"SCIENCE ITALIAN STYLE -- SPECIAL FROM ITALY
SHOW 503

EPISODE OPEN

ALAN ALDA The Leaning Tower of Pisa has been leaning a little bit more every year for 800 years. But last year it lost some of its lean. We'll find out how...

ALAN ALDA (NARRATION) We'll also meet Loretta - a bear cub with a mission. We'll visit Pompeii - destroyed by Vesuvius - ready to erupt again. We'll meet a very smart octopus.

ALAN ALDA Oh look, he got in , he got it open...

ALAN ALDA (NARRATION) I'll perform long distance surgery - and learn how to build a cathedral.

ALAN ALDA I'm Alan Alda. Join me for a scientific tour of Italy on Scientific American Frontiers.

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LEANING TOWER OF PISA

ALAN ALDA There's a story that goes like this. Sometime in the late 1500s, Galileo Galilei left his house just down the street here in Pisa, and headed for the tower.

ALAN ALDA (NARRATION) He had a novel idea. And the leaning tower - yes, even then it was leaning- was just what he needed.

ALAN ALDA Four hundred years ago, the conventional wisdom about how the world works hadn't changed since the ancient Greeks. They said a heavy object falls faster than a lighter one. Galileo's novel idea was to actually drop two objects and see which one landed first. In other words, to do an experiment. He was also probably the first one to say, don't do this at home. Here goes.

ALAN ALDA (NARRATION) The difference in air resistance between the two balls means they don't quite land together. But for Galileo they were close enough to suggest that all objects fall at the same rate.

ALAN ALDA Now there are spoilsports who say Galileo never did drop the balls from this tower or any other tower. But the story has come to symbolize the birth of experimental science: ask a question, do an experiment, try to figure out why you saw what you saw. For 400 years now, experimental science has changed the world. And with any luck, it may help save the tower where it all began.

ALAN ALDA (NARRATION) One of the world's greatest tourist attractions, the tower has actually been closed to tourists since 1989. Its lean had become so alarming that a commission was appointed to save it. The Commission's man on the spot is Paolo Heiniger.

ALAN ALDA When did the tower start to lean?

PAOLO HEINIGER Well, actually it started to lean from the beginning, even during construction.

ALAN ALDA When did they start construction?

PAOLO HEINIGER They started construction in 1173, and the story of the construction is a funny one, in the sense that it did not proceed regularly from the beginning.

ALAN ALDA What, they built it for a while and then stopped?

PAOLO HEINIGER Yes, the first stage of the construction was performed from 1173 to 1178, and let's say the construction was stopped more for political reasons.

ALAN ALDA They had like a strike?

PAOLO HEINIGER I do not have precise information about it..

ALAN ALDA They didn't have airlines then so they had to strike the tower.

PAOLO HEINIGER Maybe it was a matter of money as well.

ALAN ALDA (NARRATION) When work stopped in 1178, the tower was about half built. A century passed before work began again and the main tower was completed. This was when the leaning began, as the tower's weight compressed the clay beneath it more on the south side than north. Another century passed before the bell chamber was added. With the tilt now two degrees, the bell chamber was set at an angle to compensate. Since then the tower has continued tilting, and today the top is 15 feet. out of the vertical. To stop things getting worse, 600 tons of lead ingots were recently put on the north side to squash it down a little. It's ugly - but it's working.

ALAN ALDA Have you actually brought it back?

PAOLO HEINIGER Yes. The tower was, let's say... this 600 ton weight has caused the horizontal movement of the top of the tower of about 20mm, almost an inch.

ALAN ALDA Almost an inch...

PAOLO HEINIGER At the top.

ALAN ALDA Now, it's leaning that way maybe 15, 16 feet and you've brought it back an inch?

PAOLO HEINIGER Yes, correct, it is a very small..

ALAN ALDA If I was standing at the top, I don't know if I'd notice that!

ALAN ALDA (NARRATION) At the bottom, the 10 degree tilt makes just entering the tower alarming.

ALAN ALDA It's already tilting this way, I'm already falling over. This is amazing. I mean your tendency is to want to follow the building. What's all this in here?

PAOLO HEINIGER Here you can see some of the instrumentation....

ALAN ALDA (NARRATION) The tower is bristling with scientific instruments to measure even the tiniest movement.

ALAN ALDA There's something that goes up that tube? What is that?

PAOLO HEINIGER Correct, that is a pendulum..

ALAN ALDA (NARRATION) The pendulum is the instrument that really counts, because this is what measures the tower's tilt. Hanging from a beam near the top of the tower, it's hidden in what looks like a plastic drainpipe.

ALAN ALDA What's this thing over here on this wall, this box on the wall?

PAOLO HEINIGER These are strain gauges....

ALAN ALDA (NARRATION) The strain gauges sense stress in the walls.

ALAN ALDA Sorry, I didn't mean to lean on the wall. Pardon me.

PAOLO HEINIGER This is the dangerous side.

ALAN ALDA I know, I know..

ALAN ALDA (NARRATION) This strain gauge is measuring a several hundred year old crack. It's on the southern wall - the one stressed most by the lean - and also the side most affected by the seasons. In summer, the sun's warmth expands the stones on the south, pushing the whole tower a little slightly more upright. So it's the winters that are dangerous.

PAOLO HEINIGER When it freezes, when it freezes, it means that the tower kind of freezing, the stones there on the southern side - which is the dangerous side - decrease in volume, so it tilts even more.

ALAN ALDA It tilts more. So what's a good day to go up?

PAOLO HEINIGER Uh, 15th July, mid-day.

ALAN ALDA Today's a good day? Are you sure? How would I know today's good day? Do you have an instrument in here that will me tell me today's ...

PAOLO HEINIGER You must trust me. We go up and then we see what happens.

ALAN ALDA (NARRATION) What could happen almost at any moment is that the tower literally explodes. Stress at the level of the first balcony threatens to burst the stones outwards, collapsing the entire tower in seconds

ALAN ALDA O.K, I'm set. Andiamo.

PAOLO HEINIGER Andiamo.

ALAN ALDA (NARRATION) Of course, it was to the likely explosion point that Paolo wanted to take me. Adding to the excitement, the balcony has no railing.

ALAN ALDA I'd like to hook on now. Pardon me, where do we hook on - here?

PAOLO HEINIGER Yes, here to this rope here.

ALAN ALDA Like that?

PAOLO HEINIGER Now we can walk safely this way...

ALAN ALDA (NARRATION) These steel bands wrapped right around the tower - five pairs of them in all - are another temporary fix, meant to hold the stones in like a corset.

PAOLO HEINIGER They are embracing actually the external wall of the structure, and they are meant to contain the risk of local explosion of material.

ALAN ALDA That's nice. So glad to hear that. Embracing the structure so it doesn't explode.

PAOLO HEINIGER Yes.

ALAN ALDA (NARRATION) Of course the source of the tower's problems isn't up here, its underneath it, where the south side has sunk more then the north. So experiments are underway to find a way to sink the north side more to even things up. One idea being tested is to drill out some of the sand from under the tower. Another idea involves giant electrodes. In clay, water molecules have a small positive charge, so would be sucked out, allowing the clay to compress. Either plan would also employ anchors sunk deep beneath the tower, tugging down on the northern side. But whatever plan is employed, it won't take out so much lean that it's no longer the Leaning Tower.

ALAN ALDA The tower will never be straight up and down.

PAOLO HEINIGER No, it cannot be straight up and down.

ALAN ALDA Is that because you can't do it, or it won't be such a good tourist attraction?

PAOLO HEINIGER Basically, it is because it had been built like a big banana...

ALAN ALDA Right, I noticed that.

PAOLO HEINIGER So, if you try to bring it up to a vertical position, it would probably fall over..

ALAN ALDA The other way!

ALAN ALDA (NARRATION) In fact, the goal is to tilt the top of the tower back no more than about 3 of the 15 feet it's leaning now. That way the Leaning Tower should be able to lean safely for perhaps another 800 years.

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ALL IN THE FAMILY

ALAN ALDA (NARRATION) From Pisa, we headed south and east, into the rural backbone of Italy -- the Abruzzo. Snuggled into the wilderness of the Apennine mountains are little country towns and villages where I felt right at home.

ALAN ALDA (ON-CAMERA) My ancestors came from this region. In fact, the name I was born with is Alfonso D'Abruzzo, which means Alfonse from Abruzzo. They probably came from a little village just like this. Around the turn of the century many thousands of people left the Abruzzo region to go to America for the prosperity that was there. And since then a lot of modern roads have been built linking Abruzzo with the rest of Italy, bringing prosperity here, but in the process threatening the existence of some of the region's oldest inhabitants.

ALAN ALDA (NARRATION) This is Loretta, a very rare and very hungry brown bear cub.

ALAN ALDA Loretta, va bene Loretta.

ALAN ALDA (NARRATION) It was a surprise to me that Italy even has any native bears - and in fact the Abruzzo National Park is one of the last refuges of bears in the whole of Europe. Lorretta herself was found abandoned.

ALAN ALDA Why would the mother abandon a little cub like this?

FRANCO TASSI I think that in some years it's not possible that every mother bear may feed with success two or three bears. In this case she had two and the strongest was okay but this one needed help. In nature without our intervention she was lost.

FRANCO TASSI Ahhh, how good.

ALAN ALDA (NARRATION) Park director Franco Tassi's goal is to bring the bear back from near certain extinction.

ALAN ALDA Keep it on the stick, kid. As you get more and more of these bears out in the mountains what's the reaction of the people living around here? Are the bears a danger to the people coming into town and that kind of thing.

FRANCO TASSI No, they are very shy. They are very peaceful.

ALAN ALDA She sounded kind of aggressive when she came over.

FRANCO TASSI Yes, but she's a wild animal. She doesn't like to have people. She does like honey but not people. And that's the reason she survives.

ALAN ALDA (NARRATION) Lorretta's ancestors roamed all of Europe. But thousands of years of climate change and persecution by man has driven them into a few isolated pockets. One big question is just how many are left - a question the bear's very sensible shyness makes it hard to answer. In the Abruzzo, remote video cameras keep a discreet eye on the bears' favorite haunts, allowing researchers back at park headquarters to conduct a bear census. The count continues even during the night - and reveals a total population of only 80 animals - a number that puts them on the edge of a genetic precipice.

GIORGIO BOSCAGLI Having a population lower than 70 or 80 bears means that the genetic heritage/health of these animals is extremely reduced. And if you go below that number the probability of building or even retaining a healthy population in the future is very slim.

ALAN ALDA (NARRATION) The problem is in-breeding - and one obvious way to solve it is to bring in some bears from one of the other remaining European populations. But that poses its own dilemma - which is why Giorgio Boscagli is setting this snare. The alarm will bring researchers within minutes, day or night. After a month of waiting.... The bear is unharmed but angry. It's tranquilized, then a blood sample taken. A DNA fingerprint made from the blood reveals the dilemma the researchers are in. The Abruzzo bear has become genetically distinct from its European cousins. Long isolated from them, it has evolved into a unique subspecies. To breed it with other bears would destroy its uniqueness.

GIORGIO BOSCAGLI The Abruzzo brown bear has an evolutionary story completely different than other European bears. And to lose that genetic purity, that specialness would be a huge loss.

ALAN ALDA (NARRATION) So the Abruzzo bears will have to make it on their own. Which is where little Loretta comes in.

ALAN ALDA What will be her future?

FRANCO TASSI I suppose that it will be very difficult to leave her in the wild again because she needs the education from the mother. But we can use this bear to build up a breeding pair to have more Abruzzo brown bears in the future, like a genetic bank.

ALAN ALDA (NARRATION) And here's her future mate, Sandrino, an adult male injured by poachers and brought here to the park. The hope is that in a few years these two will start parenting a new generation. Today, Sandrino is due for a pre-marital blood test, to see if he and Loretta are too closely related.. But first, he must be tranquilized.

ALAN ALDA He looks like he's getting a little drowsy now, a little sleepy. There he goes, there he goes.

ALAN ALDA (NARRATION) As with the wild bear, a DNA fingerprint will be run from Sandrino's blood.

ALAN ALDA Where's he taking the blood from?

GIORGIO BOSCAGLI The jugular.

ALAN ALDA After he gives all that blood do you give him a cup of coffee and a doughnut?

GIORGIO BOSCAGLI He prefers a big steak and not coffee. Luckily, Sandrino and Lorretta turn out to be a good match - at least genetically. While all the Abruzzo bears are related, at least these two are distant cousins. And the hope is that someday their offspring will help boost the wild Abruzzo population. Loretta, meanwhile, seemed to be getting bored with honey.

ALAN ALDA Now she wants to eat something else and that's starting to bother me. What do you like? You don't like hamburger or anything? Does she eat actors?

FRANCO TASSI Hmmm?

ALAN ALDA Mange actori?

FRANCO TASSI Mange actori?

ALAN ALDA Yeah.

FRANCO TASSI A mangato.

ALAN ALDA Oh, oh yeah? She ate one already! Oh good.

ALAN ALDA (NARRATION) Right next door to the bears is a pen of Abruzzo chamoix - rare alpine goats. They offer both encouragement and a warning to the effort to save the bears.

ALAN ALDA How many these chamoix do you have now?

FRANCO TASSI Now in the Abruzzo National Park we have more than 600 Abruzzo chamois. But when the park was created in 1922 there were only 30 left.

ALAN ALDA So you went from 30 to 600 in those years.

FRANCO TASSI Yes, this was a big success. And we plan to reintroduce the chamois in other big Abruzzo mountains.

ALAN ALDA (NARRATION) There may be 600 chamoix here in the park, but they have a potentially fatal weakness - which this expedition of wildlife biologists is now hoping to fix. The weakness is exactly the one worrying those trying to bring back the Abruzzo bears - all 600 animals are dangerously inbred.

FRANCO MAURI The problem with this population is it's the last population of this kind of chamois and for a long time there was a small number of animals. So all the animals are like brother and sister, so the genetic variability is very low.

ALAN ALDA (NARRATION) The big risk when all the animals are close relatives is that a disease could wipe them all out. This chamois round-up aims to reduce this risk by taking some of the herd to new homes. But the round-up itself isn't without risk. Tranquilized chamoix overheat from the stress. Ice packs keep them cool for a while, but now they must be gotten to their new homes as quickly as possible. This trip is to a newly established national park, 50 miles away. Here they'll be isolated from the original herd, so a disease can't sweep through the whole population. One animal - an older female - is overheating, and the veterinarians are growing anxious for her safety. A shot of adrenaline wakes up the first animal, who's wearing a radio collar so she can be tracked in her new home. But the older female is in trouble. She wakes up, but doesn't have the strength to run.

LEONARDO (IN ITALIAN) She's very stressed. The whole process has stressed her system. Her reaction is panic and an inability to run.

ALAN ALDA (NARRATION) They try helping her to her feet - to no avail. It's a heartbreaking loss for the biologists, whose attempt to ensure the species' survival has cost this chamois her life. But she's only the third animal to be lost out of 150 airlifted in the last four years... and the other chamoix on this trip are all fine. Safe here on an Abruzzi mountain that hasn't seen a chamois in living memory, these animals will, with luck, establish a new herd that will call this mountain home. From the wilds of the Abruzzo, we traveled to the eternal city, Rome. Much less well known than its monuments and statues are Italy's contributions to medicine. It was in Italy that the science of anatomy began in the 1500s - opening the way, eventually, to surgery.

LONG DISTANCE DOC

ALAN ALDA This is the Policlinico Umberto Primo, where they've been performing and teaching surgery for almost a century now. But up there on the top floor they're pioneering a new form of surgery which may take us into the next century. This is how you normally see doctors washing up before an operation. But today Dr. Angelini and I don't have to be too careful about how clean we are because we're very unlikely to infect the patient, who is about 360 miles, away in Milan.

ALAN ALDA (NARRATION) And there's another reason we didn't have to scrub too carefully. Our patient in Milan is an assembly of plastic parts - which, as it turned out, was just as well. The liver is the organ we were to operate on. The cyst we were after is a fluid-filled balloon, and the skin is latex. The Rome-Milan research team is one of several in the world working on long distance remote-control surgery - the idea being that one day surgeons could operate on battlefields or in space without leaving the office. In today's experiment, video of the operation is transmitted to Dr. Angelini's office in Rome.

LICINIO ANGELINI We start the system.

ALAN ALDA (NARRATION) At least, that was the plan. When the satellite link went down, we were left with the phone line - and still images only.

ALAN ALDA Ahhh, buon giorno!

LICINIO ANGELINI Ah, Professor Rovetta.

PROFESSOR ROVETTA Good morning, how are you?

LICINIO ANGELINI Now we see you. Are you ready to start the procedure for the biopsy?

PROFESSOR ROVETTA Start now, okay.

LICINIO ANGELINI I have selected the first spot for the incision. I am confirming now.

ALAN ALDA How do you know where you want to put the first incision?

LICINIO ANGELINI Because that's my job.

ALAN ALDA But I mean all you see if this square of skin.

LICINIO ANGELINI Yes but we know how the field is selected. So this would be the ribs and I know that the first cut should be there.

ALAN ALDA Okay.

ALAN ALDA (NARRATION) At the click of the mouse, the robot arm plunges the scalpel into the selected spot.

LICINIO ANGELINI I ask Dr. Alda to make the cut.

ALBERTO ROVETTA Wonderful. He becomes a surgeon today.

ALAN ALDA (NARRATION) You'll understand, I was having a little trouble taking this seriously.

ALAN ALDA This will only hurt for a second. I cut.

ALBERTO ROVETTA Once more please.

ALAN ALDA There. I cut again.

ALBERTO ROVETTA Yes. That's enough now. The cut is very long.

ALAN ALDA Well, let's delete some of those cuts.

ALAN ALDA (NARRATION) The scalpel is switched for the biopsy needle. By this time, the patient is already a little the worse for wear. So that we surgeons in Rome can find the cyst, the Milan team employs an ultrasound probe.

LICINIO ANGELINI Can we get the image of the cyst from the ultrasound screen?

PHONE VOICE Yes, in a few seconds.

LICINIO ANGELINI Great.

ALAN ALDA Oh, okay, this is an ultrasound.

ALAN ALDA (NARRATION) The image shows us inside the body.

LICINIO ANGELINI You see, this is the cyst. This black hole is the cyst in the liver. This is all liver.

ALAN ALDA So if you're operating remotely like this and you're looking at what you're doing on this ultrasound picture. Is that more accurate than if you were there in the room or less accurate?

LICINIO ANGELINI At least as accurate as by hand but probably more accurate, because there is no way to make a mistake. You can calculate exactly the depth where you want that the needle. And that will be inside this black area which is the cyst. We can be sure that the needle goes there.

ALAN ALDA (NARRATION) But Dr. Angelini's optimism proved a bit premature. The needle goes in to the selected depth ...

LICINIO ANGELINI And now we pump.

ALAN ALDA (NARRATION) ... but when he tries to pump the fluid out, nothing happens.

DOCTOR IN MILAN The position is not correct. You were in the right position but then the needle moved. So you should repeat once again the puncture.

ALAN ALDA (NARRATION) The patient has to endure a second puncture. But still, no fluid.

LICINIO ANGELINI I pushed the pump again. Is it sucking?

ALAN ALDA (NARRATION) Now here's an intervention you couldn't do in real life -- open the abdomen and reposition the cyst. Finally, on the third try, Dr. Angelini hits the cyst, and pumps out the fluid. Mercifully, the operation is over. Now, I should point out that in other tests - including a satellite link up between California and Milan - the operation went much more smoothly. This clearly

wasn't Dr. Angelini and Dr. Rovetta's day - or, if it comes to that, Dr. Alda's either..

ALAN ALDA How did we do today with this patient. Did this patient survive? Is the patient happy?

ALBERTO ROVETTA Everything is okay, because the cuts can be repeated. And I think the patient will be very happy for his health.

ALAN ALDA (NARRATION) Tele-robotic surgery is clearly an idea whose time will come - one day.

LICINIO ANGELINI Frankly speaking, if I were the patient today, I wouldn't be very happy.

ALAN ALDA Thank goodness he's a dummy.

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SPINELESS BUT SMART

ALAN ALDA (NARRATION) Early morning in Pozzouli, on the Bay of Naples - and the fish market is open for business. I'm here with biologist Graziano Fiorito. He comes to market not to buy his dinner but to find subjects for his lab.

ALAN ALDA What about these guys?

GRAZIANO FIORITO These are good enough.

ALAN ALDA (NARRATION) This is the animal Fiorito works with -- the octopus, one of the least-loved creatures of the sea. At first it's hard to figure out just how the octopus is put together.

ALAN ALDA Where are his eyes?

GRAZIANO FIORITO The head is this. This is eyes.

ALAN ALDA And what's this? It looks like a big nose.

GRAZIANO FIORITO This is the abdomen of the animal.

ALAN ALDA Oh, the abdomen. It's not his nose. And where's his mouth?

GRAZIANO FIORITO The mouth is underneath.

ALAN ALDA In the middle of his hands.

GRAZIANO FIORITO Yes, here, you see it.

ALAN ALDA (NARRATION) Graziano Fiorito takes his subjects back to the zoological station in Naples, Europe's oldest marine biology laboratory. As an invertebrate, the octopus may be spineless but it is a skilled hunter. Lurking behind a rock, this one is stalking a hermit crab. Octopuses live alone, so it's thought that their hunting skills are partly pre-programmed in their genes and partly self-taught from experience. The idea that a creature as lowly as an octopus might also learn as we do, by watching others, would be heresy to most scientists. But that's just what Fiorito believes he's seen. Here's the challenge he sets for the octopuses he buys from the market - a glass jar containing a crab, and sealed tightly with a plug. Some octopuses, perhaps because they've opened a lot of shells for their dinner, open the jar on their first try. Others, like this one, can be given the jar time and time again without getting inside. I joined Fiorito for the key experiment. The octopus on the right is the one that can open the jar. The one on the left can't.

ALAN ALDA You already gave him a jar and he couldn't do it?

GRAZIANO FIORITO No. Half the population of animals that come from the sea are able to do it and the other half they are unable to do it. So it depends let's say from the individual's experience. There are some octopus that are more skilled than other ones.

ALAN ALDA (NARRATION) The unskilled animal will be given a chance to watch how it's done.

ALAN ALDA So now the octopus over here in this tank is going to watch this one open the jar.

GRAZIANO FIORITO That's right.

ALAN ALDA (NARRATION) Even knowing how to do it didn't help me.

ALAN ALDA I need suction cups on my fingers here. I can't do it.

ALAN ALDA Does he see it yet do you think?

GRAZIANO FIORITO Yes.

ALAN ALDA (NARRATION) The skilled octopus sees the crab immediately and moves in. The unskilled octopus seems to be watching intently, as the skilled one explores the jar.

GRAZIANO FIORITO It's crawling now on the jar and it recognizes the plug. Now its behavior is changed - now it's carrying it right back home to be more safe from the other animal.

ALAN ALDA He doesn't want the other animal to interfere?

GRAZIANO FIORITO That's right.

ALAN ALDA (NARRATION) The performer pulls the plug and the crab is his. Meanwhile, the observer octopus is scrambling for the best view.

ALAN ALDA Do you think that this animal from observing that this time may know how to do it?

GRAZIANO FIORITO We can try.

ALAN ALDA Great, can we see?

ALAN ALDA (NARRATION) Now remember, this animal has never before been able to open the jar. What's new is that he's observed the solution.

ALAN ALDA Oh here he goes, here he goes. Look, look, look, look. Oh wow, look at him. Just went right at it.

ALAN ALDA Look, he got in, he got it open. And he was never able to do that before?

GRAZIANO FIORITO No.

ALAN ALDA This is unbelievable.

ALAN ALDA (NARRATION) What Graziano Fiorito's has shown for the first time is that an invertebrate can learn by observing. Social learning like this is a domain of intellect usually reserved for mammals like us. But as I learned in the fish market, you have to you know how to handle an octopus if you want it to show you its secrets.

ALAN ALDA Why do you need to be relaxed with an octopus?

GRAZIANO FIORITO If you would like to study behavior of animals the animal must be sure that you would never kill him. There is such a kind of, let's say, good relationship between you and the animal, a good feeling.

ALAN ALDA You have to have a sure touch, huh? Well I don't have it. I think these animals can sense it.

GRAZIANO FIORITO Yes, they are sensitive.

ALAN ALDA What's the best way to pick them up?

GRAZIANO FIORITO Here ...

ALAN ALDA Oh, ho. Ohhh. How do you get used to this? You like that?

GRAZIANO FIORITO Yeah.

ALAN ALDA It's a little like a hand full of worms.

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ERUPTION!

ALAN ALDA (NARRATION) Looming over the Bay of Naples is Mount Vesuvius, a volcano that caused one of history's most famous disasters. Nearly two thousand years ago, the Roman city of Pompeii was destroyed when Vesuvius erupted. The city and two thousand people disappeared under a wave of volcanic rock and hot poisonous gas. Seventeen centuries went by before Pompeii was re-discovered ... under twenty feet of ash and rock -- a city frozen in time. Today, the site is a popular spot for tourists. Among the sights - the world's oldest "Beware of Dog" sign.

ALAN ALDA How old was Pompeii before ...

GIUSEPPE LANZIANO More or less 700 years.

ALAN ALDA Before it got destroyed?

ALAN ALDA (NARRATION) My guide to this Italian ghost town was Giuseppe Lanziano.

ALAN ALDA What are these?

GIUSEPPE LANZIANO Okay. You have here the special tracks of the chariots left here by the wheels, very deep in some places.

ALAN ALDA They'd come through here and make these marks through the stone?

GIUSEPPE LANZIANO Yes, through the stone.

ALAN ALDA So I can see that 700 years of chariots would make those marks.

ALAN ALDA (NARRATION) Archaeologists just uncovered this tragic scene -- victims caught inside their house. Suffocated by gas and ash, they were cast in volcanic rock where they fell.

GIUSEPPE LANZIANO Here we can see the family, complete family. Piece of wood.

ALAN ALDA That wood came down from the roof?

GIUSEPPE LANZIANO Fell down from the roof. And a pregnant woman, six months pregnant here, the lady. Husband here.

ALAN ALDA It looks like he's trying to shield her.

ALAN ALDA (NARRATION) This family was obviously taken completely by surprise - even though they knew they lived next to a volcano.

ALAN ALDA They knew it could go ...

GIUSEPPE LANZIANO Could go, yes.

ALAN ALDA And yet they carried on their normal lives. They lived right here at the base of the mountain. Where do you live?

GIUSEPPE LANZIANO Actually now in New Pompeii.

ALAN ALDA Where's that?

GIUSEPPE LANZIANO Just there, half a mile far from here. But we are not afraid.

ALAN ALDA (NARRATION) Giuseppe's confidence - and that of other Neapolitans - lies in the belief that there will be plenty of warning before another eruption. The person whose responsibility that warning would be is Lucia Civetta,

who directs a team that continuously monitors the volcano. She was willing to sit beside the crater, so... PROFESSOR CIVETTA This is the crater of the last eruption of Vesuvius, the 1944 eruption of Vesuvius. This crater was formed during that eruption. Before 1944 you can walk from this side to the other side.

ALAN ALDA So what happened to all the stuff that was there, between here and there, that went up? PROFESSOR CIVETTA Ya, ya.

ALAN ALDA That's what I thought.

ALAN ALDA (NARRATION) Vesuvius's eruptions have a pattern. The 1944 eruption counts as a small one, happening about once a century. Pompeii-sized eruptions happen every 2000 years or so - and Pompeii was destroyed just over 1900 years ago. Which means the stakes get higher every year for Lucia Civetta and her Vesuvius monitoring teams. Every week, researchers climb down into the crater to take the volcano's pulse. These steaming fumeroles are venting from deep within the volcano. The gases provide clues to what's brewing in the chamber of molten magma that sits three miles beneath the summit. Today's measurements are reassuring. Both the radon gas levels and temperature are stable. But while the volcano sleeps, the population on its flanks is exploding. Two million people now live within a few miles of Vesuvius. And if they believe the science of prediction will save them - they need look only 300 miles to the south. In Sicily, in December 1991, Mount Etna erupted. Scientists monitoring the volcano knew for months activity was building - but no-one predicted what would prove to be the real danger - an eruption a mile below the main crater on the mountain's flank. The unknown now was where this river of molten lava would lead. In an attempt to find out, scientists turned to a new predictive tool - computer simulation. On a three-dimensional computer model of Mt. Etna, researchers sited the vent and an estimate of how much lava was flowing. The model simulated the possible routes the lava could take. The most likely, shown in red, was channeled through a narrow pass right above the town of Zaffarena. If the eruption was a long one, the model predicted the town's total destruction. Taking the prediction seriously, officials hastily built an immense earth dam across the pass - a barrier 60 ft high and a half-mile long. Meanwhile, the lava crept down the mountain - following exactly the course the simulation had predicted. The barrier held back the lava for a month. Then in April 1992, it crested the barrier. But the prediction had brought time for the authorities to plan their next move. In an extraordinary effort, helicopters from the US Navy joined the battle in an attempt to directly plug the lava vent. But even American dumpsters couldn't stop the flow. In Zaffarena, nerves were fraying. With the lava now just half a mile from town, residents awaited orders to evacuate - and dug last ditch defenses. But then the computer simulation suggested a dramatic new strategy. The model suggested that high explosives could divert the flow into an artificial channel dug to the left of its original course. The strategy worked. The

lava emptied into an unpopulated valley. And the original lava flow stopped three hundred yards from Zaffarena. In Sicily, a computer model had helped save a town. Back on Vesuvius, I met up with Flavio Dobran, who hopes his computer simulation might prevent a modern-day Pompeii. Vesuvius isn't like Etna. A large scale eruption here would produce not slow moving lava but a 200 mile an hour avalanche of super-heated gas and rock.

ALAN ALDA 200 miles per hour? There's no hope of ever getting out of the way.

FLAVIO DOBRAN 200 miles an hour at a temperature of about 2000 degrees Fahrenheit. And to give you an idea it takes about five minutes for these flows to reach from here all the way down to the sea. Five minutes. In about three minutes you're already to the autostrada, which passes about seven kilometers down there.

ALAN ALDA And that's the way out.

FLAVIO DOBRAN No, that's not the way out. That's panic.

ALAN ALDA (NARRATION) When Flavio's results were published, they caused a political uproar in the area. Here was a detailed scientific model predicting a modern-day Pompeii in the making. The only evacuation route, the autostrada, will be wiped out in three minutes, trapping 700,000 people. Flavio Dobran believes the only practical strategy is to somehow block the path of the flow before the eruption occurs.

ALAN ALDA Now you would like to see barriers built?

FLAVIO DOBRAN Not necessarily barriers. A barrier can be just a part of a condominium.

ALAN ALDA So you could live in an apartment-dash-barrier.

FLAVIO DOBRAN That's right. One part of the building could just be a barrier, which you don't see. So you could build ... speaking freely ... you could build a set of houses down there, which one part looking toward the volcano is really a barrier.

ALAN ALDA Do you think that these people would get a little break on the rent?

FLAVIO DOBRAN Actually no, because the closer you come to here the more it would cost because you get a more beautiful view.

ALAN ALDA For a while anyway.

ALAN ALDA (NARRATION) To test this idea, Flavio built 90-ft high barriers in his computer model. The first is quickly over-run. But the second, 3 miles below the summit, shields the autostrada.

FLAVIO DOBRAN We ran the simulations up to 1000 seconds and the barrier was holding the flow.

ALAN ALDA So not only would many lives have been saved if that held true in reality, but the escape route would also have been preserved.

FLAVIO DOBRAN Well, you would save several hundred thousand people.

ALAN ALDA (NARRATION) So for those who choose to live with volcanoes, simulated eruptions may help them survive the real thing. Still, there are easier ways.

ALAN ALDA Can you point out to me where you live down there?

FLAVIO DOBRAN I don't live down there.

ALAN ALDA Where do you live?

FLAVIO DOBRAN Right now we are doing simulations in Pisa.

ALAN ALDA Ahhh, that sounds far enough away.

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WHERE'S THE MATTER?

ALAN ALDA (NARRATION) Between Rome and Italy's east coast the autostrada cuts through the mountainous spine of Italy - the Apennines. The highest peak is called the Gran Sasso.

ALAN ALDA Most people come to the mountains for the breathtaking views. But for some people the most breathtaking sights aren't on top of the mountain - they're underneath it. This tunnel runs for about five miles underneath the Gran Sasso mountain. There's supposed to be a turn off here somewhere....

ALAN ALDA (NARRATION) What we're looking for turned out to be one of the most amazing - and certainly most unexpected - of all the places we visited in Italy, a laboratory cut into the heart of the mountain.

ALAN ALDA Hello. Alan Alda, Scientific American Frontiers.

ALAN ALDA (NARRATION) It's hard to believe it from here, but the laboratory beyond these doors is trying to solve perhaps the biggest puzzle in the universe - where, and what, most of the universe is. The lab looks like the set for a science fiction movie. This giant yellow box, 40 ft high and almost a football field long, is actually one of the world's biggest scientific instruments. My guide to the lab is its scientific director, Doug Michael. What he's using the instrument to look for is the 90% of the universe no one can find.

DOUG MICHAEL .....We know that the galaxy needs more matter to clump it together. There's just not enough matter....

ALAN ALDA (NARRATION) The detector is trying to find what's literally lost in space.

ALAN ALDA Is this place that we're in, in a way a telescope?

DOUG MICHAEL Yeah. Only it's under a mountain. So it's really a telescope under a mountain.

ALAN ALDA (NARRATION) When we look into space with conventional telescopes the galaxies we see are unimaginably large clusters of stars. But the visible stuff in galaxies is only about 10% of what's needed to provide enough gravity to hold them together. Something out there is providing the cosmic glue - but what? One idea about what this invisible missing matter might be suggests that a lot of it is flying though us all the time. The earth is being constantly bombarded by invisible particles from outer space - cosmic rays. Most of them can't get through a lump of rock as big as the Gran Sasso. But a few do - and they're the ones that are candidates for what's missing in the universe. Down here they can be spotted because they create other particles called muons.

DOUG MICHAEL A muon is essentially a high energy moving-at-the-speed-of-light particle, and it just comes flying right through the detector right? There goes one right now - they come through every few seconds.

ALAN ALDA That's amazing, I missed it, it goes so fast.

DOUG MICHAEL It just came right through. Anyway our electronics are capable of recording that muon when it comes in, because we have detector planes..

ALAN ALDA (NARRATION) The detector has been put down here under 5000 ft of solid limestone precisely because the rock shields it from most cosmic rays -

allowing through only the ones that Doug Michael and his colleagues think are interesting.

DOUG MICHAEL It's sort of like if you had a flute playing in a thousand piece brass band or something like that. You would never hear the flute.

ALAN ALDA So in a way this is creating a quiet room.

DOUG MICHAEL It's a quiet environment that allows us to be able to see these really rare events.

ALAN ALDA (NARRATION) The rare event he'd most like to see is the track left by what has to be one of the strangest things I'd ever heard of - something called a magnetic monopole.

DOUG MICHAEL Any magnet we've ever built on earth always has two poles to it, a north pole and a south pole, OK? What a magnetic monopole would be is as if you could just separate out one of those poles from the other. You can try it with a magnet if you like - you can chop a magnet up into as many pieces as you like and you'll never succeed.

ALAN ALDA You'll always have a piece that has north on one side and south on the other. So how could you possibly have a monopole that's only north or south?

DOUG MICHAEL Ah. First of all, there's no reason that you can't have it . It's just-that we don't seem ever to have found such a thing.

ALAN ALDA (NARRATION) The reason for looking for magnetic monopolies is that they are prime candidates for being some of that missing matter in the universe. They may be so small as to be invisible except to an underground telescope like this - but they have one thing going for them if you're looking for missing mass.

DOUG MICHAEL They're so massive that they could have only been produced in the very earliest, earliest moments of the Big Bang.

ALAN ALDA So, they're not being produced now in stars or supernova or anything.

DOUG MICHAEL Absolutely, there's no process in the whole universe that could produce a magnetic monopole.

ALAN ALDA Only the big Bang was powerful enough. So from that time, that event, that Big Bang, they're still out there somewhere...here somewhere.

DOUG MICHAEL We think they have to be there. The problem is we have no idea of how many of them there have to be. There could be anywhere from millions of them floating around us all the time, to one in the whole universe!

ALAN ALDA (NARRATION) So far, in the year the detector's been looking, no monopoles have turned up - not surprising if there's only one in the universe! But the search continues. Because if magnetic monopoles exist, they could be the missing cosmic glue that sticks the whole universe together.

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RENAISSANCE MACHINES

ALAN ALDA This is the city of the Renaissance, Florence. Here, for 200 years starting in 1400, art and architecture were reborn. It all began right down there in the heart of the city, in the Piazza del Duomo.

ALAN ALDA (NARRATION) In the late 1300s, Florence was experiencing a building boom. A brand new cathedral was almost finished, and the old baptistery was being renovated. New doors for the baptistery were planned, and a competition to design them was won by a sculptor named Lorenzo Ghiberti. The striking perspective and realism of the bronze panels are often taken to mark the beginning of the Renaissance. The big loser in the door contest was Ghiberti's arch-rival, Filippo Brunelleschi.

ALAN ALDA Ghiberti may have beaten out Brunelleschi for the design of the Baptistery doors, but Brunelleschi managed to get his revenge - and in doing so he achieved the greatest feat of engineering of his age.

ALAN ALDA (NARRATION) The building of the cathedral was going well - except for one big problem. No-one could figure out how to build the immense dome that now dominates the Florence skyline. There the cathedral sat in 1418, work at a halt, domeless.

ALAN ALDA Brunelleschi and Ghiberti were jointly appointed master architects of the dome. But there was one big difference between them. Brunelleschi had a plan and Ghiberti didn't. Brunelleschi wanted the job all to himself, so he called in sick. He pretended to be ill which left the job to Ghiberti, who before long was completely lost. Then miraculously Brunelleschi recovered and returned to the job. Here's the problem he faced. The area that had to be covered by the dome was 180 feet wide and 180 feet high. In those days the way you made a dome was you filled the entire space with scaffolding. In fact they just restored the dome and that's how they did it. They're just removing the last of the scaffolding

now. But in Brunelleschi's time wood was extremely expensive. The city fathers couldn't afford all that scaffolding. Brunelleschi's plan didn't need it. Instead, he invented some unique machines, machines so secret that he made sure nobody ever saw the designs.

ALAN ALDA (NARRATION) Luckily, sketches of Brunelleschi's machines were made later by - of all people - the grandson of his losing rival. They reveal a grasp of mechanics usually associated with Leonardo da Vinci, who worked 50 years later. Brunelleschi invented hoists, cranes and machines to position the stones in the dome, as well as a unique design for the dome itself, consisting of an inner and outer shell. One of his cleverest machines was the huge hoist that hauled the stones 180 ft up to the masons working in the dome above. Recently, this machine has been given a new - electronic - life. A short walk across Florence from the cathedral is a museum most of the city's tourists overlook - the Museum of the History of Science. The museum is involved in an ambitious plan to recreate in the computer working models of Brunelleschi's machines. Here's the hoist. And in the computer reconstruction you can see what made it so clever - it's reversible.

ALAN ALDA Let me see. When it's up it goes in this direction. When it's down it goes in the other direction, like that. And the horse goes in one direction only.

ALAN ALDA (NARRATION) Without this reversible gear, the horse would have had to be unharnessed and turned around between loads. It was the first time anyone had built such a machine.

ALAN ALDA (ITALIAN) It was the first time.

MARCO BERNI (ITALIAN) That they had something like this, yes. Brunelleschi wasn't the only 15th century Italian designing machines - though most of them stayed on the drawing board. This human-powered pile driver by Francesco di Giorgio has also been now built in the computer, and is today driving piles for the first time. This water powered saw designed by an engineer named Taccola also seems to work just fine. Di Giorgio designed a water pump. He also went in for high- tech weapons, like this missile launcher. A mechanical ladder for scaling walls. Even a nasty device for stopping enemy ships. Machines like these - even if only imagined - were very much a part of the spirit of innovation that characterized the Renaissance. Thanks to Brunelleschi's machines, the citizens of Florence saw his magnificent dome slowly materialized between 1420 and 1470 - and Florence's crown jewel was complete.

ALAN ALDA (ITALIAN) That's all for this edition of Scientific American Frontiers. Goodbye - see you soon.

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