look at the difference between June and May and look at that change in water storage all over the world on a monthly basis.

Interviewer – Kerry Klein
So what has GRACE really been able to show us so far?

Interviewee – James Famiglietti
GRACE has really showed us some incredible things. At the global scale, some of the biggest contributions have been monitoring changes in the Greenland and Antarctic ice sheets and melting alpine glaciers, changing ocean mass related to sea level rise. But on land, it's really been phenomenal. It's allowed us to see ground water depletion, and we're seeing it now happening all over the world. It's happening in most of the major aquifers in the arid and semi-arid parts of the world where we rely on those aquifers. But we're able to see now the impact that we're having on this over exploitation. The other thing that it's showing, and we covered a little bit in the paper, is this redistribution of water, this drying of the mid-latitudes so the dry air is getting drier and wetter areas, like the tropics and even high latitudes, getting wetter.

Interviewer – Kerry Klein
So much of this we do already know, at least to a certain extent. We know that ice sheets and glaciers are melting. How does this technology augment the other technologies that we're using to monitor water movement?

Interviewee – James Famiglietti
First of all, if we rely just on our ground-based observations, it would be wonderful if we could, but we really can't because most of the time in most parts of the world, we just don't have the money, the resources, to fully instrument the ground and our water bodies the way that we need to. We have other satellites that can help out, of course, but most of those satellites are focused on maybe one specific thing like changes in vegetation and the color of the vegetation, the greenness of the vegetation or changes in hydrology. So with GRACE, you have a fundamentally different kind of mission, because it's really like a scale. It's weighing mass changes, but it also gives us a holistic measure of all the water storage changes in a region, like a combination of all the snow, all the ice change, all of the soil moisture, all of the surface water, all of the ground water.

Interviewer – Kerry Klein
So collecting this kind of high accuracy gravity data is one thing, but what are the next steps? What can we then do with that data?

Interviewee – James Famiglietti
Well, it's been very important for regional water management, because one of the things that it does is, first of all, put a regional picture into a global context so we can look, say, at California but understand that it's not just California what we're seeing. The ground water depletion and the snow melt that we're seeing is something that's happening all across the mid-latitudes all over the world. The other thing that it does is that it allows us to quantify these storage changes over these large regions. And, we haven't had this information before. In a sense, if we go back to the scale analogy, we're looking at the fluctuations of water weight, or water availability, the ups and downs, in a way that we've never been able to do before. So it's like, you know, tracking your weight for the first time as an indicator of your health. And if you never had that information before, you'd suddenly realize how valuable it is, all the things you could do with it, and you know, you would wonder how you got by all this time.

Interviewer – Kerry Klein
So while GRACE may have a very high accuracy in how it's measuring this gravity, it does have some limitations, one of which being that the regions that it studies have to be relatively large. You know, what are some drawbacks to how GRACE measures gravity?

Interviewee – James Famiglietti
The biggest limitations of the GRACE mission with respect to hydrology anyway are its coarse spatial and temporal resolution. The regions that we look at have to be 150,000 square kilometers to 200,000 square kilometers or greater in area. And we get the data on a monthly basis. What would be really beneficial for hydrology and for water management would be GRACE information at the scales at which water management decisions are actually made, which are more like tens of thousands of square kilometers, the size of smaller river basins or aquifers rather than hundreds of thousands. And on a weekly basis, or a couple of times per month compared to the monthly data that we're getting right now.

Interviewer – Kerry Klein
Okay. So the team that created GRACE is planning on launching a few follow-up missions in coming years. So what will be changing in future iterations?

Interviewee – James Famiglietti
Well, the next mission due up is called the GRACE Follow-On, and not very much will change at all, if anything, in the GRACE Follow-On, hence the name. It's what we call a climate continuation mission, and the reason for launching that one without much change is just to have continuity in these very important climate and hydrological records. And so the GRACE Follow-On, or GRACE-FO, will launch in 2017, or at least that's the current plan, and if it is as healthy as the current GRACE mission, it could last a good 10 years. It's after that, that we're planning for a more advanced mission that maybe could get down to these finer space and time scales. And that is much more uncertain and that's just because of the nature of our economy today and competition for a satellite mission. They cost lots of money in the billions of dollars and so nothing is guaranteed beyond this GRACE Follow-On mission.

Interviewer – Kerry Klein
Right. Well, James Famiglietti, thank you so much.

Interviewee – James Famiglietti
My pleasure. Thank you.

Host – Kerry Klein
James Famiglietti and co-author Matthew Rodell write about detecting the Earth's water from space in a Perspective this week.

Music

[21:56]
Host – Sarah Crespi
Sometimes watching things from the sky isn't enough—you have to get down in the dirt. The EarthScope project is an attempt to get at some ground truths about the formation of the North American continent and some of its more unusual features. I spoke with Richard Kerr about his News Focus on the project, including what arrays of seismographs, a line of GPS trackers, and one deep borehole can tell us about the sources of West coast quakes, the heavy volcanic activity of Yellowstone, and interactions at the edge of the North American plate.

Interviewee – Richard Kerr
The plate tectonics revolution of the 1950's and 1960's was largely driven by geophysics – that is, seismologists detecting earthquakes running down the middle of the North Atlantic ocean sea bed, earthquakes, say, beneath South America near the deep-sea trench there, paleomagnetic measurements that show that continents actually had moved. They had drifted. The geologists were largely on the sidelines because so much of this evidence for plate tectonics was coming from geophysics and in particular from the oceans. So plate tectonics did help out continental geologists. It explained how the Appalachian Mountains were pushed up, for example. But that left plenty of features that didn't really fit in to the plate tectonics picture – the Colorado Plateau – why was it there? Why was that ground high? Yellowstone volcanic activity – a very hot, hot spot, but it didn't fit into plate tectonics either.

Interviewer – Sarah Crespi
So here's the new approach – EarthScope. It's not exactly a scope, but it's attempting to take a look at these phenomena. What exactly is the EarthScope?

Interviewee – Richard Kerr
Well, somebody coined that term early on. It's a program that has beefed up the geophysical observation of North America, particularly the lower 48 states. Scientists have intensified their observations. They've created a much more dense and more sophisticated network of seismometers across the country – a very novel idea of taking 400 seismometers, spreading them up the western edge of the continent, and then moving

them one by one to the east so that later this year, the last of those are going to come up against the eastern seaboard. So this gives seismologists a much sharper picture of what's going on underneath the continent.

Interviewer – Sarah Crespi
So why move them? In your story, you said that there was already a grid deployed of the seismometers, but then there's also this moving line. Why do both?

Interviewee – Richard Kerr
Just as your electronic camera will give you a sharper picture with more pixels, more seismometers give you a sharper picture of what's going on underneath. The seismic waves are coming up through the continent, and the rock beneath the continent alters those seismic waves in a way that lets seismologists reconstruct a 3-D picture down for hundreds of kilometers beneath the continent. So they put 400 out there in a dense array and left them for a couple of years, which turned out to be long enough to get a good number of earthquake signals. And then when they've got enough there, they move them to the east and collect data there.

Interviewer – Sarah Crespi
They are basically bringing high resolution along a line very slowly across the entire continent.

Interviewee – Richard Kerr
They are scanning the continent, I guess.

Interviewer – Sarah Crespi
Yes, great. So there are a couple other components to the EarthScope besides these seismometers. Can you talk about those?

Interviewee – Richard Kerr
Yes. They are not quite as broad a view as the seismic network ended up getting, but there is a so-called Plate Boundary Observatory, which involved GPS sites rather than seismometers – same idea though – get a lot more stations, a much denser array. And this Plate Boundary Observatory only covers the western, far western part of the United States from Mexico to Alaska, and these very precise GPS instruments are able to measure any motion of the surface to a precision of 1 millimeter per year. So as the western boundary of the North American plate grinds along the Pacific plate, a lot of it happening on the San Andreas Fault. As that happens, the crust gets distorted and the GPS can pick up these infinitesimal motions and tell scientists how quickly and where the strain is building along that fault.

Interviewer – Sarah Crespi
And then there's another even, another approach to looking at the San Andreas Fault. It folded into this project.

Interviewee – Richard Kerr

There’s a third component to EarthScope, and it’s, as you say, very localized. One hole, I think it was maybe 15 centimeters across toward the bottom, and they drilled that just off the San Andreas – drilled it down and then bent the hole as they drilled so it would penetrate the San Andreas Fault. And they were able to bring rock back from the fault 3 kilometers down, and that let them see that there was clay in the fault. Clays, as you might intuitively realize, are slippery when wet, and apparently these clays are allowing this particular spot in the San Andreas to slip without creating earthquakes, which is something they’d been wondering about for decades.

Interviewer – Sarah Crespi
Alright. This project has been in progress for what – 10 years?

Interviewee – Richard Kerr
About 10 years.

Interviewer – Sarah Crespi
And we’re really starting to see some results. Can you talk about results from the seismology array?

Interviewee – Richard Kerr
Sure. One big find only recently announced was that beneath Yellowstone, the rock is hotter than normal. That had been known for many years, but that unusually hot rock is now seen to extend down to at least 900 kilometers depth. That’s right through the upper mantel and into the so-called lower mantel, and that demonstrates that all this heat and volcanism at the surface where geologists had been looking at it and wondering for a long time actually must originate from very deep in the Earth, perhaps down to the Earth’s core. This has been a very controversial question for a long time. Some other features that are showing up very clearly are drips. These are globs of rock that formed as the bottom of the North American continent of the plate, but because they got colder than normal, they are falling away into the deeper mantel. And that can open up possibilities for volcanism where they left the plate, so you get this extra weight off the plate and the rest of the plate can rise up. It probably let the southern of the Sierra Nevada Mountains rise up.

Interviewer – Sarah Crespi
Your description in your article makes me think of a lava lamp with things coming up from the bottom and hitting the surface and then other things kind of falling away in this almost like a cycle [crosstalk]…

Interviewee – Richard Kerr
That’s a good analogy.

Interviewer – Sarah Crespi
And it’s got the word lava in it.

Interviewee – Richard Kerr

The lava lamp is a lot of what's going on in the deep Earth mantle. There's heating at the bottom and you get the plumes and now we have drips, kind of the anti-plume. There's one other thing going on under North America that EarthScope is clarifying and that is the ocean plates coming in from the west used to be diving under most of the west coast – they are still down there. And you can see them in the seismic images. This plate that dove under North America tens of millions of years ago eventually stopped, and scientists think that happened when something got jammed in underneath the western edge of the coast. And then it fell apart. And it's obviously continued to fall through the mantel, and that's really stirring things up, probably getting in the way of that Yellowstone plume, also probably stirring up some volcanism places like Columbia River basalts which was a huge eruption 15, 16 million years ago, Oregon or other spots around the county. So the geologists are getting a better understanding of where some of these surface features that they had been studying so long actually are coming from.

Interviewer – Sarah Crespi
So what are the next steps for this project? Will there be other proposed parts built or maybe more data analysis?

Interviewee – Richard Kerr
Well, each component has its own prospects. The drill hole in San Andreas did not get much farther. Its planned penetration of an actual earthquake patch on the San Andreas never happened. It ran short of money. The seismometer array, as I said, it's arriving on the east coast right now, and the plan firmly in place is to, when its two years are up, send it to Alaska where it will keep an eye on a lot of ocean plate going underneath Alaska creating earthquakes in the process. And the Plate Boundary Observatory, the GPS on the west coast, is going to stay there and keep observing as long as they can. They are very interested in a phenomenon that was totally unknown when they were planning it, but it turns out it can keep a very close eye on this so-called episodic tremor and slip that's going on underneath Washington and Oregon, which is where our next great earthquake could come – a magnitude 9, possibly. And what's happening is the fault down there doesn't slip in a big earthquake all that often, but it's day by day or over a course of a month it can quietly, seismically quietly, slip. And they are keeping a close eye on it, because every one of those slow slip events appears to be loading the main fault for its next big one.

Interviewer – Sarah Crespi
Well, Richard Kerr, thanks so much for talking with me.

Interviewee – Richard Kerr
Good to be here, Sarah.

Host – Sarah Crespi
Richard Kerr is a staff writer for *Science*. He writes about the EarthScope project in this week's issue.

Music

[32:10]
Interviewer – Kerry Klein
Finally today, I'm Kerry Klein, and I'm here with online news editor, David Grimm, who is going to give us a rundown of some of the recent stories from our online daily news site. So Dave, our first story is about a new method of monitoring animals in the wild. The cheetah is considered to be the fastest land animal on Earth, and a high-tech new radio collar is helping us to understand the secrets of its speed.

Interviewee – David Grimm
And it turns out because of this research that we're finding out that speed isn't everything when it comes to cheetahs. They are the fastest land animal on Earth. They've been clocked at more than 100 kilometers per hour, which is as fast as many cars on the highway. And researchers have longed believed that just because they are that fast is why they are so successful at catching prey, but these radio collars you alluded to are shedding some new light on really why cheetahs are such good hunters. It's really hard, actually, to take a lot of these measurements in the wild. And so what researchers did, they spent 10 years perfecting these radio collars, and what's cool about them is they have a GPS system so the researchers can monitor exactly where these animals are. They also have gyroscopes, magnetometers, accelerometers, all the sort of things that you want to know to figure out exactly how a cheetah is moving when it is chasing down prey. And these things are solar powered too, so they'll last for about a year.

Interviewer – Kerry Klein
So what types of things can we learn about cheetahs in a year?

Interviewee – David Grimm
Surprisingly a lot. These collars were so good, they were able to actually collect data 300 times a second. So these researchers really had a wealth of information to sort through. They had fitted the collars on three female and two male cheetahs, and they actually watched them over about an 18-month period during their time in the African savannah. And what they found is that these animals do run really fast – actually clocked one of the cheetahs at 106 kilometers per hour. But much of the time, the animals were actually not running that fast. They were topping off at about 60% of that speed. When they did run that fast, it was only for about one or two seconds. What really seemed to matter was how quickly the cheetah could out-maneuver its prey, and it did this by breaking very quickly, by turning very quickly. It could make these really sharp turns, and it accelerated with four times the power of the fastest human sprinter. So it wasn't really that the cheetahs are able to take down prey because they are so fast, it's because they are able to stop and start very quickly, able to turn very quickly – all the things you'd want to be able to do to chase down a prey that's running fairly erratically.

Interviewer – Kerry Klein
So are researchers planning on trying to use this sort of technology with other animals?

Interviewee – David Grimm

Well, yes. That's the really cool thing about this study is because these collars have been so effective, the researchers actually want to try them on lions, wild dogs, and even domestic cats. You can figure out what your kitty has been up to while you've been gone during the day. So some pretty cool applications of this work.

Interviewer – Kerry Klein
Okay. And next up is a story about the advantages of record-keeping. Modern science takes advantage of many ways of observing the past – sediment cores, ice cores, tree rings, things like that. But we shouldn't underestimate the power of a medieval quill pen.

Interviewee – David Grimm
That's right, and especially the writing of medieval Irish monks. It turns out, there is something in Ireland called the Irish Annals, and this is an anthology that includes more than 40,000 entries chronicling many aspects of medieval Ireland. The dates range from between 431 and 1649, so there's a lot of stuff in there. And the reason scientists are interested in those writings is because they are trying to make a connection between volcanic activity and cold spells. Volcanoes belch a ton of sulfur dioxide into the atmosphere, and what the sulfur dioxide does is actually reflects sunlight back into space and that can actually cool various regions of the Earth when you have a volcanic eruption. But it's been hard to draw exact links between the timing of those volcanic events and actually cooling spells on Earth. And the reason is, is because even though we have these ice sheets and these ice cores that you referred to – that's sort of when the ash falls down, it creates layers kind of like tree rings in the ice and researchers can drill these cores and sort of figure out when the layers relate to certain climate events in history. The timing isn't super precise, and they would love to be able to correlate that with other sources of data.

Interviewer – Kerry Klein
Cue the chronicles of these medieval monks.

Interviewee – David Grimm
Exactly and it's actually not just monks. It's monks, but it's also family historians, writings from Ireland's aristocratic families, and also as time went on, the researchers actually got information from personal letters and military historians. But they actually got a wealth of information. They were able to identify 70 cold spells over this more than thousand year period that they considered very reliable indications of the weather at the time. It's understandable that people would be writing about this stuff because cold spells – it's not just like, hey, it's cold outside but actually they are worried about things like livestock and crops and the impact the cold weather has on society in general. Especially when you're talking about populations that don't have the modern heating technology that we have today. So this was actually something that people wrote a lot about. And the really cool thing is that the researchers were able to time the writing of these events to 48 distinct volcanic eruptions.

Interviewer – Kerry Klein

So we already knew that volcanic eruptions could cause this cold weather. We already had evidence of these in ice cores around the world. So how exactly do these added records actually help us understand these events?

Interviewee – David Grimm
Well, it gets the timing more precise about the link between the eruptions and the cold spells. It also suggests that there may be a lag time between when the volcanoes erupted and when the cold spells happened. 38 of the 48 eruptions occurred within five years of the episodes of cold weather. And often, that was five years before the cold weather happened is when the volcano erupted. And that may seem like a long lag time, but it could take a lot of time for these particles to get into the air so researchers are getting a better sense of the timing. They've also just got more data now. They can, sort of, tweak their climate models when they are trying to predict how future eruptions are going to impact climate. They now have this additional source of data to draw from.

Interviewer – Kerry Klein
And then of course today, we've got social media. We've got Twitter.

Interviewee – David Grimm
We do. We still have Irish monks but we don't have to rely on Irish monks as much. We've got Facebook and Twitter to take their place.

Interviewer – Kerry Klein
Right. And in our final study, we're contemplating what happens when we stare into the face of death. There's a saying that goes "there are no atheists in foxholes," implying that the fear of death turns people to faith, but a new study suggests otherwise.

Interviewee – David Grimm
Well, a new study suggests that people will turn to science as well. It's a little bit of a biased study, because the people they recruited for the study already didn't have a strong belief in religion. So these weren't necessarily people that were going to turn to God anyways in a very stressful situation. But it does suggest that when people don't have religion in their lives, they find something else to turn to when they are confronting death, and in this case, that something else is science.

Interviewer – Kerry Klein
So how did a scientific study make people confront death? And not face a lawsuit?

Interviewee – David Grimm
Right. Well, they didn't go to foxholes. What they did was they actually turned to competitive rowing, which is a very stressful sport. They recruited 100 rowers, mostly in their 20's, and again, these people didn't have very strong religious convictions. And they broke the rowers into two groups – one that was about to race in a regatta so they are very stressed out. And the other was preparing for a less stressful training sessions. And then they had the rowers complete surveys, which asked them to agree with statements like "we can only rationally believe in what is scientifically provable" and "a scientific

method is the only reliable path to knowledge." And what they found is that athletes that were getting ready for this big rowing competition had higher anxiety levels, as you would expect. They were also significantly more likely to express a strong belief in science based on the survey. In fact, 15% more likely than the rowers in the other group.

Interviewer – Kerry Klein
But that doesn't quite have an element of death in it.

Interviewee – David Grimm
That's right. So actually the researchers did another experiment where they recruited staff members and students at two large universities in the United Kingdom who also didn't have very strong religious beliefs. And they asked some of them to write about their own death and others to write about the experience of dental pain. So subjects who contemplated their own mortality again showed about a 15% stronger belief in science based on a similar survey that had been used in the previous experiment – 15% stronger than the subjects that were just contemplating dental pain. So this we got death more into the equation here. People aren't actually confronting death, but they are actually thinking about their own mortality a lot.

Interviewer – Kerry Klein
But of course, this wasn't people that were religious and asking them to turn over to science.

Interviewee – David Grimm
Right. The point of this study isn't to show that everybody's going to turn to science. It's that people that don't have faith to turn to will find comfort in science. If science and religion have anything in common, they are both ways that help us understand our world and sort of feel comfortable in our world. If we believe in God, then we sort of believe we have a place in this world, and that helps us take comfort in life when things don't always go well. With science, it can be kind of similar. If we believe that there's very sound scientific principles that guide everything around us, then when things don't go well, some people can take comfort in these principles realizing that the world is a very logical, ordered place, and that seems to be what's happening here.

Interviewer – Kerry Klein
Alright. And what else have we had on the site this week?

Interviewee – David Grimm
Well Kerry, for *Science*NOW, we've got a story about how zapping your brain can make other people look more attractive. Also a study about how a rare genetic disease in humans is getting some explanation thanks to a similar disease being found in dogs. For *Science*Insider, our policy blog, we've got a story about a scientific flash mob in Rome. Also a story about how the genomic business has added nearly one trillion dollars to the U.S. economy. Finally for *Science*Live, our weekly chat on the hottest topics in science, this week's *Science*Live is about bioelectronics – our cyborg future – man melding with machine. And next week, our *Science*Live is about the science of summer blockbusters.

What do Hollywood movies get right and wrong when it comes to science? So be sure to check out all these stories on the site.

Interviewer – Kerry Klein
Great. Thanks, Dave.

Interviewee – David Grimm
Thanks, Kerry.

Interviewer – Kerry Klein
David Grimm is the online news editor of *Science*. You can check out all of our news at news.sciencemag.org, including daily stories from *Science*NOW, science policy from *Science*Insider, and *Science*Live, live chats on the hottest science topics every Thursday at 3 p.m. U.S. Eastern time.

Music

Host – Sarah Crespi
And that concludes the June 14th, 2013 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