SHOW 201

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EPISODE OPEN

NARRATION A race beneath the sea is the ultimate test for submarine designers. Jump aboard for sub sea adventure on Scientific American Frontiers. Also...will a boy's courage help beat a killer disease? Can a computer cope with common sense? And how do endangered sea turtles find their way home? Don't go away - it's all next on Scientific American Frontiers.

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HUMAN-POWERED SUBMARINES

NARRATION Hi, and welcome to the second season of Scientific American FRONTIERS. I'm Woodie Flowers, your host for this series. In my day job I'm professor of mechanical engineering at MIT - that's why I have a special interest in the rather unusual craft these guys have built What's brought us from Boston, and these other folks from all over the country, to Florida's Riviera Beach? Not just the great weather and the waves. These teams are here to push the envelope of sub sea technology, with some 35 creative designs for human-powered submarines. The immediate challenge is an underwater race, but the long-term goal is new ways to explore the last frontier on Earth -- the ocean. Checking out new ideas in engineering, and having fun along the way, is just the kind of thing we do on FRONTIERS. So here we go -- let's find out who has got the style and the stamina to win this contest.

NARRATION Here's the local favorite, Florida Atlantic University, nicknamed FAU. Remember, this is a contest of submarines which run only on person power. Up front, one crew member navigates the course. The propeller is driven by the second crew member, a human engine who does the pedaling. The well-trained Florida Atlantic crew, their shark sub, and its conventional propeller drive set the contest standard. Across the country at California Poly Tech in San Luis

Obispo, the Submarine Club is struggling to create a whole different kind of propulsion system. Actually, though this concept has never been used in sub design, it has been thoroughly field tested ... by the whale. It's an ambitious scheme. And it's a first-time project for these young engineers. They're finding out how complicated building your ideas can be. But with each mistake these eager undergrads learn something new and keep on improvising.

CAL POLY "You design as you go, that's kind of the motto. And then you just modify as things don't work or as they work. That's the whole idea: learn the hard way or the easy way depending on how good you designed the first time."

NARRATION At the other end of the spectrum, professional engineers at the Battelle Institute in Columbus, Ohio are also pursuing a unique design. But their experience told them that complexity equals trouble.

BRAD DEROOS "The simplicity of the device was the real key. We kind of thought to try and get something to swim like a fish would be akin to trying to fly with wings on your arms. It can be done I think but it's a very large research project in itself."

NARRATION In Ohio, this pool is as close as it gets to ocean conditions. But that doesn't dampen the excitement of the first underwater test. The sub's body is slender, to cut easily through the water. But that makes the inside a tight squeeze - so once the navigator wedges himself in, the peddler has to climb right on top. On the maiden voyage, you can see Batelle's idea. It's modeled on how a frog or a human takes to the water. It seems to work!... The driving will take practice. The frog-kick design transmits the energy of the human peddler efficiently. But speed is a problem they're only making one and a half miles per hour. Their design goal is twice that - and the extra speed must come from the peddler himself. So the Battelle team will need some heavy training to make the frog sub fast enough.

GRANT "If we can get a stroke a second for ten minutes we'll be in good shape."

PEDDLAR "Right now, we're at a minute, 17 seconds."

NARRATION Race week dawns on Florida's Atlantic coast. The action starts here on the beach, where the submarines are launched and then towed to an off-shore staging vessel. They'll compete in a tournament - seven days of one-on-one races around this quarter mile-long racetrack set thirty feet below the waves. Doing all this underwater is tricky. There are divers to position the boats. Underwater lights to signal the start. Buoys every ten feet to mark the course. And safety is a critical concern. Each sub must tow a line to a topside safety float that can be tracked at all times. It's an engineering nightmare! But the challenge has inspired 34 teams from all walks of life: from high school students working on a shoestring, to large corporations with deep pockets. The subs come in all shapes ... from the pencil sharp ... to the wide bodied. Most have a few features in common.., such as a rudder for steering left and right.., and dive planes for heading up and down. But the flair of new engineering ideas really comes out in the propulsion systems -like this flexible tail that both drives and steers -arms that push without churning up the water -a six-bladed paddlewheel -twin propellers that rotate in opposite directions -and the adjustable blades on this flying bomb. These designs are strong contenders for the innovation award, but the real excitement is the speed race.

STUDENTS "Alright, F.A.U.! Whooee!"

NARRATION And in the first round of the tournament, it's Florida Arianfids shark sub against a Pomona California team. The systems have been tested a hundred times, but the nervous drivers just can't resist one final check.

ANNOUNCER "Green Light?

NARRATION Out of the gates Florida Atlantic is off to a blazing start.

ANNOUNCER "The second boat's coming by now, running smooth. But they seem to be pretty far behind the other boat that came by."

NARRATION And five minutes later, it's an easy win for the shark, even with some minor engine trouble.

ANNOUNCER "Beautiful finish. We have a finish!"

MIKE THE BIKE "And I pulled my foot out of the pedal so I had one foot the rest of the way."

INTERVIEWER "You couldn't get it back in?"

MIKE "Well, I didn't want to try because we're really concerned about drifting into this buoy. So, I always wanted to make sure that we had control. So I said: 'We can go with one foot?

NARRATION Another frontrunner - the US Naval Academy. Always competitive, the midshipmen bring their spit and polish approach to sub racing.

TIM "We're wet sanding it to make the surface as slick as possible, get all the little nicks and stuff out. After this, we're going to wax it."

NARRATION They're up against a sub of an entirely different color.

INTERVIEWER "What team are you guys with?"

DUDE "Santa Barbara."

NARRATION The Naval Academy, with their small, sleek hull should easily outpace the bulky, and slower, Santa Barbara boat. Navy takes an early lead.., but then ... a problem. By accident, they pull their safety float under the surface. That's illegal.., and it slows them down. The extra drag of the float nearly evens the odds. And the Naval Academy crosses the finish only a nose ahead. The midshipmen are thrilled with their narrow victory. But it's a short-lived celebration - because of the safety violation, the judges disqualify their sub. Meanwhile, the Battelle sub is being prepped for its next run. Their frog-like device has been working flawlessly, and they're ready for the water! Their opponent: Texas A&M University. It's late afternoon and the seas are starting to swell. Visibility is bad. Conditions are getting marginal. Nevertheless, Battelle gets a graceful start.

JUDGE "We have a launch!"

NARRATION Even the judges are impressed.

JUDGE # 2 "Great!"

NARRATION But on the first corner...a miscalculation. Unfamiliar with heavy ocean currents, Battelle drives too close to the course markers and they snag their safety line. Stuck on the bottom, the sub and their safety float. The Battelle boat is somewhere beneath the chop, but no one knows where.

WOMAN "There's only one thing that would've stopped them."

MAN "I think they caught a buoy."

WOMAN "That’s what I think. I think the currents are bad."

NARRATION The disadvantage of being a landlocked team has become painfully dear. The engineers from Ohio can only wait for help to arrive.

GUY "Our designs have to be conformed to whatever currents there are, whatever conditions. We design on ideal conditions but you have chaos out there."

NARRATION Back on shore, the undergraduates from Cairo Zy Tech have gotten their whale tail up and running. But their uncertain workmanship has yet for be tested in the ocean. Right out of the gate, the students realize they overlooked something:, the boat won't stay level in the water. They peddle furiously, but the whale-tail sub just dives into the sand. Exhausted, Cal Poly abandons ship. After four days of racing.., the field is thinning out. driving.., and bad design. There's back luck.., bad.

ANNOUNCER "She's coming for the top."

BENTHOS TEAM "What's our number? ONE! Whooee!"

NARRATION One team has something to cheer about - the Benthos Corporation, from Cape Cod. Their boat has a slender hull and an efficient propeller. They build submarines for a living and it shows.

BENTHOS "The prop was designed around our peddler. We found out his horsepower, used a computer program to find out the right shape for the prop, and then had a CNC machine it out for us. Other than that we've just kept it simple, we've got a lot of practice on it. We go for a good clean race and we're fast.

ANNOUNCER "Okay, I see the first boat coming. It's the Benthos boat. Holy Smokes - it is pulling! Whooee! The second boat is coming by the platform now. It's #25. It's looking good. It's got a ways to go to catch the other one. The other FLEW by."

NARRATION Round after round, Benthos has beat all comers. They're demonstrating why real submarines use propellers - its the most efficient way to move water. So Benthos heads in to the finals.

BENTHOS "One more race, that's all we got, one more race left. If they can get us off the starting block dean tomorrow we should have a damn good chance at it."

NARRATION In the final showdown, Benthos faces the shark sub - and the students from Florida Atlantic are planning to pull out all the stops.

ROB COULSON "Up until now we've kind of held back a bit, made sure we got around the course, didn't get tangled in any buoys. Today we've got to take a few chances."

NARRATION It's a head-to-head contest between two machines driven by efficient propellers - and two teams with plenty of ocean practice.

FAU "Uggy, uggy, uggy. Au, Au, Au!"

BENTHOS "Ugly, ugly, ugly. Yes, yes, yes. Is that what you meant?"

NARRATION Into the starting gates go the high-spirited students, next to the trained professionals. They'll race twice around the track: a grueling half-mile sprint. Seven days and 60 races have come down to this match. And right from the start, it's too close to call.

BLOND GUY "Let's go! Alright, Benthos! Ahh ooo!"

UNDERWATER ANNOUNCER "They're going into the second turn now, to the back straightaway. They're still not more than five feet apart, is Benthos from Fau. They're really moving now. JUDGE "The Fau boat is across the finish line! The other boat is right behind them. They're about eight feet apart."

NARRATION It's an upset win for Florida Atlantic University! Even in their moment of glory, the students recognize the biggest payoff is what they've learned about engineering.

MIKE THE BIKE "We took this baby from the basic conception to actually building it, testing it and getting it to run. And that's what engineering is all about. So basically they're training us to be engineers. And this is the result."

GUY "Uggy, Uggy, Uggy!"

RESPONSE "Au! Au! Au!"

GUY "Uggy!"

RESPONSE "Au!"

GUY "Uggy!"

RESPONSE "Au!" GUY "Uggy, Uggy, Uggy!"

RESPONSE "Au, Au, Au! YEAHHH!

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TACKLING A KILLER DISEASE

NARRATION Imagine we're here, not to play a game, but on a mission of life and death. This is a drug, or some surgical procedure, that we've just created in our laboratory. Using this new treatment to save lives - that's the goal, way down there. But in the risky and highly regulated world of medicine, it can take a decade or more to go the full hundred yards. The first steps, like testing with lab animals, take us to about here - the thirty yard line. Now we're ready for a clinical test --giving this treatment for the first time to just a few human patients. That's the point at which we join our next story. Meet Justin Cano. He's ten years old and just bursting with energy. He and his twin brother Jason have a lot in common. But Justin can't keep up with his brother these days. He has a degenerative muscle disease called Duchenne Muscular Dystrophy. As his twin grows stronger and faster, Justin grows weaker and slower. There is no cure - the harsh reality that haunts his mother.

MOM "I just thought it was a crippling disease. I didn't know it was fatal. So that was the real shocker. I think people can deal with a handicapped child. But not when it just slowly makes them whither away."

NARRATION This form of muscular dystrophy is caused by an abnormal gene, usually passed on by mother. Justin, on the left here, inherited the gene, but neither his twin Jason nor his older brother Joey got it. It's not uncommon among children - one of every 3500 male babies is affected. Once a month Justin is monitored by physicians at the California Pacific Medical Center in San Francisco. They are trying to determine how far the disease has progressed, and to stave off the crippling stiffness that eventually takes over.

DR. MILLER "Can you lie down for me?"

NARRATION Dr. Robert Miller is testing the strength of Justin's muscles.

DR. MILLER "Pick it up and hold it. Now don't let me push it down. Push. Push. Push. Push. Okay, good effort." Hold it there. Push.

NARRATION Justin's best efforts are pretty feeble -- he can't resist the doctor's push.

DR. MILLER Here we go... Pull. Pull. Pull... Let's see these belly muscles here. Let me just check them now.

NARRATION As his muscles continue to weaken, Justin will no longer be able to walk. When his heart and lungs give out, he will die.

DR. ,MILLER Can you keep it there? Okay. How about in this leg?

NARRATION Children with muscular dystrophy rarely reach their twenties. But now, there may be hope - a new treatment that Justin and Dr. Miller are helping to pioneer.

DR. MILLER Don't let me push it down. Pul1, pull, pull. Okay.

NARRATION Confronting families with tremendous sadness and grief and expectations and not being able to do anything, really, to fundamentally alter the course of the disease is an extremely difficult task. And a very discouraging one. And suddenly, to have something that has light at the end of the tunnel, where we may be onto a treatment that would actually.., potentially.., mm this around is extremely exciting." Clinical trials of the new treatment are just beginning. Justin and a handful of other volunteers will help determine if it's effective and safe.

DR. MILLER I can sit in there? I want to just chat with you about where things stand in terms of our study and what is coming up. We've had lots of discussions already about how we're going to be transferring some muscle from you over to your brother here. And I wonder if, first of all, if anybody has any questions this morning?

NARRATION The hope is that Jason's healthy muscle cells will take root in Justin and slow the disease.

DR. MILLER Are you ready for your big procedure today?

JASON Yeah, kind of.

DR. MILLER I don't blame you.
GRAPHIC
But I'm kind of scared. It is a little scary.

NARRATION The key idea of the new treatment is to get Justin's muscle cells working normally again. Under stress and strain, even a healthy muscle cell will tear. But other cells, called myoblasts, come to the rescue. They fuse with the muscle cell and produce dystrophin, a protein that helps the cell repair itself. In Justin's kind of muscular dystrophy, cells don't produce dystrophin, so tears can't heal and muscles eventually fail. By transplanting healthy myoblasts from Jason, Dr. Miller hopes to coax Justin's cells to produce dystrophin and start repairing themselves. So Justin's treatment begins with muscle tissue taken from Jason - a gift of strength from brother to brother. As Dad distracts him, the surgeon removes a small bit of muscle from Jason's arm.

DAD Everything's numb to where you can't feel nothing.

JASON Even my muscle? Oh, good.

DAD You won't feel it.

JASON I know you're using big scissors. I can see them.

DAD Don't look over because that only makes you think about what comes next. Look at me, okay?

NARRATION The tissue is bound for a Stanford University laboratory. It will take six weeks to grow the millions of myoblasts Dr. Miller needs to put the new treatment to the test.

DR. MILLER I'd be very happy if we could demonstrate that we could slow the course of this disease and have any impact on the declining strength in that muscle.

NARRATION The six weeks pass slowly for Justin

JUSTIN 45, 46, 47, 48!

NARRATION As he waits, he does what he can to hold off the advancing stiffness. Mom helps through the endless stretching exercises.

JUSTIN 98, 99, 100!

NARRATION At last, the big day has arrived. Dr. Miller will be performing the trial treatment.

JUSTIN What is that?

NURSE It's soap - just brown soap.

NARRATION He's chosen a small test patch on Justin's shin muscle. Because myoblasts don't travel very far, [Dr. Miller will have to inject cells all over the muscle - every spot on this l00-point grid will receive a shot of one million cells. This is an experiment - doctors think the treatment works, but they have to conduct an objective test. So Justin's other leg also gets 100 injections, of an inactive solution. That way no one who will evaluate the results, not even Dr. Miller, knows which leg gets the treatment. 200 injections later...

DOCTOR Justin, guess what? We're done.

EVERYBODY Alright! Yeahhh!

DOCTOR Unbelievable! I'm so proud of you. It went so well. We had no technical trouble and you would've been so proud of Justin.

NARRATION He leaves the hospital the same day...a little sore, but still on his feet. The next day is the beginning of a long wait. It will be six months before doctors know whether the treatment works. And if Justin's leg does grow stronger, they will still have to figure out how to treat all the muscles in his body. But in this new assault on muscular dystrophy, the courage of Justin and his family is the crucial first step.

MOM If it extends Justin's life one day, ifs worth it. If it can keep him on his feet longer, it's worth it. I kind of think it Will. I know that it probably isn't the answer but it will answer questions that they need to know. And that is so important, not just for Justin, but all those other kids out there. They're really suffering.

NARRATION The latest news from Justin is that he thinks his right leg might be getting stronger. Let’s hope he’s right - and let's hope it's the leg that received the treatment, too. The full results won't be in for several months - and even if they're encouraging, we'll only be here, at the forty yard line. Still an awful long way to the goal of getting this new treatment out into the world. The next step will be a full-scale clinical trial, with several hundred patients, for about two years. After that, three more years, and another thousand patients, to examine side effects. Then, after a final government review, the new treatment becomes available.

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ART OF SCIENCE - PANSPERMIA

NARRATION Science often works with pictures - from many different kinds of microscopes, all manner of different cameras, and more and more nowadays, from computers. Now many of these scientific images are not only useful, they can be extraordinary, just as pictures. It's "The Art of Science," if you like, and as a regular feature on FRONTIERS, we're going to spend a few minutes each episode showing you some of our favorites. Our first one, a film by Karl Sims, is actually an illustration of an entire scientific theory. It's computer-generated - using one of the latest high-speed parallel processing computers - and it's a spectacular visualization of "panspermia": the idea that the seeds of life on Earth traveled here, through space, from somewhere else in the universe. That's by no means a crazy idea, although it is just a theory. Right now, let's not worry if it's right or wrong - I suggest we just sit back and enjoy the show.

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TURTLE HOMECOMING HATCHINGS

NARRATION After this rough introduction, the ocean will become home to these baby sea turtles, they'll swim hundreds of miles out into the open seas. Then, after 40 years, the females will crawl ashore to nest. And that's the beginning of one of nature's most intriguing mysteries. Midnight, on Melbourne Beach, Florida. Using a surveillance night scope, FRONTIERS witnesses this female turtle emerging from the sea. Scientists have long suspected that when it's time for turtles to lay their eggs, they return to the very beach where they were born.

ANNIE MEYLAN AND BRIAN BOWEN The turtle's 40 year migration has made this theory very difficult to test.

NARRATION But that's exactly what Annie Meylan and Brian Bowen have set out to do on this stormy summer night.

ANNIE MEYLAN "We should be able to get something before the rain comes."

BRIAN BOWEN "Yeah, I hope."

NARRATION They find a flesh set of turtle tracks. Annie and Brian have to be extremely careful not to frighten the turtle, who's just settling in to dig her nest.

ANNIE MEYLAN "Hold my pack."

BRIAN BOWEN "I'll follow you."

ANNIE MEYLAN "She's just starting to dig the egg chambers. Probably, about ten minutes." So we have a few minutes.

NARRATION After several minutes, the turtle enters an egg-laying trance, and now TV lights won't bother her. She's laying her eggs here - but was she also born here 40 years ago? The traditional way of finding out would be to use an identification tag.

ANNIE MEYLAN 'There's a part of a tag broken out here. Can we get a flashlight?"

NARRATION And this turtle does have one.

ANNIE MEYLAN "Do you see any numbers? I feel them, but I can't read anything."

NARRATION But it’s from just two years ago, when she first nested here. Tagging can't answer the question of where she was born.

ANNIE MEYLAN "They grow so tremendously in size, from a few grams to many hundred pounds. It's hard to put a tag on that lasts that long that you can prove that that turtle is, in fact, the one that returned some 30 or 50 years later when it reached sexual maturity. So really an indirect way to look at that problem is to look at the genetics of the turtles that are up on the beach."

NARRATION To look at the genetics, they need to take a blood sample, easier said than done in a giant turtle.

BRIAN BOWEN "It’s alright, Mama."

NARRATION They will be taking blood from turtles at many nesting beaches around the world. How will their genetic detective work answer the question of where these turtles were born?

AMY "I'm going to hand you this one."

BRIAN BOWEN "Got it."

NARRATION Say these orange turtles hatch on the beach in Florida and swim away. And these purple turtles hatch off the coast of Venezuela. They all get together on feeding grounds in the Caribbean. But what happens when it's time to nest? One possibility is that the females return randomly to either beach. In this case, over many generations, orange and purple turtles would get all mixed up genetically. The other possibility, the long-standing theory, is that nesting turtles return to the beaches where they were born. In this case, even over thousands of generations, Florida and Venezuela turtles would remain genetically distinct.

NARRATION Back in his lab at the University of Georgia, Brian processes the turtle blood samples so unlock the genetic clues. He's taken blood samples from turtles on both the Florida and Venezuela beaches. So - do turtles return home to lay their eggs? These drops of genetic material will answer the question. And here's the unmistakable evidence, in a side-by-side comparison.

NARRATION On the left, genetic snapshots of nine Florida turtles. They're all identical. On the right, Venezuela turtles. Also identical. But here's the crucial discovery: the Venezuela turtles have a band here that's missing in the Florida turtles, and the Florida turtles have a band that's missing in Venezuela. The two populations are genetically distinct.

NARRATION The only explanation is that the turtles have been coming home to nest generation after generation.

BRIAN BOWEN "This result has astounded us. When we started this study, we thought it very unlikely that animals three inches long can leave a beach and come back forty, years later to the same beach. That for that time span they can remember where they came from and then find their way back."

NARRATION Now we know that a turtle does make this remarkable journey home. The next question is: how does she find her way? One part of the answer is that turtles might be born navigators. Biologist Michael Salmon believes that turtles may have an internal compass that they use for navigation. Maybe they can navigate the way a ship's compass does - responding to the magnetic field that runs between the Earth's North and South poles. Salmon's colleague, Ken Lohman, has designed an experiment to test this theory. The little jacket will keep the hatchling in place while it's in the pool.

KEN LOHMAN "Oops! I've actually got it upside down.

NARRATION They take advantage of the fact that the turtle is attracted to light to start it swimming in one direction.

MIKE SALMON "Okay. We found that if they swim in one particular direction, in this case east, for about an hour that that turns on an ability to respond to the earth's magnetic field when the lights are turned out."

NARRATION Sure enough, the turtle continues swimming east, even without the light as a cue. Once it's been oriented, it's able to maintain a direction. But is it really relying on some sort of internal compass to do this? The best way to find out is to change the magnetic field and see what happens. That's exactly the function of these wires surrounding the pool. They can generate a magnetic field as strong as the Earth's, but in the opposite direction.

MIKE SALMON "If it's responding to the earth's magnetic field, we now expect it to go west."

NARRATION Soon, the turtle does head west -- a convincing demonstration that it is responding to the Earth's magnetic field. The discovery of this internal-compass is a breakthrough in the understanding of turtle navigation, but alone it does not explain the turtle's remarkable journey. There's another mystery -- at journey's end, how does the turtle know she's really home? What cues does she use? Well, scientists have shown that turtles have a very keen sense of smell. So maybe they form a memory, or imprint, of their home beaches based on smell. If this imprinting theory is true, it could help save a highly endangered species of sea turtle. Rancho Nuevo, on the Mexican Gulf Coast, the only nesting beach in the world for the Kemp's ridley turtle. 45 years ago, tens of thousands of Kemp's ridley turtles came ashore to nest here every year, as this rare home movie footage shows. By the late 1970s the numbers had plummeted. Only a few hundred nesting females remained. Scientists believed a second nesting beach might help save the Kemp’s ridleys, and they used imprinting theory to create it. First, they had to catch the new eggs before they ever even touched the sand. This Way, no memory of their native beach could be formed. The eggs were flown up the coast to Padre Island National Seashore in Texas. There, the eggs hatch. As they scramble towards the sea, they are getting the smell of their adopted home beach. If the theory is right, the memory of this sand and water should guide the females back here when it's time to nest. It takes Kemp's ridleys only 10 years to mature, so the first females should have returned already. But 12 years later, no turtles have come back to the Texas beach. Maybe they died as hatchlings, maybe they will come back next year, or maybe the imprinting theory is wrong. Now, under laboratory conditions, the theory will be tested directly by Texas A & M biologist David Owens. These Kemps ridleys were briefly exposed to the Texas sand and water when they hatched, and have been in captivity ever since.

DAVID OWENS "The experiment itself is to some degree a long shot because we don't know that we can duplicate nature well enough in the laboratory to convince the turtles to demonstrate their natural behavior."

NARRATION Graduate student Heather Kalb is on a mission - the first step in the attempt to duplicate nature. They moved .through this sand as they headed for the ocean. And this is the first ocean water they swam in. Will a few buckets of sand and water capture enough of this complex environment for the turtles to recognize their home beach? In the laboratory version of nature, this is the ocean. For the experiment, the tank will be divided into four sections. To allow the turtle to swim around freely, the divisions are created by the flow of water four strong currents are pumped from the center. Three quarters of the tank will be filled with artificial sea water. For the fourth section, Heather takes the sand from the Padre Island beach and filters the ocean water through it. Heather makes her way to the middle of the tank to pump the Padre Island solution into the 4th section. Now, she's ready for a subject. For this step, timing is everything. In nature, a female would only look for a nesting beach when she's ready to lay eggs. This is also the only time she'd be interested in the Padre Island solution in the tank. So Heather and David do an ultrasound to check for the presence of follicles, the first stage of egg development.

HEATHER Looks real good.

DAVID Ahhhh, there are lots of follicles.

HEATHER She's slowly gearing up. Every month we're seeing lots of follicles. So we're almost to the size where eggs should be secreted. In which case she should be headed to whatever beach she'd want to be at.

NARRATION Time for the experiment. This struggling female weighs almost 100 pounds, so it takes a firm hand to get her into the tank. After twelve years in captivity, will this turtle recognize the smell of the beach where she hatched? Right from the start - she heads directly for the Padre Island section of the tank. And she spends a considerable amount of time hanging out there. It looks like good news for the imprinting theory. Throughout the turtle's swim, Heather watches a monitor and keeps close track of its position. The turtle is sail in the Padre Island quadrant. But as the experiment continues, she wanders all around the tank. With this turtle, as with all the others they've tested, the only dear pattern is that there is no pattern at all.

HEATHER I'm a little discouraged with the results. We all look for good results right off the bat to at least encourage us and keep us going a bit. But like I said earlier, there are a lot of doors that are open and I hope to at least narrow down our state. You know - alright, this is what's been done. Let's try it. But change some variables. And that's the only way to get the question answered.

NARRATION So the verdict on imprinting theory is still out. We know that nesting turtles come back to the beach where they were born, and we know that an internal compass helps them get there - but how they recognize the right spot remains a mystery.

NARRATION I sure hope Heather and her colleagues keep at it. But they might be aiming too high, maybe trying to go too far in one step. Here's how I think about it. My buddy Duke roams around this neighborhood, but he always comes back here in time for dinner. How does he know which house has the food? Well, I've set up a little experiment to test what Duke can recognize. This snapshot of the house is a little silly. Now here's a swatch of grass from the front yard, a sock, and some other things he might be able to identify. Just think of all the things I would have to put together to replicate Duke's neighborhood. And that's not even counting things that might never occur to me because cats and I don't see the world the same way. Sure enough, Duke doesn't seem much interested in anything, except maybe getting out of here. It's really hard to design one experiment, for cats or for turtles, that includes all the factors that could be important. Maybe Heather will get it in one incredibly clever experiment. But it seems more likely that the only way to crack the secret of turtle navigation is to chip away at our ignorance, bit by bit.

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COMMON SENSE COMPUTER

NARRATION Want to know what happens when we breathe? Ok, let's ask a seven year-old. A child could answer that.

ANTHONY Well normally, you breathe in air and you breathe out carbon dioxide.

NARRATION Wow! It's really amazing how much Anthony has already learned about the world. But, with a little effort, I could also teach my computer about breathing. And then it could do some figuring that goes way beyond a child's ability. For example, let's ask Anthony how many times he breathes, in a minute and in a day.

ANTHONY In a minute. I'd say probably 30 or 35 and in a day you'd probably breathe about 100 times or more.

NARRATION Now a computer would never make a mistake like that. Let's see - we actually breathe about 40 times a minute - times 60 minutes in an hour - times 24 hours - that's about 57,600 breaths a day. Anthony was a little off on that one. But this machine would have a lot more trouble answering questions that it hasn't been specifically programmed to answer. And that's where Anthony really shines. For example, here's a question I'm sure he's never thought about before: Can kids his age be waiters in restaurants?

ANTHONY No.

NARRATION How come?

ANTHONY Because I really think ...Well, if it was an Italian restaurant I don't think they could hold the tray up like that. Or, if it was a normal restaurant, that they just serve food in, I don't think they'd know how to do it as well as professional grown-ups.

NARRATION My computer doesn't know the first thing about Italian restaurants or professional grownups. I'm not even going to ask it. But what if I did want it to be smart in the same way Anthony's smart, in a commonsense kind of way? That's what our next story is all about. A computer with the same commonsense approach to the world as people seems like science fiction, but in fact that's exactly the goal of this small band of pioneers in Austin, Texas. They predict that by the turn of the century, no one will even think of buying a computer that doesn't have commonsense. Think about the range of subjects a computer would have to know about to match the commonsense of the average person - everything from children's stories, to mathematics, to popular films. The project is named Cyc, short for encyclopedia. But almost from the start, project leader Doug Lenat realized that this was a misleading name.

DOUG Encyclopedias are almost exactly the complement of what we want in Cyc. If you look at a large encyclopedia, it will tell you pages worth of material that you can be pretty sure the average person doesn't know about one topic or another. And what we really have to focus on is the knowledge people share in common about these topics.

KEITH ANDBILL This common knowledge is so much a part of us that it's hard to shake loose. For example, Bill and Keith are struggling to teach Cyc about feet.

BILL All feet are parts of legs.

KEITH One thing we haven't told it though, is that any leg cannot have more than one foot. You can't have like two feet on one leg. So they tell Cyc that every leg has only one foot - at least that's what they thought they were telling it.

KEITH So this would say that a foot is at most a part of one leg. So no one shares feet.

BILL But if a foot is a part of one leg does that imply all legs have one foot?

KEITH No. We need to put in both. That every leg has exactly one foot. And every foot is part of exactly one leg. It's a frustratingly slow process which the staff calls "brain surgery". They have to go into Cyc's brain and alter it every time they want to teach it something. It's a very different process from the way a child learns.

KEITH When you were little, you didn't know anything. But you had a way of moving around and learning things on your own. The computer doesn't have that, I mean, that's our ultimate goal. Our pie - in - the - sky goal is to get it to do that somehow.

BILL About 3 billion years of evolutionary creativity have gone into creating devices which learn things - which are designed to learn things.

KEITH Very well.

BILL Right. And we've been working on computers for about... I don't know, it depends who you ask.., but we might say 100 years. So we're doing it faster. And give us another 100 years and we'll have some pretty neat things happening.

NARRATION Actually, some pretty neat things are already happening. Cyc is not only learning commonsense knowledge, it's learning commonsense reasoning as well. Here's a simple demonstration: Say Karen is a musician, and Karen is married to John. Knowing these two facts, what will Cyc infer? That John is also a musician. How did Cyc come up with that? Cyc knows this commonsense rule: spouses tend to have similar interests. So applying this rule to the two facts it knows - that Karen is a musician and that Karen is married to John, Cyc deduces that John is also interested in music. Cyc's not 100% sure, but it knows this is a reasonable conclusion. This example is simple, but the ability it demonstrates is powerful: Cyc can figure things out for itself, and learn on its own, much the way Anthony learns. Here's the next step. It's 8 P.M., the end of a long day. Doug is ready to go home. But Cyc's work is just beginning. Cyc spends the night deep in thought, making its own original connections between unrelated subjects. The method is called analogy, and it's another way for Cyc to become its own teacher. Doug has high hopes for this new independent learning. And in the morning he's eager to find out what profound connections Cyc has come up with.

DOUG The profession you have in some ways is similar to what you order when you go to restaurants. Which is either extremely deep or just wrong. I think it's just wrong.

NARRATION Independent learning is risky, and Cyc sometimes makes silly connections. But it can also be an extremely creative process. Last night, Cyc also came up with this analogy: the dad of a family.., is like the dictator of a country. The logic of this connection is impeccable, as Doug explains. Anthony knows that if you brush well, you won't get a cavity. So he reasons that if you brush really wel1, you can make a cavity go away. It's a general model of how things work, and even though Anthony's not applying it correctly, ifs an inspiration to Doug.

DOUG If Cyc has those same general models, then it'll be able to fall back on them. It'll be able to give general answers and not be brittle as well. And yes, it might give the same wrong answers that Anthony does if it doesn't have the same knowledge. More importantly, I'll give the right answers, the right responses to a large range of more general situations - situations which we can't anticipate right now. The kind of situations that Anthony and all of us face as we go through life.

NARRATION If Doug Lenat succeeds, and Cyc acquires the common sense knowledge and reasoning skill that people have - will we be elated or will we start worrying? How would you feel if you couldn't tell whether you were talking to a human being or an intelligent machine? We may get some answers to those questions in a later FRONTIERS program, when we cover the first-ever contest in which computers try to fool human judges, Meanwhile, next time on

FRONTIERS, We'll look at flying robots, restored prairies, and a tree that cures cancer. Please come back and watch.

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