Are We Nearly Here Yet?

Dear reader, the introductions are at the end, so you can get on with things. If you want to find outtt about numbers (we deal in big ones here), or analogies (we use a few) or how we know about all these events, then pop right over to chapter 13,

There are a lot of big ideas in this story; times when you will think ‘Erk! I don’t understand that’ or ‘Wha-a-a-at! That’s incredible!’ Where you see a * you can look up an explanation in the notes section.

However, the notes section is not included here. If you are interested in digging deeper, contact me at Richard@BrightonScience.com.

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CHAPTER 1 – The Big Bang and other craziness.

Your story begins before you were born; before your parents were born; before any humans at all were born; before any animals existed; before the Earth, the planets, the stars; before even sound or light, space or time.

14 billion years ago, the Universe appeared, in an explosion of pure energy (*1). Space also appeared; the space the energy filled. And time appeared; the time it took for the energy to fill the space.

But, strangely, not sound or light. They came just a billion years later. (*2)

A tremor rippled through the energy. It wobbled, and divided into a Universe of atoms, called hydrogen.

You were one of those atoms.

> *Good morning, Hydrogen. Welcome to existence!*
>
> *In a little while, you will change, grow and get a new name; then change and grow, and get another new name. And again and again, as you become larger, more complicated, and more like the person reading this now.*
>
> *Which is good, because at the moment you are almost nothing at all. It's really very difficult to fully understand how utterly trivial you are. Hydrogen is the smallest, simplest thing. A million of them could just about stretch across this full stop Ø.* (*3)
>
> Fortunately, there was an awful lot of hydrogen; enough to make a universe.

Up popped Gravity. Gravity alone would build that star-speckled Universe, full galaxies and planets, light, colour and noise. And what did Gravity have to work with? Hydrogen. Nothing but hydrogen, as far as the eye could see. This was going to be a long job.

The bad news: Gravity had no idea what to do. It only had one skill; pulling things together. (*4)

The good news is, that was all the skill it needed. Here's how it worked:

> All stuff has gravity.
>
> The Earth is big; it has a lot of stuff and so a lot of gravity. When you jump in the air the Earth's gravity pulls you back down towards it. (*5)
>
> You are small; you have very little stuff and a very little gravity. When you jump in the air, you <u>do</u> pull the Earth up towards you, but so little (the height of a hydrogen atom) that nobody notices: they just see you being pulled down towards the earth. (*6)
>
> The Moon is much bigger than you. The Earth is attracted towards the Moon, but we don't even see that movement.
>
> But we do notice the sea being pulled up towards the Moon – we call that a high tide.
>
> So, the more stuff, the more gravity. This is a law which can be a problem, as we will see later.

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A hydrogen atom has piffling little stuff, and piffling little gravity. But there was a lot of them. Where they were slightly crowded together, gravity was slightly greater, so they were slightly pulled together. After 1 million years, gravity had made a lump as big as a football. Slow, but steady.

The ball grew ever bigger: as big as a house, then as big as a mountain… a planet… a thousand planets…

Surprisingly, that ball was a perfect sphere. It was round as round could be, in all directions. Why? Because all the atoms were drawn in equally from all directions. For a similar reason, raindrops are round, and so are bubbles. The Universe is full of beauty like this. You can delight in that. Gravity can't: all it can do is pull stuff together.

The more stuff the more gravity. So, unsurprisigly, you were pulled into the ball as well. In there, you found yourself part of a big crowd, a very crowded crowd. The atom next to you was squashed right up against you – harder and harder as more hydrogen was hauled in and gravity increased – so hard that suddenly it was squashed right into you.

You two joined together to become a slightly bigger atom, called helium.

> Hi, Helium! This is your new name for a little while. You are a bit bigger than hydrogen, but not much. Keep with it.

Being one helium is easier than being two hydrogens, so you had a little spare energy. You let it go as a tiny point of light. Around you in the mass, other heliums were being made, and more points of light. All the light added up to a gleam, then a beam, and the ball of hydrogen and helium became a star, and twinkled. (*8)

As your first beam of light travelled out through the darkness, it lit up other clouds of hydrogens and heliums, crowding together to make other stars. That beam of light is still travelling out through the Universe today.

Your star grew bigger and brighter. Gravity grew stronger and stronger, pulling even more atoms in and squashing them together. Soon you were squashed into some more neighbours and became an even bigger atom.

Your new name was Carbon.

Now you were a useful atom.

> Carbon atoms are important, because they are so acrobatic. They can rearrange themselves to make strong things like diamond, soft things like soot, sweet things like sugar; and living things like you.
>
> That diamond-shaped atom of carbon is still inside you today.

Other squashings made other new atoms – Lithium, Berylium, Boron… – much more interesting than plain hydrogen. Things were happening. Chemistry!

I said there was a problem with the law of Gravity. It now became clear: there is no top limit. Adding stuff just adds to the gravity, which means even more stuff gets pulled in; and so it goes, more and more. Your star became too big and too hot. It exploded (*9). The first of many crazy things in your life.

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Unlike the Big Bang, sound and light showed up. This bang was noisy and colourful and hot. It was a thoroughly complete catastrophe. All the atoms were beaten and crushed and ripped apart and smashed together to make even more new atoms. Suddenly you had 91 new aunts and uncles and cousins: Have you heard of Gold? Silver? Oxygen? Iron? 92 different atoms make up the family of stuff we call the ninety-two Elements (*10).

They have got together over the years to make everything, everywhere: stars, earth, air, water, food, homes, animals, friends, neighbours, mums and dads. (*11)

In the explosion, you and your family were flung out into space. But not for long; Gravity hadn't finished with you. It started to pull you in together again. In another billion years you were in another star, then another crazy explosion spun you outwards. Then another. And another.

So it goes, and so it went; chaos and craziness all the way. (*12).

After ten billion years of bouncing round space from catastrophe to catastrophe, you and your Elements were close to another star; this time a small one (*13), which didn't look as if it would explode any time soon, and you were not heading towards it, but spinning around it. Much safer.

All the elements gathered slowly together, pulled in by Gravity, until they formed a ball, big enough to be hot, but too small to explode. That was Earth.

5 billion years ago, Earth cooled enough for life to begin, which it did, quite soon after.

YOU were made, just a few years ago, from that Earth. (*14).

> *Are you nearly here yet?*
>
> *In the ten billion years since the Big Bang you haven't developed very far: you are a single atom of carbon. But you are going to grow much faster from now.*
>
> *You are in the best spot for that: down at the bottom of the sea, near a volcano.*

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CHAPTER 2 – Life

*Earth, our colourful planet; all blue and green and brown and wispy white with clouds! (*1)*

You might think the catastrophes are behind you now, dear Carbon. You might think warmth, water and sunshine would bathe you and your elementary friends, and change you all gently into the present-day You, there among the blue lagoons and soft green ferns.

Think again.

Five billion years ago Earth was still a very hot piece of rock; so hot it was liquid – lava. A drop of lava landing on a rock would melt it in a second. Molten lava and poisonous gases, with asteroids the size of mountains crashing out of the skies, shaking the planet as they plunged into the seas of lava, spouting sky-high fountains of liquid fire that fell hissing back into oceans of boiling acid, where you, little Carbon atom, shook and shook, but stayed in one piece, because you were a strong atom; strong as diamond.

As the Earth cooled over a billion years, a more solid crust formed over the surface (*2), and water lay in gigantic puddles as big as oceans on top of that. Where the crust stuck out of the oceans, that formed the land on which you would walk one day.

But not yet; not for another 4 billion years.

You were deep under water, not far from where two bits of the Earth's crust were pulling apart, revealing the still-melted rock beneath, which was pushing upwards, trying to explode like a volcano. But with three kilometres of water on top pushing down on it, all it could do was boil furiously and send violent spasms through the rocks around it.

You may think this was the worst place to find yourself, that you would fry and melt here: but actually this was excellent: just what was needed to bring you to life.

Firstly, you and the other elements around you had been so cooked and shaken by exploding stars, over billions of years, that sitting on an exploding volcano was a doddle.

Secondly, this was quite a party! When atoms get very hot they often join up to form teams, called molecules. It's quite crazy and very chaotic. Every time they get heated again, they leave their team, find new atoms and make new molecules.

(That's why we cook food: what comes out of the oven is different from what goes in because the heat has made the atoms vibrate, leave their partners and find new ones. They swap and change, all the way through the ingredients.)

Near that volcano all those 92 elements could join up to make many different kinds of molecule.

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For instance: Oxygen could join with Hydrogen to become water, (H_2O); iron could join with oxygen to become rust (FeO); carbon could join with Oxygen to become carbon dioxide (CO_2), and many carbons did this. (*3)

But you didn't; you became part of a really big molecule, made of 40,000 atoms arranged in the shape of two sturdy spirals.

Your new name was DNA.

DNA is a miracle molecule. It is the molecule of life.

You sat there for a little while, in the miracle molecule, surrounded by the hot, broiling stew, and then you broke up.

You might think "Broke up? That's not very miraculous; that's just crazy".

But…

You didn't break apart completely, but just into two. Your two strong spirals each stayed intact, held together by all the carbon atoms, including yours.

This is why DNA was a miracle molecule: It didn't stay forever solid (if it had, then there would be no story), and it didn't completely dissolve (if it had, then the story would be over immediately). It broke into exactly two halves. It wasn't stable, or crazy, it was *half-crazy.* And that made it miraculous.

Because…

One half of you floated into the surrounding soup of molecule pieces, and soon its missing bits were replaced by new ones – it had rebuilt itself.

Meanwhile, the other half floated off somewhere else nearby and replaced its missing bits as well.

So now there were two miracle molecules, where before there had been one:

And that is life.

After half an hour those two DNA molecules (which you will remember were a bit crazy) broke again, and again they rebuilt their other halves. So now there were 4. Half an hour later those broke, and reformed to make 8. Half an hour later there were 16. Then 32. Then 64, then 128…

Doubling in this way, they would have swallowed the entire planet in three and a half days, if they had been allowed. (You are invited to do the maths). (*4).

But they were not allowed. Many, many of your fellow DNA molecules were destroyed in the boiling, acid stew. Fortunately, not you.

In time your strand happened to find itself inside a small soap bubble (*5), which protected you a little. Now you had become the first living cell (*6). When you split apart, half an hour later, both halves kept a bubble wrapped around them. Since then, all DNA has been surrounded by a protective skin.

Your cell grew and divided, but each new cell was slightly different, because the DNA – did I mention? – was a bit crazy: not only did it split in half all the time, but often, when it rebuilt

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itself, some bits were put in the wrong place, and others repeated, or stuck on backwards, or were just lost. (*7)

So the result looked quite similar to its parent, but definitely different, just like you are similar to your parents, but definitely different.

This slightly crazy cell was the mother of all the living things on the planet today, from viruses to pine trees, from duck-billed platypuses to humans. That's you.

Scientists have a special name for you: LUCA - Last Universal Common Ancestor.

Your journey so far may seem pretty miraculous, but your most miraculous quality was that you changed slightly from generation to generation.

And that is evolution.

Are you nearly here yet?

Well, LUCA, you are a lot bigger now – not one atom, but 90 billion, in your soap-bubble cell, with your special carbon atom – your constant companion – tucked away in the middle of your DNA.

What's more, you are now alive.

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CHAPTER 3 – Evolution

*Good morning LUCA. You have to get busy, knitting your atoms (Carbon, Oxygen, Nitrogen, Hydrogen, and a few others) (*1), into useful molecules, growing a bit, dividing into two and carrying on:*

Eat, grow, divide, repeat… eat, grow, divide, repeat…. Life is under way!

Enjoy your fame as the very first living thing, LUCA; and enjoy your name – you won't have it long. You are about to step out on your next adventure.

With all that dividing and doubling in numbers, quite soon there were a lot more LUCAs, each slightly different from the others, of course, because of the slightly crazy way they rebuilt themselves. That's good. From now on your differences were going to get greater, as you all became a planet-sized variety show: plants, fungi, birds, fish, reptiles, mammals... (*2)

Another slightly crazy thing about you was your skin – the bubble that surrounded you – which leaked. This was useful because a lot of what trickled in was food. But weird stuff kept leaking in as well. You would do experiments with the strange molecules: knit them and snip them to make new molecules, then see what they could do when they leaked out again.

Sometimes carbon dioxide leaked out, rather like it leaks out of you now, when you breathe. Other LUCAs nearby were happy with this. They were becoming plants, so they liked carbon dioxide, and sucked it up. They leaked out oxygen, which leaked into you, and you liked that. We have been friends with plants ever since. We do swaps: their oxygen exchanged for our carbon dioxide.

Sometimes your knitting and snipping made acids. What use could that be?

You discovered that acids could be very useful. Here I must warn you that the next few lines may seem a little unpleasant, but I have to tell the truth so, prepare yourselves (and please don't try this at home):

You could eat your neighbours.

Your acid dissolved their skin, so you could suck up the useful molecules inside and turn them into new bits of you. This meant you didn't have to build yourself from raw atoms, you could use ready-made molecules from the meal. (*3)

Your children could do the same of course, and their children… and soon everybody was using this new brilliant trick to help them grow.

(You will notice that this is what all animals do now: we eat, and we are eaten). (*4)

So now all the LUCAs had to evolve thick skins to stop themselves being dissolved by their neighbours on one side, and at the same time try to evolve new ways to eat the neighbours on the other side.

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Soon LUCAs had become so greedy they started eating each other whole, in one gulp, then dissolving them slowly with their acids, inside. (*5)

One day you met a LUCA you had never met before. It was a bit big, but no matter; you swallowed the stranger, just like that.

Immediately, you were full. No need to eat anything else for a while; you could settle down to dissolve your meal, nice and slow, for a day or so.

But the meal refused to be eaten – it would not dissolve. It just sat inside you, looking cross.

You can imagine the conversation:

> “If you stop trying to dissolve me for a moment’, says the meal, ‘we might come to an arrangement.”
>
> “Excuse me”, say you “I am not in the habit of talking to my food. Please sit there quietly while I digest you.”
>
> “Really truly, I could be useful to you. In fact, I already am. Tell me, do you feel a little tingling?’
>
> “Is that you making me tingle like that?”, say you, “If so, could you please stop. I’m becoming very agitated.”
>
> “Precisely. That tingle is caused by my energy, which I am giving to you. That’s what makes you feel so energetic. What <u>you</u> will do for <u>me</u> is feed me and look after me.”
>
> “What! No! This is not what I swallowed you for. I’ll take the energy, but I‘ll dissolve you too, if you don’t mind.”
>
> “Well you can try, but you won’t manage it. You will find you’re stuck with me. Never mind. As a repayment, you will rule the world”. And the cheeky intruder immediately bursts in two, then four, and starts to fill your belly with her children.

You were shocked, but also you felt more alive than ever before. The indigestible truth was you did end up ruling the world. Your ‘meal’ was called Mitochondria, and what they gave you was like what batteries give to torches, mitochondria powered you up; you could eat more, grow bigger faster, and evolve better than all your cousins. And to this day every cell in nearly every animal has hundreds of mitochondria in them. And they all have different DNA to the rest of you, as if they could just pack up and leave at any moment if they felt like it.

So that was a crazy experiment that worked. Here are some more:

A bit later one of your crazy knitting efforts produced a molecule that twitched. It twitched and twitched, and made you twitch.

You moved.

Through the crowd of sleepy LUCAs you twitched. Into the open water you twitched, and as you twitched around, you found food. From now on you wouldn’t have to wait for food to come to you; you could go to the food. You had discovered movement! Later on the twitchy

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molecule evolved into a flagellum, which is like a long whip, that spins like a propeller, and drives the cell around.

You used the flagellum cleverly to find food and keep away from poisons. Here's how: If you were near poison, some would leak in, and make your flagellum agitated; it twitched quickly, which made you dance. You danced in all directions, but the farther away from the poison, the less you danced, so you tended to keep away from the poison.

And if the fragrance of food leaked in, you danced even less. When you were actually next to the food, you danced, as you guessed, not at all. You ate the food. It's not the best way to avoid pain and head toward pleasure, but it is the best way if you haven't got a brain. (*6)

With your clever flagellum you had a new name: Flagellate.

Another crazy, chaotic collection of experiments came up with a molecule that poked your flagellum into life when light hit it. The result? With your ability to smell and to see, which controlling where your flagellum moved you, you could find your way around the ocean pretty well.

From the outside, this looks like being clever; it seems like intelligence. But only a few molecules were involved. We can't call it a brain. Not yet.

Are you nearly here yet?

You are Flagellate. Admittedly you are only a one-celled animal (today, you have 40 trillion cells), but check your talents:

you have a light-sensitive molecule (the makings of an eye!);

a flagellum to move you around (an early fin);

the beginnings of a nose;

mitochondria to make energy;

a defensive skin, to avoid being eaten;

acids to help eat anything that comes close enough;

and of course a strand of DNA with that vital atom of Carbon in it.

You are practically perfect. Surely nothing can possibly go wrong…

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CHAP 4 – Selfish Genes, Generous Genes and You

…and yet, there's still some way to go…

Your new flagellum allowed you to dance away from your home on the submerged volcano and search in new places for food. Life at that time was a huge variety of creatures, but they were lying around on the rocks where they were created, or floating through the water wherever the ocean dragged them.

You and your family danced all around them with your brand new flagellum engines, ducking away from this and hunting down that.

That engine gave you a phenomenal – almost magical - advantage over the others. You needed that advantage: if you didn't beat your neighbours in the race to the food you would starve and die, and then you couldn't make babies. That would be the end of your story.

You were only interested in your own success; utterly selfish (So selfish that, if possible, you would not just beat, but eat all others around you). Life was cruel. It was the survival of the fittest. Chaos made that flagellum. You were going to use it as your passport to paradise.

Chaos, though, had other plans.

One day, you were dancing up through the ocean at the beginning of the day, up to the surface, to find something to eat for breakfast.

Suddenly it became dark. A shadowy form was moving between you and the light. You tried to swim around the shadow, but wherever you went you found this thing in the way. It stretched in all directions. You couldn't swim under it; you couldn't swim over it; you could certainly not swim through it. It was a solid sheet of cells, side by side, floating together as one. If they could have spoken they may have sounded like this – speaking as one, of course:

> Sheet: We are cells just like you. And just like you we used to suck in random chemicals, fiddle about with them crazily, then squeeze out the ones we didn't want. One day we discovered that we were squeezing out sticky slime.
>
> At first we thought that was a disaster, because we kept on sticking together, but then we discovered the good side: if we stick together we protect each other from enemy cells; we all look for food together; so if one of us finds it, we all get fed; and, as you see, we can stop you from getting to the food, so we reach it first. (*1)
>
> You: Hmm. How do you get about? How do you move?
>
> Sheet: We drift with the ocean current, like all the others, looking for food. Sooner or later cells like you bump into us and – oh, that's another good thing – they stick. Then we eat them. Why not swim a little closer and we'll show you.
>
> You (spinning around in tight circles): Do you see this neat flagellum? It's very useful. Do you want it?
>
> Sheet: What can it do?

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You: I'll show you

And you zoomed up to one edge of the sheet and stuck to it, just as they had said you would. As you churned up the water with your flagellum, like a propeller, the sheet started to move slowly upwards towards the light.

Sheet: Interesting! OK, we won't eat you; you might be useful. Stick around.

So you joined the sheet. You shared your DNA with theirs, and they began to grow flagella like you. Now they could swim wherever they wanted; and you became sticky and slimy like them, and got a portion of the food they caught.

Later on you all looped up and became a tube. With flagella on the inside, you and your new friends were now a much better food digester. The flagella worked together to waft food along the tube, where it was dissolved and digested. Some of your cousins were happy like this, and became sponges. (*2)

Your family, though, made another change: you turned half inside-out and half outside-in, with flagella now on both the outside and inside. Those on the inside concentrated on eating breakfast, while those on the outside moved you through the water to find lunch.

You had discovered that being cooperative is better than being selfish. Working together beats working alone.

But if you work together, everyone in that team has to give up some freedoms. Your flagellum had to move to the same beat as all those around you; the direction of travel was decided by everyone, not just you. But never mind; if you all worked well together, you all found the food, and that was the most important thing.

And so began a new era, Multi-celled Life. All around you, cells started to join up and cooperate with each other. And they changed through time, (like that clever flagellum of yours, which evolved into two kinds of tool, the first paddling on the outside, the second wafting food on the inside).

You were no longer the solitary Flagellate; that time was over. Now, working with all the other cells around you, you had become an animal: to be precise, a worm.

Are you nearly here yet?

So, Worm, you may be an ugly, awkward wiggly, gawky smidge of a micro-gut, but you have so many possibilities: you are made of so many cells, with so many special skills. From now on anything is possible.

Before we see what happened to your wormy self, we can learn from the story of another bunch of simple animals.

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CHAPTER 5 – Crazy Experiments

Around the seas today we still have many of the early experiments in cooperation still going on. Here is one example:

PORTUGUESE MAN O'WAR

The Portuguese Man o'war floats around the Indian Ocean, looking for all the world like a saggy balloon (*1). But it is a fearsome, scary beast. Hidden underneath the balloon, just beneath the water's surface, it has three organs (special areas), one for feeding, one for making babies and one for fishing.

The fishing tackle is terrifying. You can be swimming thirty metres distance from it – safe enough, so you think – but still be suddenly and repeatedly stung. How did that happen? The PMoW is trailing slender tentacles behind it, which are peppered with spring-action darts, tipped with special poison. When a fish touches them the darts fire into it. (*2)

The poison does not kill, but paralyses the creature, and then the thread is drawn in slowly, bringing the fish – still alive but powerless – into the body of the beast, to be dissolved and digested at leisure.

No human has been known to die from the sting, though many wished they had, the pain is so bad.

But the PMoW, though it looks like an animal in every way, is NOT an animal – it is a colony of at least four different kinds of animal, each of which has cousins swimming freely in the ocean nearby. How this came about is a story that sounds like an old folk tale, so I will tell it like that.

Once upon a time, many years ago (six hundred and seventy-seven million, two hundred and nineteen thousand, one hundred and seventy-six years ago, to be precise) a flagellate was fishing in the sea. Fisher was very skilful, with a fine, long flagellum that stuck to other creatures, so she could haul them in. But of course, while she was eating the catch she couldn't do any fishing. This, she thought, was a pity.

One of the creatures Fisher caught pleaded with her. "Please don't eat me. I'm sure I can be useful to you."

"That's what they all say", replied Fisher. "What can you do?".

"I love eating. I could do all your eating for you."

"Amazing! That is just what I need. Come, stick by me".

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You are probably thinking this is a rubbish business deal – ‘Release me and I’ll show how grateful I am by eating all your food’ – and yet it turned out to be a huge success, and this is how:

They stuck their bodies together, then drilled a hole between them. Now Fisher could catch food for Eater, then Eater could digest it, and feed Fisher through the hole. Fisher-Eater grew and thrived.

But (there’s always a ‘but’) – but they were so good that they were too good: they started to run out of things to catch. “I’ve fished the sea to death!” said Fisher. “What’s to be done? We’re going to starve!”

“Maybe I can help” came a voice from above. Another animal was floating high over their heads. It looked like a deflated balloon.

“I am a Drifter. I float from place to place. It’s easy because I’m really just a bag of air. It’s a nice, carefree life, though I don’t get much to eat. If I take you with me to new and different seas, with new and different food, will you feed me?”

“Sure”, said Fishy-Eater. They stuck themselves to Drifter, and Drifter-Fisher-Eater spent the next year travelling the world, and eating all the different types of food they found on their journey.

One day, Drifter said, “Y’know, we’re so good at this, there should be more of us. We should make babies and start a family of drifter-fisher-eaters. Do either of you know how to do that?”

“No”, said Fisher

“Anyway we don’t have time”, said Eater, between mouthfuls.

They looked at each other, wondering what to do. Suddenly a new voice spoke; “Did anyone mention babies?”

“Who are you?” Fisher asked the stranger who had suddenly appeared in front of them, “and where did you come from?”

“I came from an egg. Clearly you don’t understand the first thing. Anyway, think I can help. I love making babies. That’s all I want to do. Trouble is, I’m so busy making babies I don’t have a moment to catch food or eat, and I never get a holiday…”

“Say no more,” said Drifter. “Hop on board. You’re hired!”

So Baby-maker hopped on board, and Drifter-Fisher-Eater-Baby-maker set sail.

“Can I make babies straight away, please?” said Baby-maker.

“Of course. But I want them to look like me,” said Fisher

“And me,” said Eater

“And me,” said Drifter.

“Well I can do that, but only if you give me some of your DNA.”

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> So Drifter, Eater and Fisher gave up some of their DNA to Baby-maker, and the children were like all of them. Since then Drifter-Fisher-Eater-Baby-maker has evolved to be the fearsome creature that it is today, known by the much more snazzy name of ‘Portuguese Man o’war’. But Drifter and Fisher and Eater and Baby-maker could never swim free again, like their cousins in the sea outside, because they gave up their DNA to make the Portuguese Man o’war possible.

As complex life took off, all sorts of strange combinations of life were created by the crazed whims of evolution. Many of them live their eccentric lives around us today; so it may seem daft to have eight eyes, or your nose on your feet, or use your ears to see with (*3), but it has worked ok for millions of years, so you can’t argue with that.

Your tube of eaters, movers and sweepers, had some pretty weird adventures before becoming you.

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CHAP 6 – Becoming the best You that you can be.

Your atom of carbon is inside your DNA, inside a cell, inside a tiny, wiggly worm, about as long as a baby's finger, which feeds on particles from the ocean, wafting into one end and being pushed out of the other.

*You are now at the start of a famous period of life on Earth: The Cambrian Explosion. This 'explosion' was not like the earlier ones – volcanoes or stars exploding – this was an explosion of life. (*1)*

In the next 500 million years you will become the controller of the planet, an emperor among emperors, the designer and builder of your own destiny, acrobatic, skilled, clever. With your large brain, inside your large head, you might eventually allow yourself to be a little big-headed, and call yourself 'Homo Sapiens', which is Latin for 'wise human'.

Right now, though, you are Worm; a simple gut; not human; certainly not wise.

And you are in the middle of an explosion of life, remember. There are other worms, blobs and wiggly weirdos, all shapes and sizes, all around you, all trying to get to the food before you. No time for dreams of the future.

Oh dear, Worm, how were you going to get ahead? Well, do you remember that special quirk you had, of evolving? Now it started really making a difference.

By dividing over and over, allowing each copy to be slightly different, so that the better ones made more copies, over and over, you became better and better.

But there was danger: as you floated toward your next meal, how could you be sure you weren't going to be eaten, instead of doing the eating? All sorts of hungry aliens floated around in the waters: there was Windy Peaks, Otto the Boundless, Sidney's Surprise, Weird Warty-teeth, Elusive Fantasy, Peculiar Shrimp (*2); and they were all evolving clever ways to attack and swallow, dissolve or throttle you. You needed to be well equipped with tools and tricks, and fast.

You found a way to speed up evolution – by joining with other animals. You were good at making food, so you found other animals liked your company. You could attract an oxygen sifter, a water filterer, a poison destroyer, a liquid pump, (which would become gills, kidney, liver, heart…) And with others you evolved a thick scaly skin, muscles to help you move, and bones attached to the muscles; fins to help you aim towards your prey and dodge away from enemies; pressure sensor to tell you if something was moving nearby; eyes; a nose; and eventually a brain to make sense of all those senses. In short, you became a Fish. (*3)

Hello, Fish!

You didn't have any teeth! Without teeth you can't really eat food, only suck and lick it to bits. But back then there was no such thing as teeth. You would have to evolve some.

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You used your skin. You had already turned your soft, wormy skin hard and scaly to stop it being eaten by others. It was a small step to make its front scales harder and larger until they could scrape at surfaces like a cheese grater. Snails and slugs still do it, and so do cats. (Get a cat to lick your hand. It's not pleasant!)

The more you scrape, the more you grow. The more you grow, the bigger the scales become. It was small step from there to growing rows of sharp teeth. (*4)

You didn't have a jaw! For real eating you need to get those teeth moving, up and down to cut the food, and from side to side to chew it. You need a jaw.

Evolution can't just magic up a jaw, it must either wait patiently until random changes edge slowly in the right direction, (which was too slow) or it has to use what it already has. Evolution is clever. It found something it could fiddle with and modify – something bony, and nearby.

Down in your chest were your gills, which sucked water in, took out the oxygen, and pumped the water out again (*5). To keep your gills open there were some bones: gill arches. The top pair could be taken and re-purposed (given a new purpose), teeth and muscles added, and after a few million years, hey presto – jaws!

The jaws were in your throat, next to your gills! Wrong! But how were you supposed to know where jaws work best – it was only your first attempt, after all.

Anyway, it was ok: you swallowed the food first, then chewed it as it got to the throat. Actually it's not a bad idea to get your meal parked in your mouth before munching it. Many fish – goldfish, for instance – still do that today.

But there was room for improvement. Slowly Your jaws moved to the front of the face, where they can work better and, as a bonus, look scary.

But what was true for you was true for all the other fish. They all started competing for who could be the most efficient gripper, ripper and chewer; who would develop the biggest, most frightening front end. The evolution of teeth and jaws was a great weapons race between all the fishes in the ocean. Mouths that swallowed food whole, then chewed it up at the back of the throat, teeth that were continuously replaced on a conveyor belt. Dis-jointed jaws that swallowed a whole shoal of fish in one gulp; big teeth, little teeth … Life was cruel; red in tooth and claw. It was a fish eat fish world. (*6)

Every now and then you escaped to the shallow waters near the shore. You must have been amazed, looking out on the dry land, with forests and flowers and trees, and millions of insects. And no fish. A vision of heaven, spotted from hell.

> *Are you nearly here yet?*
>
> *If only you could get onto the land…. Just a little dab of evolution could do it, possibly.*

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CHAPTER 7 – Life on Land

You gently levered yourself out of the water on your fins.

The first thing you noticed was that you were suddenly very heavy. Without the water to support you, gravity pulled you down to the ground.

The second thing you noticed, as you hurried back into the water, was that you couldn't breathe. This was a surprise. Fishes breathe oxygen, and there is more oxygen in the air than there is in water. It should have been easy.

The trouble was in the way your gills worked. They were built for use with water only. Either you were going to have to carry buckets of water around wherever you went, or you would have to evolve a completely new way of breathing.

You looked around your body, and found something interesting. You had a swim bladder, which you filled with air to keep you afloat. This could be tweaked to make a lung. An easy job: it only took a few million years. Also you thickened your fins to give them the strength they needed to crawl, then walk, out of the sea. (*1)

Here on the earth, you were indeed in heaven. Insects were crawling everywhere – as tasty as shellfish, but without the shells (*2). You could get down to eating and eating, with no danger of being eaten by the insects, and every danger of becoming very plump indeed. You changed your name to Tetrapod, because 'tetra-pod' means 'four legs' and that's what you had now.

Guess what, Tetrapod; you were not the only one to have that great idea of leaving the sea. In no time the land was crawling with other tetrapods like you. Some of these rivals were getting bigger – bigger even than their cousins in the sea, and much bigger than ordinary tetrapods like you. They were called Dinosaurs. They grew bigger, and taller, and larger, and vaster, until all the little tetrapods were scurrying around between their toes, trying not to look like a snack. Oh yes, the giant land creatures were doing what the giant sea creatures did: eating small animals like you.

You learned a clever trick to avoid the dinosaurs. Because they didn't like the cold, they couldn't get going in the morning until the sun had warmed them for an hour or so (*3). From mid-morning onwards it was snack time, and they were looking round for tasty tetrapods. But you evolved to sleep during the day, the dangerous day, and be active only during the cold nights and early mornings, when dinosaurs were asleep or dozy.

Your trick was to carry your own heat – using energy to warm yourself up in the cold evenings. You also evolved fur, so you kept the heat in. Everything was going your way at last.

Then, catastrophe!

It's easy to take outer space for granted. You can wonder at the size of it, from horizon to horizon. You can realise that the twinkling stars are actually vast balls of fire, next to which earth is as a grain of sand. Yet they seem comfortingly far away, so you feel you are safely

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far from disaster. But every now and then the odd bit of space debris does come wandering this way.

66,000,000 years ago a block of rock twice the size of Mount Everest did that. Drifting past Earth, it was caught by gravity and pulled faster and faster towards the planet. It crashed into the Gulf of Mexico at fifty times the speed of a bullet. (*4) It smashed through the Earth's crust as if it were a pie crust and flung it into the air, up as far as the edge of space, exposing the molten rock beneath. As the ocean's water flowed into the crater, it was instantly turned to steam and another massive explosion rocked the planet. The cloud of dust and steam darkened the skies all around the Earth, hiding the Sun and bringing the temperature down to freezing. And so it remained for years. Dinosaurs, who had been rulers of the planet for so long, died from the cold in their millions. (*5)

It wasn't the end of life on the planet though. You were lucky: because you had evolved ways to keep warm you could turn disaster into opportunity.

While you had been huddled in hiding from the dinosaurs you had found a way to protect your children: instead of laying eggs and risking them being found and eaten, or perishing in the cold, you held your developing children inside your warm bodies, and 'laid' them when they were quite old (*6), then looked after them for years after that. Tetrapods had a new name now.

Your new name was Mammal (*7).

> *Are you nearly here yet?*
>
> *Species have separated far apart now: plants are very different from fishes, which have very little in common with insects, which have no similarity to lizards, which are quite unlike mammals, which couldn't be further from bacteria. And yet, and yet, they all have remnants of each other (as you will find later, as you look back on your journey)*
>
> *And in one particular you are all the same: you all – in every cell in every living thing on the planet – have a molecule of DNA. And in one of those strands of DNA, in one of your cells, is a carbon atom which has been with you since you were born in a star.*

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CHAPTER 8 – How to Make a Human

> *Not all the dinosaurs died. Crocodiles, lizards and snakes have survived, teeth intact, while you are soft little thing, very like a mouse, and still tasty. A coating of fur is not going to stop one of them crunching you up. What are you going to do now?*

As you sat, very still, hidden by a tree root, you could hear the big hungry lizard on your left, clumping around, looking for you. You could see the tasty dragonfly on your right, flying towards a nearby twig. What to do?

Your new secret weapon was your brain. It gave you a mental map of the area around. You didn't need to move a whisker. If you kept still, nobody would know you were there. Your brain silently worked out a plan: Knowing how fast the big hungry lizard could move, plus how big it was, minus its speed chasing you through a tangle of roots, multiplied by how very quick the dragon fly was, divided by how very close it had just landed, you calculated what to do. Your brain could foresee the future! (*1)

Suddenly you jumped out, caught the dragonfly in your jaws and scurried down below the tree roots with it, leaving Big Hungry to trip up over itself as it careered around the tree after you.

That clever brain was going to be needed, now you were a mammal. Bringing a young, helpless baby into the world was hard work (*2). You had to look after it, as well as yourself. You needed two brains really.

Your brain dutifully grew twice as big, so now it could think for two. Your baby had a big brain too, of course; it had inherited it from you. So as it grew it could think for you, and its brothers and sisters. In no time you had a whole family with linked-up brains.

Everyone looked out for each other. Instead of your eyes and ears checking for danger, there were dozens, peering in all directions.

The grandparents were useful for showing the young pup around the place and pointing out the poisons, the tasty food, the friendly animals and the Big Hungries. And they could remember things from years ago; where to find water if there's a drought, where the best fruit trees grow.

The young ones were useful for trying out new ways, experimenting, being a bit reckless, and finding unexpected improvements. (*3)

You all became linked:

> by sound; special calls and barks, which could connect you over long distances;
>
> by smell – special signal molecules which let everyone know if you were angry, afraid or happy;
>
> and by sight – the ability to look at someone and understand what they were feeling just by watching the way they behaved.

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Twenty heads were definitely better than one.

The ability to understanding one another was helped by the evolution of mirror neurons: Inside the brain of all of us is a kind of parallel brain, which mirrors the actions of others. When you see someone kick a ball, the same ball-kicking nerves fire off in your brain as in theirs. When you see someone bump their head, you 'feel' the pain as well. That 'empathy' is caused by mirror neurons. This links all our brains together as if they are one super-brain.

The whole tribe was almost like a single animal, with many eyes, noses and ears, and the clever result that when one found food, they all got fed.

Your family evolved super-paws, with fingers and thumbs which could work together to do complicated tasks, like fishing out tasty grubs from under the bark of trees (*4). They could find food where other animals could not. These particular mammals were going places!

They were called chimpanzees. You can look at pictures of chimps for a long time and not think that they are your distant cousins. But when you see them behave together, you realise how close we are to them, even though they are not much bigger than a dog. Their paws are so clever that we don't call them 'paws' any longer: like us, they have hands.

When a senior chimp finds a nut, the young ones gather round, hoping for a snack. What they get is a lesson. The nut has a shell, and that has to be removed. The elder chimp finds a stone of the right shape for the task (often, if they find a really splendid one, they carry it with them around the forest). They wedge the nut in a crack in a rock, then hit it at just the right angle with the stone. The shell breaks and there's the snack. The young ones will eat the snack, then go off to experiment with other stones and nuts until they have the same skill as the elder. Everyone is at school, all day.

The chimpanzee is also fit, able to swing through the trees like a gymnast; it can throw things far, fast and accurately; and it's incredibly strong for something so wiry. It is not surprising it's the animal that most looks like us humans. Chimpanzees are our nearest living relative in the animal world. 96% of their DNA is the same as ours.

So now you were on the brink of being a human, inside a chimp, 3 million years ago. At a certain moment you and a few others decided to live on the ground, rather than in trees.

You started to walk on your hind legs.

Your new name was Hominin

(which sounds pretty close to 'human', doesn't it? Not far to go now…).

Walking upright freed your hominin hands to do more complicated things than gripping tree branches. Those branches could be turned into things: bendy ones, like Yew, could be bows, while stiff ones, like Ash could be arrows, and thin Willow withies could be woven into baskets. You could make cunning traps from rocks and tree trunks. Hah! Now you needn't care how many sharp teeth Big Hungry had – you could humble him in a cage!

Your busy hands were always active, bashing stones together till they broke, then playing with the sharp flakes that flew off. And your mind was busy thinking what could be done with that sharpness.

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And so the Stone Age was formed. You and your tribe made lots of things out of stone: hammers, axes, spear heads; and arrowheads for your wooden arrows, fastened in place by string made from the skins of the animals you hunted.

A million years passed, and you were tough, strong, nimble with your fingers, ingenious with your mind and fast on your feet. You lived in Africa. You were ready to travel and explore.

Your name was Human.

> *Are you nearly here yet?*
>
> *Once you were a carbon atom, then you lived in a molecule of DNA, then the DNA lived in a single cell, then the cell lived in an animal, then the animal lived in a family, now the family lives in a tribe. You are human; your tribe is super-human (*5)*

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CHAPTER 9 – All Around the World

90,000 years ago you could run and dance, sing, laugh, love life, be happy, be sad, make tools and weapons, work and play together with your family and tribe. You were eager to have adventures.

Your tribe was growing. Africa was getting crowded, so some of you left and went walk-about around the world. The world is big. Very big. It is hot round the middle, cold at the top and bottom, with much of it either too wet, too dry, too hard, or too steep. Yet your family romped all round it, every nook and cranny, in just 90,000 years, walking and running, galumphing and yomping all the way. How did they do that?

A bit of evolution and a lot of invention; that's what did it.

Evolution tweaked them to fit in everywhere they went. Those travelling up the planet found that there was less sunshine to the north (*1). Sunlight is needed to make vitamin D, which is used by the body to make bones. So they evolved a paler skin, which absorbs sunlight easier. (*2). The ones left in Africa stayed sensibly black, because too much Sun on a pale skin burns you.

Less sunshine also means less warmth. To cope with the colder climate, they invented clothes. (*3)

They also evolved a rounder, plumper body, with a layer of fat under the skin, to keep the warmth in.

Further into the north (and deeper into the cold) at the top of the planet, they invented the igloo, to shelter from the worst weather.

And they evolved, around their eyes, a skin shield to protect them from the cold winds, called an epicanthal fold, which resulted in 'Asian' eyes.

Where there was less food they evolved to be shorter (*4). Where there was more food they evolved to be taller.

They invented cooking to make the most of all the food they found.

They invented language, to share more complicated ideas with their growing tribes.

They also evolved a lower larynx and a more muscular tongue to make the language more colourful.

What happened to the Africans who stayed in Africa? They evolved too. Africa is also big, it's hot nearly everywhere and large parts are dry. Wherever they went, humans found difficulties, which they evolved and invented their way out of.

12,000 years ago there was another explosion.

This time it was your own, special, home-made explosion. A food-filled, energy-packed, flavoursome explosion: Farming.

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All over the planet, everyone invented farming. It started at the same time in completely different places – Africa, the Middle East, China, Indonesia, America, India… and the ideas and inventions spread outwards to eventually cover the globe. (*5)

Now you started to get a grip on nature. You put evolution in the back seat while you took control, with your own, home-made ‘evolution’.

The apple, which had once been a hard, bitter berry in Kazakhstan, was gently led across the plains of Asia, and ‘selectively bred’ as it went, growing larger each year, until it became the ball of crisp juice we know today. Exactly hand-sized. You created that apple! (*6)

It is the same story for all the fruit and vegetables we take for granted today – they started small and hard and bitter; you made them big and soft and sweet.

You did the same with animals, capturing the small, lithe, dangerous buffalos and turning them into placid cows, with huge milk-filled udders, and making sheep almost too woolly to stand up. (*7)

Because you didn’t have to move around the forests, following the food, you could build solid houses, plant your food in your gardens, and graze your swollen, sleepy animals in your fields. (Those dozy animals! You have made them so meek and tame, so thick with meat, so heavy with wool, that they can no longer survive without your help. You have taken their DNA!)

Because this gave you lots of spare time, you could make more children, and keep them healthy, feed them better and make a safe world for them.

And because your new children asked you for food and games and clothes and nick-nacks, you used your spare time to invent these things, creating … what? Creating what you would call ‘civilization’.

And because civilizations are bigger, noisier and much more complicated than tribes, you had to write things down so you didn’t forget them. You invented writing. (*8)

A cacophony of civilisations – Middle Eastern, European, African, Chinese, South American, Indian and more – emerged from different tribes around the world. We know about them because they kindly wrote down everything they did.

Each civilisation started small, with each generation copying what its parents did, but with variations (copying with variations! It works for the evolution of animals; it works for the evolution of societies). This means that they each ended up with their own special styles in language, mythology, architecture, laws, clothing, music and art.

Some of the variations were brilliant new ideas, so they were taken up by the neighbours. The invention of bronze and then iron tools changed farming; so much that they have eras named after them: the Bronze Ages and the iron Age. Steam engines meant more things could be made, faster; the invention of plastic means things can be many sorts and shapes. The invention of the camera changed art. New instruments changed music. New foods changed cookery.

Inside our homes today, electricity lets us control night and day; central heating and air conditioning control our climate; rainfall happens when and where we want it – in the

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shower; we can travel around the World without leaving the sofa, using computers and the internet; when it's time to hunt food, we saunter to the fridge. We do not allow into our houses any dirt, weeds or pests (which are called soil, flowers and wild life when they are outside).

We have become emperors. Julius Caesar in all his glory had less power and wealth than a three-year-old toddler today.

We have conquered the World. We know everything, we can do everything, we eat everything, we fear nothing. Except other humans.

We still have the basic body and brain of a hominin – DNA's evolution is not as fast as the social evolution we have created. What will this mean for the years to come?

You might like to think about it, with your splendid brain. Discuss it with your splendid friends.

My job is done.

Are we nearly here yet?

Yes, you are here; we are all here.

Enjoy the future; it's going to be as exciting as the past.

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CHAPTER 10 – Remains of the past

You have come on quite a ride over the last 4 billion years, and your journey has had more twists and turns in it than the coil of DNA that started it all.

How do you know this is your story? This is a question we asked in the introduction (p***). The proof is inside you. Your story is written right through you. (1)

Evolution is untidy. It is for ever racing forward; there's no time to tidy away yesterday's remains. So long as they don't get in the way of your romping forwards, they can remain. And quite often they become repurposed: they find other jobs to do.

Here's a list, going right back in time:

Tail – Not so very long ago you were a monkey, living in a tree. Quite a lot of that monkey is still hanging around. (*2)

You have a tail, or at least the remains of one. The coccyx is a line of 5 bones at the bottom of your spine, which have clumped together into a little stump. It used to be 20 bones longer, and you used it to hang from tree branches. Not any more.

Grip reflex – When you were a baby monkey, you clung to your mother's furry chest for safety. Since she was often hanging from branches by her tail, swinging between trees, you clung very tightly. Human babies can cling tightly with their tiny hands from the moment they are born. The 'Palmar grasp reflex' is surprisingly strong; now you know why.

Bed Sense – Have you noticed that you turn over when you are asleep? Of course not; you're asleep. You turn the same number of times in each direction. If you didn't keep count unconsciously while you slept, you'd roll out of bed. A tiny corner of your brain is awake, doing the sums while the rest of you sleeps. Your ancestors, who were apes, slept in trees. Rolling out of a tree usually meant you wouldn't be making babies later, if you know what I mean. (*3)

Falling dreams – Many people dream that they are falling, then wake with a jolt. In their sleep they have returned to the ancient branch in the family tree. That jolt may have saved them from falling, back in the past.

The Appendix – This tiny, pointless pocket in between the large and small intestine was used to digest leaves, back when humans were much more vegetarian than they are today. Apes still eat leaves straight off the trees. When we invented cooking, it became easier to digest vegetables, because they get softened in the pot. The appendix, with nothing to do, shrank to the little finger-sized tube it is today.

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Wisdom Teeth – They are at the back of the jaw, hidden in the corner, pointing at the wrong angle, so when you reach ‘the age of wisdom’, at 15-25 years old, they squeeze out past your back teeth and cause misery. Why do they do it?

Blame the brain. When you were an ape you had a bigger jaw, with plenty of room for those teeth. Since then your brain has been growing. One of its clever inventions was cooking, which made food softer and easier to eat. So you didn’t need such a big jaw, nor the muscles to use it. Your jaw became smaller and weaker (though it clung on to its full set of teeth), while the brain expanded into the space, and became larger and smarter. Wisdom teeth really are a sign of your great wisdom. Doesn’t stop them from behaving as if they are stupid though.

Canine teeth – ‘Canis’ is Latin for ‘dog’. The game is up; you have a pair of doggy teeth. They used to be much bigger, and they were used for hooking onto the animals you were hunting, then tearing at their flesh. Nowadays they sit meekly between the cutters (incisors, in front of them) and grinders (molars, behind them), and they do just about nothing.

Goose bumps – You are descended from a mouse. Some of it is still in you. Like all furry animals, mice can puff their fur out when they are cold, to keep a layer of warm air next to their skin. Each hair in their fur has a tiny muscle to do this. Each of your tiny hairs on your arms and legs has a tiny muscle too. You use them when you are cold, even though the hairs are now fiddling small and useless, and all you notice is the muscular bumps.

Hackles. Those same hair muscles operate when you are scared, especially around the shoulders. The tingle you get when frightened is from neck hairs sticking out. When you were an ape, your hairs were longer, and raising them made you look larger, so you could frighten away whoever was scaring you.

Waggly Ears – We can all waggle our ears – there is a full set of muscles around them, called auriculares – but only a few of us have found out how to do it (clue – they are used automatically when you yawn, if you want to discover them). When we were mousy creatures, 60,000,000 years ago, we used them to rotate our ears, so we could listen all round for danger.

Pointy Ears – Our mouse ancestor also had pointy ears, we have a trace of that left, in a tiny bump on the inside of the outer edge of each ear (called Darwin’s tubercle).

Lactose Intolerance. (Some people react badly to milk or dairy produce). When a mammal – a deer, for instance – is feeding her young, she is vulnerable to attack; if a predator

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appears, she and the young will waste valuable seconds while they separate. Because of this, young animals quickly lose their taste for milk and start eating like adults. The natural state for mammals is to be lactose intolerant.

As our species migrated over the past 90,000 years, moving away from the equator, the sunlight became weaker. But we need sunlight on our skin in order to make vitamin D, which helps build bones and muscles (*4). So these humans evolved to like milk, which has vitamin D in it; they are lactose tolerant. Lactose intolerance is normal for people near the equator.

Third Eyelid – When our fish ancestors first emerged from the wet ocean onto the dry land, they kept their eyes wet with a transparent ‘screen washer’ called a plica semi-lunari. Cats, birds, camels, polar bears, seals and aardvarks, among others, have a third eyelid. The remains of ours are clumped around the tear ducts (caruncle) in the corner of each eye.

Hiccups – A long time ago you were fish in the sea, breathing through gills, on the side, and eating through a different tube, though the mouth. This is a sensible way to go about things.

When you emerged onto land and started using you air sac as a lung, you had to swallow food and air through the same tube. You didn’t particularly want to get air in your stomach, and especially particularly you didn’t want food in your lungs.

You evolved the epiglottis, a little flap, to flip between each opening.

Babies have a problem: they want to feed at mum’s breast long and hard, but they have to breathe as well. Sometimes their flipping epiglottis forgets whether they are feeding or breathing, and the result is confusion in the throat, and they sound like a fish out of water.

Gills – When the baby is just beginning to develop in the womb it shows signs of your past which change or disappear before you are born. Gills start to develop when you are just four weeks old, but then the parts are quickly moved away, to become bones in the ear, jaw and throat.

Fins – At the same time as the gill arches, fins appear, just as they did 400 million years ago in your fish ancestor. 100 million years ago, your land-bound ancestor removed the webbing from between the bones and separated them out into fingers. That separation happens to babies in the womb, seven months before they are born. At the bottom of your fingers and toes there is still a small membrane –a web – though not enough to either help you to swim or get in the way of your piano playing. But it’s interesting to think that not only do humans have fins, but fish have fingers.

Flagella – The old flagella, which you had when life first appeared, were given new jobs when you started to form colonies and then complex animals. You still have flagella on

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nearly every cell in the body; (they are now called cilia). They do many things: they move stuff around the pipework of the body – that's how snot gets expelled; they measure the flow of liquids in the kidneys; they are laid out neatly in the ears, like a piano, and vibrate, long ones to low notes and short ones to high notes – that's how you hear. Your cilia are a reminder that you are built from many different kinds of single-celled animals that decided to work together, on a project called You.

Cancer – The community of cells in your body is generally well behaved. To make sure, they are policed by an army of immune cells, who check them regularly. If any seem to be behaving oddly they get eaten, just to be safe. Sometimes a cell decides to return to the way it was 3 billion years ago. Enthusiastically it eats its neighbouring cells, grows, divides, and carries on eating and dividing until it eventually kills the person it lives in. Treating cancers is very difficult, because they do what they did back in the day – they evolve ways to defend themselves and new ways to attack.

Biome – The word 'biome' refers to the fact that most of you isn't actually You, but visiting bacteria. In your gut, digestion of food is done by total strangers. They crowd in there, more different species than in a zoo, and certainly more numerous than zoo animals – over 100 trillion of them – and eat your food.

This is perfectly OK. In fact it's useful, because they break it down to the chemicals your body needs, which then go through the gut wall and get delivered to the parts that needs them.

Altogether about a third of the cells that make up you are not You – they have quite different DNA. They live everywhere, especially your skin, gut, and anywhere that can be reached from outside. You don't notice them because they are very small (about a hundred bacteria could fit into each

Mitochondria – An early visitor (see page ***), mitochondria are your batteries. Every cell has about 100 of them. They have completely different DNA from you, showing that they are independent animals, who hopped on board about 3 billion years ago, and have been an essential part of you ever since. We allow them to stay because they create most of the cells' energy; reason enough to keep them.

Viruses – When DNA first started performing its trick of multiplying over and over, four billion years ago, it was a bit crazy, as we know. (There wouldn't have been evolution without the craziness). So when it broke apart and reformed, it sometimes left bits out. These fragments didn't just lie there – they were fragments of DNA, after all – they started multiplying, like DNA does.

Mostly they were aimless; sometimes they found jobs to do in cells (they are called plasmids); Some of them hitched a lift on the DNA (called transposons), and have been

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hanging on in there since; some small snippets are a nuisance to plants (viroids); and some attack animals: these are viruses.

Viruses are so weird that scientists argue about whether they are actually alive at all, because they can't make copies of themselves: they break into an animal cell and hijack the DNA, forcing it to do the job for them. One cell can produce over a million viruses, which will then find a way to the outside, usually on a cough or sneeze, where they are picked up by other animals. The effect on humans can vary from the common cold, which causes sniffles for a week, to pandemics that bring the whole planet grinding to a halt.

The Seas Within. You are 75% salty water. When you first crawled out of the ocean, you dragged a bag of ocean with you, and you have never been able to live on land without a good supply of it. Inside you, many surfaces are covered with cells which look just like coral polyps, bathed by the salty water that carries their food, just like your ancestors living on the rocks of the Earth's early oceans, 3 billion years ago.

The Stars. Our star, the Sun, is converting hydrogen into helium, and making light as a by-product, in the same way as the star that made you.

The Big Bang. When tuning a radio, you might hear a hissing noise, called 'static'. About 1% of that is the echo of the Big Bang, an explosion which is still going on.

The Universe. And of course we are all made of the basic 92 elements that were created in exploding stars – we are star dust.

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CHAPTER 11 – *E*-volution, *We*-volution, *Me*-volution

To understand how you are linked to the rest of the world, and how hard it is to be yourself when everyone else is so busy being themselves , you need to realise there are three kinds of *thing*-volution.

E-volution

Evolution got us where we are today, by slowly changing our DNA over millions of years, as we adjusted to a planet which was also slowly changing its climate, the shape of its mountains and even the location of its continents.

Evolution gave us the hard-wired stuff – a body this shape, with this many legs and arms, and this size and shape of brain.

Congratulations, evolution: a triumph!

But long, slow Evolution cannot explain how we created the modern world we live in, full of shops and docks, passions and fashions, music and art. That all popped up in just a few thousand years.

There is another evolution at work on us all, much faster and closer.

We-volution

As well as our hard-wired DNA, we have that flexi-DNA which helped us and our family, friends and neighbours create the culture we inhabit: language, laws, customs, habits, attitudes. No single person made those - everyone made them. I call the process WEvolution, because WE make them still.

Our society keeps WEvolving, as new inventions appear in our homes and streets; new teachers change our lessons; new politicians change our freedoms; new words change our language; new fashions attract our eyes.

We can do all this because, although I have my brain and you have yours and they have theirs, together WE have a super-brain:

> Mirror neurons help us imitate the thoughts of others, so we think like them.
>
> Empathy helps us to share the emotions of others, so we feel like them.
>
> Mimicry helps us imitate the actions of others, so we behave like them.

We do this on a massive scale. With the super-brain ready to solve super-problems, we can think like a nation!

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How Nations Happened:

In the past, nations formed because everyone in the area had to solve a super-problem.

For instance, Egypt 10,000 years ago had a big, wet super-problem: how to control the river Nile, which flowed right through the land, from the mountains in the south to the sea, 800 km in the north.

Between June and October it would fill with water from snow melting in the mountains. Down the valley it overflowed its banks and covered the fields beside its banks with water and fresh, rich soil. Here the farmers grew their crops, harvesting and storing them during the dry season.

Sometimes the waters were low, so farmers higher up the river channelled what they could into their fields, and the farmers down-stream got none. This made them hungry, and angry. They marched up the river to ask for some water from the selfish farmers up-stream.

The selfish farmers upstream said they were not ‘selfish’; they were ‘lucky’, and shouted at the crowd to get off their land.

The unlucky farmers pointed to the river and said it was their river.

The lucky farmers said the river was on their land, so it was theirs.

The unlucky farmers allowed the lucky farmers to claim the river bed and banks, which were on their land, but not the water, which was clearly traveling through, on the way to them downstream…

The river said it belonged to everyone. But everyone had started fighting, and didn’t listen.

So the problems came with the territory.

To avoid fighting and shouting, the people learned to talk and discuss, to share their thoughts and feelings, and in the end to share the water. (*1).

Caring and sharing is what created the great nations of history.

These super-brains of nations shared a lot more than they realised. Without thinking about it, they WEvolved the language they used, the clothes they wore, the ceremonies they went through at birth, marriage and death… deep things, that we used to think were part of our basic evolution; part of our DNA.

We, in our nation, used to think there was no other way to speak, dress or behave except ours, until we discovered other nations with their different ways of doing the same things.

When this first began to happen, a thousand years ago, we would think other societies were wrong, inferior, ignorant, even stupid. Now we understand that they are just different. We’ve all been through the same problems on the same planet over the same few thousand years; we’ve just come out through different doors.

Mevolution –

Another even more rapid evolution causes each of us to change our personal behaviour to fit in with everyone around. I’ll call this MEvolution, because it comes from Me.

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When you are born, you are clearly different from everybody else on the planet. You have your own emotions and wants and attitudes which give you your own very special character.

One thing we all have: Inside every Me is an important discussion going on between two people:

a) a Me, that wants to push to the front, to be noticed, to be respected, to be believed, to be obeyed.

b) a Me that wants to agree with everyone else, to be part of a harmonious crowd, singing the same songs, doing the same things, and believing the same beliefs. (*2)

The two are opposites: one competes, the other cooperates. One agrees to anything, the other looks for things that are wrong. One is argy-bargy, the other is lovey-dovey.

It seems crazy, having two opposite forces in the brain. It looks like a recipe for disaster. But it works.

Here's what it would be like if we didn't have two opposite natures:

a) If everyone disagreed with everyone else, then nothing would get done, and we would all go off in a sulk. If anyone tried to do something, everyone else would say they were doing it wrong, and stop them.

b) But if everyone agreed with everyone else, then things would get done, but they would be the wrong things, because they were not tested properly, and problems were not discovered and pointed out. Why? Because that might upset someone.

What thrives and survives is a community where everyone wants to agree, but keeps testing what they agree about, trying to find something wrong with it. If they can't find anything wrong, they guess that they might, perhaps, be right.

Learning about Evolution will help us understand the past;

understanding WEvolution will help us deal with the present;

dealing with our MEvolution will help us create the future.

While you are here

Why not talk with your parents and grandparents about their journey from childhood to the present; what the world was like when they were young and how different it is now. Then talk with the parents and grandparents of your neighbour or friends, and see how different their journey from childhood to the present has been.

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CHAPTER 12 – Timeline

If the story of the Universe is mapped out through the words in this book, with the Big Bang at the start of chapter 1, and the present day at the end * of this chapter then, very roughly:

Earth is formed at the beginning of chapter 8.

Life begins by the end of chapter 8.

The Cambrian Explosion (described in chapter 6) begins, on this plan, half way through chapter 11

The dinosaurs become extinct 88 words from the end of this chapter, (at around the * above).

The earliest humans appear 4 words before the end.

And all modern human history, from the moment humans spread out from Africa to the present day, takes place in the last full stop Ø.

CHAPTER 13 - Introductions

Introduction 1 - Truth

Why do we think this book is telling the truth?

Nobody can completely know how the Universe began, or how you started your journey, because nobody was there at the beginning. In fact, humans have been around for only a tiny fraction of the Universe's history.

So how can we tell the story?

For thousands of years people have looked for evidence about what happened in the distant past. (*1)

For instance, a hundred years ago an astronomer called Edwin Hubble thought he could find some clues by looking through his telescope at the stars. This he did every night.

He was using a very big telescope, as big as a train engine. He spent his hours noting the movements of the stars, and looked for any tiny changes from night to night; stars that appeared brighter, or planets that had shifted the tiniest amount from where they should be.

One night, as he looked for these very small things, he suddenly realised something very big; something so huge that he hadn't spotted it before: all the stars are moving away from each other. And we are too: everything in space is flying apart! Edwin's mind was filled with

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one thought: we are in the middle of an explosion – an exploding universe. There must have been a moment in the past when the Universe was all together in one tiny spot – all those trillions of gazillions of stars and planets – and then it exploded outward (*3).

Scientists have worked out this explosion must have been 14 billion years ago. At that moment all the stuff of the Universe burst out of that spot, plus all the space that the stuff was going to occupy, and all the time it was going to take to occupy it. Time, Space and Stuff appeared at the same moment in that Big Bang, and we must have been in there.

That's a big thought. Possibly the biggest thought in the Universe.

The Big Bang theory may be wrong, but at the moment it's the story that best fits the facts.

Introduction 2 - Numbers

We live in a world where everything is easy to deal with so long as it's not too big or too small. If you can see it, you can believe it. But you are about to enter a world where some things are so big, and some so small, it is hard to believe them. We must use some special numbers to describe them

For instance,

'You are made of 10000000000000000000000000000 *bits, called atoms, which are arranged in the most beautiful and mysterious pattern'.*

Looking at that sentence, I would politely point out that the pleasantly poetical 'beautiful and mysterious' idea is ruined by the '10000000000000000000000000000' plonked just above it. What does '10000000000000000000000000000' mean? How do you say it out loud even? It's too big!

Let's see where the number problem begins: have a look below. You'll be able to say the numbers out loud at first

1

10

100

1,000

10,000

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100,000

1,000,000 a million

1,000,000,000. A billion (one thousand millions) is a much, much bigger number than a million. To give an idea, counting a million seconds will take a fortnight; counting a billion seconds will take 32 years.

1,000,000,000,000. A trillion (a million millions) is another huge step. Counting a trillion seconds would take 32,000 years

So 10000000000000000000000000000 becomes… well, first an adjustment:

10,000,000,000,000,000,000,000,000,000 That's better. Putting a comma after each thousand makes it easier to count them.

The number is ten million, billion, trillion

10 000,000, 000,000,000, 000,000,000,000

Ten million billion trillion

So:

'You are made of ten million, billion, trillion bits, called atoms, which are arranged in the most beautiful and mysterious pattern'.

The rough rule of the book is: if typing the word is shorter than typing the 0s, then the word is used. So '100,000' rather than 'hundred thousand', but 'million' rather than 1,000,000, as measured with a ruler.

The rule of life generally, when thinking of a huge, gigantic, number is to use an exciting, imaginary word like 'zillion'. Zillion sounds mighty big, and it works until you use it too much and it loses its power, then you have to increase it to 'gazillion', which is obviously much bigger and more exciting.

A 'googol' is even bigger. It was invented by a mathematician's son in 1930, and means 'ten followed by 100 zeros'. The same child invented the even more gigantic number, 'googolplex' which, he decided, is "one, followed by writing zeros till you get tired".

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Introduction 3 - Analogies

One of the pleasures of explaining science is inventing stories that explain things in a slightly different way. I have tried to do this often, because an analogy is nice break, like a refreshing walk around the park in between difficult jobs. (Oh look; I just did an analogy).

With crazy-big and ridiculous-little numbers, analogies are almost the only way to squeeze a complicated reality into a simple thought.

For instance, if you want to know how many stars there are in our galaxy, you can look it up, and find it's 300,000,000,000 (300 billion). But if you want to get a feel for it, go and count the grains of sand in your local playground sand pit; that's how many stars there are in our galaxy.

Here's how to get a grip on your 10 million, billion, trillion atoms: if they were put side by side in a line, they would stretch to the sun and back well over 8,000 times. That's a big number.

… once you have an idea how far away the Sun is.

The Sun is 8 light-minutes away*.

> And you think:
>
> … "What kind of 'distance' is that!!! *Light* is a kind of stuff; a *minute* is a measure of time. Neither one is a distance!"

A 'light-year' is how far light can travel in a year. Lots of things are so far away that to use miles or kilometres would be futile. Light goes so fast that it can go right round the World in the time it takes you to blink your eyes.

One light year is an eye-popping 9,000,000,000,000 (nine trillion) kilometres. Astronomers deal in thousands of light years. You can see what a strange universe they inhabit.

*For your information, 8 light minutes is 144 million kilometres – the length of 4,700 trips around the World.

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