Science Magazine Podcast
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Music

Host – Robert Frederick
Hello and welcome to the *Science* Magazine Podcast for May 21st, 2010. I'm Robert Frederick. This week: controlling a bacterial cell with a chemically synthesized genome; measuring instantaneous Brownian velocity; and how animal communication provides insight into the origins of language. All this and more, plus a wrap-up of some of the latest science news—including a story about being happier after age 50—from our online daily news site, *Science*NOW.

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Host – Robert Frederick
For more than a decade, researchers have been trying to build a genome from scratch and use it to make synthetic life. And in answering, first, how big that genome needs to be, two years ago, Hamilton Smith, Craig Venter, and colleagues reported a viable synthetic genome could probably be even smaller than that of *Mycoplasma genitalium* – a bacterium that arguably has one of the smallest genomes of any living thing, with only 580 thousand base pairs. Here's an excerpt from the *Science* Podcast interview with Smith two years ago.

Interviewee – Hamilton Smith *(excerpt from 25 January 2008 podcast)*
We've published a couple of papers showing that as many as a hundred genes in *Mycoplasma* are nonessential. And it seemed to us that one of the easiest ways to reduce the genome was to chemically synthesize it and simply drop out genes until the genome wasn't able to transplant anymore.

Host – Robert Frederick
While the team had chemically synthesized the *Mycoplasma* genome, in the past two years they hadn't succeeded in getting a viable transplant. But, during that time, the team was able to transplant the genome of another bacterial species, *Mycoplasma mycoides*, into still another *Mycoplasma* species, *Mycoplasma capricolum*, which allowed the *mycoides* genome to control what had been the *capricolum*. And now, in a paper published online by *Science*, the team has combined the essence of both projects: the result – a new *mycoides* bacterial cell controlled only by a synthetic genome that grows,

divides, lives. I spoke with senior author Craig Venter from his company's facilities in Rockville, Maryland.

Interviewer – Robert Frederick
You and your team previously had completely synthesized the entire genome of *genitalium*. Why the switch to these two other species?

Interviewee – Craig Venter
So, *Mycoplasma genitalium* has the smallest genome of any self-replicating cell that we're aware of, and it drove the questions of, "What would be a minimal genome for a cell operating system that could go through self-replication?" And when we realized that we had to go the synthetic route to be able to compile the genome to try and leave out various genes to answer that question, we thought at the time that the biggest problem was going to be to synthesize the chromosome. And so, we started making *Mycoplasma genitalium*. In reality, the biggest problem was in the "booting up" of the chromosome, using computer analogy terms, because it is a software and an information system. The smallest genome also has the slowest growth, not surprisingly, and it takes about six weeks to complete each experimental cycle. So, trying to debug a system when there is problems with things not working, there's only so many of those cycles a year that you can do. And our first genome transplants were actually in a paper in *Science* in 2007, where – by taking the chromosome out of a species *Mycoplasma mycoide*s and transplanting that genome into *Mycoplasma capricolum* – a related species, about 10% difference in its genetic code – we were able to completely convert the *capricolum* cells into *mycoides* cells simply by changing the operating system. We then – after we started assembling the synthetic genomes in yeast using the recombination system there – we had to learn how to take the synthetic chromosomes out of yeast for transplantation into a bacteria. So, we worked that out with the native *mycoides* genome. And we finally solved that and that took us two years to solve and that's what we published last August in *Science*: finding that DNA had to be methylated after we took it out of yeast to protect it from the restriction enzymes in the *capricolum* cell. So, we had all these systems worked out with mycoides – our synthesis was working well – so I challenged the team to temporarily abandon the *genitalium* genome and see if we could make something almost twice as big. It took some convincing. And once the chromosome was synthesized we eventually solved all of the problems with transplanting it and we ended up with the world's first synthetic cell – powered and controlled totally by a synthetic chromosome made from four bottles of chemicals.

Interviewer – Robert Frederick
Was there some reason to choose the *mycoides* as donor and the other species, *capricolum*, as recipient? Could you have reversed them?

Interviewee – Craig Venter
We possibly could have reversed it from the beginning, but it is an important question. One of the things we want to do now is see how extendable this transplantation process is – across, at least microbial biology – how far apart can the genetic systems be to be able

to boot up a new chromosome, how dissimilar can we actually go to as we try to expand this to much more distant biology than just the *Mycoplasmas*.

Interviewer – Robert Frederick
You mentioned you and your team reported having difficulty, at first, in overcoming the recipient bacteria's defensive mechanism – the restriction enzymes that cut non-native DNA. And you reported one way of getting around this defensive mechanism: by methylating the donor or synthesized DNA. Do you and your team know which parts of the genome get methylated here?

Interviewee – Craig Venter
Yes. We used very specific methylases that were taken from the *mycoides* cell in the *mycoides* genome. But, we've come up with a simpler system – we've basically just knocked out the restriction enzyme genes from the *capricolum* genome, so it now has no restriction enzymes. And when the recipient cell has no restriction enzymes we can take naked DNA, without methylating it, out of yeast and get successful transplants. And that's what we did now with the synthetic cell: we did not have to methylate the synthetic *mycoides* chromosome because we used this restriction-minus donor that we created.

Interviewer – Robert Frederick
The naked DNA out of yeast is because that's where you're assembling it as within the yeast.

Interviewee – Craig Venter
That's correct. We used the yeast homologous recombination system – that's what puts the final base pair pieces together to make the intact chromosome.

Interviewer – Robert Frederick
This other way around this defensive mechanism – disrupt the defensive system itself – does that have any implications for the ability of these synthetic cells that divide and grow from this original cell to defend themselves from phages or viruses?

Interviewee – Craig Venter
No, because what was in the *capricolum* cell is now irrelevant and there's no parts of the *capricolum* cell left in our synthetic cells. So, what's in the synthetic cells is what's in the synthetic chromosome, and that includes three different restriction enzymes. So, it's just the *capricolum* cell that we use as a recipient cell – once the new chromosome is in that recipient cell all the traces of that recipient species disappear within a few rounds of replication.

Interviewer – Robert Frederick
Okay. Now that you've created a bacterial cell controlled by a chemically synthesized genome once, how fast could you do it again? In other words, how efficient is this process?

Interviewee – Craig Venter
Well, we've repeated the same process with the same chromosome – we've reassembled it and done transplants and have improved the efficiency. The first time we did it we only had a single colony of the synthetic cells growing. Now we have much more efficiency with it. But to start with a new system - we wanted to as we do work with some algae cells - synthesizing the chromosome would be pretty rapid. I think we could probably in a matter of three or four months make a new one- to two-million base pair chromosome. The challenge is, where we have to debug each system, is in the recipient biological system that it can read that particular DNA and convert it into a new cell. So, we think it's probably unlikely that the *capricolum* restriction-minus recipient cell that we have created would be a good universal recipient for bacterial DNA from any source. But, we in fact would like to create a universal recipient that we can use for all transplantations – that wouldn't have restriction enzymes, but would have the ability to read the genetic code, make the messenger RNA, and convert that messenger RNA effectively into proteins that would get the right glycosylation, et cetera. So, we will probably have to work out that biology for each new system. If we were just doing another *Mycoplasm,* we think we could probably get that to work with this same host.

Interviewer – Robert Frederick
You'd said before that the difference between these two *Mycoplasms* was about 10% – is that right?

Interviewee – Craig Venter
Yes, about the same difference that humans and mice are apart.

Interviewer – Robert Frederick
Now, of course, this has far-reaching implications – a kind of genetic engineering on a whole new level. At this point, what, if any, steps are you and your team taking to ensure this organism "stays in the lab," so to speak?

Interviewee – Craig Venter
Well, one of the reasons for working with the *Mycoplasmas* is they don't grow independently out in the environment. They need an extremely rich media to grow in. So, this *Mycoplasma mycoides* is sort of a commensal organism in, primarily, in goats and sometimes in cattle, and it occasionally causes some mastitis or irritation. We've eliminated 14 genes from the genome that, according to the literature, are associated with growth in goats. We have not tested to see whether this still would grow in goats, so unless a goat walks into the laboratory or somebody walks out of our laboratory and injects a goat, we're probably pretty good with self-containment. But, one of the things that has been important to us from the beginning has been that we've sought ethical review of this research. This is an important part of the discussion that we've had for 15 years, but even with that I think in all the publications that we've had over this time in *Science* on this topic, I think this will still be the first time that the majority of people hear about synthetic life and making synthetic organisms. So, I think it's important that people understand that we've been driving – in parallel and even before the first experiment – the broader ethical discussion of the work, as well.

Interviewer – Robert Frederick
Craig Venter, thank you very much.

Interviewee – Craig Venter
Nice talking to you.

Host – Robert Frederick
Craig Venter is senior author of a paper on the creation of a bacterial cell controlled by a chemically synthesized genome. Find the paper online, at www.sciencexpress.org. In the magazine, read a related News of the Week story by Elizabeth Pennisi.

Music

Host – Robert Frederick
The U.S. House of Representatives has again failed to pass a major science and technology bill, with last year's pornography scandal at the National Science Foundation playing a part in partisan politics. Here with more about it is *Science* Policy Forum editor Brad Wible.

Policy Forum Editor – Brad Wible
The America COMPETES Reauthorization Act, an update of the original COMPETES bill passed three years ago by an overwhelming bipartisan majority, sought to authorize major budget boosts for three federal research agencies: the National Science Foundation, or NSF, the Department of Energy's Office of Science, and the National Institute of Standards and Technology. The bill's chief sponsor was House Science and Technology Committee Chairman Bart Gordon of Tennessee, a Democrat who is set to retire at the end of the year.

Some Republicans, including House Science Committee Ranking Member Ralph Hall of Texas, were concerned about the budgets authorized by the bill. So they put forward a motion to send the bill back to the Science committee. That motion included several changes to the bill, including a significant reduction of funding levels. The real problem for the bill's supporters, however, came with the part of the motion that would prohibit the paying of employees disciplined for viewing pornography on government computers – such an incident came to light last year at the NSF. Many Democrats chose to vote for the motion to avoid looking like they supported pornography.

The result was an unexpected setback for proponents of the COMPETES bill. But another floor vote was soon set for May 19. This time it would require a two-thirds majority vote to pass but would have no additional amendments. The new version included some of the changes sought by Republicans, including three years of authorized funding instead of five, resulting in lower funding levels overall, and the now-infamous porn provision. But even that was not enough for opponents of the bill. It failed again, 261-148, along largely partisan lines, with just 15 Republicans willing to support it.

Host – Robert Frederick
That was Policy Forum editor Brad Wible with a policy update from *Science* and the AAAS Center for Science, Technology, and Congress.

Music

Host – Robert Frederick
If you've ever looked under a microscope at particles or other tiny bits of things, you've probably noticed the small, seemingly random jitter of those bits, the "Brownian motion." Einstein famously concluded in 1907 that it would be impossible to measure the instantaneous velocity of a Brownian particle in practice due to the very rapid randomization of the motion. But, Einstein said, if you could, then you could prove one of the basic tenets of modern physics known as the "equipartition theorem." Of course, over the years, many teams of physicists have tried. But now, in a paper published online by *Science*, Mark Raizen and colleagues report their success, providing direct verification of the energy equipartition theorem for a Brownian particle. I spoke with Raizen from his office at the University of Texas at Austin.

Interviewee – Mark Raizen
Brownian motion is an unpredictable motion. It is random in nature. That was explained by Albert Einstein, who showed theoretically that this is due to the microscopic nature of particles that ultimately everything is made of atoms. Now, suppose you could actually track the instantaneous velocity – in other words, you could look at the particle in real-time and see its velocity, its direction and magnitude of its motion. Einstein himself recognized that just by measuring that velocity you could essentially determine the average kinetic energy – kinetic energy is the energy of motion of a particle. And he said that that would follow a universal rule, which only depends on the temperature of the particle. It doesn't depend on its nature or its size or its composition. And that prediction is called the "equipartition theorem" and is one of the basic tenants of modern physics. But Einstein, in 1907, said this would be really interesting, but then he went on to say that unfortunately because the time scale would be too short this could never, in practice, be measured. And that remained true for 103 years. Here we have measured the motion of a microscopic particle and can see its velocity in real-time.

Interviewer – Robert Frederick
And how well or poorly does your team's measurements agree with that theory?

Interviewee – Mark Raizen
Our measurement agrees extremely well with the theory. Within the uncertainty error bars of our experiment it agrees perfectly with that prediction.

Interviewer – Robert Frederick
Now, you said this was a microscopic particle, what was it made of?

Interviewee – Mark Raizen

It is actually a tiny bead of glass that's only three micrometers in diameter. So, you can think about it almost like a speck of dust.

Interviewer – Robert Frederick
Is there some other substance you would rather have measured? What's the ultimate aim here?

Interviewee – Mark Raizen
The ultimate aim, from our standpoint, is to have an isolated system that we can cool down to the quantum mechanical ground state. And that fits into a larger area of research, which is to study quantum mechanics of objects that are somewhere in between microscopic and macroscopic – what we call "mesoscopic" – because they, on the one hand, they are tiny, but they are still composed of many, many millions of atoms and molecules. So, there's been increased interest in studying how this assembly of particles could essentially be cooled so that the center of mass of this solid is quantum-mechanical. And if you can do that you can study interesting quantum states. You could actually make what's called a super-position state, also known as a Schrödinger-cat state, where a bead of glass would be in a sort of simultaneously in one of two states being in two places at the same time. That is something that defies our everyday intuition. Now, we have not realized that, but a bead of glass being in a superposition of being in two places at the same time may be within reach.

Interviewer – Robert Frederick
What, if any, technical innovation allowed you and your team to measure this Brownian motion?

Interviewee – Mark Raizen
First of all, we focused on trapping beads of glass in air, whereas almost all previous work was done in water. And in water the time scale is very short. But, when you go to air, especially air at lower and lower pressures, the time scale gets longer. And so, that was one thing. The other thing is that we developed methods of launching the beads, getting them into the air, and then trapping them. So, essentially we launched them like you might launch a particle on a trampoline: we vibrate a little plate of glass ultrasonically and launch them in the air and then catch them with an optical tweezer. And that took some development and learning to do. The other thing is we have developed much faster detectors, as well. So, it's a combination of several things. And I would like to highlight and really praise the role of the students in carrying out this research, especially the first author, Tongcang Li, who really did a wonderful job in this work.

Interviewer – Robert Frederick
Now, you mentioned differences in pressure, I suppose the vacuum then that's got to be pulling on this little bead of glass has some affect on the motion, as well as gravity, too, right?

Interviewee – Mark Raizen

Well, gravity is always present. We start out at atmospheric pressure. And then, we start pumping out the gas to go to lower and lower pressures. Ultimately we have gone to vacuum, although the work that's reported in this paper is not in vacuum, because actually in vacuum Brownian motion ceases – there is no Brownian motion – because the particle becomes isolated from its environment.

Interviewer – Robert Frederick
Does holding the bead of glass in these optical tweezers you mentioned – does that affect the Brownian motion?

Interviewee – Mark Raizen
It does on a longer time scale, because the particles are – ultimately they're trapped – so they oscillate back and forth in this small trap, but that only affects their long-time motion on a time scale of the trap-oscillation period. Whereas on shorter time scales, we see first Brownian motion, then ballistic motion, then ultimately the instantaneous velocity. On a short time scale you can even forget about the fact that it's trapped.

Interviewer – Robert Frederick
So, this instantaneous velocity isn't based on a limit – it's just based on a really short time scale.

Interviewee – Mark Raizen
That's right.

Interviewer – Robert Frederick
Okay. Where do you go from here?

Interviewee – Mark Raizen
Well, our next step is to get rid of the air.

Interviewer – Robert Frederick
Completely?

Interviewee – Mark Raizen
Completely.

Interviewer – Robert Frederick
And then you'll have a vacuum?

Interviewee – Mark Raizen
Then we'll have vacuums, so there will be no Brownian motion. In vacuum, this bead becomes an isolated system, because it is attached to nothing except for a beam of light. It is isolated from the environment, because it's not colliding with any background gas. So, we think it may be the perfect macroscopic, or mesoscopic oscillator. And what we are focusing on now is how to cool the center of mass motion to the quantum limit. And along the way we can also study this equipartition theorem and see what happens when

you start to go to the quantum limit. We should actually see some deviation from the original prediction. There is another direction, but it's still not clear, but I have in mind that if we can really cool the motion down to that level, then this bead held in an optical tweezer could be a very sensitive detector. For example, we might be able to resolve collisions with individual gas molecules causing a slight recoil of the whole bead. That would be one interesting application.

Interviewer – Robert Frederick
Mark Raizen, thank you very much.

Interviewee – Mark Raizen
Okay, you're welcome.

Host – Robert Frederick
Mark Raizen of the University of Texas at Austin, is senior author of a paper on measuring the instantaneous velocity of a Brownian particle.

Music

News Writer – Michael Balter
The study of origins of language has a long and probably checkered history in the sense that it's been a research topic – or at least a topic of discussion – for at least a couple of hundred years.

Host – Robert Frederick
Science contributing correspondent Michael Balter reports in this week's issue on how scientists studying the origins of language are finding insights from data on animal communication.

Interviewee – Michael Balter
But, because the origins of language are something that it's very difficult to get a handle on – we're never really going to be able to prove with empirical data how language arose in humans – it's been the subject of probably more speculation than hard-data research for quite a bit of the history of the field. And that has begun to change over the last 20 years or so. Nevertheless, data is still hard to come by, and I think that this most recent meeting in Utrecht marked a bit of a turning point: not the first time the data has been presented, but perhaps one of the first times in the history of this biannual meeting that data really kind of had the upper hand. In other words, that hypotheses, computer simulations, models – all the kinds of things that are very typical of these evolution-of-language meetings – took a little bit more of a backseat to kind of hard data with animals and with humans.

Host – Robert Frederick
Are all the data helping scientists reach a consensus about how language evolved or are there still all these competing theories and hypotheses out there?

Interviewee – Michael Balter
Well, I don't think that the data are moving us towards a consensus very quickly, but they are moving us towards a better understanding of what the issues are. I mean one of the really big questions and debates in the field for some time now has been whether human language began as speech, like we're talking now – vocalization in the kind of broader primate sense – or whether it originated in gestures first, in other words, the types of gestures that, for example, people who use sign language engage in or the kind of gestures that we might use when we play a game of charades, where we're really trying to convey some sort of meaning to each other. And we use our hands – some of us more than others and it depends on the situation – but we use our hands, and even our faces and our whole bodies, often times when we're speaking, right in the middle of speaking. So, gestures and speech do kind of tend to go together. And this has been a debate for some time and I think that at the meeting there were some interesting developments and kind of a spirit of compromise that indicated that many researchers are now acknowledging that both gesture and speech – or gesture and vocalizations – were probably both, maybe not equally important, but both very, very critical to the development of human language.

Host – Robert Frederick
What's been some of the data?

Interviewee – Michael Balter
Well, our closest primate relatives do not really vocalize in any kind of very sophisticated way, but they do gesture in quite specific ways. And their gestures are really actually quite meaningful – that they have certain gestures that they use – one talk with orangutans, in particular, that the other orangutans understand and that convey a great deal of meaning. You know, it's meaning about simple things – like get away from me, give me your food, come play with me – things like that. But nevertheless, these are gestures that are very well understood. The vocalizations of apes tend to be just much less flexible. They don't really make it in terms of precursors to language in the minds of those who advocate gestural origins of human language. On the other hand, we're finding out that non-ape primates – in other words, primates like monkeys that are more distantly related to us – are capable of vocalizations that are much more sophisticated than we realized. One very prominent example of this, and there's been a number of papers published about this in the last couple of years, are the Campbell's monkeys of West Africa. There's a team that was present at the meeting that's been studying them in the Cote d'Ivoire in West Africa. And it's really quite extraordinary: we used to think of monkey calls as just very stereotypical – they were referential, in the sense that they referred to specific things. So, for example, vervet monkeys will have one call for an eagle, one call for a snake, one call for a leopard. But these calls were very innate, genetically hardwired, probably, with just a little bit of flexibility and learning kind of thrown in. The Campbell's monkeys, on the other hand, have a series of six different calls that they make, but not only do they have these six different calls, but they combine them in long sequences of up to 40 – the average is about 25 – but about 40 different calls that are strung together in sequences and that are used in a variety of different situations, depending on what predator is around, depending on whether it's referring to another

troop of monkeys nearby, fallen trees in the forest, and things like that. Here's an example.

[sound]

Interviewee – Michael Balter
And that was recorded when the monkeys were reacting to a tree falling in the forest. And, you know, we have no idea what they're saying about the tree falling, but the sequence of calls is so complex that they do appear to be kind of bouncing these calls off of each other. Some researchers were so impressed with this – some researchers at the meeting were so impressed with this – that they actually went so far as to say that this was some kind of proto-language. So, for example, here's the sound and the call sequences that they produce when one group of monkeys is meeting or encountering another group.

[sound]

Interviewee – Michael Balter
And they repeat this incessantly, just kind of the whole forest pretty much rings with these very complex calls. Now, if this really was a proto-language it would certainly be the first time that true language – syntactically complex language – had been identified in any species other than humans. So, most researchers are not ready to go quite that far. They agree that these calls are being combined in various ways that are somewhat unpredictable, which is certainly a feature of human language. And I think the real important point here is that we know that chimps are not very good vocalizers and good at gesturing, but we don't know what the common ancestor of chimps and humans – which lived maybe somewhere five to seven million years ago – we don't know what that beast was capable of doing, and we cannot assume that because chimps are not good at vocalizing that the common ancestor of humans and chimps was not good at vocalizing. And these results with primates – with more distant primates – do raise the possibility that this last common ancestor was a better vocalizer, and so that vocalization and gesture could have come together on the human line in the same species.

Host – Robert Frederick
Beyond primates, are there any other mammals that researchers are studying for insights into the evolution of language?

Interviewee – Michael Balter
Well, the one thing that we do share with some other animals, and it's extremely important to language, is vocal learning. Vocal learning is – with human infants, as every parent knows – the baby begins to imitate what the parents are saying, and this is really kind of the prelude to talking and to having full-blown language. It's an extremely important stage that never really goes away. But it's a very critical point in the learning of a language. Now, there are indications in whales and maybe bats that they do vocal learning, but those have not been very well studied. But, where we really see vocal learning par excellence is not in mammals but in birds. The last common ancestor of

humans and birds lived about 300 million years ago, so they're very distant evolutionary cousins to us.

Host – Robert Frederick
Is the idea that vocal learning goes back to that last common ancestor?

Interviewee – Michael Balter
No. And I think that almost for sure not, because that we just too long ago. So, the vocal learning in birds is likely to be an example of convergent or parallel evolution. And the fascinating thing about this vocal learning in birds is despite the fact that it doesn't share near evolutionary roots with the vocal learning that we do, there are some really uncanny parallels to what humans do. So, for example, in the case of songbirds, they need an adult bird to teach them the song as in humans. There's a very kind of critical or sensitive period during which learning is most effective in both songbirds and in humans. And both birds and humans kind of babble – just like babies babble and they kind of go "goo goo" and all that – birds have something that's called "subsong," which is basically where they're trying to sing those songs, but they're not really doing it very well. It's very, very similar processes that are going on. And what that tells us, and what researchers are saying, is that there's a lot we can learn from convergent evolution about – as one scientist I quote in the story put it – about how to build a brain that can engage in vocal learning. And by looking at both the anatomical, as well as the genetic and biochemical level, at how birds do vocal learning, we might be able to get some clues into how humans evolved the ability to do it as well, uniquely among apes, certainly, and probably other primates as well.

Host – Robert Frederick
Michael Balter, thank you very much.

Interviewee – Michael Balter
You've very welcome.

Host – Robert Frederick
Science contributing correspondent Michael Balter reports in this week's issue on how scientists studying the origins of language are finding insights from data on animal communication.

Music

Host – Robert Frederick
Finally today, David Grimm, online news editor of *Science* magazine, is here with a wrap-up of some of the latest science news, including a story about how life gets better after age 50. Some new survey data here, Dave?

Online News Editor – David Grimm
Exactly, Rob. There's been studies of what's called "global well being" before, and this is just, you know, attempts to get a handle on how people feel about their lives – how

happy they are, how stressed out they are, things like that. In the past, it's been really complicated to do this. What researchers have done before is they've actually had volunteers wear pagers, and researchers have literally paged them several times throughout the day, throughout the week, and then actually talked to the volunteers and said, "How are you feeling right now?" And you could imagine you can't do that with a lot of people, and something like that would take a lot of time. And so, this new study has tried to find a much simpler way to do this and with a lot more people. And what these researchers did here was – actually the leader of the research team also works with the Gallup Organization – and this is an organization that does these massive polls of hundreds of thousands of people, and asks them, for instance in the U.S., you know, "How do you think President Obama is doing?" and that leads to figures about the president's approval rating or, "What's your confidence in the economy?" and that leads to ratings about consumer confidence and spending and things like that – and so, this researcher said, "Well, why don't we just throw in a few questions about how people are doing?" You know, with these Gallup people are calling, you know, hundreds of thousands of people all the time, let's just throw a few more questions into the survey.

Host – Robert Frederick
So, these are survey results from U.S. data?

Online News Editor – David Grimm
This is U.S. data, and this particular study the survey reached over 350,000 people, so you're talking about a really large data set here. And what the researchers found is that life does indeed seem to get better after age 50. People that were 50 and over, overall they tended to report that they were getting much more happiness and enjoyment out of life than people that were younger than 50. Sadness was fairly flat through all the age groups, but negative feelings and things like worry and stress really tend to decline a lot after age 50. 50 seems to be almost this magic sort of benchmark. Anger, as well, falls steadily from about age 20 onwards. And they found that stress peaks in the 20's and starts to decline and then really plummets after age 50. And curiously the researchers also found that global well being declined – from about age 20 to about age 50 – and then all of a sudden, at age 50, it does this turnaround where it starts to go up again and people start to feel a lot better about their lives.

Host – Robert Frederick
Now, these are often referred to as the "golden years," are there any correlations here with money and people's finances?

Online News Editor – David Grimm
Well, the researchers really wanted to try to find, you know, what explains this effect that they were seeing. They looked at things like how many children the people had at home, whether or not they were employed, even whether or not they were married – and they really didn't see any correlation there – there was really no good explanation for what sort of changes after age 50 that would be responsible for this increase in global well being.

Host – Robert Frederick
Any speculation then?

Online News Editor – David Grimm
Well, one researcher, who wasn't associated with the study, says that it's possible that older people may just be better at regulating their emotions – as we age, she says, we may just be more aware that our time is running out, and we may begin to be much more careful and selective about what we focus on. So, in other words, focusing more on the positive things than on the negative things – and that makes us happier overall.

Host – Robert Frederick
It seems like this could be something that we could learn earlier in our lives.

Online News Editor – David Grimm
Well, yeah, I mean if you want to take something away from this it's pay attention to your elders – you know, maybe they are dealing with life in a much more healthy way than you are.

Host – Robert Frederick
But, all your elders, right, anyone that you know over 50 – because this is a statistical aggregation here, right, not particular to one person?

Online News Editor – David Grimm
Right. And again, the power of this study is that they looked at so many people, so maybe don't just base this on your cranky great uncle. But, talk to a lot of older folks, especially those that seem to be happier, and try to figure out what's making them so happy.

Host – Robert Frederick
Okay, well thanks, Dave. So, what other stories have you brought with you this week?

Online News Editor – David Grimm
Well, Rob, from happiness to fear. This next story is about what makes mice so terrified of cats, snakes, and other predators.

Host – Robert Frederick
Knowledge that they're going to be eaten by them?

Online News Editor – David Grimm
Well, that's the obvious one, but curiously enough researchers have found that even mice that have bred in the lab for hundreds of generations – so neither they nor their great-great ancestors – have ever seen a cat or a snake will still be petrified of them when one of these animals comes close. So, researchers know there's something hardwired in these rodents that makes them afraid of these animals, they just haven't been able to figure out what it is.

Host – Robert Frederick
So, what did researchers do to investigate this?

Online News Editor – David Grimm
Well, because they didn't want to put their research subjects in harm's way what they did was they got the essence of these animals and put them on cotton balls. And so, for cats it meant getting cat saliva on cotton balls and for snakes it meant just getting the essence of snakeskin on cotton balls. And they would drop these cotton balls into the cages with the mice. The first experiment was really to see is this something that mice sort of smell in the air – is it maybe a scent-based fear response. And they found that it is. In fact mice have – they don't just smell with their noses like we do – they have something called the vomeronasal organ, which is this specialized organ inside the nose that also helps detect odors, especially odors like pheromones, things that you and I wouldn't be able to easily detect.

Host – Robert Frederick
So, I don't have a vomeronasal organ?

Online News Editor – David Grimm
You do not. But, a lot of mammals, especially rodents, do. And what the researchers found was that – they did some complex neuroscience experiments – and what they found was that this organ was becoming much more active. When they would drop these cotton balls laced with predator scents, in the cages with the mice – and not only that, these mice, who had never seen a predator before – just dropping that cotton ball in there, and the mice would just totally freak out. They would either freeze in fear, or they would try to run away. So, the researchers knew it was something in the scent of these animals that was really triggering the fear response.

Host – Robert Frederick
Not the cotton ball itself!

Online News Editor – David Grimm
Not the cotton ball itself, exactly. So, they figured out, okay it's this scent, but they wanted to figure out can we isolate exactly what particular part of the scent is it that's causing this fear response.

Host – Robert Frederick
So, they analyzed the different scents and found out what was common between them?

Online News Editor – David Grimm
Well, they did that, but it turns out there was a lot in common between them. And so, what they did was they tried to figure out all the constituent parts of the scent, and they put all of these constituent parts on separate cotton balls until they found a cotton ball where it was just that one constituent part of the scent that still terrified the mice. And what they narrowed it down to was a class of proteins known as major urinary proteins, or Mups, for short. And these proteins, despite the name, these proteins tend to be

secreted in urine, but they can also just be secreted in other secretions, like on the snake, maybe glandular secretions on the skin. But, the important point is that these Mups are proteins that a lot of animals excrete, especially animals that tend to be predators. And so, evolutionarily speaking, it makes a lot of sense for the mice to be able to recognize and be very wary of the scent because they know when that scent comes close that there's an animal that's also coming close that has a good chance of eating them.

Host – Robert Frederick
So, do mice have these Mups, too?

Online News Editor – David Grimm
The do, in fact, mice actually use these Mups for intraspecies communication. Researchers have shown that Mups can cause male mice to fight one another, so they're somehow involved in aggression. And what experts say is interesting about this study is you've got this class of compounds, which is known already to be important for species communicating with each other, you know, within the same species, but now, all of a sudden, you've got this role of them being a sort of form of communication across species. And if you consider communication being a snake coming around and saying, "I'm going to eat you," that's sort of what's happening here. You know, you have two vastly different species, but the mice can recognize something about the snake's scent that tells them to really be afraid of this animal. But, obviously there's a difference between the mouse Mups and the snake Mups, otherwise the mice would just go around being terrified of each other.

Host – Robert Frederick
Does this have any implications for species that don't have vomeronasal organs?

Online News Editor – David Grimm
Well, the researchers say that a lot of what we know about fear behavior in mice also translates to humans. In other words, a lot of what happens on a neurological level in mice when they become afraid, is very similar to what happens to us in a neurological level and probably actually very similar among a lot of mammals. And so, the researchers say, you know, learning more about how mice respond to fear might also help us understand more about how we respond to fear and could potentially even lead to ways to treat anxiety and other phobias.

Host – Robert Frederick
Okay. So, as online news editor, what else is going on?

Online News Editor – David Grimm
Well, Rob, in addition to our *Science*NOWs and our *Science*Insiders, which we talk about in every podcast, we also publish something called *Science*Shots – and these are usually articles that we run a lot shorter, they're usually only, you know, maybe about a hundred words or so, and they usually have really nice art or a really cool video. But, you know, there's not enough going on there to really sustain a full news story. But, we just, you know, we write these extended photo captions for them, basically. And we've been

running a lot of these, actually, in the past few weeks. I'll just run through some of my favorites from the last week. We have a story that we put up this week about how wild birds don't like organic seeds. They prefer conventionally grown seeds that are grown in chemical fertilizer and pesticides. You know, and people are always saying, you know, organic is better for you, but in this one case, at least, wild birds are really shunning organic. And we have another *Science*Shot about something called the devil's grimace, and this is a type of facial expression that 15th century Europeans saw on a lot of native artwork when they landed in the Bahamas and Cuba. And there's a picture of it you can see. But, you know, it looks like somebody bearing their teeth, and so the explorers thought, you know, this was the natives who were just very aggressive because all of their artwork and all of their furniture and bowls tended to have these types of engravings on them. But when researchers compared this devil's grimace to a lot of human and even primate facial expressions, they're saying that the grimace is not actually aggressive. It actually signals submission and even happiness. So, what these early explorers were interpreting as aggression was actually just friendliness, probably. And finally, we've got a really cool video about how cobras hit the bullseye. There's apparently a group of researchers out there that, as part of their research, they wear facemasks and try to get poisonous cobras to spit at them. And this is all about trying to figure out how cobras have such deadly accuracy when they spit venom at other animals. So, be sure to check out all of these stories on the site.

Host – Robert Frederick
Any big policy things happening?

Online News Editor – David Grimm
Right. And also for *Science*Insider we continue to follow the Gulf oil spill and what's going on in terms of the science of the spill and what scientists are doing to try to figure out what's happening and what can be done to stop it and prevent spills like this in the future. And we've also got a story about a new National Academy report about geoengineering – how more research should be done into geoengineering. And geoengineering is this whole idea of using technology to try to stave off global warming – everything from launching mirrors into space to seeding the ocean with iron so you create more microorganisms in the water that will suck up carbon dioxide. So, a very controversial area of research, but the U.S. National Academy is saying definitely an area of research we should be putting a lot more attention into.

Host – Robert Frederick
Okay, well thanks, Dave.

Online News Editor – David Grimm
Thanks, Rob.

Host – Robert Frederick
David Grimm is the online news editor of *Science*. You can check out the latest science news – *Science*NOW, *Science*Shots and the policy blog, *Science*Insider – at news.sciencemag.org.

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Support for the *Science* Magazine Podcast is provided by AAAS—the Science Society—at www.aaas.org.

Host – Robert Frederick
And that wraps up the May 21st, 2010, *Science* Magazine Podcast. If you have any comments or suggestions for the show, please write us at sciencepodcast@aaas.org. The show is a production of *Science* Magazine. Jeffrey Cook composed the music and I'm Robert Frederick. On behalf of *Science* Magazine and its publisher, AAAS, thanks for joining us.

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