Robyn Williams: Time for *The Science Show*. This week it's presented by my partner, Dr Jonica Newby, who was with *Catalyst* for 20 years. The story is one of the most remarkable in years, that mammals, all of them, evolved here in the south. It goes with the recent discoveries that birdsong also evolved here, and giant whales. You see, Australia isn't, as the first Brits believed, a weird, remote afterthought, it's a biological treasure-trove.

Jonica Newby: Every now and again as a science reporter you come across a story that's big. I mean, change our understanding of the entire origin of mammals big, including a whole age of mammals we didn't even know about, all of whom laid eggs.

Tim Flannery: Look, this discovery, it's one of the fundamental discoveries that I've made, I suppose, because what it's revealed is a whole age of mammals that we just didn't know about before. And that's a rare thing. I mean, I don't think I'll see it again in my lifetime.

Kris Helgen: I call it the world of monotremes. And I think the picture that we're seeing is that Australia in particular may be the place of origin, not just for monotremes, but for all other living mammal species.

Jonica Newby: And this story has everything; lost worlds, a who's who of stars of Australian science, a treasure hunt with actual gemstones, dinosaurs, a weird echidnapus, even a camp under the shade of a coolabah tree. And the crazy thing is, none of it might ever have been uncovered if it weren't for Covid.

Act One: Indiana Jones and the Temple of Bones.

We begin our tale on one of those eerily quiet days of the pandemic. It's early 2022, and a rare opportunity between lockdowns when a scientist enters the huge sandstone framed doors of the Australian Museum and traverses the even more hushed than usual corridors on a hunt for treasure. Now, you'd have to say this was one of his more sedate quests. You see, the scientist was one Tim Flannery. You may know him best as a climate advocate or author of books like *The Future Eaters*, but he's also one of the world's foremost paleontological adventurers. He spent his youth in the badlands and backways of Papua New Guinea, searching for undiscovered species. He's the Indiana Jones character, if you like, for the purposes of this story.

Tim Flannery: I've had a bow and arrow pointed at my chest. I've had people plot to kill me for the wrongs of others.

Jonica Newby: Definitely *Raiders of the Lost Ark* vibes.

Tim Flannery: I had an engine blow up on me once. I remember getting out of the plane and just vomiting on the tarmac because it was just so stressful.

Jonica Newby: In between movie-worthy near-death scenes though, he discovered 30-odd new species of mammal.

Tim Flannery: Which is 10% of the island's mammal fauna, which is pretty amazing.

Jonica Newby: Mind you, Tim's friend, mammologist Kris Helgen, who was also in the museum that fateful day, as the new director of research, could give him a run for the Indiana Jones title.

Kris Helgen: I was catching mice at night in a riverbed, and a lioness came up to me, looking straight into me like, okay, maybe this is the end of everything. I've been chased by elephants. I didn't even expect ever to make it to 30.

Jonica Newby: But like Tim, and sometimes even right beside him because Kris was once Tim Flannery's student, Kris has discovered and named dozens of hitherto unknown mammals, even a dire wolf (yes, dire wolves are real), an extinct wolf twice the size of a modern wolf, with a fearsome dentition to match.

Anyway, here they were, two real-life Harrison Ford characters, Covid hits, and they're suddenly confined to Sydney. So, like so many in Covid, they pivoted and hatched a plan to hunt for treasure closer to home, inside their own cupboards in fact, here in the labyrinthine corridors of the Australian Museum.

Now, 22 million specimens are stored here, only a fraction of which have been fully evaluated. So it was a reasonable assumption that they might find something, but not this.

Oh my goodness. It's not a drawer, it's an actual safe.

Tim Flannery: Yeah, it's a pretty old safe.

Jonica Newby: I've been brought by Tim and the museum's curator of palaeontology, Matt McCurry, to the scene of the find.

Tim Flannery: Wow. So that's it. That takes me back.

Jonica Newby: So what are we looking at?

Tim Flannery: This is a collection of opalised jaws that just appeared one day in 2022. During lockdown I came into the museum, and Matt handed me this and said, 'Do you want to have a look at it and see what you make of it?' And each one of them is a little jawbone. You can see there the tooth sockets the teeth would have gone into.

Jonica Newby: These are so beautiful. And they're literally made of gemstones.

Tim Flannery: They are. It's made of opal. So you can see through them. You can see that one there, yeah, look at that, you see there's a paler coloured band there? That's the infill of the dental canal, which in monotremes is very large.

Jonica Newby: Inside a little box in the safe were nine exquisite mammal fossils, all from an opal mining town called Lightning Ridge, all about 100 million years old. So we're talking the age of the dinosaurs. Tim could immediately tell they were monotremes—you know, egg laying mammals—but not what they were. He'd never seen anything like them. The only monotremes alive today are the echidna and the platypus.

Tim Flannery: Well, I was stunned for a moment. I remember opening the box and thinking can this be true? Can this be real? And then I went up to show them to Kris, and asked him what he made of them.

Kris Helgen: Tim came up, and there was an incredible excitement from Tim. And, you know, Tim gets excited about these things, we all do, but look at these things, Jonica, they sparkle and they shine and they're just absolutely gorgeous. And there's just those moments in your career where you stare at something that you can tell this is something that doesn't have

a name, and it's more with these, because these are morphologies, anatomies, that stop you in your tracks, like these aren't just new species, these are new genera, some of these are new families. These are completely different ways to be a mammal.

Jonica Newby: So let's explain exactly what stopped the seasoned treasure hunters in their tracks. Fact one: three of the animals were completely new to science. For context, only three other fossil monotreme species had been found at Lightning Ridge in the previous 100 years. So that box, in one go, doubled the known number of ancient monotremes from there. Fact two: as Kris mentioned, they weren't just new species, some were new families. In total there were now six species of ancient monotreme, of which five represented an entire family.

Kris Helgen: So a mammal family is a big deal. The dogs are a family, all the wolves and foxes and everything, the cats are a family, bears are a family, rhinos are a family, horses are a family.

Jonica Newby: So these monotremes were as different as cats to horses, which meant there had to be way more species of egg laying mammals alive 100 million years ago than just the six they'd found. Now, this is where it gets really good. Fact three: there are no other kinds of mammal from that time period ever found at Lightning Ridge, no marsupials, no placental mammals. Nada. It's egg layers all the way, which suggests there was a time in Australia, back in the age of dinosaurs, when egg laying mammals also ruled. They'd discovered the age of monotremes.

Tim Flannery: Can I tell you what it felt like when I found these things? So as I was gradually putting together in my mind what these nine fragments represented, I felt, my God, we've discovered the equivalent of the Etruscan civilisation. You know, the fossil record of mammals is pretty well known globally now, so to fill a gap that is as big as this is really extremely rare.

Jonica Newby: Kris, your rating?

Kris Helgen: Well, you don't get to name a whole bunch of monotremes very often…

Tim Flannery: No, almost never, Kris.

Kris Helgen: Exactly, I mean, that's an understatement. These incredible egg laying mammals, they're the first offshoot on the mammal tree of life. This is an Australian story. This is a story of evolution going wild into all these different monotreme forms. So how does it rate? Oh, it rates towards the top, because…

Jonica Newby: What, better than the dire wolf?

Kris Helgen: Oh, better than the dire wolf. The dire wolf is just a dog. These are some of the greatest and strangest mammals out there.

Jonica Newby: Well, we're not going to get a better intro than that! Time to meet the fossils.

Tim Flannery: So the most spectacular fossil of them all was this thing we're calling informally echidnapus. It was a jawbone about eight centimetres long, about the size of a modern platypus, but it had five molars in the jaw, and the back of the jaw was very much echidna-like, and the front of the jaw, it looked like it had a beak of some sort, but a very

narrow beak, almost echidna-like again. And yet there were other features of the jaw that were very platypus-like.

Jonica Newby: Part echidna, part platypus; echidnapus. Get it?

Do you have any idea what it was like? I mean, whether it was furry, spiky, what was going on?

Tim Flannery: It had to have been furry, it almost certainly didn't have ears and didn't have whiskers, because none of the living monotremes have those. And it was living in a polar environment, so my guess is it had pretty dense fur and good insulation.

Jonica Newby: 100 million years ago, Australia was much further south and attached to Antarctica in the supercontinent of Gondwana. Lightning Ridge sat at latitude 60 degrees south, which today cuts through Antarctica.

So, polar was cold back then.

Tim Flannery: It was, particularly in winter, 60 degrees south, even during the age of dinosaurs, was chilly.

Jonica Newby: And it's dark a lot.

Tim Flannery: Yeah, exactly.

Jonica Newby: And so do these creatures have big eyes?

Tim Flannery: My guess is they didn't, and that's because they weren't reliant on eyesight for food. These animals had an electrosense, just like platypus, which in a dark environment is far superior to eyes. If you can detect the electrical signals given off by other living things, you can find food without light. That's why platypus close their ears and their eyes as they're foraging for food because they have this superior sense.

Jonica Newby: Wow, because people think of egg laying mammals as somehow primitive, but actually they have these superpowers that we don't have.

Tim Flannery: Yep, and the electrosense is one of the great superpowers. Imagine living in a world where you saw through the electrical emissions given off by other organisms. Just as we're sitting here and I move or I get excited, my electrical emissions are going to change, and you'd be able to see that if you're a monotreme. Isn't that cool?

Jonica Newby: So it's a way of reading almost emotions as well.

Tim Flannery: Yeah, I'm sure they could read fear. That's kind of useful if you're a predator, you know? So yeah, look, it's a very sophisticated sense. Its evolution is probably related to this polar environment, where the challenges of living in a perpetually wet, highly seasonal environment with three months of darkness, you know, eyesight is limited in its value really.

Jonica Newby: Right now I'm feeling quite deprived because we lost that evolutionary sense. It sounds fantastic.

Tim Flannery: Well, it is, it was fantastic. And, you know, monotremes also have a poisonous spur on their back foot, so they're one of the only venomous mammals. They also have very large brains. The frontal part of the brain of echidnas is more convoluted and

complex and large relative to the body size than that of humans. And of course the frontal area is where all of our higher thinking goes on. So, those little beaky faces, they don't give away a lot in terms of what the animal's thinking, but my guess is there's actually a lot going on back there.

I'll tell you though, they get to know people very well, and they've got excellent memories. I remember working with a long-beaked echidna in New Guinea, which I'd actually collected in the field in 1981. I went back in 1990 to the zoo where it was kept, and I was doing some filming, and so I was just standing there waiting for my cue, and I felt this long, slimy thing go into my boot, and it was the echidna putting its beak down into my boot and its tongue was licking my toes. He knew who I was, he was kind of very friendly.

Jonica Newby: What was this, a sign of affection?

Tim Flannery: I believe so.

Jonica Newby: Well, I'd like to interpret it as that, either that or you had ants in your shoes.

Tim Flannery: Well, that's possible, but unlikely.

Jonica Newby: Well, while the echidna's possible ancestor had the beak to be a possibly affectionate, possible bootlicker, it sadly didn't get to keep its affectionate name of echidnapus. So instead it has a splendid new scientific name.

Tim Flannery: It's *Opalios splendens*, the splendid opal animal.

Jonica Newby: We'll meet more of these splendid opal animals later. Meanwhile, I must say I find it a bit ironic that out of all their adventures, one of Tim and Kris's greatest discoveries was just in a little box in their own museum.

Tim Flannery: It's so often the way though, Kris, isn't it. Museums are the best places to look for things.

Kris Helgen: They are the best places, there's so many incredible specimens tucked away waiting for the right set of expertise to come and look.

Jonica Newby: So how on earth did this precious little package, direct from the age of monotremes, end up here? Well, to tell that part of the story, I'm excited because I'm finally getting to visit a place that's long been on my bucket list. I packed up my trusty old Prius, and I'm heading to northwest New South Wales and to the legendary dust and opal town of Lightning Ridge.

This is Act Two of our program: *Westworld*, Aussie style.

My plan is to meet up with palaeontologist Elizabeth Smith, who found most of the fossils way back in the '90s. I want to know how they went missing so long. But I have other questions, like what was life like here 100 million years ago? How did the monotremes get on with the dinosaurs? So many questions. And a lot of driving.

Well, I've been traveling for about nine hours now, and I'm starting to hit the flatlands and rich red earth so typical of our nation's massive heart. And it honestly feels a bit like I'm traveling back in time, like I'm about to visit some fable town full of frontiers folk, eyes

glittering with the gemstone craze of opal fever. I'm kind of expecting everyone to be riding a horse.

An hour later I'm rolling over red gravel and onto the wide streets of the low-slung town of Lightning Ridge. Sadly, not a horse in sight, but there is a certain time warp quality here.

Well, I've been in town for about two minutes, and so far I've seen a young man with an '80s mohawk, an older man with a gold miner's beard, and a woman wearing purple pants.

And that time blurred feeling is about to get worse because before I meet Elizabeth, I've arranged to visit local opal miner Tim Warhurst. I want to know exactly what Elizabeth walked into 30 years ago, and it's a lot more than I expected.

Tim Warhurst: Yeah, that's where I live, here, yeah, in the bush, a couple of caravans, and a bit of tin. I love it.

Jonica Newby: For starters, I thought I was being fanciful about the Wild West, but this honestly feels like a life barely changed since the days of the goldrush. There are no big mining companies here, just bushland dotted with shanty shacks, where people dig their own mines. It's quiet today, but back in the '90s this place was heaving. There were shootouts.

Tim Warhurst: We could hear it, automatic gunfire and everything. Pretty hectic.

Jonica Newby: There were parties.

Tim Warhurst: We were on the piss. Yeah, it was great.

Jonica Newby: And there were 'ratters', a new word for me. Ratters are people who hide in the tunnels and steal your opal, or anything else they can find.

Tim Warhurst: I come here one day and they'd even stolen stole meat out of me freezer and me toilet roll. Cleaned me out. Found out who it was, I went and got it back, with an axe.

Jonica Newby: So are you gonna take me down the mine now?

Tim Warhurst: Yeah, we can go down the mine, for sure.

Jonica Newby: As we walk over to what looks like a ridiculously small hole with a metal ladder sticking out of it, it's doing my head in a bit that 95% of the world's opal comes from Australia, and most of it is mined like this.

Okay, so this hole is a little bit wider than me. All right, here's the ground, 40 foot.

Tim Warhurst: There we go.

Jonica Newby: Wow, look at this.

Tim Warhurst: It's different under here, isn't it.

Jonica Newby: This is white above me, sandstone, shot with pinks and reds. And I can see one, two, three, four, five tunnels leading off.

I've never been in anything like it, literally hand-carved tunnels propped up with tree trunks. Talk about old-school! All of a sudden, I spot my first opal in the wild.

Oh, blue, I can see blue there.

Tim Warhurst: Yep, colour, there it is, yeah, see there's colour there, see? We'll go round the corner and grab a pick. [sound of pickaxe hitting rock] C'mere you bugger. Look at that! [whistles] Baby!

Jonica Newby: Oh wow, yeah, that's that blue-green.

Tim Warhurst: Yeah, nice ay, a nice colour. We'll go and have a look, ay?

Jonica Newby: Let's go. Bring it all!

Tim Warhurst: Let's go. Bring it all, for sure, definitely. You'd make a great mining partner.

Jonica Newby: Yeah, okay, back to the science. Alongside the gems that could make their fortune (or not, most people out here end up making a basic wage), the miners were digging up another kind of treasure.

Butch MacFadden: Yeah, the main thing I'm finding is fossil.

Jonica Newby: This is opal miner Butch MacFadden.

Butch MacFadden: I've had some plesiosaur teeth. I've had dinosaur bones. I've given up looking for million-dollar claims, I can't see that happening to me, but finding the fossils is just as much a thrill for me as finding opal.

Jonica Newby: And this of course is what drew palaeontologist Elizabeth Smith here back into the wild west days of the '90s. She's brought me out to the nearby Coocoran campsite where she lived for a decade.

Elizabeth Smith: This is like coming home. This is where we were living in a couple of caravans here, under these beautiful coolabahs.

Jonica Newby: Elizabeth and her husband were site caretakers, tasked with making sure no one messed with the machines at night, those pesky ratters. They weren't paid, but in return they had the right to speculate the tailings for fossils.

Elizabeth Smith: It was not easy, because dust and storms and rain, but none of that mattered, because there was so much action and so many beautiful things coming out of the ground.

Jonica Newby: Really? Like what?

Elizabeth Smith: Bits of turtles, bits of dinosaurs. I found part of one of the monotreme jaws here, the little one, *Parvopalus*.

Jonica Newby: People tend to focus on the dinosaurs, but why were you so excited about the mammals?

Elizabeth Smith: Because mammal material older than about 55 million years in Australia is incredibly rare and highly significant scientifically.

Jonica Newby: And in the whole ten years Elizabeth was camped here, despite sifting through literally tens of thousands of bits of opal, she only found a handful of mammal fossils. *Opalios*, our new friend the echidnapus, was first discovered by her daughter, Clytie.

Elizabeth Smith: She knew that it was something really exceptional, and I knew too, as soon as I saw it, it was mammal. So we went back to the tailing heap, which was enormous, and we eventually found three other pieces. So, it was incredibly exciting at the time.

Jonica Newby: Did you realise even then how significant it was?

Elizabeth Smith: Absolutely, and those specimens were donated to the Australian Museum way, way back, 2001, something like that, and it took a long time to get them studied.

Jonica Newby: As for the mystery of why they went missing so long? Well, the answer is disappointingly mundane. As can happen with museum collections, scientists have different priorities, the fossils went off site, and despite the best efforts of Elizabeth and a few other palaeontologists, they were only returned to the museum recently, just in time for Tim and Kris to turn on the light and unleash their stories. So that's a perfect cue to jump back to the museum and continue the monotreme introductions.

Tim Flannery: This one is really amazing. We ended up calling this *Dharragarra*, which is the local Aboriginal word for platypus. But this little jawbone here really blew me away, because it is so uncannily similar to what you see in a juvenile living platypus today. They have three molars, and you can see that tiny little stub of a third molar there. You get the same tiny stub of a third molar in juvenile living platypus. It's uncanny that that could remain unchanged for nearly 100 million years.

Jonica Newby: And way back then we were little shrews.

Tim Flannery: Every other mammal living on Earth looked like a rat compared with what there is today. Platypus are the only mammals, I dare say, Kris, that appear to have looked the same 100 million years ago, at least as far as their jaw goes.

Jonica Newby: Wow. And who else do we have here?

Tim Flannery: Well, this one here is…again, this is the mind-stretching one. This is *Parvopalus*. See that beautiful colour? Can you see that flash of green there? That's the only one with precious opal.

Jonica Newby: This is the most gemstone-like.

Tim Flannery: Yeah, it is. This animal would have been the size of a large rat. So it's a monotreme, but it looks more like the sort of morphology you see in terrestrial animals, maybe even small climbing animals.

Jonica Newby: Was it in trees?

Tim Flannery: Maybe. Maybe tree climbing creatures.

Kris Helgen: Maybe darting around. There's a bigger one as well, *Stirtodon*, that's in here somewhere, and there's *Kollikodon*, which is these big crushing molars. So all of these are different ways to be a monotreme, sharing the landscape, they're divvying it up, they're capitalising on different resources. And that's, in part, why we're so excited.

Tim Flannery: And look, the most exciting thing, Kris, of those six different kinds, four of them are known from a single specimen. And what does that tell you?

Kris Helgen: Well, it tells you there's a lot more to find.

Tim Flannery: Exactly, if we keep looking, we'll find more. This is just the beginning of a story of monotreme diversity.

Jonica Newby: So what was life like for these monotremes way back in the age of dinosaurs? I want to paint a picture so vivid we could walk into a TARDIS and step out into that lost world. Luckily, everything we need to know for the trip has been exquisitely preserved in opal, which brings us to act three of our story.

Act Three: Cretaceous Park, or Meet the Neighbours.

Jenni Brammall: I'm actually going to start by showing you *Fostoria*, which is one of the new dinosaur species from Lightning Ridge.

Jonica Newby: Jenni Brammall, another palaeontologist, is director of the Australian Opal Centre at Lightning Ridge, which has the world's largest collection of opalised fossils.

Jenni Brammall: So in this cabinet we're looking at a block of claystone that has grey bones in it. Now, that grey is actually opal, it's common opal or potch, and we're looking at a beautiful tailbone of a dinosaur. It's from the sheepyard fields at Lightning Ridge and has now been published as a new species of iguanodontid dinosaurs.

Jonica Newby: What was he doing? Was he out munching and terrorising other dinosaurs or actually meekly just grazing on the nearest piece of vegetation?

Jenni Brammall: Probably fairly meek, maybe like the cows of the dinosaur world. So it had a sort of a beak-like structure on the end of its face that it would use to pluck leaves, and it stood on its hind legs, it had a long tail, maybe five metres from nose to tip of its tail, so a fair sized animal. And yeah, we know that they were living here in potentially a small herd, it might have been a family group, and that's something really fantastic also about the dinosaur material here is that some of it is from baby dinosaurs.

Jonica Newby: *Fostoria* sounds kind of sweet for a big bugger. Not so this next monotreme neighbour.

Jenni Brammall: This is Lightning Claw. Lightning Claw doesn't have a scientific name yet, but it is a very big megaraptorid dinosaur.

Jonica Newby: How big?

Jenni Brammall: Oh, maybe seven metres long.

Jonica Newby: Are these a dinosaur I should run from?

Jenni Brammall: Definitely, yeah, these are really big bitey buggers. Yep. Yeah, here's a picture of what we think Lightning Claw might have looked like, and you can see it had massively strong hind limbs, short forelimbs. It has these claws on its forelimbs that would have been fatal if they made contact with you. And it had a mouth that was absolutely full of little razor-sharp teeth, each tooth with tiny little cutting serrations down one edge. Awesome animal.

Jonica Newby: Last, but not least (well, a little bit least), the wonderfully named Weewarrasaurus.

Jenni Brammall: Weewarrasaurus is a small ornithopod dinosaur. It was one of the herbivorous plant-eating dinosaurs, but this one was much smaller, probably the size of a Kelpie dog, so they were probably getting around in herds. They would have been pretty cute. I'd like to have one as a pet.

Jonica Newby: Is this why they're called wee-warrasaurus?

Jenni Brammall: No, no, they're named Weewarrasaurus for the Wee Warra opal field where they were found.

Jonica Newby: Alongside all the amazing dinosaurs are just a gobsmacking array of glittering time capsules from the Cretaceous; turtles, freshwater snails, flying pterosaurs, swimming plesiosaurs, crocodiles, sharks and yabbies.

Jenni Brammall: So we're looking at a hemisphere-shaped object. It is glowing, and it is in fact what's called a yabby button. So, freshwater crayfish or yabbies, before they moult they transport minerals from their external skeleton through their body, store the minerals in the buttons, then they moult, then they re-release the minerals from the buttons, and use those same minerals to harden their new shell. So the yabbies here have been recycling the same minerals for at least 100 million years.

Jonica Newby: How fabulous, and it's extraordinary to look at. As I tilt my head this way, it glows in greens and blues, and come back this way and I'm getting into the reds and purples. They change colour depending on where you are.

Jenni Brammall: Yeah, that's one of the wonderful things about opal and precious opal, so opal that has what we call play of colour. It really is a sort of a natural, choreographed miracle juice in a stone, it's just great.

Jonica Newby: Well, thanks to this miracle juice in a stone, we have all the information we need now to jump in the TARDIS, dial it back 100 million years and open the door to the age of monotremes.

Jenni Brammall: We'd have trouble opening the door for a start, because it would be just so heavily vegetated. There would be ferns and horsetails, and around us we would look up and see towering conifers, incredible trees, not unlike today's Bunya pines and Norfolk pines and Wollemi pines.

Tim Flannery: We're standing on a floodplain. The rivers would have been draining the mountains of New Zealand and Antarctica.

Jonica Newby: So the rivers flowed to the middle?

Tim Flannery: Yeah, they did. Antarctica was joined to Australia, and the mountains, say where Kangaroo Island is today, were probably about four kilometres high, with glaciers on them, they would have drained into Central Australia. There were similar mountains probably along what is now New Zealand. And we would have been in that part of Australia where the rivers are starting to slow down, they're coming out to the floodplain. Volcanoes, glaciers, enormous river systems, you know, and in the distance a glimmering inland sea with sea

turtles, and presumably icebergs, we've found evidence for icebergs in South Australia in the inland sea.

Jenni Brammall: We might be by the banks of a beautiful, slow-moving river that was running west towards the Eromanga Sea. We might see little Weewarrasauruses at the edge of the forest, nervously having a pick. We might see Lightning Claw having a drink from the river.

Tim Flannery: Lung fish, pterodactyl-like animals, turtles, crocodiles, but also the monotremes.

Jenni Brammall: We'd need to be very quiet and very still, and we'd probably need to wait for a while, but I'd wait. Hopefully I'd have coffee in my TARDIS, and I would be just sitting and waiting and watching and looking for the monotremes on the riverbanks and perhaps in the water too.

Tim Flannery: In my mind I was standing on that floodplain next to a billabong, seeing a platypus or an ancient platypus in there, imagining echidnapus maybe on the edges of the water, thinking about that pig-size thing, whatever it was, crunching away, maybe on small dinosaurs or whatever else it was eating.

Jonica Newby: It's a crazy thought, isn't it. We imagine prehistoric mammals as dinosaur snacks, but some of the monotremes here are so big and some of the dinosaurs so small, it could easily be the other way around. And of course monotremes had something polar dinosaurs did not; don't forget that amazing electrosense, extremely handy when hunting in the dark.

Tim Flannery: One like a sea otter, maybe foraging for freshwater clams, maybe another little species in the treetops eating insects, maybe another one like a brushtail possum eating maybe small dinosaurs, maybe lizards, maybe something else.

Jonica Newby: And while we're still sitting with our cup of coffee on the banks of a billabong in monotreme world, let's take a moment to consider Dharragarra, the ancient platypus who's finally emerged. He's got teeth. Modern adult platypus do not, though baby platypus have them and lose them. So how, between the Cretaceous and now, did the platypus lose its teeth? Kris Helgen has got this one.

Kris Helgen: An incredible thing is that 100 million years of evolution where we had three molars in that first platypus that we see at Lightning Ridge, those three molars are maintained across that whole evolutionary span until the very, very recent modern platypus, which essentially loses its proper teeth. And possibly, we wonder, you know, does it have to do with the water rat basically disrupting that monopoly.

Jonica Newby: To explain, the water rat, otherwise known as rakali, arrived in Australia just 2 million years ago and became a direct competitor for the aquatic foraging niche. Similar size, similar food, great teeth. So Kris Helgen and Tim postulate that it was the arrival of rakali that caused the platypus to diversify into feeding on small invertebrates, which is better suited to a sort of horny, padded bill.

Kris Helgen: Honestly, I think it's the best explanation. You know, how did the platypus lose its teeth after 100 million years? It met the water rat.

Jonica Newby: So how did this great age of egg-laying mammals end?

Tim Flannery: Well, that's one of the great mysteries. There are several possibilities. One is that when the asteroid hit the planet that killed off the dinosaurs, that it also killed off the monotremes. It's possible that when the marsupials came into Australia 54 million years ago, they out-competed the monotremes. But that's a less convincing hypothesis, because we have one fossil site which dates to the time that the early marsupials came in. There are abundant remains of marsupials there, but we have found no monotremes.

It's also possible that monotremes became totally extinct in Australia with the big meteorite that destroyed the dinosaurs, but that they survived in South America and that they came back into Australia subsequently, at 50-odd million years ago. But we just don't know. And this is why we need more palaeontologists. There's a whole story of our continent out there yet to be revealed.

Jonica Newby: Okay, time to put the coffee down, farewell Cretaceous Park, and head back to the future and home. Now, you might think that's the end of our story. But no, this is where I introduce a surprise fourth act, because, you see, the monotremes weren't the only major discovery Tim and his colleagues made during lockdown, and this one could be even bigger than uncovering a whole age of mammals, because it calls into question the entire story of mammals we've understood to date.

This is Act Four of our program: Mammals: The Origin Story. And to tell it, I'm going to have to jump back in the car and drive frantically in the opposite direction to Gippsland on the Victorian south coast, otherwise known as dinosaur coast. I just have to pick up Tim from Melbourne Airport on the way.

Hey, Tim, hop in.

Tim Flannery: Thank you so much. Great to see you. That was very efficient,

Jonica Newby: Yeah. Well, okay, we're going to Inverloch. We'd better put it in the GPS I think.

I've heard of Victoria's dinosaur coast of course, and its most famous site, Dinosaur Cove. In fact, it was one of the first stories to capture my imagination back as an aspiring young science reporter.

Tom Rich and his wife Patricia Vickers-Rich discovered an absolute trove of dinosaur bones here back in the '80s and '90s, a trove which put Australia and indeed the polar dinosaurs on the world dinosaur stage. What I never knew until now was that way back a young Tim Flannery was in fact instrumental in their discovery.

We're looking out over Bass Strait. There are some beautiful sets of waves coming in actually, I can see a couple of surfers out there, and there are some incredible rock formations. What are we looking at, Tim?

Tim Flannery: See that big rock stack there? That's called Eagle's Nest, and it's quite a landmark.

Jonica Newby: Eagle's Nest is where Australia's first dinosaur bone was discovered by WH Ferguson back in 1901, but then nary another for decades, until the 1970s when teenage Tim Flannery came along, convinced he could be the one to find the next dinosaur.

Tim Flannery: So I'd come down here a couple of times with no luck. But then I met an old geologist, a guy called Rob Glenny, who told me he had a map showing exactly where Ferguson had found that dinosaur bone.

Jonica Newby: That's right, Tim met a man with an actual treasure map.

Tim Flannery: Well, he had the map, Rob opened it up, and there was a big red X marking the spot where the dinosaur bone had been found. So anyway, we scrambled down the slope, couldn't find the X because it was high tide, but we did walk around on the shore platform and my cousin picked up a boulder and there was a dinosaur bone in cross-section in it.

Jonica Newby: No way. So the first stone you pick up is a dinosaur bone?

Tim Flannery: That's right, the first dinosaur bone discovered here for 80-odd years.

Jonica Newby: That was it; every weekend, every chance he got he was down here.

Tim Flannery: We found limb bones of a thing called a hypsilophodon dinosaur, which is an animal about two metres long, kind of the size of a medium sized kangaroo. I found the jawbone of a huge amphibian called a labyrinthodont that was supposed to have been extinct 100 million years earlier. So there were astonishing discoveries.

Jonica Newby: And this is where the grand old man of Australian palaeontology, Dr Tom Rich, comes into the story. Tom was encouraging young Tim, mentoring him, and ultimately taking these initial heady discoveries forward into major excavations here and at Dinosaur Cove on the Otway coast.

Tim Flannery: These sites were really the first sites discovered that gave us a detailed insight into what life was like right near the South Pole during the age of dinosaurs.

Jonica Newby: Because before, I guess, most dinosaur bones came from the northern hemisphere or further north in Australia.

Tim Flannery: Well, that continues to be true today. These sites are very special. They were laid down, these sediments, at 76 degrees south. So if you think about that, at the moment it's kind of in the middle of the Antarctic continent, just kilometres of ice. But back then, even though there was three months of darkness a year, conditions still allowed for plants to grow and even trees to grow, and dinosaurs to live and small mammals to live. So Tom Rich refers to the dinosaurs down here as the dinosaurs of darkness, because they survived three months of darkness each year.

Jonica Newby: These dinosaurs of darkness really turned the orthodoxy of the northern hemisphere being the centre of evolution on its head. Here was a whole new world of dinosaur evolution, some of which may even have originated right here, including triceratops, you know, the ones with the big frills.

Tim Flannery: So it's a tiny little ancestor of the triceratopsians, but it's the oldest triceratopsia known. And again, you know what that tells us is maybe those ceratopsian dinosaurs first evolved in the southern hemisphere.

Jonica Newby: Really? Does that upset a few northern hemisphere palaeontologists?

Tim Flannery: Well, it does, but it really shouldn't, because back in the day, Gondwana was the largest land mass on the planet. It shouldn't really be surprising that a lot of subsequently successful organisms started off on the largest land mass on the planet and spread to the smaller ones.

Jonica Newby: And while I'm absolutely loving the dinosaurs of darkness, they're not the main reason we came here. You see, while Tom Rich is most famous for dinosaurs, what he was really after was the ever-elusive mammals.

Tim Flannery: He was looking for them for ages, 23 years, I think, from when he first arrived to when he found his first mammal from the age of dinosaurs.

Jonica Newby: And what was that mammal?

Tim Flannery: It was the jawbone of a little animal that he called Ausktribosphenos. It's a thing about the size of a rat. What was so surprising about it was the teeth looked amazingly modern. They looked like the sort of thing you might expect to see in a hedgehog's mouth today.

Jonica Newby: This hedgehoggy tooth, which Tom found at nearby Flat Rocks, was no monotreme. It looked like what's called a tribosphenid, hence the name Ausktribosphenos. Now, here's why that's startling. Tribosphenids, which refers to the type of teeth, were a key step in our mammalian line of evolution.

Kris Helgen: These are teeth that interlock really intricately. And what does it allow? It allows the teeth of these mammals to do most of the things we think of today that our teeth do. They can cut and they can grind and they can shear. It's basically this tool kit that we have in our mouths that doesn't just simply move up and down and break something, you know, it can process food.

Jonica Newby: Way back in the Cretaceous, the mammal lineage split in two. One branch gave rise to the monotremes, the other branch gave rise to the tribosphenids, which then split again into placental mammals (that's all of us) and marsupials. In other words, tribosphenids are widely accepted as the ancestors of all modern mammals, bar the monotremes. And here's the kicker; surely modern mammals evolved in the northern hemisphere, right? I mean, that's where all the other tribosphenid fossils were found. That's the standard story we've had for at least 150 years. So what the hell was a 100-million-year-or-so-old tribosphenid mammal doing here in the southern hemisphere, near the South Pole for goodness sake?

Thomas Rich: I'm Thomas Rich. I'm Curator of Vertebrate Palaeontology at Museums Victoria.

Jonica Newby: That's Tom, obviously. He's the other reason we're here in South Gippsland, where Tom lives. Tim simply did not want me to tell this story without him.

Tim Flannery: Tom, you know, I remember when you first told me, it must have been 1989 or thereabouts, that you'd found a mammal at Flat Rocks…

Thomas Rich: Yes.

Tim Flannery: And the excitement in your voice and the fact that this was just no ordinary mammal, it looked like a placental mammal, and I remember when you first published that paper suggesting it was a placental mammal, and the long journey we've had since then. That has been a battle in itself, hasn't it?

Thomas Rich: Oh yes, yeah. I mean, the paper in 1997 when this first one was described was published in *Science*, and there was one northern hemisphere colleague who bought in, and most of the rest of them just sort of shook their heads.

Jonica Newby: Ultimately, this was even more challenging than the idea some dinosaurs may have come from here.

Tim Flannery: Nobody believed him. Other authors came out saying, no, that's just wrong, these are just some bizarre group of animals that have nothing to do with the modern placentals. And it sort of chagrined me a bit that people weren't taking the argument seriously and actually challenging it based on information.

Jonica Newby: And there the idea that we had placental mammals here in the south sat languishing, not really further discussed for decades, until Tim was grounded in 2020 and began looking closer to home for something exciting to do. And this is before he'd found the monotremes, by the way.

Tim Flannery: I thought about the work Tom had done, and I realised that I felt he'd been short changed, that Tom's ideas had not been listened to sufficiently.

Jonica Newby: With time on his hands, Tim decided he'd revisit the implications of Tom's original 1997 paper. And I can see how much this means to Tim; he actually starts tearing up even talking about it.

Tim Flannery: Really it was my tribute to you, Tom, I wanted to do it in a way that gave voice to what you had found.

Jonica Newby: And in the intervening years, two big relevant things had changed. Firstly, in the late '90s and early 2000s, more of these unusual tribosphenid fossils turned up elsewhere in the southern hemisphere. Second, advances in dating technology (that's the fossil kind, not the relationship kind) meant that in 2021, new and more accurate dates were published.

Tim Flannery: So I said to Tom, how about we sit down and try to take a global view of this and where these fossils came from. And as we started to do that, we realised there were similar animals to the placental-like mammals that Tom had described from South America, but dating back 150 million years. There was a jawbone from Madagascar about the same age. There were some teeth from India. And we had fossil evidence for these placental-like mammals 50 million years prior to anything in the northern hemisphere.

Jonica Newby: Was that a shock?

Tim Flannery: It was a shock, yeah.

Jonica Newby: Tim roped in Tom, and Tom's wife Pat who is also a noted palaeontologist, his old friend and expert mammologist Kris, and another colleague Elizabeth Veatch, to put it all together. And their conclusion was big.

Kris Helgen: Southern continents, and Australia in particular, may be the place of origin not just for monotremes, but for all other living mammal species. I think that that split happened down in the southern part of the world, and the monotreme fossil record shows us that, in a way. And the fact that we're starting to get mammal fossils from a variety of places on southern continents that have teeth that look like they're on the path to becoming modern placentals and marsupials, at the earliest point that we see these kinds of teeth, these are key clues that Australia is the fundamental kind of linchpin in the evolution of potentially all the living mammals on Earth.

Jonica Newby: That's huge.

Kris Helgen: It's huge, and it's controversial still.

Jonica Newby: In 2022 their provocative claim was published in a paper entitled *The Gondwanan Origin of Tribosphenida*, and was met with a resounding…

Tim Flannery: There's been resounding silence, I'd say, from our colleagues the northern hemisphere about that.

Thomas Rich: Yeah, the northern hemisphere colleagues are very reluctant to accept the fact that things might have originated in the southern hemisphere and gone north.

Kris Helgen: I think it's just starting to sink in.

Jonica Newby: So you haven't had any pushback yet, nor have you had endorsements.

Kris Helgen: Yeah, I think the aspects of monotremes, these aren't controversial. The other story, tribosphenic mammals, the potential ancestors of the rest of the living animals, marsupials, placentals, still really controversial. And it's been a quiet reception, it might even be an icy reception, but that said, we've only published these papers in 2022, 2023, 2024 and so we are injecting these hypotheses into the literature, and we're doing that on the basis of an evidence base that has only recently emerged, and most of our colleagues in the northern part of the world maybe haven't had a chance to really closely examine that. We may be wrong as well, but there's a lot to think about, and a lot going for this story of a southern origin.

Jonica Newby: They may be wrong. The counter arguments will come, more studies will be done, this hypothesis may be overturned, but for now, it's out there, finally.

So these are big, big, epic findings, an age of monotremes, the origin of all modern mammals coming from the southern hemisphere rather than the north. Do you think it would have happened without Covid?

Tim Flannery: Maybe not. Maybe Covid was that period of grace where we had time to focus in on detail, and I'm certainly grateful for that time.

Jonica Newby: Yeah, I've been thinking about time since I started looking at this story, and what strikes me too is that you've all been alive long enough to see time deliver on the questions that you had about the origins of life.

Tim Flannery: Completely. Look, I remember when I started at the age of 18, working with Tom, we had no mammals in Australia at all from the age of dinosaurs, and we wouldn't have had them for decades after that, you know. So we've lived through a period of enormous illumination of Australia's prehistory. And that illumination has come through the hard work of people like Tom and Kris and I guess the contributions that I've made.

Jonica Newby: Yes, this is a story about time, but also, I've come to realise, so much more. It's about our connections down through the generations.

Kris Helgen: Tim called me on Father's Day, he said, 'Kris, I just…I needed to call you.' And I said, 'Well, I'm glad you did, because I needed to talk to you too.' It's just a special relationship that is just not like any other relationship that I have. I've known Tim essentially since I was a kid, and I wanted to be like Tim, and that helped guide me to where I am and who I am today.

Jonica Newby: What I was thinking about in the last few days is that this story that I'm making, it isn't just a story about the origins of life, but it is a story about life, about a life in science and watching how people can mentor and pass on information and passion between the generations like this together to create something incredible. I find that really moving.

Kris Helgen: I think it is part of how science advances, and it's one of the parts that people might not instinctively think about. They might think of the eureka moments or the hard work.

Jonica Newby: Yeah, because when you think of scientists, what you don't think of is what you're describing, which is love.

Kris Helgen: That's right. When the relationship works and is beautiful, that is a lucky thing, but it is also, I think, part of the rocket fuel of science. When it's there, it can just really drive and inspire anybody. That's rocket fuel.

Jonica Newby: It seems the perfect place to turn off my recorder, and then I turn it back on because Kris has something he urgently wants to tell me about love and its role in the story of mammals.

Kris Helgen: Yeah, I wanted to talk about that concept of love. That concept is fundamental to what it actually means to be a mammal. So you ask someone, what makes a mammal? It boils down to the simplest answer is that a mammal is an animal where the mother feeds its young with milk, and there's that intimate connection that has been the way that any mammal ever born on this planet has survived and thrived. And so whether you are a platypus or whether you are a human being, you are here on the planet because that love sustained you. So what is it to be a mammal? I think it comes down to love.

Jonica Newby: Opalised fossils aren't the only precious gift to have been passed down through the eons, to Kris, to you and to me.

Robyn Williams: That *Science Show* special was written and presented by my partner Dr Jonica Newby, production by Russell Stapleton. But why are the world's opals so abundant in Australia? That's next week. Another stunning story. Yes, Australia is very, very special. I'm Robyn Williams.