

Making Stuff: Colder

DAVID POGUE: *Cold is the new hot.*

Join me on a journey down the thermometer, away from the warm world we inhabit, to the realm of cold.

Cold is a force we can harness to save us, the stuff we are made of,...

GREG FAHY (21st Century Medicine): The ability to preserve organs for transplantation.

DAVID POGUE: *...and even bring us back...*

NEWSCASTER: ...back from the dead.

DAVID POGUE: *...came back to life?*

MARK B. ROTH (Fred Hutchinson Cancer Research Center): Oh, yeah.

DAVID POGUE: *We are going to a topsy-turvy world, where heat is the enemy,...*

ERIC CORNELL (JILA/National Institute of Standards and Technology): Heat is like noise.

DAVID POGUE: *...random energy and vibration that disturbs and destroys,...*

ERIC CORNELL: But if you get things really, really cold, you can listen to what nature is whispering to you.

DAVID POGUE: *...so cold that ordinary physics breaks down and the rules change. Things levitate.*

We will travel to a place so cold that new states of matter are born, where cold is creating a new breed of computers, a quantum leap beyond the most powerful today.

GEORDIE ROSE (D-Wave Systems, Inc.): By the time you get to about 500 bits, you have more possibilities than there are atoms in the visible universe.

DAVID POGUE: *I'm David Pogue. Join me tonight, as we journey down the thermometer,...*

MARTIN ZWIERLEIN (Massachusetts Institute of Technology): This is the coldest spot in the universe right now.

DAVID POGUE: *That's amazing. I want to get its autograph.*

...to make stuff colder.

I'm beginning my voyage down the thermometer from a very warm place in the universe: Earth. Now, you may think it gets pretty cold here. The lowest temperature ever recorded was minus-128 degrees Fahrenheit, in Vostok, Antarctica, in 1983. But that's a heat wave compared to Saturn, Pluto and most of outer space.

We'll get a lot colder than that as we journey down into the weird world of cold, towards absolute zero.

But I'm getting ahead of myself. Our first stop is one we can all relate to: 98.6 degrees, the temperature of my body. Before I came here,...

JOHN CASTELLANI (United States Army Research Institute of Environmental Medicine): We're going to go into the chambers.

DAVID POGUE: *The chambers? Sounds ominous.*

Turns out, to learn about the cold, first, I have to get hot.

Eighty-two-point-nine? That really doesn't sound so bad.

JOHN CASTELLANI: We are going to put you a little hotter than that today.

DAVID POGUE: *John Castellani is a scientist at the Army's Doriot test chamber.*

Wow.

JOHN CASTELLANI: Yeah, so this is our environmental chamber: 60 feet long,...

DAVID POGUE: *This gigantic room is designed to re-create every conceivable environment that a soldier might face, from the frigid mountains of Afghanistan, to the 120-degree deserts of Iraq.*

JOHN CASTELLANI: ...with the wind, and the humidity control.

DAVID POGUE: *In order for this place to work, there's one more thing they need: volunteers.*

Will we be seeing one of these poor victims?

JOHN CASTELLANI: The only victim that we're going to see in here today is yourself.

DAVID POGUE: *Castellani "enlisted" me to help test ways of keeping soldiers cool in the heat. To do this, they'll need to track my vital signs.*

MARISSA SPITZ: For core temperature, you'll be using this rectal probe.

DAVID POGUE: *Rectal probe?*

MARISSA SPITZ: It may feel a bit uncomfortable, but...

DAVID POGUE: *No kidding!*

MARISSA SPITZ: ...all the way past, to make sure it doesn't fall out.

DAVID POGUE: *How about I just go in there and tell you how I am? Pretty hot!*

MARISSA SPITZ: This is mostly for your safety.

DAVID POGUE: *Oh, thanks for thinking of me.*

Next, they outfit me in 40 pounds of body armor. And then, it's into the chamber.

JOHN CASTELLANI: It's a hundred and four degrees in here.

DAVID POGUE: *A hundred and four?*

JOHN CASTELLANI: Yes.

DAVID POGUE: *Can I get a little lemon?*

Within minutes, my temperature is going up.

What is that? An hour?

WOMAN: Actually, it's been about four minutes.

JOHN CASTELLANI: Their heart rates will start to rise, their core temperatures start to rise.

Your core temperature is around 101.5 degrees Fahrenheit.

Eventually, what will happen is they'll become a heat exhaustion casualty.

DAVID POGUE: *After two hours, I called it quits.*

Please tell me there was some valid scientific purpose for that.

JOHN CASTELLANI: There is. I mean, really, what we're trying to understand is—when we develop this kind of gear—is can we develop it in such a way that we can allow the body to be able to be able to get rid of the heat?

DAVID POGUE: *Oh, man.*

And why did I get so hot? Because of some basic laws of physics, which I seem to have missed in my high school science class. For example: What is heat? What is temperature? And what is cold?

EDWARD YARMAK, JR. (Arctic Foundations, Inc.): What did they teach you?

WOMAN: Heat is energy.

ERIC CORNELL: Disorganized energy.

BRIAN WOWK (21st Century Medicine): The vibrations of molecules.

ERIC CORNELL: The motion of atoms.

DAVID POGUE: *The faster they move around, the more energy they have. That's heat. Temperature is a measure of how much heat energy they have.*

ERIC CORNELL: Temperature is measuring the motion of atoms.

DAVID POGUE: *Okay, so heat really is something. It's energy, motion, and you can measure how much of it you have.*

ERIC CORNELL: More and more heat, your temperature goes up.

DAVID POGUE: *But cold is another story.*

ED YARMAK: Because there's no cold flow, there's heat flow.

DAVID POGUE: *Really?*

ERIC CORNELL: If you take heat out, your temperature goes down.

DAVID POGUE: *You mean, you don't put cold in? No?*

ED YARMAK: No. No. There's really no such thing as "cold."

DAVID POGUE: *So cold is just the absence of heat? So things don't ever really get colder?*

ED YARMAK: No, they just get less hotter.

DAVID POGUE: *Yeah, that has a great ring to it: "Making Stuff: Less Hotter." That just seems backwards.*

JOHN CASTELLANI: So, I have a spoon here for you.

DAVID POGUE: *But Castellani showed me that how we think "cold" works, ...*

Cold is just rushing right into my flesh.

...can really be the opposite of what's happening.

JOHN CASTELLANI: Actually the heat from your hand is moving into the spoon, not the other way around. Heat moves from areas of hotter temperatures, or high energy, to areas of lower temperature, or low energy.

DAVID POGUE: *You can see it through the eyes of this thermal camera, where warm things, like my hand, show up as light orange, and colder things like the spoon are dark.*

And sure enough...

JOHN CASTELLANI: If you put the spoon up against your hand, we can see, heat's going from your hand into the spoon.

DAVID POGUE: *That's crazy.*

The reason I was getting so hot on my forced march was the air was hotter, at a higher energy state, than my skin. So, instead of the heat from my core flowing out to the room, the heat from the room flowed into my core.

The army has a cool solution.

JOHN CASTELLANI: So, David, this is how we're going to cool you off. So what this is is a cooling garment. It's essentially going to circulate water through here. We're going to hook this up to a small refrigerator.

DAVID POGUE: *Ooh! I just got chills.*

JOHN CASTELLANI: ...and keep it at about a nice, cool 70 degrees.

DAVID POGUE: *I don't know, but I've been told...*

SOLDIERS: I don't know, but I've been told...

DAVID POGUE: *...hundred and four degrees gets old.*

SOLDIERS: ...hundred and four degrees gets old.

DAVID POGUE: *Just like last time, my core temperature rises in the 104-degree environment. But this time, the heat's got somewhere to go: into the vest, and out through the refrigeration unit.*

JOHN CASTELLANI: A significant difference: 82 degrees Fahrenheit, compared to last time, when it was up around 95 or 96 degrees.

DAVID POGUE: *A vest is best if it is cold.*

SOLDIERS: A vest is best if it is cold.

JOHN CASTELLANI: He is feeling better. He seems in better spirits, and those are all the benefits that we see with this particular technology.

DAVID POGUE: *An hour and a half later, as they remove my Kevlar vest, that dark blue area, that's my chest: 78 degrees. Cool, baby!*

But this is just the beginning of what Castellani has in store for me.

Forty-one degrees, that's the temperature in the chamber, as ice water rains down on me.

That's cold!

JOHN CASTELLANI: We're going to do this for 10 minutes.

DAVID POGUE: *Ten minutes?*

JOHN CASTELLANI: So, to kind of give you an idea of what's going on with you physiologically right now...

DAVID POGUE: *I know what's going on with me physiologically! I'm turning into an ice cube!*

JOHN CASTELLANI: Yeah.

DAVID POGUE: *Castellani and his colleagues developed this procedure, not to torture folks, but to solve a mystery. In 1995, a squad of army rangers waded through a swamp in Florida. Within hours, four died of hypothermia, yet the temperature was 59 degrees.*

To understand why they died in such temperate conditions, the army developed this experiment.

So after my cold shower?

A 30-minute march,...

JOHN CASTELLANI: We're going to increase the wind.

DAVID POGUE: *...in 15-mile-an-hour wind.*

JOHN CASTELLANI: To mimic, again, you're outside.

DAVID POGUE: *He repeats this...*

JOHN CASTELLANI: We're going to have it rain on you again.

DAVID POGUE: *...over and over.*

Suddenly, I'm dreaming of the days when it was a hundred and four.

Their investigation discovered that it was this combination of wet, cold and wind that killed the rangers.

JOHN CASTELLANI: So, if you were, say, in 50-degree water and immersed to the chest, that water is conducting so much more heat away from you than would air.

DAVID POGUE: *I can see that.*

Their research established safety guidelines for troops in the cold.

JOHN CASTELLANI: We may be able to tell people, you know, you may be able to last maybe an hour or an hour and a half, in those kinds of conditions.

DAVID POGUE: *What are the early onset signs of hypothermia?*

JOHN CASTELLANI: Well, certainly, very intense shivering.

DAVID POGUE: *Check.*

JOHN CASTELLANI: Changes, for example, in a person's ability to walk or their gait.

DAVID POGUE: *What?*

JOHN CASTELLANI: They start to grumble, they start to mumble.

DAVID POGUE: *[Mumbles.]*

JOHN CASTELLANI: Three, two, one, go!

DAVID POGUE: *The test is designed to go on for six hours, but after just an hour of this, it was time for my career as an army test subject to come to an end.*

JOHN CASTELLANI: I think we're going to call it quits now, okay?

DAVID POGUE: *So far, I've learned how deadly hypothermia can be, but as I continue down the thermometer to our next stop, 91.4 degrees, I'm about to discover that sometimes the opposite can be true.*

CLIFTON CALLAWAY (University of Pittsburgh): This is actually a device to induce hypothermia in patients.

DAVID POGUE: *Excuse me! Have you never heard of "First, do no harm?" Hypothermia kills you!*

Dr. Clif Callaway is a professor at the University of Pittsburgh.

CLIFTON CALLAWAY: There are situations in which hypothermia can be beneficial, for example, patients after cardiac arrest.

DAVID POGUE: *Patients like Susan Koeppe, a mother of three. A few years ago, she set out for a run with friends.*

SUSAN KOEPPEN (Cardiac Arrest Survivor): It was a beautiful Sunday morning, in November.

DAVID POGUE: *She had no idea what was in store.*

SUSAN KOEPPEN: We're about two miles into the run,...

DAVID POGUE: *When a heart valve suddenly failed.*

SUSAN KOEPPEN: I put my hands on my knees, and then collapsed on the sidewalk.

CLIFTON CALLAWAY: Her heart stopped.

SUSAN KOEPPEN: I was gone.

CLIFTON CALLAWAY: Cardiac arrest; paramedics arrived. They were able to stabilize her and transport her to the hospital.

DAVID POGUE: *Fortunately, Callaway and his colleagues were there. Their goal: to stop the brain damage that immediately follows cardiac arrest.*

CLIFTON CALLAWAY: She was in a coma. We used cooling blankets for hypothermia therapy.

DAVID POGUE: *To prevent permanent brain damage, in the aftermath of cardiac arrest, they dropped her body temperature to 91 degrees. Two days later, they warmed her back up. And soon after, ...*

CLIFTON CALLAWAY: She came around and talked to her husband for the first time.

SUSAN KOEPPEN: I said, "Where am I?"

(Susan Koeppen's Husband): You're in Shadyside Hospital, Honey.

SUSAN KOEPPEN: Why?

(Susan Koeppen's Husband): You never made it home from your run on Sunday.

DAVID POGUE: *A year later, she had fully recovered.*

SUSAN KOEPPEN: Hypothermia treatment saved my life, saved my brain, and I'm a mom and a wife, like I was before.

DAVID POGUE: *The procedure that saved her life is called therapeutic hypothermia, and I'm about to discover how it works.*

VOICE ON MACHINE: Therapy started.

DAVID POGUE: *I recognize her. She's the lady on the Star Trek: Enterprise.*

CLIFTON CALLAWAY: This device has water coming in through this tubing and pulls heat out of your body.

DAVID POGUE: *Very cold.*

Just like the army's cooling vest, but here, in order to fight brain damage, Callaway brings down body temperatures to 91 degrees.

CLIFTON CALLAWAY: It lowers the metabolism, it reduces brain swelling, it reduces the likelihood of having seizures.

DAVID POGUE: *This has proved remarkably effective.*

CLIFTON CALLAWAY: The odds of waking up are almost two to three times greater for the patient with hypothermia treatment, compared to the patient without.

DAVID POGUE: *But, amazingly, in North America only 40 percent of cardiac arrest patients get this treatment.*

Wait. It triples your chance of survival, but only 40 percent of patients get the treatment?

CLIFTON CALLAWAY: Yeah, it's disappointing. We really wish it was done more reliably for more patients.

DAVID POGUE: *Yeah, me too.*

But there's a limit. His treatment can only save the fortunate few cases where paramedics bring back a heartbeat within minutes. Many trauma patients die on the way to the hospital.

But biochemist Mark Roth says he has a way to save many of them: by getting colder, a lot colder.

MARK ROTH: Well, a simple way to think about it, David, is that we're trying to take the "emergency" out of "emergency medicine."

DAVID POGUE: *For years, he's been trying to develop a method that could one day buy trauma patients time, by dropping their core temperatures down as far as 60 degrees. The problem is that when people get that cold, it usually kills them—usually.*

MARK ROTH: There are these outliers.

DAVID POGUE: *He believes the answer to saving thousands of lives lies within these mysterious cases; cases of people who suffered hypothermia so severe, it stopped their hearts, and yet they came back to life.*

Consider the case of Janice Goodger.

NEWSCASTER: ...to the brink of death and back.

DAVID POGUE: *Her heart stopped. She was unconscious, in the freezing snow, for four hours.*

MARK ROTH: She was brought to the hospital. Twenty-four hours later, walked out of the hospital, refusing any treatment, and has been fine since.

Her core temperature dropped to 70 degrees.

Another example: Erika Nordby, in Canada.

DAVID POGUE: *A one-year-old, her core temperature dropped to 61 degrees, after she wandered into freezing cold weather, wearing nothing but a diaper.*

MARK ROTH: They didn't find her 'til morning.

DAVID POGUE: *After two hours without a heartbeat, she too was revived.*

MARK ROTH: ...and also made a full recovery.

DAVID POGUE: *But no one's gotten colder than Anna Bagenholm.*

MARK ROTH: She has the record for the lowest core temperature, at 56.7 degrees Fahrenheit.

NEWSCASTER: She was skiing down a waterfall gully near Narvik, in north Norway, when she fell head first into a river.

BRYANT GUMBEL (News Clip): ...clinically dead for three hours.

DAVID POGUE: *Three hours?*

MARK ROTH: Right, right.

NEWSCASTER: It took doctors nine hours to revive her.

DAVID POGUE: *She came back to life?*

MARK ROTH: Oh, yeah. Oh, yeah.

BRYANT GUMBEL (News Clip): Anna Bagenholm is back at work and well enough to be with us.

DAVID POGUE: *In each of these cases, their hearts stopped beating for hours, yet their brains weren't damaged by lack of oxygen.*

MARK ROTH: How do the exceptions come to be? There must be some way to exist out there and not require oxygen, there has to be, or these people would be dead.

DAVID POGUE: *He is searching for a way to do the same for trauma patients: curb their demand for oxygen and not damage the brain, by cooling them way down.*

But there is a big problem.

MARK ROTH: If you're trying to use the cold to create medical benefit, there's a sort of fundamental problem: mammals fight that, and they make heat, using up resources in your body in order to do that.

DAVID POGUE: *As I discovered when I was shivering in the army's test chamber, when people get cold, their metabolism actually increases and they burn more oxygen to make heat.*

That's what killed the rangers in the swamp. As they fought to stay warm, their bodies burned through all the available calories, starving their brains of oxygen.

MARK ROTH: Because that's the fuel that, once you burn through it, you are dead.

DAVID POGUE: *Roth knew that the reason that Anna Bagenholm and the others survived and the rangers didn't, is that they were able to somehow shut off their body's demand for oxygen. But how could he do the same?*

MARK ROTH: So how do I do that? That was a real puzzle.

DAVID POGUE: *The answer came to him one night, while he was watching TV.*

MARK ROTH: While sitting on my couch at home, watching a NOVA show about a cave in Mexico, they said cave air had a little bit of hydrogen sulfide in it.

SCIENTIST ON NOVA (NOVA Film Clip): So we wear these gas masks to help filter out the hydrogen sulfide.

MARK ROTH: And she said that if you go in there without this respirator, then you will collapse to the ground. Immediately I thought, "That's it!"

DAVID POGUE: *He thought that hydrogen sulfide might just be the key. He knew that it naturally occurs, in small quantities, in the brain, where it helps the cells regulate oxygen consumption. But he also knew that too much of it overwhelms the cells, turning off their ability to absorb oxygen, starving them.*

He wondered if he added just a little to the air, to increase the amount in the brain by just a minute quantity, that instead of starving the brain, he could drastically reduce its need for oxygen.

He tried it on mice.

MARK ROTH: ...room air laced with hydrogen sulfide.

DAVID POGUE: *After three hours, its core temperature drops almost 30 degrees.*

MARK ROTH: The mouse is hovering now at about 70 degrees Fahrenheit.

DAVID POGUE: *Usually the mouse would fight the cold and burn through its supply of oxygen.*

MARK ROTH: The mouse no longer responds to cooling by making heat; it actually just gets colder.

DAVID POGUE: *Because of the hydrogen sulfide, its brain's demand for oxygen has dropped by 90 percent.*

MARK ROTH: An animal in this state would survive otherwise lethal oxygen deprivation.

DAVID POGUE: *Roth thinks that he can do the same for people. The goal is to clinically duplicate the miracle that saved these people's lives by delivering hydrogen sulfide intravenously. And if he can do that, he will revolutionize emergency medicine and save thousands of lives.*

It seems the farther down the thermometer we go, the more potential cold has for saving lives. So why stop at 60 degrees? Why not get even colder, to freezing, like in the movies?

Prometheus clip: Suspended animation.

DAVID POGUE: *Yes! Suspended animation, ...*

Prometheus clip: It's inevitable.

DAVID POGUE: *...to make human time capsules, ...*

Austin Powers clip: Powers volunteered to have himself frozen.

DAVID POGUE: *...or to travel to another solar system.*

2001: A Space Odyssey clip: I tucked my crew in for the long sleep.

DAVID POGUE: *But there's a reason this is called science "fiction." The human body is about 60 percent water. And when water changes from a liquid into ice, the molecules stop moving around freely and lock together to form crystals, and that destroys cells.*

So far, no one has been able to get around that problem with people, but there is a creature that has.

JON COSTANZO (Miami University): So we find it, generally, under the leaf litter.

DAVID POGUE: *Cryobiologist Jon Costanzo studies an animal that has beaten the problem of freezing...*

Hey!

...the North American wood frog.

JON COSTANZO: Some of these animals can, in fact, survive freezing and thawing of their body fluids.

DAVID POGUE: *Back at his lab, he pulled one out from a deep freeze.*

JON COSTANZO: Let's go take a look.

DAVID POGUE: *Whoa. Oh, man.*

JON COSTANZO: There's no heartbeat. There's no brainwaves.

DAVID POGUE: *A dead frog.*

JON COSTANZO: No. No, it isn't.

DAVID POGUE: *It's a brick of ice.*

JON COSTANZO: It's very much alive.

DAVID POGUE: *If there's no brain activity, it's dead.*

JON COSTANZO: Clinically, perhaps, but we've seen them thaw and come back to life.

DAVID POGUE: *How would that be possible? Ice destroys cells, right?*

JON COSTANZO: This frog has worked out a number of different ways to avoid that kind of damage.

DAVID POGUE: *The frog's vital organs shrivel up, releasing their water safely away from the frog's organs. And something else happens.*

JON COSTANZO: Most importantly, as soon as the frog begins freezing, the liver begins producing compounds that allow the cells and tissues to survive.

DAVID POGUE: *A kind of antifreeze, or as Costanzo calls them,...*

JON COSTANZO: Cryoprotectants.

DAVID POGUE: *Cryo...?*

JON COSTANZO: ...protectants, in huge quantities.

DAVID POGUE: *Which protect the frog until the spring, when something amazing happens.*

JON COSTANZO: The ice begins to melt, and water returns to its usual location. So, the cells take the water back up. And, after a time, the heart begins beating again. We don't know how this happens; it just spontaneously resumes beating.

DAVID POGUE: *That's crazy.*

JON COSTANZO: That's one of the first signs that the frog is really not dead at all. It's alive. And then the frog begins to breathe. Eventually the frog will be able to move its limbs, sit upright, and, eventually, it can hop away.

DAVID POGUE: *With these cryoprotectants, the frog has survived the cold of winter.*

If we could figure out a way to do this for people, we could save lives. Not by freezing our bodies, but by preserving our organs for transplantation. That's because organs, even on ice, have a limited shelf-life. Hearts, for example, last, at most, six hours.

Thousands of people die each year waiting for an organ.

So, could we not just inject these cryoprotectants into our bodies?

JON COSTANZO: Unfortunately, it doesn't work that way. Some of the cryoprotectants that these frogs use are very toxic to mammalian muscle tissue.

DAVID POGUE: *So, how to come up with a similar chemical for human organs? That's the problem researcher Greg Fahy is trying to solve.*

GREG FAHY: The ultimate goal is to be able to set up real banks of organs, so that they can be moved anywhere, ready to be plugged in within a couple of hours' notice.

DAVID POGUE: *After years of work, he thinks he may have come up with a cryoprotectant that's safe for mammals.*

GREG FAHY: Unlike the chemicals that the frog uses, we have optimized this particular mixture for the mammal, over the last 30 years or so.

DAVID POGUE: *With this mixture, Fahy has successfully preserved rabbit kidneys at below freezing temperatures.*

He starts by removing as much water as possible.

GREG FAHY: So, the kidney might start off being 80 percent water. We're going to reduce it to about 30 percent water.

DAVID POGUE: *All right, so water out, antifreeze in.*

GREG FAHY: Yes.

DAVID POGUE: *The "antifreeze" is the key. It's called M22, a strange substance that's not toxic to rabbits or humans.*

BRIAN WOWK: And, as you can see, at room temperature, it's clearly a liquid.

DAVID POGUE: *I imagine M22 must, of course, work better than M20 and M21 did.*

GREG FAHY: Well, M22 is named because it's intended to be used at minus-22 degrees Celsius, which is minus-eight degrees Fahrenheit.

DAVID POGUE: *And when they take it down below those temperatures, it behaves strangely.*

BRIAN WOWK: Cooled to below minus-100 degrees Fahrenheit,...

DAVID POGUE: *Whoa!*

BRIAN WOWK: ...and it's now like a viscous syrup.

DAVID POGUE: *Pump this into a kidney, and no matter how cold the organ gets, it won't freeze.*

How does that work?

Unlike solid ice, where molecules are tightly organized, Fahy's cryoprotectant remains liquid, no matter how cold it gets.

GREG FAHY: At a certain point, there's insufficient heat energy in the system to maintain molecular motions, and the system just locks up as a solid. But it's not a frozen solid. It's going to a very different kind of solid state.

DAVID POGUE: *So it's a solid, but it's not ice.*

GREG FAHY: It's called a glassy solid state, sort of like a windowpane.

DAVID POGUE: *So it's not called "freezing" organs, you're...?*

GREG FAHY: Vitrifying those organs.

DAVID POGUE: *Vitrifying.*

It took them about four hours to bring the kidney into this state.

BRIAN WOWK: This is now solid. The kidney, and the solution surrounding it, is at a temperature of minus-190 Fahrenheit. It is a solid glass through and through.

DAVID POGUE: *Frozen only in time.*

GREG FAHY: It's just like it was in the liquid state. The only difference is that nothing in the liquid can move anymore. And, of course, if nothing can move, nothing can change. If nothing can change, then you have perpetual preservation.

DAVID POGUE: *Forever?*

GREG FAHY: Well, practically.

DAVID POGUE: *A hundred years?*

GREG FAHY: Forever, as far as you're concerned.

DAVID POGUE: *Fahy and his team have successfully re-implanted one of these kidneys into a rabbit.*

GREG FAHY: And we believe that we can put any organ into a vitrified state with enough effort and time.

DAVID POGUE: *By making organs colder, without actually freezing them, he hopes to make organ-banking a reality.*

GREG FAHY: If we can do that, then that organ can wait as long as it takes for the right person to come along who needs it.

DAVID POGUE: *From cooling soldiers and saving heart attack victims, to preserving organs, the cold has amazing potential. And, as I continue my journey down the thermometer, moving from the world inside us to the world around us, I'm headed to the last place you'd think anyone would want to make colder: Fairbanks, Alaska. I trekked there to find out why.*

Life here seems to revolve around snow and ice, whether it's just play or beautiful works of fine art. It's very handsome.

And while snow blankets the ground from early fall to late spring, much of the earth underneath stays frozen year round. It's called permafrost, but there's a big problem: it's not so perma. When you put a heated building on it, or even an asphalt road, permafrost melts.

It wasn't always wavy like this?

DOUG GOERING (University of Alaska Fairbanks): Oh, no. When this road was first constructed, it was perfectly level.

DAVID POGUE: *Houses are sinking into the ground.*

DOUG GOERING: You can see that many of them are not particularly level.

DAVID POGUE: *And this doesn't just happen overnight?*

WOMAN: No, of course not. It started about 40 years ago, maybe 30-something. No one ever thought it would get like that.

DAVID POGUE: *You must've noticed that things were tipping a little bit. Your coffee cup would slide across the table?*

WOMAN: Well, it wasn't that extreme, 'cause anyone with common sense would level the table, no matter what condition you're in.

DAVID POGUE: *Good point.*

But what exactly is permafrost anyway?

DAN WHITE: Watch your head.

DAVID POGUE: *Dan White, of the University of Alaska Fairbanks,...*

Whoa.

...took me underground to find out.

Welcome to my lair, Mr. Bond.

This tunnel is the Army and University of Alaska's permafrost joint research facility.

DAN WHITE: Everything here is permafrost.

DAVID POGUE: *When it comes to building houses and roads, there are two different kinds of permafrost.*

DAN WHITE: Gravelly materials...

DAVID POGUE: *...the kind you can build on...*

DAN WHITE: If you had a building, a road, on top of this, and you thaw that out, it would remain stable.

DAVID POGUE: *The other kind of permafrost is the problem.*

DAN WHITE: Fine grain soil,...

DAVID POGUE: *...which gets its structural integrity from frozen water that acts as cement.*

DOUG GOERING: So long as it's in the frozen state, you can see that it's structurally sound. You can build roads or bridges or houses on something like this.

DAVID POGUE: *Mm hmm.*

DOUG GOERING: The problem, though, is that once it warms up, it turns into this.

DAVID POGUE: *A scientific principle we call "melting."*

DOUG GOERING: Exactly.

DAVID POGUE: *And it's only going to get worse as global temperatures rise. So how to stop it?*

ED YARMAK: We use these thermosiphon devices.

DAVID POGUE: *Thermosiphons. Ed Yarmak is chief engineer with the company that invented these things.*

ED YARMAK: Well, it's pretty simple; it's just a tube.

DAVID POGUE: *Here's how it works: first, you put some liquid in. Next, you suck out all the air to create a vacuum. Then you get something cold.*

ED YARMAK: I've got a little Fairbanks snow.

DAVID POGUE: *Remember how things always move from hot to cold? Well, because the snow is colder than the air in the room, ...*

Whoa! It's going nuts!

...the cold draws the heat from the room into the tube, and...

It's cool to the touch, it can't be boiling!

Why is it doing that?

ED YARMAK: Your boiling point is dependent, not only on temperature, but on the pressure inside your tube or in your system.

DAVID POGUE: *Because it's in a vacuum, it boils at room temperature, moving the heat from the room into the snow.*

Okay, got it. But how in the world is this going to save the permafrost?

Well, when you place one of these in permafrost, the heat from the permafrost moves into the thermosiphon.

One doesn't think of permafrost as having heat.

ED YARMAK: Everything has heat, David. In the wintertime, the permafrost is warmer than the air above it. And we all know that heat goes from warm to cold.

DAVID POGUE: *Okay, so the heat from the permafrost moves into the thermosiphon. The liquid inside boils, turning into a gas, which rises up, carrying the heat with it. When it gets to the surface, the heat moves out into the colder air.*

So it stops thawing?

ED YARMAK: Exactly.

DAVID POGUE: *And that works?*

It's true. In Fairbanks, you can see them around buildings, in roads, and along the 800 miles of the Alaskan pipeline, you'll find 124,000 of them.

Okay, so right now, the building's heat would be thawing the permafrost, except that these devices are sucking the heat out, right, ...

ED YARMAK: Exactly.

DAVID POGUE: *...blasting it into the colder air? But I've found a problem with your system. In the summer, the air out here is not cold, so it would not be sucking heat out. I've got you.*

ED YARMAK: Well, in the wintertime, we supercool it, so to speak.

DAVID POGUE: *So that it will have excess cold for the summer?*

ED YARMAK: Exactly. All summer.

DAVID POGUE: *Okay, well what evidence do I have that it's actually working?*

ED YARMAK: You can use this thermal-imaging camera.

DAVID POGUE: *Oh, wow. They're glowing.*

You remember the thermal camera. It sees cold areas as darker and warmer areas as lighter.

So, we can see that there is heat coming out of them there pipes, but there's only one way to know for sure.

Ahh, ahh, ahh! I'm just kidding.

But Fairbanks is hot compared to where we're going. We're plummeting over 200 degrees colder than any place on Earth, where physicists say a whole new world begins: minus-320 degrees Fahrenheit. That's the temperature of this liquid nitrogen.

And so much fun! Liquid nitrogen, folks, the ultimate in cold!

ERIC CORNELL: Actually, nowhere near the ultimate in cold.

DAVID POGUE: *Physicist Eric Cornell knows cold.*

ERIC CORNELL: Liquid nitrogen isn't even close.

DAVID POGUE: *He and his colleagues won a Nobel Prize for using it to discover a new state of matter. Cornell says we're headed to a place so cold that someone had to invent a whole new thermometer just to get there.*

ERIC CORNELL: Yes, Kelvin, an entirely different one, where zero really means something: the bottom, the very lowest temperature you can get to. We call it "absolute zero."

DAVID POGUE: *But this, this has a zero on it.*

ERIC CORNELL: Yeah.

DAVID POGUE: *So, check this out. Check this out.*

ERIC CORNELL: It went down to zero. And look, I've got an amplifier that goes up to 11. It doesn't mean anything.

DAVID POGUE: *The "Kelvin," in the Kelvin scale, is 19th century physicist Lord Kelvin, who wondered, if temperature is a measure of atomic motion, with less and less the farther down you go, why not make zero the place where all motion would stop?*

He calculated that would happen at minus-459-point-six-seven degrees Fahrenheit, which he made zero on his scale.

ERIC CORNELL: A real zero, an absolute zero.

DAVID POGUE: *So, in the Kelvin world, room temperature would be...?*

ERIC CORNELL: About 300.

DAVID POGUE: *And water freezes at...?*

ERIC CORNELL: Two-hundred-seventy-three Kelvin.

DAVID POGUE: *And this liquid nitrogen?*

ERIC CORNELL: Seventy-seven Kelvin. Truth of the matter is, compared to where we're going, 77 Kelvin is positively balmy. In fact, as you get things colder and colder, that's actually when they start to get the most interesting.

DAVID POGUE: *Indeed.*

To continue on, we'll need to shed our Fahrenheit scale, and replace it with Lord Kelvin's. Then take a rapid plunge, from 77 degrees Kelvin down to...

MELISSA GOOCH (University of Houston): Four Kelvin.

DAVID POGUE: *...four Kelvin, where the bizarre property of superconductivity was first discovered.*

MELISSA GOOCH: There are certain materials that when you get it really cold, weird things happen.

DAVID POGUE: *Little did I know that the substance that would take us there really isn't bizarre at all.*

MELISSA GOOCH: Helium.

DAVID POGUE: *It's really not that cold; that's the funny thing.*

MELISSA GOOCH: But if we turn it into liquid, it's four Kelvin, so, really cold.

DAVID POGUE: *Melissa Gooch, at the University of Houston, is about to show me how when certain materials...*

This is a piece of lead.

MELISSA GOOCH: This is lead.

DAVID POGUE: *...get supercold, they start behaving in ways once thought impossible. To do this, she lowers the lead into this tank of liquid helium, to cool it to a temperature of seven degrees Kelvin.*

It looks like the temperature is plummeting into warp core, Captain.

MELISSA GOOCH: If we keep cooling,...

DAVID POGUE: *That ordinary lump of lead, in there, undergoes a transformation.*

Is it, in fact, a superconductor?

MELISSA GOOCH: Yes.

DAVID POGUE: *Wait. What is a superconductor? Or for that matter, what's a regular conductor?*

Conductors are materials that allow electricity to flow through, like copper. Most of the wiring in your house is copper. But copper has a problem, when electricity flows through it, electrons bump around, wasting energy as heat. That's called resistance. A superconductor has no resistance, zero. So the current flows through it without wasting any energy.

MELISSA GOOCH: This is copper wire that we have in our house, normally.

DAVID POGUE: *And these are normal light bulbs. But Gooch is going to run much less power through them than normal.*

MELISSA GOOCH: So we're at 12 volts.

DAVID POGUE: *That's only a tenth of the voltage we use in our homes.*

MELISSA GOOCH: It's not very bright.

DAVID POGUE: *That's what we get from the copper wire. Watch what happens when we run the same 12 volts through the superconductor.*

From a dull glow, to full throttle. So you're getting a lot more out of your electricity.

MELISSA GOOCH: You're getting a lot more out of it.

DAVID POGUE: *Oh. You're wasting a lot less.*

MELISSA GOOCH: Yes.

DAVID POGUE: *Scaled up, that wasted energy, just in the United States grid alone, could power 14 New York Cities every year. But that's just the start. Scientists have been working on harnessing the properties of superconductivity for much more exotic applications.*

ALAIN SACUTO (Université Paris Diderot, Paris 7): Now, I put the superconductor...

DAVID POGUE: *Here at the University of Paris, Professor Alain Sacuto showed me something extraordinary that happens when a really cold superconductor meets an ordinary magnet.*

ALAIN SACUTO: And there is levitation, you know?

DAVID POGUE: *And this little puck is just the tip of the iceberg.*

Whoa, come on!

ALAIN SACUTO: Let's go.

DAVID POGUE: *Back to the future! I'm actually surfing above the ground. I'm flying!*

And it's more than just fun and games. Engineers in Japan are already scaling it up to create the world's first superconductor Maglev passenger train. It flies above its tracks at speeds up to 311 miles per hour. And it's cold that makes it happen. So what's the trick?

You might think that the superconductor is acting just like a magnet, but you'd be wrong.

ALAIN SACUTO: It's not like a magnet, because here you have both repulsion and attraction.

DAVID POGUE: *So these two discs have repulsion and attraction?*

ALAIN SACUTO: Both.

DAVID POGUE: *And that's not how a proper magnet behaves. It can't do both at the same time. The superconductor can, because it warps the magnetic field of the magnet to a point where it attracts and repels at the same time.*

But it's both directions. It's locked.

ALAIN SACUTO: Yes, both directions.

DAVID POGUE: *But how is this possible? How do superconductors actually work?*

Look at that.

The crazy part is scientists don't really know. It has something to do with that q-word and, okay, where we're going now: two degrees Kelvin. Physicists are unlocking a whole new world of cold, where the laws of nature appear to break down.

You again.

ERIC CORNELL: Yes. Welcome to my world.

DAVID POGUE: *What is this place?*

ERIC CORNELL: This is the "matter menagerie," you know? Like in states of matter.

DAVID POGUE: *I do know states of matter: solids, liquids, gases.*

ERIC CORNELL: Nah. Way more. You've come to, like, a whole zoo of different states of matter that is called "strange matter."

DAVID POGUE: *Well named.*

ERIC CORNELL: We think that it only exists in the centers of neutron stars. This one, I'm particularly proud of. That is the "Bose-Einstein condensate," and when we discovered that stuff, I won a Nobel Prize.

DAVID POGUE: *Nice. I like how you worked that in.*

ERIC CORNELL: Yeah, well, you know.

DAVID POGUE: *How many more states of matter are there?*

ERIC CORNELL: Truth is, some people say hundreds.

Look at that. It's called a "superfluid."

DAVID POGUE: *Superfluid?*

ERIC CORNELL: Yes. Give that thing a swirl. What do you think is going to happen?

DAVID POGUE: *When I stir it? It's going to go around and around in the bucket.*

ERIC CORNELL: Give it a shot, a little faster.

DAVID POGUE: *A superfluid is a state of matter found at temperatures below two Kelvin.*

Oh, weird.

ERIC CORNELL: Now, go a little faster yet. Yeah.

DAVID POGUE: *Weird!*

And once these get started, they'll swirl forever.

Whoa!

ERIC CORNELL: That is quantum mechanics in action.

DAVID POGUE: *As I'm discovering, quantum mechanics is a kind of physics where the usual rules don't apply.*

ERIC CORNELL: Think of it this way: in the ordinary world, you, me, atoms, anything you want, they kind of act like balls, just like these balls, here. They bounce, they roll around, they bash off each other. But in the quantum mechanical world, each of the atoms starts to act more and more like a wave. And eventually, the wave of one atom starts to grow into the wave of the other, and before you know it, you can't tell one from the other. The atom could be over here, or it could be over there. And the cool thing is that it could, in some sense, be, really, both at the same time.

DAVID POGUE: *Both at the same time?*

ERIC CORNELL: Yeah.

DAVID POGUE: *I mean, how can something be in two places at once?*

ERIC CORNELL: It's not something we understand that well either, we just go with it.

DAVID POGUE: *No kidding!*

ERIC CORNELL: Quantum mechanics is like that, yeah.

DAVID POGUE: *And so I, we, depart for colder places, to see how this quantum weirdness can be harnessed to solve real-world problems.*

To do that we'll need to inch closer, a tenth of a degree, a hundredth of a degree above absolute zero.

GEORDIE ROSE: Welcome to one of the coldest places in the universe.

DAVID POGUE: *What? In an office park, in a Vancouver suburb?*

Meet physicist Geordie Rose, of D-Wave Systems, who claims they've used the cold to build the world's first commercial quantum computer.

Oh, my gosh! It's C-3PO's wedding cake!

GEORDIE ROSE: This is a quantum computer.

DAVID POGUE: *And what does that mean?*

GEORDIE ROSE: You have to rethink the way that you think about computers to wrap your head around it.

DAVID POGUE: *Remember that quantum strangeness below two Kelvin? Well, inside this giant refrigerator, Rose's team keeps a few atoms a hundred times colder, all to harness those weird abilities to make a new kind of computer.*

So, let me get this straight. This entire company, this entire building, this entire meat locker, this entire million-dollar apparatus is all designed just to make that tiny chip cold?

GEORDIE ROSE: Yes.

DAVID POGUE: *What does the cold have to do with the computing?*

GEORDIE ROSE: In quantum mechanics, the properties that we're trying to harness are very easily washed out by the movement of the atoms in the processor.

As you go down the plates through four Kelvin, point seven, point one. At each stage, we want to remove the wiggling of the atoms so they just calm down, take a seat on the couch, relax. And when they do that, these wonderful, powerful, magical properties that exist in quantum mechanics blossom out.

DAVID POGUE: *Quantum properties like being in two places at once: that magical ability allows D-Wave to program their computer in a very special way.*

GEORDIE ROSE: The fundamental piece of information storage in this is a device called a qubit.

DAVID POGUE: *Like the biblical measurement?*

GEORDIE ROSE: Very unlike the biblical measurement.

DAVID POGUE: *A qubit is the quantum version of a bit, the basic unit of information. In a regular computer, a bit can be either a zero or a one. But a quantum bit can be either a zero or a one, or both zero and one at the same time. This gives it exponentially more power than a conventional computer, which would use eight bits just to store a single number between zero and 256. In a quantum computer, eight qubits can store all 256 numbers at once.*

GEORDIE ROSE: The real kicker is when you have a lot of these bits together, the total number of possibilities doubles every time you add a bit.

DAVID POGUE: *So, while ten qubits can store $(2^{10}) = 1,024$ numbers, 11 qubits can store $(2^{11}) = 2,048$ numbers. When you get to 100 qubits, you can store $(2^{100}) = 1$ nonillion, 267 octillion, 650 septillion, 600 sextillion, 228 quintillion, 229 quartrillion, 401 trillion, 496 billion, 703 million, 205 thousand and 376) numbers*

GEORDIE ROSE: So by the time you get to about 500 bits, you have more possibilities than there are atoms in the visible universe.

DAVID POGUE: *Wow.*

What this means is that a quantum computer can tackle problems on a scale beyond any conventional computer: from weather prediction and air traffic control, to forensics and finance. Problems on this scale are everywhere and have simply outstripped our abilities to solve them.

And though some have questioned their claims, there are buyers. D-Wave's first customer? Aerospace giant Lockheed Martin.

Their F-35 fighter plane is incredibly sophisticated.

And we have touchdown! Whoa! This is a fairly software-dependent little plane.

MICHAEL: Yes. It's got about 9,000,000 lines of code.

DAVID POGUE: *Nine-million lines of code? Those nine-million lines of code can land a plane on a carrier, evade enemy radar and hover like a helicopter.*

Trouble is, no conventional computer could ever check that software for errors without an army of engineers.

Is it just too many variables to all consider at the same time?

BRAD PIETRAS (Lockheed Martin): That's exactly right. If you have a million, suddenly you can't manage it with any computer on Earth.

DAVID POGUE: *Which is why now NASA and Google partnered to get a quantum computer, too, in hopes of better finding habitable planets and speeding up the search.*

Can I have one?

GEORDIE ROSE: How much money you got?

DAVID POGUE: *Not enough.*

So, D-Wave's chip is one of the coldest things in the universe: a hundredth of a degree above absolute zero.

Well, we're not done yet.

I'm about to meet a scientist who can't be bothered with hundredths or even thousandths of a degree for that matter, a.k.a. a millikelvin.

MARTIN ZWIERLEIN: We are bored by a millikelvin; we like to go to nanokelvin.

DAVID POGUE: *Nanokelvin?*

MARTIN ZWIERLEIN: Nanokelvin; that would be a billionth of a degree above absolute zero.

DAVID POGUE: *A billionth of a degree?*

MARTIN ZWIERLEIN: It's very cold! It's a million times colder than interstellar space.

DAVID POGUE: *It's just about the lowest temperature ever reached: a place so clear and cold, physicists can see the fundamental laws of nature in action.*

M.I.T.'s Martin Zwierlein is going to use sodium atoms to show me how to get there: the final frontier of cold.

Wow. And, so, how do you do that?

MARTIN ZWIERLEIN: So, we can start over there, at the oven.

DAVID POGUE: *The oven?*

Step 1: Cook up some sodium atoms, the same kind in your table salt, to about 700 degrees Fahrenheit. That way you can separate them.

MARTIN ZWIERLEIN: You want to get single atoms to play with, single sodium atoms, lots of them, a whole stream of them.

DAVID POGUE: *Step 2: Hit them with lasers.*

I know you M.I.T. guys have the reputation of being very smart, but I have a little tip for you: lasers are hot. You might be a little backwards there.

MARTIN ZWIERLEIN: Yeah. You might think about *Star Trek*, where they kill people with lasers. Turns out here, we cool atoms down with lasers. They get a recoil from it, just as if you hit a billiard ball with another billiard ball.

DAVID POGUE: *In other words, when you hit atoms with just the right amount of laser light, it acts like a little shove in the opposite direction that the atom is moving, slowing it down.*

MARTIN ZWIERLEIN: If you look down here, you will actually see the cold cloud, right there in the center of the vacuum chamber.

DAVID POGUE: *That glowing star thing? It looks like the sun, it ought to be super, super hot.*

MARTIN ZWIERLEIN: No. It's actually extremely cold. Those are a billion atoms, cooled to a millikelvin.

DAVID POGUE: *A thousandth of a degree above absolute zero. But lasers can only get us so far.*

MARTIN ZWIERLEIN: You cannot reach the nanokelvin temperatures just with laser cooling, so we need another technique.

DAVID POGUE: *Which brings us to Step 3: Get out your coffee cup.*

MARTIN ZWIERLEIN: What takes over after laser cooling is what we call evaporative cooling. It's the same thing that happens to your coffee right now, because it's just cooling down. So, if you now force it a little bit, by blowing on the coffee, huh? You speed that process up. The coffee gets cold more quickly, that's exactly what we do here.

DAVID POGUE: *But instead of a coffee cup, Zwierlein uses a cup made of magnetic fields to trap his atoms. Then he “blows” on it with radiation and lowers the rim of the cup to let the hotter atoms escape.*

MARTIN ZWIERLEIN: So, now, we’re going to do this coffee-cup cooling. It’s going to bring us to nanokelvin, okay?

Ready for this?

DAVID POGUE: *Yes.*

MARTIN ZWIERLEIN: Let’s do this.

So, can you please switch on this stuff? Do this, this is great. Let’s switch on this guy, and then this awesome knob, here.

DAVID POGUE: *Press the awesome white button.*

MARTIN ZWIERLEIN: Fantastic! So, that’s good. Please press F12.

DAVID POGUE: *I’ve always wondered what F12 does.*

MARTIN ZWIERLEIN: You see, now, that the atoms are cooling, because the cloud size gets smaller and smaller and smaller. Here you see the temperature drop, drop, drop, drop, drop.

DAVID POGUE: *Oh, wow!*

It takes a few minutes, but eventually the atoms become so cold, they lose their individual identities altogether and coalesce into that new state of matter called a Bose-Einstein condensate.

MARTIN ZWIERLEIN: And that has formed right now.

DAVID POGUE: *Wait a minute, wait a minute. Okay.*

MARTIN ZWIERLEIN: Yes?

DAVID POGUE: *So, that’s the condensate?*

MARTIN ZWIERLEIN: That’s the condensate.

DAVID POGUE: *But look at the temperature.*

MARTIN ZWIERLEIN: Yeah, it’s very cold.

DAVID POGUE: *A hundred-and-seventy-seven-billionths of a degree? Billionths?*

MARTIN ZWIERLEIN: Billionths, billionths of a degree.

DAVID POGUE: *A hundred-and-seventy-seven-billionths of a degree Kelvin.*

MARTIN ZWIERLEIN: This is the coldest spot in the universe right now, right here.

DAVID POGUE: *That's amazing.*

MARTIN ZWIERLEIN: Yep.

DAVID POGUE: *So, not even outer space?*

MARTIN ZWIERLEIN: No, no, no. Outer space is a million times hotter.

DAVID POGUE: *Not the dark side of the moon?*

MARTIN ZWIERLEIN: No, it's, like, all hot.

DAVID POGUE: *Comets?*

MARTIN ZWIERLEIN: Terrible.

DAVID POGUE: *Black holes? Nothing?*

MARTIN ZWIERLEIN: Nothing.

DAVID POGUE: *This is it, in this room. That's amazing. I would ask it for its autograph if I could.*

But it's not about setting obscure records. What Zwierlein is excited about is what these exotic states of matter can teach us about the universe.

MARTIN ZWIERLEIN: Our puff of gas teaches us about the neutron stars, or the split second after the Big Bang, there was this weird form of matter called the quark-gluon plasma.

DAVID POGUE: *A superhot type of matter in the early universe that would give rise to everything we see today.*

So, you're telling me that this tiny, freezing cold dot can teach us something about enormous, blazing-hot stuff?

MARTIN ZWIERLEIN: That's the fun part of physics. It connects these very different areas. The very hot, very cold, everything is governed by the same laws.

DAVID POGUE: *Amazingly, what happens at these ultracold temperatures is that atoms get so smeared out, their waves start looking indistinguishable from those of superhot particles under extreme pressure, like those inside the inner core of neutron stars, so dense, a teaspoon of them weighs 10-billion tons.*

Zwierlein and others can now simulate substances like this in their labs and probe their mysteries.

That's incredible. And in a couple more years, you'll finally do it. You'll hit 0.0, absolute zero, and we'll be done.

MARTIN ZWIERLEIN: Yeah, unfortunately, it's never possible to reach absolute zero.

DAVID POGUE: *What?*

MARTIN ZWIERLEIN: There's always going to be a little, little drop of energy sitting around somewhere.

DAVID POGUE: *Turns out, it's impossible to get to absolute zero, because no matter how cold you get, everything has tiny quantum jitters. And where you have motion, even a tiny amount, you have heat.*

But that's not stopping scientists from getting even colder to explore the fundamental laws of nature and how our universe came to be.

ERIC CORNELL: Just the way noise can drown out music, heat is sort of the noise that obscures things. If you get things really, really cold you sort of drown out, you damp down all the noise and you can listen to what nature is whispering to you.

DAVID POGUE: *It's uncharted territory. Like other frontiers of science, cold has opened the doors to new worlds. Where the dead may get a second chance, the planet can be cooled by clever innovation and the universe may be made more understandable. The secrets are all around us, as we learn to make stuff colder.*