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00:43 MC: Welcome to Science Podcast for December 14, 2018. I'm Meagan Cantwell. On this week's show I talk with Tine De Moor and Brett Frischmann about their contemporary take on Garrett Hardin's 1968 paper, "Tragedy of the Commons". How does Hardin's paper hold up 50 years later? I also speak with Simon Fisher about the link between Neanderthal genes and less globular heads in living humans.

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01:14 MC: This week marks the 50th anniversary of a hallmark paper published in science, "Tragedy of the Commons" where ecologist Garrett Hardin questioned society's ability to manage shared resources. Using a communal piece of land or commons as an example, he made the argument that because people are motivated by self-interest, the land would eventually be over-used and destroyed.

01:38 MC: He concluded that government control and intervention, through sanctions or penalties were solutions to this problem and would prevent the free rider dilemma, those benefiting from resources without any payment. Since 1968, many have challenged Hardin's conclusions, notably Elinor Ostrom, who won a Nobel Prize in 2009 for her analysis on commons governance. She contended that communities could in fact manage their own resources without oversight by central authorities, and outlined principles for how commons could be successful. I spoke with two of the authors from a Policy Forum in this week's issue of Science entitled "Tragedy of the Commons Re-visited" to see if operating commons really is so tragic. First for a historical update on Hardin's take, we have Tine De Moor who is a professor of social and economic history at the University Utrecht. Hey Tine.

02:36 Tine De Moor: Hi.

02:38 MC: In Hardin's tragedy of the commons, what did the commons refer to and why did it lead to problems in his opinion?

02:45 TM: Well, he actually referred to what could be described as a sort of early modern, maybe even medieval pasture land, whereby a lot of cattle was grazing, and basically the farmers were
using it to graze their cattle and they didn't really have according to Hardin at least a lot of rules, or a lot of consensus about how to use that common. And in his article he actually assumes that when people use resources collectively then tragedy will follow.

03:15 MC: Did commons in early modern agriculture actually face these challenges from your research?

03:20 TM: They went through a lots of difficult periods in history with environmental, political, economic shocks etcetera. But what is quite striking is that regardless of these crisis, the commons of which we still have quite a lot of documents left, they did a pretty good job in surviving even if they had to work together, they find ways to solve the problems they were facing as a collectivity.

03:46 MC: Hardin's argument suggested that a solution to these problems could be property rights or government leviathans. Were these common in these early commons?

03:56 TM: You can't really speak of property as such as we know it today yet in that period, you can only do that from the early 19th century onwards. Basically commoners were farmers that at some point discovered that if they would use their pasture land together it would actually be more efficient to do so. So then they went as a group of farmers collectively to the local Lord and said, "We want to do this differently and we want to set up an arrangement whereby we as commoners, as local farmers, have the right to exploit this according to the rules we set ourselves." But they were actually managing the land by themselves. The rules they made to make sure that the group of people could work together in a proper way and do so in a resilient way, and these document, the survival of commons for hundreds of years, 700 years is not an exception.

04:47 MC: Of those documents that you evaluated, what did you find were the qualities that promoted resilience and success within a historical commons?

04:55 TM: We came up with several conclusions, and we're still continuing to work on those data. One of them for example is that, the graduated sanctioning that Ostrom describes as being so important, is hardly ever found on the commons we study. We actually think that the variation and the local embedded-ness of different types of sanctioning is far more important than this particular type of sanctioning, graduated sanctioning. The other thing we also find is that maybe we're overall over estimating the role of sanctioning in the prevention of free riding. In fact, if we compare the longevity of the commons in our study or we look at commons survive from 200 to 600-700 years. And we compared this to the intensity of the sanctioning that they came up with, then we find that there's actually a sort of negative correlation between the two. So the commons that survived the longest were those that actually invested the least in coming up with sanctions as a way to prevent free riding. So, commons that lived longer didn't necessarily invest a lot of time in inventing sanctions.

06:09 MC: What would you say is the insight that this historical perspective can give to how land management is carried out in this day and age?

06:17 TM: I think this has several implications. On the one hand, when it comes on to land
management, we learned that land can be managed in a sustainable and resilient way by commoners themselves, without overusing it, as long as they're sufficiently involved in the process and they're aware of the limits that the resources have. I think that that's the other issue as well. I hear that today, we see huge development in commons, especially, for example, in Europe. Commons is a real buzzword, and I think what it can really do to society in a positive way, is to help people realize, again, what the limits are of the resources they work with.

07:00 MC: Thanks, Tine. Now, we have Brett Frischmann, a professor in Law, Business and Economics at Villanova University, to talk about a different kind of commons, the knowledge commons. Hey, Brett.

07:12 Brett Frischmann: Hey there. Thanks for having me.

07:13 MC: How does the concept of Tragedy of Commons apply to something a little more abstract, like knowledge?

07:19 BF: In the context of knowledge or data, or information, there's a version of the Tragedy of the Commons that's called the free-rider dilemma. So the free-rider dilemma is this concern that it's not about over-use of the resource, or cleaning the resource. But, if you think about what happens when ideas are made, or information, or data is made openly accessible, free for all to use, that presents a risk sometimes to investors that a second comer, a third comer, or someone else, will be able to use it cheaply without having to contribute to the investment that was made to produce in the first place. And so, there's this concern that that will lead to a dilemma where we'll have the underproduction of things that we might want to see, which is quite different from the conventional Tragedy of the Commons, where you've got a pasture or a lake, or an irrigation system, and you have it already, but you're worrying about it becoming depleted.

08:16 MC: It's more like you're worried about it not being produced further, because people aren't incentivized to keep creating it. So, your piece is centered specifically around something that you refer to as the knowledge commons. Could you give an example of what falls under this category?

08:30 BF: So we use the word knowledge broadly, to encompass all kinds of products of human intellect, ranging from data to scientific research to even patented inventions, and the idea of a knowledge commons is where you've got a collection of those kinds of resources, brought together within a community, and so they're produced and sustained and sometimes curated by the community itself. We've had things as varied as genomic data pools collected together to Rare Disease Research Consortia, so a consortia of clinical researchers, distributed around the country, working at hospitals and who have patients with rare diseases, and they're collecting their data and pooling it together. So there's lots and lots of different examples. The interesting thing about knowledge commons is, we tend to take them for granted because they're so frequent. They're part of the way we communicate and share our experiences socially more generally.

09:29 MC: From those case studies that you've looked into, what are things that they have in common in terms of hurdles that they face?
09:36 BF: The more that we look at these case studies, we realize that groups that come together with the purpose of generating and pooling and sharing knowledge resources, they do confront free-rider problems. They do confront some of these Tragedy of the Commons style problems, but there's also a whole bunch of other dilemmas that they simultaneously have to overcome in order to be successful as a knowledge commons. So, if I use the rare disease research example that I mentioned before, the researchers are spread all around the country, doing other things besides clinical research on that particular disease. And so, if you can reduce the cost for them to collaborate, that's not really a free-rider problem but it's a structuring problem. Other dilemmas that they face sometimes have to do with more conventional cooperation problems. We're just getting people who are different from each other, who are coming from different backgrounds and have different sets of interests, to be able to see a joint purpose. There's an array of different dilemmas that these communities face in order for them to be successful in achieving their objectives.

10:38 MC: Overall, do you think there is a way to promote the sharing and curating of these intellectual and cultural resources?

10:46 BF: One step to figuring out how to be successful with knowledge commons is to study knowledge commons systematically and see what works and what doesn't work across different groups. And from there, you learn lots of interesting things. One of the things we started to see in a bunch of our case studies is how important it is to invest in the infrastructure for knowledge production within these groups. So oftentimes, it's sort of a shared set of standardized protocols that enable researchers to collect data in a standardized fashion, so it can be contributed to a pool, right? That sort of underlying basic infrastructure is quite important to success.

11:26 MC: Thanks so much, Brett.

11:27 BF: Oh, you're welcome. It's been a pleasure.

11:29 MC: Special thanks to editor Brad Wible for soliciting these perspectives within the policy form. You can find a link to the entire piece, "Tragedy of the Commons Revisited", at sciencemag.org/podcasts. Stay tuned for my interview with Simon Fisher on my Some Humans Have Less Globular Heads than Others.

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11:54 MC: This episode is brought to you in part by Opsgenie, incidents happen, and they require a complex coordination between operations and software development teams. We're putting out fires every day. That's why getting alerts immediately is critical. Thankfully, there's Opsgenie by Atlassian. Opsgenie empowers Dev and Ops teams to plan for service disruptions and stay in control during incidents. It also gives teams the power to respond quickly and efficiently to unplanned issues. And helps to notify all the right people through a smart combination of scheduling in escalation paths, and they count for things like time zones and holidays. Better yet, Opsgenie allows for deep flexibility in how, when and where alerts are deployed. With over 200 integrations, like Jira, Amazon CloudWatch, Datadog, New Relic and more. Plus it tracks all activity and provides useful insights to improve future incident responses. With Opsgenie, your next
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13:07 MC: I'm here with Simon Fisher to talk about why Neanderthals had elongated skulls, and what that can tell us about head shape in living people. Hey Simon.


13:17 MC: So what exactly are the differences between the Neanderthal skull and human skulls?

13:23 SF: One of the most distinctive features of the human brain, and the human skull is this globular shape. So a bit like a basketball, whereas Neanderthal skulls have a quite elongated shape, which is very different.

13:39 MC: And how did you determine how globular the heads are within living humans? Is there a spectrum of more globular versus less globular?

13:48 SF: We started by taking fossil Skulls of Neanderthals and of anatomically modern humans. And we used morphometric techniques to compare the shape between these different skull types. And what we were able to show then was a metric that distinguished between the Neanderthal brains and the human brains. And what we found was that there was a range of variation within humans of the same population, but nobody, importantly nobody is shaped like a Neanderthal. There's still a very clear distinction between a human brain shape and a Neanderthals.

14:31 MC: What did your team uncover was the driver of that difference?

14:35 SF: We wanted to know what genetic factors might be important for leading to this variation in brain shape within our different healthy human adults. And what you can do is take DNA samples from people, and then you could scan across the genome to look for DNA variants that people might carry that might affect how globular their brain is. Now we only had about 4500 people that we could do this, and then we know that effects on human brain anatomy in living humans are subtle. So we know that any individual genetic effect would be very small on the shape of the brain. So, we didn't want to do a unlimited search through the genome because we know that for effects that are subtle, that we would need many thousands, tens of thousands of people, maybe hundreds of thousands of people. We wanted to have a hypothesis about which variants in the genome might be the most important ones to look at.

15:39 SF: For this we took advantage of the fact that living humans carry, buried in their genomes, fragments of Neanderthal DNA. So we thought we should target these Neanderthal fragments in people, test the Neanderthal fragments that we could see. And we were asking a specific question, which is; if you carry a Neanderthal fragment of DNA, does that push your brain away from globularity in a very subtle way? And we tested each of these fragments, tested a few thousand fragments across the genome, and we came across a couple of fragments that were pushing people's
brains just that little bit towards an elongated shape. And then we could ask what were the genes that were contained in these fragments, and could we find out anything interesting about the biology of this difference from studying those fragments?

**16:30 MC:** Yeah, so the Neanderthal alleles that you discovered that influence the expression of these genes, what exactly do the individual gene variance control?

**16:40 SF:** One of these genes, a gene called UBR4, is important for the ways that neurons divide and the way that they proliferate in the developing brain, and we know that because when a mouse lacks this gene, it leads to a microcephaly, it leads to a smaller brain. And what we found here was that, of course people carrying the Neanderthal version of this gene is not that the gene is inactivated, but we found that the gene was less active in a part of their basal ganglia. And that's interesting because that's exactly the kind of difference that might lead to changes in the shape of the brain. The other gene that we identified is also very interesting, and this is a gene called FILIP1. And this gene seems to be important in myelination, so in the development of the myelin sheath that goes around axons. That can influence how well-connected different brain regions are to each other.

**17:41 SF:** And we found in this case, this gene was slightly more active, so this over activity would be correlated with a kind of a less myelination of the cerebellum, or maybe less connectivity. And again, the cerebellum is this structure at the base of the brain, that seems to have changed quite a lot in recent evolution, changes in those kind of structures might actually feasibly lead to changes in brain shape. But again, to emphasize, we think that this trait, this globularity, is influenced by many different genes, and the effects of these individual fragments are small, so we think there's many more things that we will... We could hope to discover by looking at this kind of trait. And the nice thing about its first studies shows how we can get clues to the biological pathways that might help to drive differences in brain shape.

**18:37 MC:** So you found that the presence of these Neanderthal alleles lead to a reduced roundness in the head, but could it also have any kind of behavioral implications?

**18:46 SF:** One of the things that we don't yet know is how differences in brain shape, in globularity might connect to behavior and to cognition. We actually don't know anything about that at this point. That's something that we'd like to find out by studying more larger samples and studying more phenotypes and more traits in relation to this.

**19:06 MC:** You work with a limited data set. But, within that data set, was it more common for Europeans to possess this gene variant or not?

**19:16 SF:** Because these fragments are rare, it's only a small percentage of people within this big sample who would carry each particular Neanderthal fragment. The people who carry these Neanderthal fragments, the particular ones that we've associated in this study, those people that wouldn't look any different from... If you saw them on the street, they're completely within the normal range of variation, and it's a subtle effect.

**19:39 MC:** Why do you think it's important to learn how Neanderthal DNA influences living
people?

19:43 SF: What I like about what we're doing here is that we have a really tractable difference in anatomy that's so distinctive, and we know that it evolved quite late. We know that 300,000 years ago, our brains were elongated, and 100,000-50,000 years ago, there were much more globular. So that's what's really attractive here, is that we have a good handle on this very clear difference that we don't have to debate about. And we're trying to understand what that could mean for the brain, and what that could mean for human evolution. I don't necessarily think that Neanderthal biology by itself is the goal of what we're doing. What's really intriguing is that we can use those fragments as a kind of window into the biology of ourselves.

20:33 MC: What is the next step with this research?

20:35 SF: What we'd like to do next is to take advantage of these really big data sets like the UK Biobank, where we could potentially look at tens of thousands of brains. And what we could then do, is do a kind of unbiased scan across the entire genome, looking beyond Neanderthal introgressed regions, and try and see how much of the variability in the globularity we can explain, asking about the different biological pathways. And we might be able to ask other questions about evolution that we haven't been able to answer yet.

21:08 MC: Thank you so much, Simon.

21:10 SF: Thank you.

21:11 MC: Simon Fisher is a neurogeneticist and director at Max Planck Institute for Psycholinguistics. You can find a link to his research at sciencemag.org/podcasts.

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21:26 MC: Just a reminder, this episode has been brought to you in part by Opsgenie. Incidents happen. Thankfully, Opsgenie empowers devs and ops teams to plan for service interruptions. So, plan for service disruptions and stay in control during incidents. It also gives teams the power to respond quickly and efficiently to unplanned issues and helps to notify all the right people through a smart combination of scheduling in escalation paths. With Opsgenie, your next incident doesn't stand a chance. Visit opsgenie.com to sign up to get a free company account and add up to five team members. That's opsgenie.com, O-P-S-G-E-N-I-E.com. Never miss a critical alert again with Opsgenie.

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22:08 MC: And that concludes this edition of the Science Podcast. If you have any comments or suggestions for the show, write to us at sciencepodcast@aaas.org. You can subscribe to the show anywhere you get your podcasts, or you can listen on the Science website at sciencemag.org/podcasts. To place an ad on the Science Podcast, contact midroll.com. This show was produced by Meagan Cantwell and edited by Podigy. Jeffrey Cook composed the music.