"GOING TO EXTREMES"
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EPISODE OPEN

ALAN ALDA It's hot. It's dry. It's the Arizona desert. On this edition of Scientific American Frontiers we'll see how nature gets by under the most extreme conditions.

NARRATION We'll see how a desert spider has to fight to capture an ant, and to win a mate... We'll ask what it takes to be the fastest on four legs... We'll find out how frogs and flounder make it through the big freeze... And we'll discover the life of the ocean depths, and the dangers of mountain peaks.

ALAN ALDA I'm Alan Alda. Join me now as we go to extremes.

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SPIDER CANYON

ALAN ALDA (NARRATION) We're in Southern Arizona. After the brief summer rains, the desert's deceptively green. But this is a harsh environment, posing extreme challenges to the plants and animals that live here.

SUSAN RIECHERT Usually what we have is a sort of a permanent sheet that's kind of large, because these are hungry spiders.

ALAN ALDA Could they be anywhere? Could they be in any one of these little plants, or...

SUSAN RIECHERT They're gonna need shelter from the heat.

ALAN ALDA There's a... there's a web.

SUSAN RIECHERT Yep, see, you did better than I did.

ALAN ALDA (NARRATION) I doubt it. Susan Riechert, a biology professor from the University of Tennessee, has been studying the desert funnel web spider for thirty years.

SUSAN RIECHERT They're touching the web and they're feeling the vibration of anything that might be coming down the web. In addition they're... picking up airborne vibrations of flying insects that are moving the air. And so they can tell what kind of insect that is that's in the vicinity and um... whether they want to come out and attack it or not.

ALAN ALDA They can tell just by the vibrations on the web or... or in the air what kind of insect is sitting on their trap, huh?

SUSAN RIECHERT That's right.

ALAN ALDA (NARRATION) These are fire ants. They're tough and aggressive, with a nasty bite.

SUSAN RIECHERT Here we go. I'm dropping the ant.

ALAN ALDA (NARRATION) The spider attacks without hesitation. It's a female -- summer is breeding season so she has to eat, even though she's risking her life in the process.

ALAN ALDA She grabs at it then she pulls back.

SUSAN RIECHERT That's right.

ALAN ALDA What's she doing when she does that?

SUSAN RIECHERT She's trying to avoid the jaws of that ant. She's trying to inject venom. Oh... she has to try and get her little fangs that are very small in through that hard casing of the ant.

ALAN ALDA (NARRATION) But it's not just the ant that could kill her -- the hot desert sun could, too. She'd be protected back in the shade, but she can't take her prey in until it's subdued and safe to move. Five minutes into the struggle the sun comes out. As the web rapidly heats up, the spider's forced to retreat to its shady funnel. It's now over a hundred degrees out on the web.

ALAN ALDA How does she know the ant will still be there when she comes back?

SUSAN RIECHERT She doesn't. But she doesn't have a choice, because if she heats up and she goes into a stupor she'll die... she'll get... she'll cook. But they're hungry so they have to try for everything.

ALAN ALDA (NARRATION) She's back within a minute for a quick check on her victim. Now it seems safe to take in. Susan thought she had her desert spiders pretty well figured out until one day she discovered the spiders who live up in this canyon. The canyon's a lush oasis, so biologists would expect the plant and animal species living here to be different from the ones coping with desert extremes. But to Susan's surprise, the spiders were the same. This launched her on a journey of discovery that's still continuing, and that may eventually lead to a glimpse of evolution itself in action.

ALAN ALDA Well this is a lot nicer here. I mean, I can see how the spiders feel about this...

SUSAN RIECHERT It's better for us, isn't it?

ALAN ALDA Yeah, but I... I can... it's cooler.

ALAN ALDA (NARRATION) Susan first noticed that, even though it's cool here, river spiders often stay in their funnels. They're timid and fearful, unlike their desert cousins. That makes sense, she realized, because under the trees the enemy's no longer the sun -- it's hungry birds. But seeing the same species changing its behavior like this, to fit a different environment, was a big surprise -- an important discovery in biology.

SUSAN RIECHERT Let's try an ant, shall we? Let's see... do you see her at all? If she's there, she's back pretty far.

ALAN ALDA I see something in the tunnel.

ALAN ALDA (NARRATION) The threat of birds stops river spiders coming out to fight a tough ant. There are plenty of softer insects around anyway.

ALAN ALDA There's a definite lack of interest in this ant here.

SUSAN RIECHERT They're gonna ignore her... the vibratory patterns that an ant's gonna make. They're not gonna come out...

ALAN ALDA It's not worth the trouble, because you could get killed that way.

SUSAN RIECHERT Yeah.

ALAN ALDA (NARRATION) Susan set up a natural laboratory -- an eight-acre enclosure running from the river up the canyon side. At the top the lush river environment gives way to dry woodland, where the spiders are very aggressive -- like those in the extremes of the desert. For Susan the question was, what happens when the tough guys above meet the softies below? The first thing that happens is any spiders heading down into the canyon are stopped by the border patrol. They come up against the study area's boundary, and get caught in pitfall traps.

ALAN ALDA I'll check the ones coming from this side...

SUSAN RIECHERT We'll see who finds the first animal, how's that?

ALAN ALDA ... all right.

ALAN ALDA (NARRATION) Both sides of the fence are checked, but most spiders are heading downhill toward the easy life on the river.

ALAN ALDA Ah... there's something in here... oh.... oh geez... watch out, there's something in there!

SUSAN RIECHERT Yeah, a cricket or something.

ALAN ALDA What? A cricket?

SUSAN RIECHERT A cricket, and an itsy, bitsty spider, and...

ALAN ALDA You never know what it could have been. It could have been a scorpion.

SUSAN RIECHERT Well, you're losing out on...

ALAN ALDA I don't want it back!

SUSAN RIECHERT I emptied it.

ALAN ALDA Oh.

SUSAN RIECHERT You always have to empty all the insects out... when you do this.

ALAN ALDA You know...

SUSAN RIECHERT By... by the way, there are scorpions... um...

ALAN ALDA There are or aren't?

SUSAN RIECHERT There are.

ALAN ALDA There are. Of course there are! What do you think I was screaming about?

SUSAN RIECHERT So watch your fingers when you reach in.

ALAN ALDA Nothing... something, something! Huh-huh, a spider...

SUSAN RIECHERT Yeah, probably another cricket...

ALAN ALDA No, no, a spider.

SUSAN RIECHERT Oh yeah?

ALAN ALDA Yes.

SUSAN RIECHERT Let's see. What kind?

ALAN ALDA Very aggressive spider... ha... That's a spider!

SUSAN RIECHERT Oh.

ALAN ALDA What is it?

SUSAN RIECHERT Well, that is an Agelenopsis aperta.

ALAN ALDA I told ya!

ALAN ALDA (NARRATION) Every day trapped spiders are brought to the lab close to the enclosure. They'll be returned to the wild just across the fence, at the point they were caught, to continue their journey. But first they're put through their paces. This is a test for aggression. Two males are placed on a web built by a female who's been removed. Immediately one male takes possession of the web funnel, looking for the female. Susan's seen this kind of face-off many times in the wild. The result can be anything from one spider's running away, to a fight to the death. These are both aggressive, dry-land spiders so neither is prepared to back down. In fact, after he's first driven off, the attacker heads right back to the web funnel. Inside the funnel the defender slowly edges toward the attacker, who's lurking just outside. They're both looking for a fight. When it finally erupts

it's ferocious. In a surprise reversal the attacker, now on the left, bites the defender's leg and hangs on -- it could all be over. But then the defender pulls free, scares the attacker off and pauses to nurse his leg. He once again takes possession of the funnel. But it's not over yet. The defender wants the attacker well clear of the area. But the attacker stays lurking nearby. This particular confrontation took about two hours, although Susan's seen them run for an entire day. The end came like this -- with a vicious tangle that was going to lead to death, until the referee stepped in.

SUSAN RIECHERT I've got them separated.

ALAN ALDA (NARRATION) Susan doesn't want to lose any of her spiders. The aim is to score them for aggression, mark them, and then see how they do back in the enclosure. The contestants will be returned within the hour. There are about fifteen hundred spiders within the enclosure, and Susan has caught and tested every one. Females are kept in the lab until they build webs in their plastic boxes, then they go back in the field with the males. Now the study moves to the next stage.

ALAN ALDA You know exactly where it is?

SUSAN RIECHERT Ah... yes.

ALAN ALDA It's like, there's a favorite night spot they go to or what?

SUSAN RIECHERT Um... no, well, potentially any one of these spiders that is in a box could be mating. Now, I think if you were to look inside that funnel you will see...

ALAN ALDA Down in here?

SUSAN RIECHERT Yes, you will see that there are two spiders.

ALAN ALDA Oh, yeah yeah. OK.

ALAN ALDA (NARRATION) There's a mating going on between an aggressive, dry-land male who came down the hill, and a timid river female. It would have gone something like this, with the male cautiously approaching while doing his mating dance, to signal his intention to the female. Both spiders have to be careful because things can turn ugly pretty quickly. A fight could start, especially if male and female are very aggressive. Or if one's too aggressive and the other's too timid, then the timid one might simply run away. But in this case wedding bells ring out and the tough, dry-land male wins his shy bride from the river. The happy couple will be blessed with about three hundred kids. Susan's been

following the spiders in her enclosure for twenty years now and she's run into a puzzle -- the spiders just aren't behaving right.

ALAN ALDA Right there?

SUSAN RIECHERT Yeah.

ALAN ALDA (NARRATION) Many spiders are much more aggressive than makes sense here. Susan's figured out they are the hybrid offspring of aggressive, dry-land males and timid, river females.

ALAN ALDA That really seems aggressive. You think that's a hybrid?

SUSAN RIECHERT It's gotta be. I mean, here's a spider that obviously isn't hungry. She takes these ants, that could kill her, into her funnel and she lets them go.

ALAN ALDA Just catching them for no reason? And they're dangerous to catch?

SUSAN RIECHERT And she probably won't even eat it.

ALAN ALDA (NARRATION) Here's the kind of super-aggressive behavior by the hybrids that Susan discovered. Dangerous fire ants are pulled into the funnel without first being subdued. Not even a hungry desert spider would take this risk, and sure enough, Susan's found most hybrids don't make it. Many are taken by birds, many don't breed because they scare off their partners. So now Susan predicts a new behavior will evolve among the river females, that prevents them from mating with aggressive males. The offspring of those females would survive, unlike hybrids. If she's right, she'll see much more of this -- a male with no partner.

SUSAN RIECHERT Hey Terry!

TERRY You got something Susan?

SUSAN RIECHERT Yeah I'm at A134 and I have a male. It looks like ah... white, yellow, pink...

TERRY He was there last check.

SUSAN RIECHERT The female is... ah, not here, so he must have chased her off.

ALAN ALDA (NARRATION) Susan expects that somewhere there's a timid, river female who won't mate with an aggressive male from up the hill. Her offspring will inherit that behavior, they'll thrive, and eventually they'll take over the canyon. They'll never mix with the guys up the hill again. It'll be a shift to a new species of spider -- evolution in action. To make that discovery Susan Riechert's prepared to put in another few decades.

ALAN ALDA Do you ever at night before you go to sleep say to yourself, wouldn't it be great if in the next few months I started to see this shift.. and I... I was there to experience it?

SUSAN RIECHERT Oh... we'd all love to have that kind of... ah.. event happen. But... that's nature. It does what it wants. Whatever happens, happens, and we can just follow it.

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FROZEN ALIVE

ALAN ALDA (NARRATION) Beneath the waters of the North Atlantic as November comes, life faces a conundrum. How to survive at a temperature that turns blood to ice? Here to find out is biologist Sally Goddard.

SKIPPER What we're going to do, we're moving close to the headland here, and the divers will have about 20-30 feet of water and you should find quite a few flounder there, hopefully.

ALAN ALDA (NARRATION) These divers - warm-blooded animals - survive the cold by burning body fat to generate heat - and by wearing elaborate protective gear. But the creatures below are cold-blooded, living at the temperature of their surroundings. Which here means their cold blood gets very cold indeed.

SALLY Most fish blood freezes at about minus 0.7, and the water around here can go down to minus 1.8. So you could tell they'd have a real problem.

ALAN ALDA (NARRATION) At minus 1.8 degrees Celsius, sea water isn't yet frozen. Hidden but for their eyes under a layer of sand, these flounder aren't frozen either - though their blood is also at minus 1.8 degrees. As long as the water itself doesn't freeze, the flounder survive - thanks to an antifreeze protein in their blood, manufactured to order for the long winter months.

SALLY The production of anti-freeze protein in the flounder is really triggered by the days getting shorter. So the flounder can sense that the day length is shorter

and winter's approaching, and the whole system for making antifreeze proteins is triggered round about November time.

ALAN ALDA (NARRATION) Alive and well back at Sally Goddard's lab at Memorial University in St. John's, this flounder becomes a blood donor. The fish will survive till another day - and its blood will demonstrate the property that makes it so remarkable - and potentially valuable.

SALLY Pleased to be back.

ALAN ALDA (NARRATION) As well as the blood sample she's just taken,

SALLY has some blood from a flounder caught during the summer.

SALLY I'm going to set the temperature of the bath to really cold sea water-winter temperature-which is about minus 1.8-that's as cold as sea water gets before it freezes solid. Now this is the blood taken from a fish in summer. This fish doesn't have any antifreeze in its plasma. Now once I disturb the blood, ice crystals start to form in the blood, and they propagate very quickly, spread through the blood, and turn it into something looking like a slush puppy, a red slush puppy. If this was a fish with blood like this, the fish wouldn't be able to breathe, the blood wouldn't circulate around the fish. You'd have a dead fish, for sure.

ALAN ALDA (NARRATION) But at the same low temperature, the winter flounder's blood stays liquid - thanks to the antifreeze protein.

SALLY The proteins have a special affinity for ice crystals...so at the first hint of an ice crystal forming, these proteins bind onto it, and effectively lower the freezing point. So a fish with high levels of antifreeze is just about protected under any circumstances in Newfoundland waters.

ALAN ALDA (NARRATION) Sally Goddard now has a small business purifying the fish antifreeze, anticipating the day when it could be useful to humans as well as flounder. One of her best customers is across the continent in Berkeley, California. Here Boris Rubinsky looks at what freezing does to living cells. He's hoping to radically improve the availability of human organs for transplant surgery.

BORIS One would like to be able to preserve organs for long period of time in order to facilitate organ transplantation. There are many organs available, but because of the lack of compatibility in terms of time and placing, one cannot really implant all the available organs. If we would be able to preserve organs for long periods of time, then obviously we could resolve some of these problems.

Learning how animals solve their problems is probably, in my opinion, the best way to actually resolve the problem of organ preservation for transplantation.

ALAN ALDA (NARRATION) The big problem with preserving human organs is that freezing destroys the cells it's meant to save. This is human blood. As it freezes, the blade-like crystals trap and squeeze the red blood cells.

BORIS Most of the cells are being pushed to the side by the ice crystals and all the cells are being pushed inside these channels and compressed, and this is where they're destroyed. The walls become leaky, the cells are not nice and round anymore like they were at the beginning of the freezing process.

ALAN ALDA (NARRATION) Adding Sally Goddard's fish antifreeze to the cells not only holds back freezing. Even at very low doses - not enough to prevent ice crystals growing - it helps keep the red blood cells round and intact. But the fish antifreeze alone won't solve the problem of preserving human organs for transplantation. So Boris Rubinsky's conviction that nature will teach him how to freeze then bring back to life human tissue, has led him beyond fish to an even more remarkable winter survivor. It's hunted in the woods of Ontario every year by Carleton University biologists Janet and Kenneth Storey.

KEN It takes a lot of hard work. It makes you wonder what a middle-aged scientist is wandering around the woods picking leaves. It's like my mother says that the good news is that my son is a doctor, and the bad news is that he's the wrong kind. I end up looking for frogs.

JANET There's one. Oh.

ALAN ALDA (NARRATION) They're here to catch - or attempt to catch - wood frogs.

JANET Oh, a beauty.

ALAN ALDA (NARRATION) Obviously still quite active in the late fall, the frogs are approaching a long, hard Canadian winter.

JANET This is an adult wood frog. Looks to be a female. You can see that her abdomen's quite extended-she's already got the eggs in place that she will lay in the spring at the breeding ponds. Could be in the jar with her.

ALAN ALDA (NARRATION) And during that winter, like everything around them, they'll simply freeze solid.

KEN This is probably a young of the year. That is, he was a tadpole months ago- he's been eating flies ever since. And now, if we didn't disturb him, he would just burrow down, and live frozen all winter underneath the leaves. If you're frozen your metabolism slows down to nothing and you can live in a state of suspended animation. Instead of having to grow huge and eat a lot of fuels and then use them up, if you're frozen, for many months, you're not using your fuels. In the spring they come out before there's any insects to eat, and they mate and lay eggs in ponds that are still covered with ice.

ALAN ALDA (NARRATION) For these frogs, winter is coming a little early this year.

JANET What we're doing is getting ready to freeze the frogs at what is a natural temperature to them, about 25 degrees F.

ALAN ALDA (NARRATION) The freezer may not be as comfortable as a forest floor, but once the temperature starts falling, the frogs settle down, tuck themselves in - and over the course of several hours, freeze solid.

KEN Frosty, hard frogs. The animal's completely frozen now. About 67% of their body is turned into ice. The heart is truly stopped. The blood is all frozen in a big pool in the center of the frog. There's no blood in the arms or the legs at all. And they're hard. They're ice crystals on the skin, and the frog can't even be flexed at all.

ALAN ALDA (NARRATION) For Ken and Janet Storey, only one thing is more entrancing than watching a frog freeze - and that's watching it thaw.

KEN The first thing you can see in a newly thawed frog is the heart beginning to pump blood. The thickened blood is now being pushed back into the exterior limbs and around the brain to get the frog re-oxygenated and back to work. He seems to be doing fine...no need to notify his next of kin!

ALAN ALDA (NARRATION) It's a sight right out of science fiction - the frozen body coming back to life. Which is why this wood frog is now in Boris' lab - where it's about to be frozen while its insides are imaged by an MRI scanner of the type usually used in hospitals. As soon as ice forms on its skin, a wood frog starts pumping out huge quantities of the blood sugar glucose from its liver. Like the fish antifreeze, glucose seems to both lower the freezing point, and protect cells from damage when ice does start forming. And in the MRI images - where frozen tissue appears darker - it's the triangular shaped liver - the source of the glucose - that freezes last. But what Rubinsky is especially intrigued by is how the frog unfreezes. Because if it thaws as you'd expect, from the outside in, then its limbs and head would unfreeze before the heart, and so begin to die through lack of

blood. The MRI explains the mystery, as it reveals that the frog thaws evenly throughout its body.

BORIS Now nature has somehow ensured that, essentially through glucose, as we found later, it has ensured that the whole frog thaws simultaneously throughout all its tissues, and therefore, as soon as it thaws, the blood circulation perfuses all the tissues and brings them back to life simultaneously, and the frog can begin hopping.

ALAN ALDA (NARRATION) Copying nature's solutions to surviving extreme cold, perhaps one day human organs will freeze and come back to life with the same unconcern as the wood frog.

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ULTIMATE SPEED

ALAN ALDA (NARRATION) It's a race we've all seen on television nature shows. The cheetah gives chase; the antelope flee. But what we're watching is much more than a race between hunter and prey. It's a race between two entirely different biological designs, each fine-tuned through evolution to achieve the highest speed land animals can reach: 60 - even 70 - miles per hour. It's another example of nature at the extreme. How animals run is a fascination of University of California, Berkeley physiologist Rodger Kram.

RODGER KRAM I got interested in studying locomotion because that's what I enjoy doing... I enjoy exercising and running myself. But, I think what the most interesting thing about animals is, is that they move.

ALAN ALDA (NARRATION) Rodger Kram is especially intrigued by the extremes of animal locomotion, and the limits - like gravity - that set those extremes.

RODGER KRAM The ant is a very small animal...it's not very fast in absolute terms but even though it moves it legs very quickly, it has short little legs. Ants are in no danger of breaking their legs-they're so small, gravity's not an important force for them. The elephant, on the other hand, is really dominated by gravity-it's huge, it can take enormous strides, but it can't run, because if it started to run and left the ground and landed, it would literally break its bones.

ALAN ALDA (NARRATION) The cheetah is a spectacularly successful compromise between the lightness of the ant and the power of the elephant. Here at the Phoenix Zoo, Rodger is at the very beginning of a research project that he hopes will reveal the secret of the cheetah's speed. He's about to film a chase, not between a cheetah and an antelope but between a cheetah and a

rabbit's foot at the end of a very long line. For the zoo's cheetahs, even a rabbit's foot is a welcome reminder of the thrill of the hunt - though on the first trial run, it's disappointingly easy prey.

RODGER KRAM He caught it.

ALAN ALDA (NARRATION) One rabbit's foot down - but fortunately plenty more to go. And on later runs the rabbit feet pose more of a challenge - enough to give the cheetahs a workout and Rodger several seconds of high speed video. For both cheetahs and scientist it's been a rewarding morning.

RODGER KRAM I feel really lucky to have the opportunity to study cheetahs, I spent...building my career on studying how animals run, and cheetahs are the fastest animal in the world. Not only are they the fastest animal in the world, but they're endangered and the next generation of scientists might not be able to study how cheetah's run so fast.

ALAN ALDA (NARRATION) At full tilt the cheetah takes such enormous strides that it's literally flying half the time. It's secret, Rodger believes, is its extraordinarily flexible back.

RODGER KRAM It flexes and the extends its back to lengthen its stride. But you can see that there's a dip in its back at one part of the stride.

ALAN ALDA (NARRATION) The cheetah's flexible spine may give it another advantage.

RODGER KRAM It not only allows it to lengthen its stride, but it also may be used as a spring to store energy when the animal lands, then give that energy back as it takes off.

ALAN ALDA (NARRATION) So Rodger's research will aim to find out if the cheetah owes at least some of its speed to spring power. What's certain, though, is that the cheetah pays a price for its ability to accelerate from zero to 45 miles an hour in two seconds. Like any sprinter, after a few hundred feet it's exhausted - and takes a full half hour to recover. Completely uncheetah-like in design - and endurance - are these pronghorn antelope, here running at over 50 miles an hour in Colorado. Once endangered, there are now over a million pronghorn in the Western United States. And two here in the Boston suburbs, where I recently helped out at a mini-round-up at Harvard University's field station.

ALAN ALDA How did they get the ability to go this fast in the first place?

JIM JONES Well historically, up until about the time of the Pleistocene-about 10,000 years ago-there was a cheetah in North America. We can argue that perhaps they co-evolved such that predation from this very fast cat then led to their escape mechanism being developed at high speeds themselves.

ALAN ALDA When did the cheetah check out? JONES The cheetah checked out about 10,000 years ago.

ALAN ALDA So for 10,000 years they've had this ability...I mean they're all dressed up and no place to go!

ALAN ALDA (NARRATION) Jim Jones, like Rodger Kram, is setting out to answer the basic question

JIM JONES How are these animals able to achieve speeds as does the cheetah that are simply far, far in excess of what almost every other mammal is able to do?

ALAN ALDA What have you found so far? How can they run so fast?

JIM JONES Well, we look at it in a very general sense as two possibilities. One is, either the animals have a very large motor, which is their metabolism, how much energy is available, to fuel the running, or alternatively, maybe they have a specialized transmission.

ALAN ALDA (NARRATION) It's the pronghorn's transmission - the way it converts its motor power to speed - that's about to be checked out today. Judah is being chased down a corridor past an observation port manned by Jim Jones' student Seth Wright. SETH WRIGHT OK, that's good, we've got a right rear.

ALAN ALDA (NARRATION) The aim is to get Judah to step on a plate that will measure the force behind each stride at the same time that a high speed video camera records it. Finally they get a perfect shot of a rear leg in action. SETH WRIGHT One of the most dramatic features is that they have these huge extensions at the ankle, which is in the same place as the knee on the human-it's the first major joint off the ground. That means that the muscle is acting very far from the joint-and that gives it a great deal of leverage, akin to pushing on the side of a door, far from the hinge gives you a great deal of leverage for opening the door.

ALAN ALDA (NARRATION) The ankle lever allows the pronghorn to leap into its run with the acceleration it once needed to keep one step ahead of North American cheetahs. In marked contrast to the cheetah's strong sinuous back, the pronghorn's is rigid and light - as are its long delicate-looking legs. But as the

high speed video reveals, its gait minimizes the risk of breaking its bones. SETH WRIGHT You can see that as the antelope lands, its skinny forelimb is perfectly straight. That's the strongest arrangement for a bone-it's not undergoing any bending as it strikes. So these antelope aren't compromising safety to achieve their high speeds.

ALAN ALDA (NARRATION) Judah's companion, 4x4, will also be getting a work-out today. In her case, though, not to test her transmission - which seems in fine shape - but to run a detailed check on her motor.

ALAN ALDA Your treadmill is ready, Grace. RESEARCHER We will put this mask on her, which will collect the gases that she's expiring as she's running. This is the mask...

ALAN ALDA (NARRATION) I think I've just discovered the ultimate in recycling...

ALAN ALDA An old Wisk bottle.

ALAN ALDA (NARRATION) The treadmill is cranked up and 4x4 is off and running - with a little encouragement.

JIM JONES Flap it behind her and that'll be enough to ....

ALAN ALDA How Long can she keep going like this, at this speed?

JIM JONES At this speed, forever.

ALAN ALDA She'd just go on and on at this, forever

JIM JONES This is so easy for her...this is one-tenth of what she can do.

ALAN ALDA (NARRATION) A force plate under the pronghorn's front legs records her gait, displayed as she trots by the red line. The green line is her breathing - one breath for every three steps.

JIM JONES Now she's going up to 8. This will be about 18 mph.

ALAN ALDA (NARRATION) At this speed, 4x4 breaks into an easy gallop. But to keep going at over 20 miles an hour, she really needs to feel there's a cheetah on her tail. By now her breathing pattern has changed. Instead of three strides per breath, at a gallop her stride and breathing rate seem to be locked together.

JIM JONES The question that's been raised about that is.. might it be that every time the animal's body goes forward in its stride, it hits down as it begins to

momentarily slightly decelerate before the next stride goes forward and the inertia, the momentum, as it were, of the guts going forward would push the air out of the lungs a little bit, then as the animal accelerates forward the inertia causing those guts to move backward a little bit might help it to inspire.

ALAN ALDA (NARRATION) For an animal its size, the pronghorn has huge lungs - and it could be, then, that the gallop itself is helping her take the great gulps of air she needs to keep going. To run the pronghorn's motor even harder, the angle of the treadmill is cranked up to a grade of twenty percent. Now it's Judah's turn - and she seems to be looking forward to it. As Judah set off uphill, Jim Jones summarized what makes her and her kind such extraordinary athletes.

JIM JONES The largest single part of it is that indeed the animal has a huge motor. She has got muscles that are designed to utilize oxygen at a rate...It's about as much as five times as a not highly aerobic athletic animal like a goat. To support that, she has to have this very high ability to pump blood from the lungs to the muscles, so she's got an extremely large heart-very, very large for her size- and in turn, she gets the oxygen from the air into that blood, she's got the lungs that we mentioned earlier that are much, much larger-about two and a half times larger-than those of a less aerobic animal.

ALAN ALDA (NARRATION) In Africa, unlike North America, the race between extreme solutions for speed - one emphasizing endurance, the other lightning sprints - still goes on everyday. Sometimes one wins, sometimes the other.

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HIDDEN DEPTHS

ALAN ALDA (NARRATION) Early morning fog shrouds the harbor of Moss Landing, 75 miles south of San Francisco, as the research vessel Point Lobos heads out to sea. Operated by the Monterey Bay Aquarium Research Institute, its destination is the edge of the last great unexplored region on earth. Just 10 miles out, the ocean floor plunges into a canyon bigger than the Grand Canyon, poising the Point Lobos over water as deep as almost any in the world's oceans. Below the top few hundred feet, these depths were until recently almost entirely unknown, though by volume they make up more than 90% of the earth's living space. On board the Point Lobos is one of the first regular visitors to these hidden depths, the submarine Ventana.

ALAN ALDA What is all this stuff here?

BRUCE ROBISON Well, we've got a variety of tools that we use at depth. These are samplers that we use to collect the more fragile and delicate animals. Down

here is the big eye. Up here along this middle bar are four metal halogen lights. The depths we'll be working at today are very dark. Less than a hundredth of a percent of the sunlight which reaches the surface penetrates as deep as we'll be working today.

ALAN ALDA If we were down there without a light, what would it be like? Would it be like being in a room that just has a tiny crack somewhere under a door?

BRUCE ROBISON Even less than that. About the only thing you can see is that looking up towards the surface is less dark than looking down.

ALAN ALDA (NARRATION) Bruce Robison has been using the Ventana to explore the darkness below for some 7 years now. The submarine has no crew. Bruce and his crew operate it remotely from the surface, where the ocean swell is making life distinctly uncomfortable for me and our camera crew. Unfortunately, going below only makes things worse. The control room is small, dark, hot and constantly pitching. As I munch saltines to settle my stomach, the pilot takes the Ventana on a dive that will penetrate a half-mile into the darkness. The view from Ventana's camera is like something out of Star Wars...

ALAN ALDA So we're just traveling through space here, it looks like we're, oh what went by? Something good went by. What was that?

ALAN ALDA (NARRATION) ...complete with aliens.

BRUCE ROBISON Oh, Peralia. Peralia.

ALAN ALDA What's that?

BRUCE ROBISON These are great big, brown colored medusi.

ALAN ALDA Oh, that's gorgeous.

ALAN ALDA (NARRATION) In a sense, the creatures down here are like aliens...

ALAN ALDA Look at this guy.

ALAN ALDA (NARRATION) ...adapted to an environment quite unlike the one the rest of us who live on earth inhabit. This creature is called a siphonophore.

BRUCE ROBISON This is the propulsive end. There are two swimming bells, one on either side, that allow the animals to pull itself through the water.

ALAN ALDA (NARRATION) In fact, the siphonophore may not be a single animal at all but an assembly of many. Until it was seen here in its habitat, no-one knew much about it.

ALAN ALDA You couldn't have ever brought this up in a net, could you?

BRUCE ROBISON No. We would have had only bits and pieces. We wouldn't have known how many siphonophores were there, whether there was 1 or 100. These animals get to be extraordinarily large. We have measured them up to 120 feet long. That is a very big surprise.

ALAN ALDA (NARRATION) And it makes it one of the longest creatures on earth. Capturing siphonophores and the deep's other gelatinous creatures in one piece is a job for one of Ventana's specialized collection devices.

ALAN ALDA You gonna put him up the vacuum cleaner there?

BRUCE ROBISON That's right. We're gonna draw this siphonophore into the suction sampler. So that we can look at it's stomach contents.

ALAN ALDA You can get a big guy like that into one of your containers?

BRUCE ROBISON Sure.

ALAN ALDA And it wont break?

BRUCE ROBISON It will be, what's the polite term, "wadded up".

ALAN ALDA Ha, Ha. This is why I don't believe in flying saucers coming down and taking samples of humanity. I don't want to be "wadded up" by one of those things.

ALAN ALDA (NARRATION) The siphonophore is gently sucked aboard in one piece - accompanied by some of the dust-like particles that are everywhere down here.

ALAN ALDA What's all this snow-like stuff we are seeing around the animals?

BRUCE ROBISON You called it by the right name. We refer to it as marine snow. It's sort of all of the junk and detritus and dust of the upper layer of the ocean.

ALAN ALDA So, that's stuff falling off of animals up above. And it passes through this region and continues on it's way all the way down to the bottom?

BRUCE ROBISON That's right.

ALAN ALDA And animals are feeding on it all the time?

BRUCE ROBISON Yes, certainly bacteria feed on it while it descends. But there are other animals, filter feeders, that occur in mid-water, and they process these particles. But eventually, they all reach the sea floor.

ALAN ALDA (NARRATION) Since Bruce Robison and his colleagues began their deep water explorations, they've identified dozens of new species. Creatures down here range from the gruesome fangtooth... to the angelic-looking ribbonfish. Some 2100 feet down, the Ventana passes through a layer where oxygen levels are very low. Among the creatures adapted to hanging out here is the splendidly named Vampyroteuthis infernalis, a distant cousin to octopus and squid. It glares at us balefully through a huge blue eye.

BRUCE ROBISON Oh boy, time out. This is a paralepidid. A very, very beautiful little fish that we don't see all that often. It's nose is up, it's keeping itself almost vertically in the water column. It's looking up trying to see it's prey silhouetted against the surface. Very soon, it's going to take off and it will be gone just like it vaporized. There he goes. He's history.

ALAN ALDA (NARRATION) To evade shadow stalkers like the Paralepidid, potential prey are often transparent... Or, like this little fish, they generate their own internal light. When viewed from below, this makes them less visible against the lighter surface. Bioluminescence is used a lot down here. The otherwise-black angler fish has a luminous beard to attract prey. But why so many animals glow in the dark is still a mystery.

BRUCE ROBISON This is a red-bellied tomachtarid. It's a type of polechite worm that lives down here. This animal has bioluminescent organs at the ends of all it's legs.

ALAN ALDA What a great shot that is.

BRUCE ROBISON It's like having glowing toes.

ALAN ALDA (NARRATION) There are so many questions down here. This catcher's mitt shaped creature seams to propel itself along with shimmering hairs along its edge, but otherwise is utterly mysterious.

ALAN ALDA How does this animal reproduce?

BRUCE ROBISON Good question, I don't know.

ALAN ALDA Ha, Ha. Well, you know what's wonderful is how much there is to learn down here.

BRUCE ROBISON Oh sure.

ALAN ALDA It's a whole other universe.

BRUCE ROBISON That's part of what makes it so exciting. Each dive can, and often does, bring us something new, something unexpected.

ALAN ALDA (NARRATION) Unfortunately, my own curiosity had begun to lose its battle for attention with my stomach.

ALAN ALDA I think I have to go up and get some air.

BRUCE ROBISON Okay.

ALAN ALDA It's not that this isn't fascinating. But I think staying in one piece will be more fascinating.

BRUCE ROBISON Certainly more enjoyable.

ALAN ALDA (NARRATION) Up in the light and air, it's hard to believe that just beneath us lies the earth's strange final frontier. Pioneers like Bruce Robison will be exploring its mysteries for many years to come.

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HIGH ANXIETY

ALAN ALDA (NARRATION) The Alps. Beautiful. Enticing. And all too often, deadly. Hardly able to move, this climber is a victim of mountain sickness. Here at 15,000 feet, thin air is starving her body of oxygen. She could become one of the one-in-ten climbers who get so sick their lives are in danger. It's an all too common sight for the mountain guides.

SWISS GUIDE It's mostly from the high altitude, why they get very tired. Sometimes they vomit in the snow. They walk like drunken people. But mostly they don't like any help, but they don't like to go down also. Strange. It's difficult to say why they don't go back.

ALAN ALDA (NARRATION) Like most new climbers, she probably had no reason to suppose that she'd be especially vulnerable to the altitude. Which is why

there's a research program at the University of Heidelberg in Germany to try to predict who's most susceptible to mountain sickness. This young man, named

ARNDT, is one of a group of volunteers willing to push their bodies to the limit to help find a test that will tell people before they climb if they're likely to get sick. Arndt's testing begins by finding out how fit he is. As he works harder, his body responds by increasing his heart rate, pumping more blood to his muscles and so supplying them with more oxygen to burn.

SYNC (Yelling in German)

ALAN ALDA (NARRATION) To get that extra oxygen into his blood, he breathes faster and more deeply. Now the real test begins. Arndt's oxygen is cut back, simulating high altitude. The idea is to see how he responds when there is less oxygen available. Again his heart rate increases - and again his breathing gets faster and deeper. At the equivalent of 15,000 feet, Arndt is breathing five times more air than usual, even at rest. This is Michael, another of the volunteers for the test. On the fitness test, he's as good as Arndt. But when Michael's oxygen is reduced, there's a curious difference. At a simulated 15,000 feet, Michael's breathing is little different from what it was at normal altitude. Even during moderate exercise, his body - unlike Arndt's - seems to be ignoring the fact that his oxygen supply is dropping. The Heidelberg researchers wondered if people like Michael, whose bodies don't seem to recognize they're getting into trouble when oxygen is scarce, might be the ones most susceptible to mountain sickness. There was one way to find out - and perched at 15,000 feet on the Italian-Swiss border is the perfect laboratory - a 100-year old mountain hut, the highest building in Europe. Peter Bartsch, the leader of the Heidelberg team, is heading there now. He's taking it slowly, giving his body time to acclimate. But the subjects in his experiment don't have that luxury. They climb fast, rising two miles in elevation in just over a day. The experiment is designed so that neither Bartsch nor his subjects know how they performed in their tests. So Arndt, for instance, doesn't know his test suggested he'd cope with the mountain air by breathing much harder.

ARNDT I feel good, very good. Good air.

ALAN ALDA (NARRATION) Michael, who didn't breathe harder in the test, is finding the going rough. As the test predicted, his body just isn't getting the message that the air up here is thinner. But then there's a third subject, Udo, who like Arndt breathed harder in the lab - but may be having the first hint of a problem. UDO I've just a little bit of a headache, very little bit. Except for this I'm feeling really good, and I'm lucky to do this now.

ALAN ALDA (NARRATION) We are going to see what happens to Arndt, Michael and Udo once they reach Peter Bartsch's mountain top laboratory. Night falls - the most dangerous time for those vulnerable to mountain sickness. During the shallow breathing of sleep, blood oxygen levels can drop steeply. Six hours after arriving, Arndt - whose test suggested he'd do well at high altitude - is absorbed in a murder mystery. But Udo, whose test results also suggested he'd cope by breathing harder, is in trouble. UDO And when I came up I was feeling quite good. But then it was developing a big headache. And it was a stomach ache and wasn't good. I had to vomit.

ALAN ALDA (NARRATION) All he wants to do now is rest. UDO My body is exhausted and I have to sleep. So I hope that I will have a good night.

ALAN ALDA (NARRATION) Knowing the dangers of the night, Bartsch makes regular checks. At 5:30 am, the only one complaining is Udo.

DR. PETER BARTSCH Udo has a lot of problems. He was vomiting once at night and he had headache. I gave him some drugs. His symptoms went away. He didn't feel nauseated anymore but he couldn't sleep.

ALAN ALDA (NARRATION) Neither Udo nor Bartsch knows that his test predicted his breathing should adjust to the altitude. But if it has adjusted, it hasn't been enough to prevent his worsening symptoms. Arndt, meanwhile, as predicted, is still doing fine. His balance is good, his blood oxygen normal.

ARNDT Now I feel me good. Only muda, in German, tired.

DR. PETER BARTSCH He would love to climb the Dufourspitze or any other mountain here. I actually think he's enjoying himself here, that's my impression.

ALAN ALDA (NARRATION) Which leaves Michael - who is definitely not enjoying himself. His pre-climb test suggested he wouldn't adjust his breathing to high altitude - and he is now very sick.

DR. PETER BARTSCH The problem with him was he didn't call us last night. When he went to bed he already realized that something was wrong and no one called us. And when I saw him this morning he was really in a severe condition. I think if we had caught him earlier we could have stopped the process at an early level.

ALAN ALDA (NARRATION) Michael's decision to tough out the night could have been a fatal error.

MICHAEL I didn't quite notice that I was getting worse and worse. So just this morning at half past five they wake me up and I couldn't do anything. I couldn't breath and I couldn't stand on my feet. It was an extremely bad feeling.

ALAN ALDA (NARRATION) X-rays show Michael has advanced pulmonary edema. The lace-like pattern in his lungs, especially the right, means they are filling with fluid.

DR. PETER BARTSCH This means that we have a very severe illness. If we do not treat Michael he's most likely going to die. Fluid will accumulate in all his lung and he will eventually drown. And we have to immediately install treatment by giving oxygen now and fly him down as soon as possible.

ALAN ALDA (NARRATION) The oxygen will stabilize Michael's condition for a while - but the only way to clear the fluid from his lungs is to get him off the mountain - fast. A rescue helicopter is called in from Zermatt, Switzerland. Once he gets to a lower altitude, Michael will be fine. It turned out that Peter Bartsch's pre-climb test correctly predicted his sickness and Ardnt's health, but missed Udo's vulnerability. So the mystery of mountain sickness isn't solved yet. Meanwhile, Michael's experience dramatically demonstrated why being able to predict the effect of extreme altitude could potentially save so many climbers' lives.

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