YOUR INNER FISH - EP 1- YOUR INNERFISH
VERBATIM SCRIPT CLOSED CAPTIONING – FEBRUARY 19, 2014

SHOTS	COMM / SYNC
PRE-TITLE	
01:00:00:00	**When I look at my fellow humans - I see ghosts of animals past… Glimpses of an epic story that's hidden inside us all.** **My name's Neil Shubin.** *Neil: As a scientist I look at human bodies different from most people* **The way we grip with our hands, we can thank our primate ancestors for that.** **How we hear so many sounds… That dates back to creatures the size of a shrew.** **And the further back we go – the stranger it gets.**
01:00:58	**To reveal why we look the way we do, we'll travel through the distant reaches of our family tree…** **And meet a strange cast of characters…** **The ancestors that shaped your body…** [ROAR] **The family you never knew you had…** **From the badlands of Ethiopia…** *"She's beautiful.."* **to the shores of Nova Scotia…** *"This is the spot…"*

01:01:30	**We'll search for clues that lie buried in rock…** *Neil: His eyes are like globes and he said: 'I said I've found it, I've found it'.* [ZIPPER SOUND] **And search for answers written in our DNA.** *Peter Holland:* **"***I think it gives us a glimpse into the brain of our ancestors...***."** *Neil: "I mean ... I find that mind-blowing."*
01:01:47	**The adventure begins with a search for some of our most elusive relatives…** **Fish that crawled onto land almost four hundred million years ago.** **From our necks and lungs - to our limbs and hands – we owe a lot to these intrepid pioneers.** *Neil: So if you really want to see why you're built the way you are… it's time to meet your inner fish.*
01:02:22 **SHOW TITLE**	**YOUR INNER FISH**
01:02:30 **VLY**	**Announcer: YOUR INNER FISH IS BROUGHT TO YOU IN PART BY VIEWERS LIKE YOU. THANK YOU.**
01:02:37 [HELICOPTER SOUND] 01:02:51	[RADIO CHAT] *Ted: Now look at that! Paradise!* *Neil: Yeah!* *Ted: It's perfect!* *Neil: He's going right up the valley.* **The Canadian Arctic is one of the most desolate regions of the planet… but there's nowhere else I'd rather spend the summer.**
[MUSIC] 01:03:11 01:03:34	**What draws me here is treasure… My kind of treasure: fossils hidden inside ancient rocks. In particular - the fossils of long dead fish, but not just any old fish.** **I'm hunting for fish that carry the story of our own bodies inside of them.**
01:03:42	**How I got here and what I found could change the way you think about yourself and your body.**

[ORCHESTRAL MUSIC] 01:03:52	**This is a story that ends on top of the world with the most important discovery of my life.** **But it begins in the City of Chicago… with a room full of human cadavers.**
ANATOMY LAB	
01:04:10	**It was more than a decade ago, and I'd just moved to the University of Chicago as chairman of the Anatomy department.**
01:04:24	*Neil: And I remember, you know, hanging around with the students around the tables here, just getting to know them and letting them get to know me. They launching their carrier as future physicians and there are some nerves and skittishness those first few days and they almost invariably asked*
01:04:41	*'Dr. Shubin, what kind of doctor are you? Are you a surgeon? Are you a cardiologist?' and I'd say 'Well no, I'm a fish palaeontologist!' and I'd get this look like 'What? I want my money back'.*
01:04:53	*Neil: But it soon became clear that being a palaeontologist, and not just any palaeontologist - a fish palaeontologist, is a very powerful way to teach human anatomy. Because often some of the best road maps to our own bodies are seen in other creatures.*
FISH ANCESTORS	
01:05:09	[Big water splash sounds] **Now you might not think your body has much in common with a fish, but I see a family resemblance.** **On the surface you are not very fish- like, I'll admit.** **But you <u>are</u> related to them. And the clues to that connection are etched in ancient stone . . .**
01:05:43 [COMPUTER WRITING SOUND]	**Fossils unearthed around the world reveal that fish are the first creatures with bony skeletons. They have backbones and skulls– just like you and me.** **This shared anatomy connects us to fish . . . and to a long line of other animals.**
01:06:10	**To see what I mean… Imagine the complete history of life on a giant family tree, from the first microscopic organisms billions of years ago, to all animals alive today.**
01:06:28	**Our history lies on one branch of this Tree of Life… and we can trace**

	our ancestry back.
01:06:37	**Around 400 million years ago you'll find fish swimming in oceans and streams.** **Forty million years later the first amphibians appear on land.**
01:06:53	**Then we see reptiles . . . followed by the first mammals around 200 million years ago. And much later, we arrive at our special branch, primates.**
01:07:08	**This history tells us something remarkable: every reptile, bird and mammal alive today is descended from ancient fish—And that includes us!**
ANATOMY LAB HAND	
01:07:21 Webmarker pbs.org | Learn more about your fishy past at pbs.org/innerfish	**So how does this legacy play out in our anatomy?** **Neil SYNC:** *Each one of us walking around in this lab today carries the history of life within us. And the evidence is seen in every part of our bodies.* **And not just in our bones…**
01:07:46 [COMPUTER WRITING SOUND]	**Even the complex tangle of nerves inside the human head makes much more sense when you realize it's the same basic wiring found in fish.**
01:07:56	**But there's one defining piece of human anatomy that seems remote from the world of fish…**
01:08:04	**And I vividly remember when it first captured my imagination.**
01:08:08	*Neil: When I walked into the* anatomy *lab for the first time I was sort of scared about what I was going to see, what I was going to feel, but the reality is after the first few weeks, that fear turns into a sort of a cocky self confidence. And these things... when you dissect them it doesn't look very human, it kind of looks like a wax model in a lot of ways, but then you hit the hand.*

01:08:28 [ORCHESTRAL MUSIC]	*Neil: And for me, as I unwrapped the gauze off the hand and revealed the palm, the fingers, the fingernails, something else hit me entirely. And that was a deep sense of connection, a connection to another human body lying on that slab – this was not a wax model that I was dissecting, this formerly was a person who lived a life just like I'm living now.*
01:08:57	**When I see the anatomy within the human hand I'm in awe of the intricate connections between bone, tendon and muscle.**
01:09:08	*And really it's through the action of these muscles through the tendons that the hand does its magic, if you will. So that when the muscles fire it pulls on these tendons and watch – the fingers flex.*
01:09:24	*Now the fine muscles of our hand… these little tiny muscles that lie along the tendons. These are the muscles that control the fine motion of our fingers. These are the ones that are quintessentially primate and human.*
01:09:41	**So where did this marvel of evolution come from?** **It clearly has deep roots in the past…** **And you can see evidence of that in the bones of modern creatures.**
OWEN	
01:09:59	**More than 150 years ago, scientists were finding connections between the hands and limbs of four legged animals.**
01:10:07	*Neil: Sir Richard Owen was an anatomist back in the 19th century - he was fortunate to be an anatomist in an age of discovery.*
01:10:15	*Neil: And so people were coming back to London with new and oddball creatures for him to analyse, and in analysing all the different creatures he found common patterns.*
01:10:28	**Although the overall shape and structure of each limb was very different – he started to see that there was an underlying theme…**
01:10:39	**It was as if the same set of bones was being squashed or extended to perform different functions.**

01:10:49	*Neil: Here's a dog – dogs run and jump, what do you have? One bone, two bones, little bones and then the digits, the equivalents of fingers or toes. And, of course, here's a bird its limb has been modified into a wing, and it has one bone, two bones, lotsa bones, and digits.*
01:11:14	*Neil: The amazing fact is, in each of these creatures the skeletal architecture, is largely the same as ours, and what's was utterly surprising is that the skeleton of every animal walking the earth today has this fundamental pattern of one bone, two bones, little bones, fingers.*
01:11:32	*Neil: Owen didn't know why creatures had that pattern, it was a mystery to him, it really took a new insight, an insight from Charles Darwin, which basically said the reason why animals have this common pattern is because at some time in the distant past they all shared a common ancestor that had a version of this pattern too.*
01:11:50	**According to Darwin we should be able to trace the evolution of our limbs' and hands by going back in time down our family tree.**
01:12:01	**Starting with our primate ancestors we see hands and limbs that look very similar to our own.**
01:12:10	**Go back a bit further to the first mammals and we find deeper similarities in the paws… And we see how paws emerged from more distant relatives…**
01:12:20 **01:12:33**	**And if we go back even further, we reach our most distant four-legged ancestors. These animals, the earliest 'tetrapods', were among the first to have Owen's "one bone, two bone, lots of bones" pattern.** **But when we enter the underwater world around 400 million years ago~~,~~ instead of animals with limbs we find prehistoric fish with fins.**
01:12:43 **01:12:52**	**And that brings us to a great mystery of biology: how did we get from fish with fins to animals with arms and legs?** **Darwin boldly predicted that there must have been ancient animals – transitional forms – that bridged this gap.**
01:13:00	**But what would such an animal look like? Would it have limbs or fins—or both?**
01:13:08	**Such a creature reflects a critical step in the origin of the human hand.** **I set out to find one.**

PHILADELPHIA	
[WATER FOUNTAIN SOUND] 01:13:16 Webmarker pbs.org | Learn more about fossils at pbs.org/innerfish	**I started my search back in the early 90s when I worked in Philadelphia.**
01:13:30	**I knew that finding this transitional fish was going to be a tall proposition… And the first question was where to look…**
01:13:42	*Neil: The world's a big place; the earth is a giant planet, and fossils are very small so how do you find those things?*
01:13:52	*Well there's a checklist we run through – we look for places in the world that have rocks of the right age. If you're interested in the origin of dinosaurs there's one age of rock to look at, if you're interested in the origin of transitional creatures between water to land there's another age of rock.*
01:14:05	*Then you look for places in the world that have rocks of the right type – the kinds of rock that are likely to hold fossils,*
01:14:13	**We knew from previous discoveries that rocks from the Devonian era - around 360 million years old - were likely to contain early tetrapod fossils. And it turned out we had rocks of that age right here in Pennsylvania…** **To look for good sites I teamed up with geologist, Ted Daeschler… And we've been fossil-hunting buddies ever since.**
01:14:37	*Ted: We tried it through here, even going down into West Virginia.*
01:14:40 Lower Thirds: TED DAESCHLER Academy of Natural Science, Philadelphia	*Ted: We are sort of maybe an odd couple – Neil is excitable and enthusiastic, which is wonderful. I'm enthusiastic as well but I think maybe not quite as vociferous. I might tend to hunker down more and focus on recovering the material as we start to find it, and Neil might be a little bit more 'okay what's over the next horizon, what's over the next hill?'* *Ted: Neil is on that edge, always thinking about the new place to go.*

01:15:16	*Neil: Ted and I would sit in the car with maps in one hand, and geological papers in the other, and we tootled through these state roads looking at the rocks, saying 'Okay what rock is this again? What kind of age is it?' But the problem in Pennsylvania is that it's not a desert, the bedrock is not exposed to the surface. You have forests, you have grass-– turns out the best exposures of rock in the state were made for us by the Pennsylvanian Department of Transportation, because they were dynamiting. They'd exposed sections of the geological record, and we eventually had this one road cut, a giant exposure. It's called Redhill.*
01:15:57	*Ted: There it is.* *Neil: Oh, my God.* *Neil: And then we knew, this was the place to hit.*
01:16:05 [SOUNDS OF CARS AND TRUCKS GOING PASS]	**We had ambitions to explore the globe. But our first expedition didn't take us to an exotic desert half way around the world, it happened by the side of a Pennsylvania Highway.**
01:16:28	*Neil: Ted revisited Red hill one time when I was not there. He made a phone call to me, he says 'Hey Neil, I think I've found something really important' 'What did you find? 'I think I found a Tetrapod'. I said 'Ted, are you kidding me? No, your not going to find a Tetrapod on your 2nd or third trip to Redhill. It's gonna take years of work'*
01:16:51	*Ted: So moving along this layer…I saw beautiful little fossil bone material, chipped around it a little bit, right in this layer, lo and behold uncovered what turned out to be a very significant specimen. This is the shoulder girdle of an early, limbed animal. It was a new species, it was a whole new kind of animal. And although we only have a shoulder girdle…. it's actually a very informative part of the skeleton –*
01:17:23 [COMPUTER WRITING SOUND]	*It would be on the left side, the skull would go off in that direction, the animal itself would be about a metre long, and just from the shoulder girdle we can learn things about how it may have held that limb*
01:17:38 [COMPUTER WRITING SOUND]	*And of course it does compare to other animals that are similar that are know from other parts of the world and we can use those to learn other aspects of hynerpeton.*
Jenny Clack - Greenland	
01:17:47	**These early four-legged animals belong to a group I like to call the Stegas.**
01:17:53	**Some of the best specimens had been found in Greenland by a palaeontologist, named Jenny Clack, who began working there in the Eighties.**

01:18:10 Lower Thirds: JENNIFER A. CLACK University of Cambridge [COMPUTER WRITING SOUND]	*Jenny - The idea of the transition between animals with fins and animals with limbs has been thought about for a long time. But until recently there had only been 3 data points. Something was obviously a fish at one end; something was obviously an animal with legs and walking around at the other end; and in the middle was this very peculiar thing called* ***Ichtyostega***
01:18:39	**Using the latest scanning techniques to build a 3D model of Ichtyostega, Jenny's trying get a better sense of how this creature lived.**
01:18:54	**She's working with animal motion expert Stephanie Pierce at London's Royal Veterinary College.**
01:19:01	*Stephanie – basically what we wanted to see was how much movement was possible at each of the limb joints. And how this compared to modern animals.*
01:19:09	**They compared Icthyostaga to modern Tetrapods, like salamanders, to figure out how this fossil might have moved.** **Using pressure pads and high-speed cameras they could measure how the limbs of modern animals work… and compare this to the bones of Ichthyostega.**
01:19:29	*Jenny – Icthyostega's forelimbs could push the top half of the body off the ground. But the back end has got these paddle-like hindlimbs – which are useful in water for swimming with, but on land act as stabilizers to stop the thing toppling over.*
01:19:48 [COMPUTER WRITING SOUND]	**The anatomy of the bones suggested that this four-legged animal had just come onto land – it was right at the edge of our search.**
01:19:56	**But between these tetrapods and ancient fish there was still a gap spanning millions of years…** **If we could find an animal within that gap… we'd be filling in a crucial piece of evolutionary history.**
WHERE TO LOOK?	
01:20:14	**So now there was a new challenge – where on earth should we look next?**
01:20:20	*Neil: So I remember sitting in the office and we doing the usual banter one day about something geological. We had a college textbook and were just thumbing though the diagrams in the book – and boom there was this figure that changed our lives.*

01:20:35	**It was a map of North America, which highlighted 3 areas of Devonian rock of just the right type to hold fossil fish moving on to land.**
01:20:45 [COMPUTER WRITING SOUND]	**There were our Red Hill rocks in Pennsylvania…** *Ted: Been there done that –worked on those very rocks…*
01:20:50 [COMPUTER WRITING SOUND] [COMPUTER WRITING SOUND]	**Then there were rocks in Greenland… which Jenny Clack had already searched.** *Ted: But then there was that little worm shaped land….* **Finally, there was this strip across northern Canada… And these rocks were 10 million years older.**
01:21:02	*Neil: I remember seeing that and saying to myself 'Holy cow, this is what we're looking for!' my heart was racing when I saw that because no palaeontologist worked on that expressly looking for early Tetrapod. Then you dug out the aerial photos, and that's when I got kind of terrified! I remember seeing this for the first time, thinking 'You gotta be kidding me, look at all this snow – how do you work there?'*
ARCTIC BEGINS	
[SOUND OF GUNS SNAPPING AND ZIPPERS] 01:21:32 [SOUND OF SMALL PLANE TAKING OFF]	*Neil: Right, so one, two, three, four, five, six, seven, eight.* *Control centre: OK, 2-6 is clear.*
01:21:50	**Back in 1999 when we embarked on our first Arctic adventure, we had little idea what we were in for… Nor that we were starting a search that would last over a decade.** *Neil: "Wow – that's a lot of snow!"*
[HELICOPTER SOUND] 01:22:09	**Here in the high Arctic of Canada there are no human settlements for miles and miles; no roads and all you've got is what you bring with you.** **Here there's always the risk of being trapped by some of the worst weather on the planet.**
01:22:26 [RADIO CHATTING]	*Neil: We're entering the valley now.* *Ted: This is the big gate window.* *Neil; Oh there shift – I am looking over the quarry*

01:22:30	**We had a narrow window during the month of July, when the snow melts just long enough to let us in.**
01:22:49	**We were trained fossil hunters, but now we would have to figure out how to become Arctic explorers.**
01:22:55	*Neil: So when the helicopter drops you off in the Arctic for the first time you're standing here saying 'what am I doing here?'* *You know you're thinking of polar bears – that's the first thing you look for. Is there anything on the landscape… Everything white becomes a polar bear. The last things on your mind are fossils.*
ANCIENT RIVER DELTA	
01:23:15	**It's hard to believe when you look out across this frozen terrain that once this was a warm, watery world swimming with life.**
01:23:24	*Neil: Here we are in the arctic and we have a snow-storm coming in and we're looking at rocks behind us but there is a huge disconnect between the present and the past. What you see today is valley red and green rocks, that are tilted stacked one on top of the other – but that's not how it was in the past*
01:23:42	*These valleys have been caused by glaciers that moved back and forth and those red and green rocks at some point actually extended across the valley and they were straight – they weren't tilted.*
01:23:53	*Now look inside the rock and what those rocks tell us that this valley 375 million years ago was a giant floodplain and that flood plane was filled with rivers that swelled their banks and sometimes shrunk but in those conditions formed swamps and streams of all different sizes... And inside those streams was diverse life.*
01:24:25 [WATER SOUNDS]	**Somewhere out there we were hoping to find an intrepid fish, on the brink of the historic transition to life on land.**
01:24:43	**Could we ever find evidence of this momentous event buried in sediments that had been crushed and distorted by 375 million years of geological upheaval?**
01:24:57	*When you think about everything that has to go right for a creature first to be a fossil and then a creature's fossil to be discovered by a palaeontologist. It is like finding a needle in a haystack*

01:25:21 [WATER SOUNDS OF A LITTLE CREEK]	**We were determined to find that needle… if it was out there...**
CLUES IN LIVING FISH	
01:25:30 [ELECTRONIC MUSIC]	**Back in Chicago I had another way of tracing the anatomy we share with fish… using a different kind of window into our evolutionary past.**
01:25:54	*When I wasn't looking for fossils in the summers I would spend my time looking under a microscope at embryos. And I was watching at the time, bodies forming from egg to adult. And there is an incredible beauty to that process.*
01:26:10 [ELECTRONIC MUSIC]	**In the early stages of development all animals start as a single cell… They divide again and again until... gradually a body emerges…with a front, a back, a top and a bottom.**
01:26:24	*It became very clear early on in the process that some of the most important embryos were fish. Because fish have the basic body plan in their embryos that was to become our own bodies.*
01:26:37 [COMPUTER WRITING SOUND]	**If you see an early fish embryo and a human embryo side by side you see something remarkable… they look almost identical! We really do look like fish. Both embryos have a head, a body, a tail and many other similar features.**
01:26:55	*Neil: And one of those similarities exists in the neck or what's called the pharyngeal area –*
01: 27:00	**In both fish and people what you find are a series of swellings called gill arches.**
01: 27:06 [COMPUTER WRITING SOUND]	*Turns out that in fish those swelling become components of the gill apparatus –* *in people they become portions of our lower jaw, portions in our middle ear and part of our voice box.*
01:27:22	*Neil: So this is a wonderfully elegant developmental process – but sometimes things go wrong.*
MOLLY'S GILL	
01:27:27 Webmarker pbs.org | Explore the history of your body at pbs.org/innerfish	**And when they do… Your Inner Fish can come out…**

01:27:33 [LAUGHTER]	*Neil: My kids are really good friends with the Richardson's, one day I get an e-mail from Seth, their father, says 'Doctor, my wife's a fish' and I said to myself 'I gotta check this one out!'* *Neil: We're here for the fish.* *Seth: The fish is available, it's fresh. Come right through, I think if you go towards the back.* *Neil: Hey Seth, is this your family album?* *Seth: Yes exactly.*
01:27:59 [LAUGHTER] [COMPUTER WRITING SOUND] [LAUGHTER]	*Neil: So you're a fish? Now first off, if you are, and you're more of a fish than I am, I'm very jealous. So prove it!* *Molly: All right, so, here it is – there's my gill!* *Neil: Right there. So what happens during development is that we all have gill arches, we all develop them. This little pit is a leftover from an ancient gill, and I am incredibly jealous of you Molly because you are more of a fish than I am – we're all fish, but some are more fish than others.* *Molly: That's right, so I just haven't evolved very far.* *Neil: No you're the lucky ones!*
01:28:38 [COMPUTER WRITING SOUND]	*Neil: So what's really cool is when you know palaeontology and embryology… many of the muscles and nerves and bones I'm using to talk to you with right now, and many of the muscles and nerves and bones you're using to hear me right now, correspond to gill structures of fish. We see that in fossils, we see that in embryos, we see that in DNA, and we see that in you!* *Molly: My brother-in-law has webbed feet.* *Neil: I love your family by the way!*
01:29:05	**While features like fish gills have been retooled in our anatomy . . .**
DIRK THE FISHMONGERS	
01:29:10	**Other body parts perform the same job, but end up in different places… like testicles.**
01:29:23 [LAUGHTER]	*Neil: Well we're here to see some gonads.* *Dirk: Okay, well…* *Neil: Fish gonads!*
01:29:29	*Dirk: Dissect this little guy here.* *Neil: Yeah if you pop that bad boy.*

01:29:40	*Neil: Yeah so there you see – there's the heart, there's the liver, gonad is right there. So you know what's funky about these things? Is the gonad is towards the chest, right near the heart… But what's stunning is that you and I, like every other mammal, our gonads started up there and descended down here.* *Dirk: I think they're better where they were, no!* *Neil: Well in some senses they would.*
01:30:00	**Having gonads close to the heart is fine for our cold-blooded fishy relatives… Not so good for warm-blooded mammals.**
01:30:13	**The sperm can't stand the heat… So that's why our testicles have to drop to a cooler place – <u>outside</u> the body.**
01:30:22 [COMPUTER WRITING SOUND]	**When a human embryo develops the gonads start deep in the body – just like they do in a fish - and then descend through the body wall - mirroring evolution**
01:30:35	**But that creates a weak spot <u>in males</u> where our guts can pop through. This leaves us vulnerable to certain kinds of hernias.**
01:30:42 [LAUGHTER]	*You think about why humans have hernias, it's because our testes descend, and as they descend they start up here, they go down into the scrotum and the body wall gets weaker because of that reconfiguration, and so we'll find that you have a weakness in the body wall and in some cases folks get hernias.* *Dirk: That's why fish don't get hernias?* *Neil: That's why fish don't get hernias.*
01:31:02	**Flaws in the human body, like our susceptibility to hernias, remind us that we're all adapted from ancient ancestors.** **We are, every one of us, just a Jerry rigged fish!**
JASON STORY	
[WIND & WATER SOUNDS OF A LITTLE CREEK] **01:31:26**	**In July 2000 we were back in the Arctic for a second season, continuing the search for our elusive fossil.** *Neil: Now we actually stand foot bluff on this level. Let's just stay close*
01:31:40	**We widened our explorations across the region, but we were finding hardly anything, let alone the transitional fossil of our dreams.**
01:31:49	**Then just before we began to pull out, we were suddenly confronted with the real dangers of working in this wilderness.**
01:31:58	*Neil: The team had separated into several different groups – we usually go out in pairs, this is a dangerous place. One pair went down the valley, one went up the valley, we spread apart for the day.*

[TENTION MUSIC] **01:32:19**	*Neil: Two-six, two-six this is Bird Fjord, this is Bird Fjord, over.*
01:32:23 [TENTION MUSIC]	*Neil: We all return to camp at the end of the day – the idea is everybody needs to return back to camp by radio call. It's 7 o'clock when we make our safety check back to the station.*
01:32:36	*And so we're making dinner and we're waiting for the radio call.. 'Hey you guys seen Jason?' 'No I ain't seen Jason, you see Jason?' I said 'I asked you the question, you didn't see Jason?' and all of a sudden it became nobody saw Jason, where's Jason?*
01:32:49 [ZIPPER SOUND]	*Neil: This is our youngest member; we were looking out for him the entire season, and no Jason. I mean my heart was beginning to race, and then I hear footsteps outside the tent, zip zip zip, tent fly opens, there's Jason, his eyes are like globes – 'I said I found it, I found it', 'Jason what did you find, a polar bear, what?'*
01:32:11	*Neil: Every pocket was burgeoning with bones. He goes 'I got these bones', he's laying them out on the table one after the other.*
01:32:19	*It's daylight 24 hours a day so we ran down to Jason's site and we began that night, to crawl it, looking for the layer that was kicking out the bones.*
01:33:33	*Neil: As soon as we came to this bluff here and looked down, we saw why Jason was so excited, because beneath our feet were fossil fish bones – fragments of fossil fish, many of them, thousands of them.*
01:33:33	*It wasn't just one fish it was a whole aquarium, it was different species and it got better! Because as we walked up the hill and we followed that carpet of fossil fragments it stopped. Meaning it likely came from one layer and if we had any luck at all we'd find that layer and see what's inside.*
01:34:03	**It took several weeks, but we eventually located the layer of rock from which the fossil fragments were spilling...** **And then looked for tell-tale signs of bones protruding… in the hope it might lead us to more complete specimens.**
01:34:17	*Neil: You can see this tiniest little white fleck here… that told us stop! Because what we have is that little white fleck shows the structure of a scale.. and if you look carefully – there's clearly a scale at one end.. And once you see that scale on end, you see another piece of bone here… you see another piece of bone here. We're on the layer... So it's just a*

	matter of 'stop!' Now what we are going to do is remove this ice and rubble to expose the layer as a little platform.
01:34:43	**To reach the buried fossils we'd need to mine the rock face… but we were running out of time.** **Once again, our short window of snow-free weather ended.**
01:35:02 [SOUND OF RAIN & SATELLITE PHONE CONVERSATION]	*Radio control: Now you guys are looking for that flight tomorrow? Or were you guys delaying it for the 4th?* *Neil: We got free way.* *Radio control: OK. Roger that.*
01:35:11 [HELICOPTER SOUND]	**We'd have to wait for another summer to dig out our ancient riverbed.**
GENETICS	
01:35:30 [ELECTRONIC MUSIC]	**Back home, a very different kind of scientific adventure was unfolding.**
01:35:36	**A revolution was underway in evolutionary biology—one that would reveal a profound genetic connection between fins and limbs.**
01:35:48	**My lab would play a role in the search but we were part of a much bigger effort.**
[ELECTRONIC TENTION MUSIC] **01:36:07**	**At the forefront of this quest was my colleague Cliff Tabin, a geneticist at Harvard University.**
01:36:15	**Cliff had been focusing on how digits -- like fingers – form. And in his work he relied on chick embryos.**
01:36:27	**For biologists, chicken eggs offer a window into the process of development.**
01:36:32 Lower Thirds: CLIFF TABIN Harvard Medical School	*Cliff: If you take a chick egg and cut a hole in the shell and throw it away you can see the embryo floating on top of the yolk - it's right there, it's accessible.*
01:36:40	*You can start to probe what's important for it to form by removing little bits and saying 'does that disrupt the process?' or by moving tissue from one place to another and say 'what does that do?'*
01:36:53 **GFX –SAUNDERS**	**Cliff was following a long line of scientists using chickens to investigate how limbs develop.**

01:37:01	**In the 1950s John Saunders was one such scientist.**
01:37:06 [SOUND OF HEART BEAT]	**Saunders and his colleagues experimented on chick embryos just a few days old. They focused on little protrusions, called limb buds, from which the wings would eventually emerge.**
01:37:23 [SOUND OF HEART BEAT]	**In one experiment, Saunders took a small patch of cells from one side of a bud . . . and transplanted it to the opposite side to see what would happen.**
01:37:32 [SOUND OF CLOCK RUNNING FAST]	**When he came back a week later -- much to his surprise -- he found that the chick embryo had grown a second set of digits – one a mirror image of the other.**
01:37:42	**That tiny patch of cells was clearly special – somehow it was telling the digits where to form.**
01:37:51	*Cliff: The way that we now think of it is those cells instruct the rest of the limb by making a long-range signal – a beacon that they send out that the other cells see and respond to.*
01:38:03	**The identity of that signal was a great mystery that went unsolved for decades.** **But Cliff had a hunch….** **He and some colleagues suspected that the signal might be a single molecule that came from a single gene.**
FLY GENETICS	
01:38:22	**He based his suspicions on research that was changing how we understand the role of genes in making body parts.** **It was work that had been done with an entirely different animal.**
01:38:35 [BUZZING FLY SOUND]	*NEIL: It's a tiny little creature, it's really small, it breeds very rapidly and that you can study in the laboratory. And it's this. The humble little fruit fly.*
01:38:53	**By studying how fruit flies develop, scientists had made some amazing discoveries.**
01:39:06 [BUZZING FLY SOUND]	**Individual genes can do complex things—like guiding the formation of entire body parts.**
01:39:14	**There was one gene, dubbed hedgehog, that caught Cliff's attention. It stood out because it seemed to send out an organising signal.**

SONIC HEDGEHOG DISCOVERY	
01:39:27	*Cliff: In a fly this signal hedgehog told different cells to do things in a particular order depending on how close they were to the source of the signal.*
01:39:39	**Cliff wondered if a gene like hedgehog might play a similar role in chickens.** **So his team took the fly hedgehog gene, and looked for a match in the chicken.**
01:39:50 [SOUND OF HEART BEAT]	**After months of searching, they found it.** **Then, remarkably, they discovered the gene was active in exactly the same patch of cells identified by Saunders. They dubbed this new gene "Sonic Hedgehog" after the video game character.** **So did sonic hedgehog produce the mysterious signal everyone wanted to find?**
01:40:12	*Cliff: Ultimately we wanted to know whether this gene that we discovered, sonic hedgehog, really is the key signal for making the array of digits in the hand.*
01:40:25	**In a groundbreaking experiment Cliff and his team added a bead containing pure Sonic Hedgehog to the wrong side of the growing limb bud, echoing Saunders' experiments…**
01:40:35	**When he returned a week later he found his chick had two sets of digits just like Saunders' chick.**
01:40:42	**This was a major discovery… S*onic hedgehog,* a single gene, was the source of the signal responsible for generating the pattern of the digits.**
01:40:53	*Cliff: And that really nails it - it meant we had the lynchpin in our hands and could start working out the process in detail*
01:41:01	**It turns out Sonic Hedgehog shapes not just the wings of chickens, but the paws of mice and other animals. And it even shapes our own hands.**

POLYDACTYLY - THE HUBBARDS	
01:41:11 [SOUND OF BALL BOUNCING]	**If you want to see just how important Sonic Hegdehog is to us… Meet the Hubbard family.**
01:41:27	*Neil: Can I count your fingers? Let me see if I can count.* *Neil/Kamani: One, two, three, four, five and six, and six is special!* *Neil: Look at that hand – that is just incredible.*
01:41:41	**Kamani was born with an extra digit on each hand and foot.** *Neil: Squeeze my fingers hard as you can, let me see your grip, no harder than that, you can go way harder!*
01:41:53 [KID PLAYING TALKING IN BACKGROUND]	**Why this happens had long been a mystery…** **It turns out that people like Kamani often have mutations that alter the effect of their *sonic hedgehog* gene.**
01:42:02 [COMPUTER WRITING SOUND]	*Dad: With the condition that Kamani has… I just want to know what's allowing him to be so different?* *Neil: The way our arms and legs originally develop in the womb is they push out of the body as a little bud – so we have four little buds sticking out of us as we're little embryos. Then those buds grow out, and eventually they grow out and they elongate – what you have is a paddle, a big broad paddle.*
01:42:26	**Just as in the chicken limb, sonic hedgehog sends out a signal to shape the pattern of our digits.**
01:42:34	**When it's strong, a pinky forms. And as it weakens – one by one - different fingers are made until we end up with five.** **If we turn down *sonic hedgehog* fewer fingers are made.** **But if we were to increase the effect of *sonic hedgehog* we would get extra fingers… like Kamani's.**
01:42:54	*Cliff: "It's really quite beautiful that something as simple as a single signal moving through the limb could have such a profound and differential effect on digits."*
BACK TO FISH	

01:43:07 Webmarker pbs.org | Discover more about your body traits at pbs.org/innerfish	**We now knew that sonic hedgehog played a powerful role in shaping the limbs of all sorts of four legged animals. So how far back did it go? Could it be a legacy passed down from the earliest fish?** **Back in my lab - that was a question my post doc, Randy Dahn was tackling.**
01:43:29	**Randy was investigating an ancient type of fish - skates - whose embryos grow in a sac called a Mermaid's purse.**
01:43:41 Lower Thirds: RANDALL DAHN University of Chicago	*RANDY - I guess the thing that struck me most when I first opened the skate egg was how shockingly similar that embryo looks to a chicken embryo, a mouse embryo, a human embryo. As an embryologist I should have understood, of course they are going to look similar, but still when you see that you thinking there's 400 million years of evolution that separates me from that embryo and at one stage in my life that was exactly what I looked like.*
01:44:14	**It's clear we have a shared history with fish, but do the genes that shape our hands also shape these skate fins?** **To find out… Randy manipulated the skate embryos like Cliff had done with the chick embryos.** **He put a bead containing the sonic hedgehog molecule on the opposite side of a growing fin bud.**
01:44:35	*And it turns out that Sonic Hedgehog was sufficient to cause a mirror image duplication a second fin to form in the skate.*
01:44:47	**This is exactly what Sonic hedgehog had done in Cliff's chickens.**
01:44:51	*We were absolutely stunned – and you have to remember that this is a skate embryo…* *And what that tells us is that these very basic patterning mechanisms are performing the exact same functions in the skate, in the shark, the chicken in the mouse all the way up to humans…*
01:45:17 [DEEP WATER SOUND]	**We had traced *sonic hedgehog* all the way back to life in ancient oceans.** **A gene that determines the shape of our hands was also shaping the fins of some of our most distant fish relatives.** **Our Inner Fish runs deep.**
ARCTIC - TIKTAALIC DISCOVERY	

[SOUND OF STARTING GENERATOR] **01:45:46**	**But there was still a big mystery to solve…** **How did our fish ancestors make the transition onto land? And what did they look like?**
[SOND OF A DRILL] **01:45:58**	**We were still looking for our elusive fossil, frozen forever, on the brink of this great transition.**
01:46:11	**Each summer we returned to Jason's ancient riverbed to continue excavating.**
01:46:20	**We needed to move lots of rock, to expose the narrow seam containing the fossils…** **But then we'd switch to brushes and dental picks to uncover the delicate fossilized bone.**
01:46:34	*Neil: It's this incredibly funny paradox… We're in this huge landscape, but we're always cramped together… My head's next to Ted's feet… Marcus's head's next to my feet in this tiny little spot..*
01:46:47	**It was in such a tiny corner of this vast landscape – that we finally struck gold.**
01:46:56	*Neil: It was the second week of July in 2004 we were all working in series in this hole. And Steve says 'Hey guys what's this?' Ted and I go running over to see what Steve was referring to – and what we saw was this 'V' here, it was covered with rock and it became very clear that this little 'V' we are seeing is the tip of a snout and that this was the snout of a flat headed fish.*
01:47:27	**We stopped in our tracks –-a flat head was a likely sign of a transitional fish.**
01:47:32	*Neil: Here was the snout of exactly the creature we were looking for and it was sticking out of the rocks so if we had any luck whatsoever the rest of the creature would be encased in the rock.*
01:47:43	**So we dug all the way round the fossil, leaving a chunk of rock that we then encased in plaster…** **We couldn't wait to see what was inside.**

01:47:55 [COMPUTER WRITING SOUND]	*Neil: Ok we get home, we knew we had a flat-headed fish but how much of it did we have? Well then the preparators had to take over. They removed the plaster jackets, and the first thing they did was to etch away at the rock, exposing the front part of the snout. And about a month and a half goes by, and they start to find the orbits, the eye holes, and then we see the shoulder, and then we see the fins, and then we see more and more and more and more until we see pretty much the entire topside of the body.*
01:48:27 [COMPUTER WRITING SOUND]	*Neil: What's really wonderful about this specimen is that we have the head connected to a body, and the body is connected to the fins, so we know that this fin comes from this animal, and we know its size and how it fits together.*
01:48:46	**Later, we found parts of other specimens – and some of these were really big – up to nine feet long.** **The local Inuit people named our fossil - "Tiktaalik" which means large freshwater fish.** **And as we took stock of our discovery, the real excitement began.**
01:49:06 [SLOPPY SOUND OF FISH MOVING]	**Here was an animal Darwin had predicted — a real anatomical mixture. It had some features of fish -- like scales and fins and gills. It also had lungs for breathing air.** **And, to our astonishment, it had a neck – the earliest one like ours ever found.**
01:49:25	**But inside the fins lie the clincher. We see an early version of Owen's one bone, two bones, lotsa bones pattern that we see in our own limbs today. It even had a kind of wrist, the first signs of a link to the human hand.**
01:49:44	**Every time you flex your wrist or shake your head you can thank Tiktaalik and its Devonian cousins adapting to life in these ancient streams.**
01:50:03 [SNAPPING SOUND] **01:50:15**	**Unlike other fish, Tiktaalik could use its neck to watch out for predators – and to hunt smaller prey.** **And because those fins were strong enough to lift its body out of the water – a whole new frontier opened.**
01:50:24	**Over millions of years, the two pairs of fins in fish like Tiktaalik would lead to the two pairs of limbs in every bony animal on earth….** **It's a powerful legacy we can see in our own arms and legs today.**

24. TIKTAALIK'S LIMBS	
01:50:39	*Neil: Well the thing about Tiktaalik, think about this – think about a push-up – what are we doing when we do a push-up? We're using the muscles that are attached to our chest, and attached to the other side of my arm to get the power to raise up, we use our elbows, and there's flexion in the wrist, which is very important because it allows our palm to contact the ground.*
01:51:02	*Neil: Here's the fin of Tiktaalik, and what does it have? It has a massive surface for a connection of muscles that would attach the shoulder to the underside of the upper arm.* *It has evidence of a highly mobile elbow, and it even has a wrist that can flex so that the equivalent of the palm can contact the ground – here's a fish that can do a push-up!*
01:51:28	*Neil: I remember looking at the wrist of Tiktaalik for the first time and at that moment I felt akin to what I felt in the anatomy lab and when I saw the cadaver and it's hand.* *The hand actually defines us in many ways.*
01:51:46 [CLAPPING SOUND]	*When you think about what makes our species unique and special it's having thoughts and being able to make those thoughts real. And the way our thoughts become real is through use of our hand – to build things – to make things.*
01:52:03	**Yet the basic form of this wonderfully complex, quintessentially human piece of anatomy can be traced back to the fins of ancient fish.** **It's an incredible evolutionary story that we can now unravel…**
01:52:20	**When Tiktaalic was first conceived, like every animal that has ever lived, it started as a single cell, which slowly formed into a body.**
01:52:38	**Small buds appeared… And genes like Sonic Hedgehog shaped them into fins.**
01:52:50	**Over millions of years, fins like these evolved into a myriad of forms…** **Like the limb of this early amphibian with eight fingers.**
01:53:03 [WATER BUBBLING SOUND]	**As millions more years passed new variations emerged…**
01:53:08 [WATER BUBBLING SOUND]	**From the clawed limbs of reptiles that would colonize dry land…**

01:53:19 [WATER BUBBLING SOUND]	**To the powerful arms of primates that could traverse through the trees.**
01:53:28	**Until eventually a remarkable piece of anatomy arose that would itself transform the world… The human hand.**
01:53:40	**This history is not just in our bone, flesh and muscle – it's in our DNA.** **And that's what connects us all the way back to our Inner Fish.**
01:53:52	*Neil: Fundamental portions of our own bodies originally came about in fish living in water, and the great transition from life in water to life in land set the stage for a whole new set of anatomical inventions that were themselves to form the core for our own humanity.*
01:54:17 **NEXT TIME TEASE**	**Next time on Your Inner Fish…** *Neil: We're related to egg-layers, we're related to reptiles* **Our skin and hair…** **Our exquisite sense of hearing and our complicated teeth can all be traced to ancestors that walked the Earth over 200 million years ago.** [ROAR] *Neil: Forocious! Look at those teeth. It wasn't messing around!* **It's time to meet Your Inner Reptile.** **Your Inner Fish is brought to you in part by viewers like you. Thank you.**
01:54:47 **VLY**	**YOUR INNER FISH IS BROUGHT TO YOU IN PART BY VIEWERS LIKE YOU. THANK YOU.**
01:54:55 **CREDITS**	
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