SCIENCE FRIDAY

"Ice Science a Slippery Quandary for Physicists" Transcript

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JOHN DANKOSKY: Why do curling stones and skate blades glide across the ice? It's a physics quandary. Scientists have been investigating since the 1800s, if not earlier, and it's still a bit mysterious. Here to talk about it is Robert Carpick, professor and chair of the Department of Mechanical Engineering and Applied mechanics at the University of Pennsylvania in Philadelphia. I should also add that he is a curler himself. Welcome to Science Friday, Dr. Carpic.

ROBERT CARPICK: Thank you so much, John. Good to be here.

DANKOSKY: OK. Why is ice slippery?

CARPICK: Well, like you said, it's been a debated topic for years and we're still not completely sure. But there's been some recent discoveries over the last few years that have given us some more insight, and I think we're starting to get a better idea of what causes it.

And, you know, if you go into just about any physics textbook, you might crack it open and you're likely to find the wrong answer. A lot of people were misled by the fact that water and ice has this funny property that, when water solidifies-- when it freezes-- it becomes less dense.

This is why ice cubes float. And if you turn it the other way around, you have a property called pressure-induced melting. So when you apply pressure to ice, you can turn it into water.

And people thought, well, that must be the explanation. When you press on the ice with your skates or your skis, that pressure that you apply turns it into water and that gives you a nice slippery layer to slide on.

Well, it turns out that if you check the numbers, it doesn't really work very well. The amount of pressure you have to apply is extremely high, and yet even very light objects will be slippery when they try to slide on ice.

And this pressure-induced melting, it only holds up down to a few degrees below the freezing point, around minus 3 and 1/2 degrees. So that doesn't explain why ice stays slippery when you go to even lower temperatures.

So there's been some new discoveries, and there's sort of two competing, or perhaps different theories, but they may both be correct. And one is showing that the surface of ice actually has a little thin water layer on it.

Even if you go many tens of degrees below freezing, there's a microscopic-- actually, a nano-scale layer-- of water and highly mobile water molecules. And that can give you a slippery layer.

The other contribution could be that the friction force you get, if you just initially start sliding on that ice, can be kind of high. So that will melt-- thanks to frictional heating, that will melt the ice around it and then you get a water layer, again, that helps you slide. So the bottom line is there is a water layer on the top of that ice that's got to be what's helping you slide, but we're still debating in the science community as to exactly what causes it.

DANKOSKY: Well, before we get to this friction theory, let's talk about this very, very small layer of water here. Your colleagues have traced the surface of ice using an atomic force microscope. Tell us how thin this water layer is on top.

CARPICK: Well, if you take your hair-- a human hair-- and try to divide it maybe another 1,000 times, you might get down to the thickness of that layer. It's a very difficult thing to measure, but a group at Berkeley has done that, and some other groups have done that by using, like you said, atomic force microscope.

It's like a nano-scale record player, a tiny tip that can probe along the surface, measure surface topography, and measure the thickness of layers, and also measure friction at the nano-scale. And that's where they show that they could see the effects of this layer just a few nanometers thick, but it was there even when they cooled the surface of their ice sample down to several tens of degrees below the freezing point. So extremely thin.

DANKOSKY: And so that on its own is enough to make the surface slippery? Or does it take this frictional movement along the way as well?

CARPICK: Well, see, that's the debate. Some people think that that thin layer may be enough. Maybe if you are sliding along it, it sounds like it's very little, but maybe you can pool up a little bit in the little gaps around the little bumps of contact that you have between materials, typically. But other people think, well, no, that's just too thin to be any good for large-scale objects like skates and skis, or curling rocks.

And so they said, well, no, you've got to have some extra water. And that comes from the melting of the ice all around the contact point because of the initially high sliding friction. And it's an interesting idea because you know that when you first step on to ice, you can have a little bit of force needed to get going, but then you can slide more smoothly after that.

So it's such a difficult question to resolve because of the fact that friction and studying interfaces is very tough. You're trying to look at what's happening at this buried interface.

Two materials in contact, and what's happening in between them is hidden from your view. So even some of the best scientists have to work very hard and use some rather sophisticated tools to try to get at what's going on at that hidden interface.

DANKOSKY: Robert Carpick is professor and chair of the Department of Mechanical Engineering and Applied Mechanics at the University of Pennsylvania in Philadelphia and an avid curler. Thank you so much for joining us today, and happy Olympics watching.

CARPICK: Thank you. Same to you.