DEATH ON EARTH

Adventures in Evolution and Mortality

JULES HOWARD

BLOOMSBURY

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DEATH ON EARTH

ADVENTURES IN EVOLUTION AND MORTALITY

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sigma

Contents

INTRODUCTION

Neck ligaments. A cross-section of a trachea. An eyeball. In front of me is a white shelf filled wit cylinders of varying sizes that contain a host of pickled parts. Swollen human hands, bleached spin and knee joints, some sort of sawn-off skull cap, brains in jars. This is not my usual day out. Son body parts are in cylinders, some in Perspex rectangular cubes; all are resting within some unknov embalming fluid that seems to bleach things in just the right nightmarish sort of way.

I walk to the next set of shelves. I stop. I sip my coffee and calmly put it back on its saucer. I realis I am shaking – the teaspoon on my plate starts knocking rhythmically against the coffee cup like I a a tiny alarm clock. I am ringing, and people start to look my way. I try to gather myself. The irony that I am genuinely a bit alarmed by all of this. The room is about the size of two tennis courts – the is a good space in the middle, overlooked by two tiers of metal balconies that loom above us. Th glass ceiling covers the hundred or so attendees to the event in a sepia glaze, as though we're in bizarre lucid dream from which we can't escape. For a century or more this enormous room was a operating theatre; thousands of medical procedures and post-mortems have been undertaken here. An it really was a theatre: the light from above, the balconies in tiers that would once have been home hundreds of students, eager to perfect their science and their future trade. This is a strange place to be

I am attending something called Death Salon, an American movement holding its first event in th UK. It's taking place here, at Barts Pathology Museum, just around the corner from the financi sector of the City of London. According to the blurb on the welcome pack in my hand, Death Salon an event 'that brings together intellectuals and independent thinkers engaged in the exploration of o shared mortality by sharing knowledge and art'. It had sounded really interesting, partly because have always wanted to be an 'independent thinker'. I am pleased to report that I have achieved th aim admirably. Here I am independently thinking about things like tracheae, intestines and tin testicles bobbing up and down in a preservative solution. I am here for three whole days, I realis Three whole days.

I look around at the other attendees – there certainly is quite a mix of punters here, old and young. is the first conference that I have attended for years where the gender bias is very female-heavy. Th is a welcome change. I'm struck by how many young people there are, too – not just studious sort either. The style here isn't exactly preppie. It's something … it's something I've never seen befor

Many of the attendees have a kind of … *mortician chic*. The men have so much style – geek glass are in, as are leather satchels and skinny jeans. Some wear pinstripe suits and trainers. I notice on man wearing bowling shoes and managing, inexplicably, to pull it off. And the women, too. There's a air of burlesque about some: flowing curls, long clinging black dresses and black nail varnish. Mar of them have fringes. Not for the first time in my life, I stick out like a sore thumb. I continu drinking my coffee, my little coffee spoon trilling like my beating heart.

My literary agent Jane was one of the people who had told me about Death Salon, and she's actuall attending. I see her in the front row talking to another of her clients, a kind-looking lady who is here give a presentation about her experiences of grief after the death of her mother. Just as th presentations are beginning I stumble down a row of chairs, heading to one of only a handful of emp ones at the far end. I catch Jane's eye from the back of the room. She gives me a thumbs-up and lool at me gleefully. She mouths the words 'ISN'T THIS WONDERFUL?' from across the room. I give he a slightly saggy thumbs-up back. I find a seat and gather myself. I'm here to write a boo Goddammit. I'm here to begin my journey.

Everyone says not to start work on a book until it's been commissioned. Only now do I realise wh Like Alice, I'm falling into a rabbit hole from which I'm struggling to escape – if the book isn commissioned, this is a journey I will end up making unpaid and my family will, for a few years, ha me for it. Jane and I are still waiting for the green light but, what the hell, I'm starting anyway. Deat life and evolution seems like too interesting a topic to ignore any longer, and hopefully the book wi be commissioned so everything is going to be ok, I think. Jim, my editor at Bloomsbury, has recentl been giving me little supportive messages, but he's deeply worried that the whole death idea won pan out. His normal friendly manner has become edgy of late; I can tell that he's worried that h colleagues won't go for it. One of Jim's concerns is that he doesn't think a book will sell if it ha 'Death' in the title. But he has other worries … One of which is that he doesn't think a book will se if it has the word 'death' on most pages. Jim has warned me that people don't like to think abou death. And that people don't like to buy books about people that think about death. Jim doesn't like when people don't buy books, which is why he's advised throughout NOT TO START THIS BOO until it's green-lit. He's anxious. That's ok, I tell him – this book will be different. I won't be writin a clichéd book about how DEATH IS NATURAL and that THERE'S NOTHING WE CAN DO ABOU IT because people *always* say stuff like this and it's all got a little patronising.

In human terms – well, for me – I hate thinking about death. I hate it. I haven't written a will. haven't got a retirement plan. I have no health insurance. Plus, I have just discovered that I also have surprise suppressed squeamishness about human body parts in flasks of alcohol. But I *love* nature. love evolution and the myriad ways in which natural selection makes and creates things mo incredible even than humans can imagine. I love the diversity. The variety. The varieties. I love th colour, the roles, the niches, the behaviours, the true stories, the magic, the wonder. Surely death plug into these wonders? I had said to Jim. Surely death is the universal thing that awaits all of the things? I had pitched the idea a few weeks ago to him. 'Jim,' I said. 'Jim, there is a story to tell abou the impact that death has had on evolution, and on the niche-filled planet on which we find ourselv in the twenty-first century. I think there are miraculous acts that death imbibes into nature; acts th power it; acts that power its diversity. I want to chart this. I want to chart death's impact on nature an evolution and look at it in the context of our own mortality.'

I have unfinished business with death, after all. In my previous book *Sex on Earth* I had broug together a collection of ideas about sex in the animal kingdom. In the book I felt the world (an particularly some parts of the media) needed to appreciate a wider view of sex in nature, unburden

by human interests about whose penis is larger and which animal can orgasm for the longest. I stoo up for pandas as creatures as fully evolved for sex as anything else. I took on penis-obsessed nev editors, extolling the virtues of studying female reproductive anatomy alongside studies of ma reproduction. I shouted up for mites and slugs and spiders and, I hope, allowed readers to re-evalua their opinions about creatures many would rather step on than sexually appraise. I stood up f diversity. I stood up for sex. But with every story there was a nagging problem that never left me. was simple: animals evolve to become masters of sex but … why don't they evolve to avoid death, to live longer lives? This question was in my mind the whole time. Think about this for a second, you will. Why must everything die? Why can't multicellular life evolve ways to replenish cells f longer, thereby allowing them greater opportunities for sex? Surely genes for such modificatio would flourish, so why is it not something we see more of? Why is death so pervasive in nature? Wh aren't there more immortals, whose genes could theoretically flood gene pools with sexual survivor Questions, questions, questions. We live on a planet where life shares one primary drive: to mak more of itself. After four billion years of evolution the world has filled up with animals that surviv and reproduce ably. But death? Why would *that* persist? Why hasn't natural selection fixed death an filled the world up with immortals? It's not like death happens in one or two genera, or families on th periphery. *Everything dies*, I had thought. Somehow, it powers life and everything we see around u Why? Why is the world like this? Questions, questions, questions.

I'm not totally new to the science of death, by any means. As I mentioned, I have had a deep intere in animal sex for many years, and there are a host of examples where the life principles of sex an death rub comfortably up against one another in such stories. Famous examples include those salmo species that migrate as juveniles from rivers into the ocean, and then return to rivers to spawn, whe they then die. The female spiders (and possibly mantids) that devour their male partners during se The female mites that have evolved not to lay eggs externally, but instead allow their offspring t hatch from eggs within their body and then eat the female from the inside out. The female toads th often drown after being grabbed and wrestled by seven or eight eager males during breeding bout The mayfly species that live as larvae in freshwaters for a year or two yet live for only a matter days as paid-up flying sexual adults. You'll know all of these stories, I'm sure. But these are just fo starters. We all are the product of liaisons between creatures that got sex and death in the corre order. Untold trillions didn't, and untold trillions don't.

But there are other phenomena related to death that appear throughout the zoological literature whi are simply a bit odd and make no immediate sense: tortoises that can survive for centurie caterpillars that, according to some definitions of life and death, die – that become cellular goo with a chrysalis then manage, inexplicably, to reorganise into an animal we call a butterfly. And then ther is the bigger picture: why is it that 99 per cent of species are already extinct? How does dea contribute to life? What does it give us? And what causes cells to age? Can ageing be stopped? Can w live forever? And, would we really want to? This is where the scientific rubs up uncomfortably wi the mortal mind and the modern experience of being an animal in a modern human world. I wonder if I could cross that line and try to understand why, on the whole, we humans are a little bit strang about death.

Researching the sex lives of animals for my previous book, I felt enormously appreciative of th scientists whom I interviewed. Each was making great strides in our understanding of the evolution sex, and many were trying to explain exactly why it is so prevalent across the tree of life. They wante to talk about it. They loved it. But death is equally prevalent across nature and I haven't ever hea anyone, really openly and clearly, explain much about it in zoological terms. It seemed to me to be

part of the biological sciences still kept in the dark – frowned upon, maybe. Ignored. Spooky, perhap
I am drawn to topics like these, it seems … So it seemed like an interesting one for a zoological writ
to explore. We all know death, but less about the science. Nearly all of us will know the shock
death, the awfulness, the suffering and the deep life-changing impact that the death of close fami
and friends (and pets, of course) has on us. But do we talk about the zoological side of death? No, v
don't. So let's give it a go, I said to Jim. Let's do it. And so my journey had started. I was beginnin
even if I was still waiting on the book being commissioned.

Over the three days of Death Salon, something that started out as a slightly ghoulish and macab
experience developed into something totally different – it actually became a place of life. I listened
what living people are legally allowed to do with the dead bodies of their relatives. I heard about t
history of CPR. I learned exactly how organ donation works, and how bodies can be donated
science. I saw graffiti-decorated coffins. I saw my first CT scan of an autopsy. I sat there, agog,
someone took off all of her clothes and we were asked to draw her holding a golden skull, h
memento mori. I saw a virtual human autopsy. At one point a man stood up to tell us about a miniatu
railway he'd built with a toy-town cemetery, and how each tiny plastic ghost had been carefully teas
off a job lot of novelty Halloween earrings he'd bought at Claire's Accessories. I saw people smilin
and laughing and laughing – yes laughing, having fun – in the face of death. But over those three da
at the conference I was always an observer; a bit of a loner who was sat quietly in the corner. Dea
Salon opened up my eyes to human death, yet no one, in the three days of the conference, mention
biology. My world – of science, of life, of evolution – was barely mentioned. I found this rath
strange. Death, as we know it, is a biological condition; it's that *other* whirring cog in natur
selection's clock.

What follows in this book is my attempt at unravelling the many complicated threads surroundi
biological death. The word 'journey' in popular science is pretty much the most overused descriptiv
going, and so I can only apologise about this. But this book really did become a journey – a journey,
hope, as life-affirming as it gets. It's a journey without taboos or (I hope) clichés. A journey guided b
science at (almost) all times. A journey through the minds of the scientists that study it. And a stud
of the great merry(ish) journey that all life must take, from birth, to sex, to death and back in son
other earthly form that is probably, at some point, going to be worm-like. And, predictably, it was
journey that almost killed me … Thank goodness (and Jim) it got commissioned. Thank goodne
(and Jim) I got back from where it took me. Whether anyone chooses to read it is, of course, anoth
story. But thanks, at least, for getting this far.

PART ONE

THIS IS A DEAD FROG

CHAPTER ONE

Life and Death in the Universe

What is life? thought Erwin Schrödinger. The answer was simple: it was something to fill his time. subject to write a book about. So he did. Though many know him best for cats in boxes (or not), it with life that his ideas first united and then fragmented domains of science. He published *What Life?* in 1944. Based on a series of public lectures at Trinity College in Dublin the year befor Schrödinger's book really was a rare gem: a fairly readable account of the how and why and what life on Earth. Four hundred people attended Schrödinger's original lectures on the subject, eve though they came with a warning that 'the subject-matter was a difficult one … even though th physicist's most dreaded weapon, mathematical deduction, would hardly be utilized.' *What is Life* really was breathtaking, though. Not only did it attempt to reconcile the world of biology with th realms of chemistry and physics, it was also an early contender for first speculating on the existen of an 'aperiodic crystal' that could carry genetic information through the generations in comple configurations of molecules (read: DNA). Among the many things covered in the book, Schröding identified life as perhaps the biggest paradox in the universe. Life just shouldn't occur, he realise Yet it does. He attempted to explain how and why.

Think about the universe. It's chaotic. Mightily chaotic. Suns burn brightly – their energy radiatin off into more loosely organised forms of energy (you and I call this, mostly, heat). Mountains erod Continents split. Complex chemistry, produced under pressure or from lightning that befell plane like ours, falls apart with time. Radioactive particles smash and split. Chaos reigns. It really does. the language of physicists, states drift naturally toward entropy – disorder, chaos, mixed-upnes Allow me to offer an analogy to explain this. The classic analogy of states drifting toward disord involves libraries. Picture yours now … now imagine there were no librarians there. Imagine peop coming and going from the library, taking books and bringing them back, every week or so. Some the books will be put back in the wrong place or will be left haphazardly on tables or on top of th shelves. Give it a few weeks and you'd barely notice a big change, of course. Go back in a yea however, and you will probably start to have trouble finding what you want. There will be gaps in th shelves; some of the books will be stacked horizontally or left on the floor; the astrology books will b muddled up with the astronomy books; the spines of the romantic fiction will be worn; the Malcol

Gladwell books will have all their pages folded. You get the idea. Come back in two years and thing will be even worse. Things will be messy. Five years, worse still. Ten years later? Total chaos. Com back in 200 years and the library will barely be standing. Come back in 500 and there will be nothi of the books but dust. Come back in a million years and the strata will contain nothing but the mu upon which the building stands. And that's if you're lucky. And that's chaos, ladies and gentlemen Without someone (or something) being paid to maintain order, things drift into mixed-upness – that how nearly all things work (it's also a good argument for why we should pay librarians much mo than we currently do).

This understanding of states moving endlessly toward disorder (in a closed system) was first offere up by Newton: it was, famously, his Second Law of Thermodynamics. It explains everything we s out there. Except for in jellyfish. Or hamsters, for that matter. Or worms. Or walruses. Or wallflower Or winkles or white-tailed sea-eagles or, well, you get the idea. For in life, something strange happen Cells don't leak and slop into one another after 10 minutes or 10 hours. Bodies don't just erode an fall apart and become functionless everywhere one looks. They are complex. And they remain s throughout life. Their patterns and make-up are the antithesis of disorder. Bodies are honed machine and they work. They remain, throughout life, ordered. Unrotten. And this is rather strange when yo think about it, because so few other things in the universe manage this.

'How does the living organism avoid decay?' This is the question Schrödinger attempted to tackle *What is Life?* And the answer, he realised, is that it pays. To temporarily avoid death throughout the life, animals must pay. They must invest energy. In this respect, their cells and cell processes are lik career librarians, holding back the chaos. Pushing against inevitability. Eventually the cost wi become too high and they cease to be, of course – they die. Disorder whirls out from their organise bodies, much of which is recycled back into order within the life of others on Earth. But there is mo even to life than this, Schrödinger realised. Far from it being a freakish unexpected one-off in th universe and flying in the face of Newton's Second Law, physicists like Schrödinger realised tha there was a certain inevitability to life. For there is a universal quirk of animals which many of us tak for granted: we take energy from the sun (albeit by eating plants that have taken energy from the su or animals that have eaten plants) and we produce heat. We make a highly disordered form of energ (heat) from an ordered one (light). We are part of the chaos, in other words – as well as paying th universe for the thrill of living, we also help maintain its universal tendency toward chaos. We f right in. As absurd as it sounds, you and I are nothing more than heat pumps (though some pump mo heat than others).

So, life plays by the rules. Life emerges because … well, because it can. It fits into the universe way of behaving; it emerges because it fulfils a natural universal tendency toward an overall increa in entropy, essentially. Schrödinger's explanation was a good one. And like all good explanations, has stuck around precisely because it has proved so hard an argument to better. One assumes that a life across the universe will obey this fundamental law; that life can be defined by its energetics. S that's it. All finished. We've defined life. That's that done then, right? Well, no. For there are othe definitions of life, and there are other definitions of death. And it is with these definitions that m journey begins.

A grandfather stands with his five-year-old grandson in the busy canteen of one of the world's fine natural history museums. He faces a dilemma. The queue for the cafe is very long and it'll take hi

ages to get served. He can't stand around with a grumpy five-year-old for 15 minutes, he thinks. B
he needs a coffee, desperately. What should he do? He thinks. He considers his options. And then h
makes a decision. He does something no one else does in modern times: he looks around the tables
the busy canteen for people who look friendly and caring and who definitely won't take his your
grandchild off in a van if he asks to leave him with them. He scans the room. Who looks trustworthy
There are older people scattered in little groups talking to one another. Not them, he thinks. There is
small group of students. Not them either. A lady on her own reading a book? No, not her. And then h
sees them. There are two people animatedly discussing something, talking very deeply and lookin
very intensely at one another while one of them scribbles things in a notebook. One – a woman –
friendly and talking passionately. The other – a man – is furrowing his brow and keeps looking up
the ceiling while scratching his chin pretentiously. Those people are us.

Perfect, the older gentleman thinks, for reasons I now struggle to comprehend. He walks over to
with his young grandchild in tow. 'Excuse me,' he says with slight reticence. 'Excuse me, but woul
you take my grandchild while I go and queue?' He rethinks the wording of his sentence. 'Will you
look after my grandchild while I get a coffee?' 'Oh …' we say. 'I'll be right over there,' he says. H
points at the coffee bar. We have been chosen. We are trustworthy. It's quite a nice feeling. We smile
a little nervously. 'Erm, yes … sure, ok …' says Louisa, smiling politely. 'I'm only round the corner
says the gentleman. 'Just in the queue for a coffee … you know, it'll be fine.' He makes it sound lik
the most normal thing in the world to leave his grandchild with strangers. In some ways it is. Or
was. It's an honour, really; an honour to be chosen for looking like the people least likely to steal th
child. 'Erm, yes, of course, yes,' I say. 'Yes, that's fine. Sure.' The boy sits down, looking a bi
uncomfortable at having to sit with two complete strangers. 'Sit *straight* Harry,' says the grandfathe
'Come on, sit right.' He jiggles Harry about in his chair. The boy shuffles and sits up straight facing
both, still with his eyes locked firmly down at the floor. He looks up at us sheepishly and places h
little hands on the table. The grandfather trundles off to join the back of a very long queue. We bot
look at the young lad. 'Hi,' I say. He says nothing. 'Hi,' says Louisa. He says nothing again. H
doesn't know it yet, but he has just stumbled into one of the weirdest conversations he may ever know
It is about life and death in the universe, and whether this little child might be part of the fir
generation to discover it on a planet other than Earth.

I was sitting with Dr Louisa Preston, a freelance astrobiologist, TED Talk supremo and, well, expe
in lots of impressive things to do with space. I had been introduced to her at a book launch a fe
months before and she'd been one of those interesting people I thought I'd quite like to keep in touc
with for zoological purposes such as this. 'What do you do?' I had asked her at the party. 'Well,
search for life on other planets,' she had replied. Conversations like this do not happen to me ver
often – I felt like I had won some sort of competition. 'What planets?' I'd said meekly. 'Mainl
Mars,' she had said, casually. She told me that she was most famous for using infrared light to exci
leftover organic molecules in rocks, unveiling the tell-tale signs of once-living organisms. She hope
one day to use this technique on the rocks of Mars, to see whether such biomarkers really are or a
not present on planets other than ours. She'd be a perfect place to start the book, I'd thought when w
met. Perfect in a number of ways. Louisa had spent her career considering all forms of life so she'd b
good to talk to about definitions of life and death. Might we expect death on other planets that harbo
life? I wondered. Her perspective on life and death would be so universal (in the truest sense); a wor
away from all the Victorian body parts in jars that I had been forced to politely inspect whilst drinkin
my coffee at Death Salon a few weeks earlier. I emailed her and asked if we might meet in the Natur
History Museum, London. This was, surely, the perfect place for a journey like this to begin. In i

collection are 80 million specimens, and all of them are dead.

We had sat laughing and talking animatedly before Harry, the little boy, had arrived. Louisa ha been very keen that before tackling the big question of 'WHAT IS DEATH IN THE UNIVERSE?' w first discussed what, exactly, the definition of *life* in the universe should be. To Louisa, this was (ar is) the vital bit. The vital question. It was like a palate cleanser before the main course. In fact, ju before we were interrupted by the little boy and his grandfather, Louisa had been trying to question m on whether I believed that a mule was alive or not. 'Of course a mule is alive,' I had said bluntly. 'C course,' she had agreed, smiling wryly. 'But a mule is missing one of the central definitions of li because it is unable to replicate.' 'Oh,' I murmured. 'People say a definition of life is reproduction she continued. 'Well, a mule is sterile. It's not alive.' I gave her a withering and disgruntled 'O DON'T GIVE ME ALL THAT PHILOSOPHICAL CRAP' face, which she read masterfully. 'C'mon, she laughed. 'It's true. One of the classic criteria of life is that it can reproduce, regulate itsel metabolise, grow, move, excrete. Mules can do all of the things on this list, but they can't reproduc So does that make them not alive?'

I gathered myself in the moments Harry, the little boy, was thrust momentarily into our care. H really was going to find this conversation more than a little strange, I realised. Only a minute after h arrival, Louisa had me justifying a long-held belief of mine that my refrigerator is definitely not aliv 'Why not?' she said, clearly enjoying herself at this point. 'Fridges can regulate their temperatur Thermostats respond to changes in the environment in much the same way that a living thing woul By some definitions there are those that would say that your fridge is alive.' I managed to pull a fac that this time said to Louisa 'My fridge is definitely not alive.' Louisa looked puzzled at me, unable t read my face. She continued in this vein for a while, naming other examples of things that some wou justify as alive, but that, like fridges, are definitely not alive. 'And fire!' she laughed. 'Fire's a gre one!' Louisa particularly liked talking about fire, it seemed. I caught the little boy giving us anoth fleeting glance. Louisa didn't notice. His grandfather had barely moved in the long queue. 'In eve sense fire should be a living organism,' she said. 'It grows, it eats, it reproduces, it spreads, regulates itself – lots of its products are maintained within the flame, almost like how cells work. S what makes it not alive?' I waited a few moments, silent, waiting for her to continue. I realised the that she was not being rhetorical. 'Why *is* fire not alive?' I heard myself say. There was some silenc at this point as Louisa waited for an answer. I drew breath, thinking about it a little more … 'A FIR IS … A FIRE IS JUST NOT ALIVE!' I offered up grandly. 'The problem is,' she said. 'when you star down the line of asking about what life is, it's easy to get drawn into the very dangerous realm talking about a *life force*, or a *consciousness*, or a *vital spirit*.' She shook her head. 'That's a mistak we don't want to make.'

Though it was admirably tackled by Schrödinger, he certainly wasn't the first to ask the (im)mort question 'WHAT IS LIFE?' In fact it is arguably one of the oldest and most philosophically wel trodden questions in science. Among the first to discuss it were materialists such as Empedocles (490–430 BC). They argued that life was caused by an exact and appropriate mixture of 'element called earth, water, air and fire (the 'roots of all'). Not long after the materialists came Democritus (460–370 BC), who was among the first to promote the idea of a soul – a kind of manifestation of fie atoms that interact in a certain way to produce what our minds define as 'you' and 'I' – our 'spirit Such ideas were chewed upon further by the French philosopher René Descartes (1596–1650), wh held that animals (including humans) worked more like machines, assemblages of parts that togeth produced an emergent property: something you or I might describe as a life and a soul. Descartes ideas and his more rational approach to the definition of life challenged the fuzzy notion of a soul, c

at least, encouraged discussion of what the notion of 'soul' is and how it might interact with th physical body.

In the centuries that followed other definitions were put forward, including the more recent (ar even more rational) scientific definitions to which Louisa had alluded and that many of us (includin me) remember from biology school: 'MRS GREN'. Many textbooks say that life is defined b Movement, Respiration, Sensitivity, Growth, Reproduction, Excretion and Nutrition (MRS GREN And under the rules of MRS GREN Louisa is right: mules might not be considered truly alive an fridges and fire might be (and please, please, no one ask about viruses – things, it seems, get ver messy indeed when people start asking whether viruses are alive). Overall, when one considers lif one thing is clear. MRS GREN definitions of life are clearly a bit lousy.

'What definition do you work to, then?' I had asked Louisa. Her response was simple. It's the sam as NASA's. 'Life is something that undergoes Darwinian evolution,' she said. So that's what she i searching for: evidence of evolution on planets and moons other than our own. 'How exactly does on search for evolution?' I asked, slightly confused. 'I know. I know,' she laughed. 'For my kind of wor it's a pretty ridiculous definition. I mean, we're hardly going to sit there staring at something th *might* be alive, waiting for it to evolve. How can we test that? We can't really. But it's the best an perhaps most all-encompassing definition we have. So that's what we work with.' And so it stuck. In weird sort of way, though, this definition of life being Darwinian in nature pairs nicely wi Schrödinger's when it comes to life and death. Both life and death are inherently linked to on another, after all. Life is a flamboyant and whacky conveyor belt that ultimately moves thing endlessly from a state of borrowed order toward a state of chaos. And life breeds more life throug Darwinian evolution. 'So if that's your definition of life,' I said to Louisa, 'then what is you definition of death? How do you define death in the universe?' The question hung in the air. There wa a brief pause. Harry squirmed. Louisa thought about it some more. 'I don't know,' she admitted. guess I don't really think about it that often.' This surprised me, a little.

So how can we consider death, exactly? What *is* death? How might we define it? By ploughing in this question we find ourselves, frustratingly, back in that same rats' nest of definitions. Most agre that death describes the state that exists when life … runs out. But I find this too woolly a definitio For instance, for the Victorians a stopped heart meant you were dead. It was as simple as that. But no it doesn't. Because of defibrillators, a stopped heart is only a symptom that can be potentially fixe provided too much time hasn't elapsed. Death hasn't occurred. Another example is with drowning there was a time when a drowned man or woman was considered definitely and most certainly dea but then, once CPR was hit upon, they weren't. In both of these cases death was a term used whe describing something lacking any remaining potential for life. But this isn't fixed or written in stone.

Nowadays we consider death as being a fixed, easy-to-label state, but actually our clinical definitio aren't that much further on from those of the Victorians. Even today occasional medical cases sho that our definitions of death may be wrong and need changing. In the late twentieth century those in vegetative state were still considered by many to be 'brain dead' – yet those in such a condition ca continue to grow and develop, and even give birth. So the term 'brain dead' is clearly not accurate an more, and not appropriate either. Things we consider 'dead' now may not always be so, which is fascinating thought. But allow me to consider this thought experiment with non-human animal Consider those creatures that undergo cryptobiosis, able to survive for long periods as lifeless shel or hardy eggs. Consider, for instance, the tiny sexless metazoans that live in birdbaths (among oth places), the bdelloid rotifers, which expel all water from their bodies and form a hard stone-like ba when their puddles dry up. Think about them. They can last for seven years in this dehydrated stat

They undergo no growth or metabolism, nothing like that, in all that time. They are surely not alive this state … but they are surely not dead either. They might revive. And then there are the se monkeys (brine shrimps), which can undergo cryptobiosis like bdelloid rotifers but for far longe perhaps for centuries in some cases. Not all of these dehydrated life forms will find water. Many them may blow away or be buried in places without water, and many will break down over years decades, eroded by the elements. Entering chaos. But at what point do we say that these creatures hav died? At what exact moment could we call the time of death for a dehydrated seed such as this, as doctor might? This is surely impossible. It's hard to escape woolly definitions, it seems.

'HARRY? HARRY!' A loud voice broadcast itself over the busy museum cafe and sliced through o conversation. 'OVER HERE!' The grandfather returned carrying a tray with a cafetière, a soft drin and some biscuits. He'd been ages. I realised at this point that we had both totally forgotten abo Harry. I looked immediately to the seat next to us and was thankful to see him still sitting there. H was swinging his legs underneath the chair, looking a bit solemn and pretending not to listen to u again. 'Harry, *this* table,' said his grandfather, gesturing him to leave us and come over to his tabl nearby. I gave the grandfather a nod and a polite wave. He smiled and gave us a little thumbs-up. Th little boy slid himself off the chair and went to join his grandfather. I wondered what in God's nam this child was going to tell his grandfather we had been talking about.

Louisa told me more about her work investigating Mars, describing it as a new and exciting fronti in the search for extraterrestrial life. 'Mars is accessible. It's where we can search easily, but also it had a history like Earth's. It had an atmosphere. It had water. It had an environment probably muc like the early Earth.' 'But should we really expect to find life there?' I asked. She shrugged. 'Li arose here on Earth,' she said, 'so there's really no reason why it couldn't have evolved on Mars a well.' Louisa clearly loved Mars. Her voice was full of awe and passion and she started to talk muc more quickly whenever it was mentioned, which may have been the coffee, but I really didn't think was. 'The geological processes during Mars's history are so different to ours,' she said. 'It doesn have plate tectonics, for a start. It hasn't destroyed its history as happened so often on Earth. We ca look at the rocks from the beginning of Mars's history and they could still preserve fossils or evidenc of early life on the planet.'

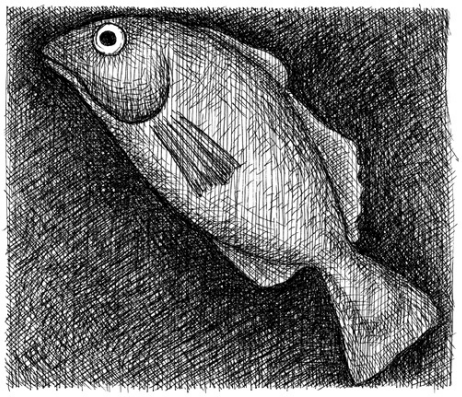
She told me about the ExoMars rover, which goes to Mars in 2018 with the sole mission of findin life. 'It could be that in the next few years we drill into the surface of Mars and find that protein,' sh said. 'That crucial evidence: evidence of life outside of Earth.' 'And what do you think everyone wi say if you find it?' I asked. I have often fantasised about that moment, as we all have, I think. Whe we realise, as a species, that we aren't alone in the universe. 'Well …' she said. 'I think the public wi probably be incredibly disappointed.' She sighed. This wasn't what I had expected. I had expecte Louisa to have entertained ideas of global celebration, peace and unity spreading across humankin an acceptance and early understanding that we weren't alone and that we should look after each oth a little better. 'Why will everyone be disappointed?' I asked. She shook her head sadly. 'They'll b disappointed because everyone wants to find life on Mars, and then we'll stand up in front of a glob audience and say "So everyone, we found a *fatty acid*!" … and they'll be like … A *FATTY ACID* ? N bugs? No aliens? … A FATTY ACID?' We both laughed.

It struck me at this point that the popular view of astrobiologists is that they are searchers for dista life, but in reality most of Louisa's job is about looking for death. Evidence of former life, throug fossils and fossil biomarkers, rather than life. I mentioned this observation to her. 'That's actuall quite interesting,' she agreed. 'Yes … death is essentially what we're looking for …' She looked int her empty coffee cup. 'I've never thought of it like that. But you're right, death is almost certain

what we'll find on Mars.' She continued to stare at her coffee cup. 'I guess, yes, all I study is deat
really. Fossils … remnants of dead organisms. All of the building blocks of life I look at are what
left after something has lived, died and degraded – been destroyed, basically.' The disorder again.

We sat in silence for a few moments. I looked over at the little boy. He was talking animatedly to h
grandfather, who was listening intently to what he was telling him. Grandfather looked interested b
there was a tiny bit of concern and seriousness in his eyes, as though he was deeply worried abo
what Harry had been describing to him at that moment. It dawned on me that Harry could be telli
his grandfather that his fridge was quite probably alive and that the thermostat is unable to produ
sterile offspring. But then another thought crossed my mind. I wondered if it was the first time th
anyone had discussed death in front of that little child. Hardly anyone speaks about death in front
children. Had that moment with us been Harry's first time? And I wondered if what we'd talked abo
had damaged him or whether, perhaps, it had done him good. It was a thought I knew I would com
back to. And I did a few months later.

Louisa and I said our goodbyes to one another and promised to keep in touch. She wished me we
with the book. I wished her well with finding new life on other planets. It had been a useful place
start, on the whole. Hearing about Louisa's work had been fantastic, but finding a clear definition wi
which I could begin my journey had proven quite hard. As Supreme Court Justice Potter Stewa
famously said of pornography, 'I know it when I see it.' … Well, I guess I was left to think this wa
about death. We know death when we see it, in much the same way we know life when we see it. C
the train home, I thought about where to go next. And then I realised something. Louisa had been
little surprised when I had mentioned that, really, she studied death in the solar system and not lif
Well, in a funny sort of way, I was the opposite. I had assumed I would be studying inert things whil
researching this book, dead things like the fossils in the museum, but really I would be studying lif
The *potential for life*. To understand why frogs, on the whole, live for a few years, I would need
look at living frogs. To understand why spiders occasionally kill one another I would have to look
living spiders. To understand why some jellyfish apparently manage near-immortal feats I would hav
to understand the life of a living jellyfish. I would have to see living things and speak to livi
scientists. And suddenly I got it. This wouldn't be a book about death at all, I realised. It would be
book about life. I would be studying life. I would be reporting on life. This would be a life story.
proper life story. And in the bits in which it wasn't a life story, when death was inevitable or ha
actually happened, the spectre of potential life would still lurk, even if it was in the form of oth
creatures like worms, blowflies or scavenging foxes.



CHAPTER TWO

Senescence and What Waits for the Lucky Few

‘He’s going to be a little bit floppy here, just be careful.’ The vet deftly hauls the bulky fish from water-filled tub on the floor and gently places it upon a foam bedding on top of the operating table. wriggles slightly but seems quite calm. It is about the size of a salmon. According to the aquarium it a copper rockfish. There is activity all around: technicians gather around the table on which it flaps its foam bedding. There is some to-ing and fro-ing in the background of the shot. Someone places hose into the fish’s open mouth to keep the gills oxygenated, while someone else has the simple tas of keeping the fish’s skin nice and moist. This looks an easier job. Yes, the fish seems surprisingl relaxed about all of this attention. Someone clamps it in place on the bedding. It looks less relaxe now; it flips and waggles a bit. Ready to operate, one of the two lead vets pulls the overhanging lam up close to the fish’s cold head and gets ready to perform.

Where its eye should be, the fish has a gaping pink eye-socket, which recedes deep into its skull. It missing its eyeball. The vets look anxious. Suddenly a host of bystanders appear at one end of th room – this is what they’ve been waiting a while to see. A vet is going to do something to the fish wit one eyeball, but the viewers (including me) aren’t yet sure what that might be. They quietly watch th two lead vets do their thing. I am sitting and watching this miles away on my laptop. ‘So …’ says th male vet, holding what looks like a needle and thread. ‘So where do we …?’ He gets up close to th eye socket and looks very closely at it. ‘Do we do him there?’ He points to the top of the arch of th socket above the missing eyeball. ‘Or there and there?’ He points to another part of the socket. Th female vet leans in. ‘I normally put it up against the fish first …’ She takes an object from her han and places it into the fish’s empty eye-socket. It is a cheap-looking plastic googly eye. She arrange the cheap-looking plastic googly eye neatly into the socket. ‘Nice job,’ someone says quietly in th background. The operating room seems increasingly tense and there is definitely a hint of exciteme in some of the bystanders. The male vet continues: ‘So I just use a needle to make a hole through th bone …’ He carefully moves the needle, pulling through the thread. ‘And then I try to run the sutu through the same hole.’ Someone in the background looks slightly nauseous at this point. Wate continues to pump via a tube through the fish’s gills. The fish shudders ever so slightly. Minutes pas The video cuts forward. We are near the end of the operation now. And then, ‘So … we’re cutting th

suture.' The male vet remains calm under the pressure, narrating each movement. Almost there .
'Getting rid of the little tags …' Almost there. 'And … nice,' he says.

Everyone admires his handiwork. He looks pleased. And he should be. He has just successfully sew what looks like a plastic eyeball onto the side of a fish's head with the skill and dexterity of a your Jim Henson. And this really did happen. The unusual operation was undertaken by experts at th Vancouver Aquarium, and the video of the operation is freely available online for all to see. It interesting. Interesting because it tells us a little something about animals and the rarity of the reaching old age. Why did this copper rockfish need a googly eye? The answer is that it had develope cataracts. It was old. The cataract had occurred in only one of its eyes, resulting in that eyeball bein surgically removed, but this hadn't worked out well for the rockfish. Other fish in the aquarium ha been observed to 'bully' the one-eyed rockfish (which they are rather prone to do), so Vancouve Aquarium decided to do the right thing and reached for the needle and thread, and the Hobbycra Multipack of Googly Eyes. Cataracts are one of many diseases of old age. And, kept away fro predators, aquarium fish age in many of the same ways that we do. Cataracts can be quite commo Ageing is natural.

So why do we all age? Why don't we just carry on living in perpetuity? Why can't we be immorta It is one of the questions that has plagued humanity for centuries. From ancient Greece's Tithonus requested to be made immortal by Zeus without anyone throwing in the bit about eternal youth – almost every Hollywood star you care to name, our obsession with ageing is absolute and (ironicall timeless. So *why* do we age? Why can't cells just continue to replace themselves in a predictable an healthy manner forever? Why do animals fall apart in old age? And why do cataracts often feature as symptom of old age in animals as seemingly unrelated as fish and humans? Dig about in the science senescence (as ageing is called) and you'll quickly come to realise that the answer is, almo spectacularly, that no one is entirely sure. Not that this really matters; as with all of zoology's know unknowns, scientists over the last century have gathered into camps supporting a host of differe hypotheses that may explain what might be going on, particularly at a cellular and molecular level, produce the phenomenon we call ageing. There are many hypotheses out there, and I will outline th three most common nice and early in this chapter before returning to them in the course of this book.

The first hypothesis to explain ageing is that cell damage simply builds up over time. As generatio after generation of new cells is created within the body, accumulated DNA damage occurs tha somehow affects cell renewal. These errors build up. Bit by bit, organs fail to repair properly. Bit b bit, cells become dysfunctional and the diseases of old age result. The second of the main hypothes for ageing relates to 'free radicals' – the highly reactive atomic particles generated particularly whe mitochondria (the biological battery-packs present in each of our cells) manipulate oxygen to fuel th energetic reactions required for life. Free radicals have the potential to stress a cell's function, th much is certain. It may be that they lead to an accumulating cellular burden with age, much like th first suggested cause. And then there's the third hypothesis: that of a telomere. As you will know, a of the cells in your body contain chromosomes in which are housed your genetic blueprints. Th structure of these chromosomes is interesting: each of them, when pulled apart, is capped at each en by a 'telomere'. Telomeres are special lines of genetic code which act a little like the plast protective tips at the end of a shoelace. Experiments suggest that, for each successive division of cell, the telomeres shorten. This puts a finite limit on cell division. The hypothesis is that, somehow this shortening puts a kind of cap on the number of replications a cell can undergo, potentially limiting the activities of bone marrow and arterial lining, where repeated division is conducive sustaining life. The result, as with the other hypotheses, is cellular breakdown: what you and I ca

ageing. There are certainly other possible explanations for ageing, but these three (accumulating DN damage, free radicals and telomeres) hog much of the limelight, partly because they have been studi the most intensively.

Research into senescence is anything but an unappreciated zoological backwater. Understandi ageing is becoming a key battleground for those from a host of scientific disciplines, many eager tackle diseases of old age that include cancer, cardiovascular disease, arthritis, osteoporosis, type diabetes, hypertension, Alzheimer's disease and cataracts. These are natural diseases in many way But how could natural selection have produced them? Could there really be a point to these disease or are they simply by-products of some other process? This question has rattled scientists for generation.

Among the first to offer a Darwinian perspective on animal ageing was the British biologist Pet Medawar. Medawar became the so-called 'father of transplantation' through his pioneering work o immune tolerance and organ transplants. He understood that every animal alive at any given time h a particular chance of dying. In fact, this probability of death was integral to his theorising abo ageing (senescence) and why animals age like they do. Medawar's 1951 inaugural lecture University College London, *An Unsolved Problem in Biology*, went on to underpin all three of t modern theories for senescence by flipping the problem of death on its head. Rather than focus t heavily on any given species, he asked why it was that natural selection didn't 'cure' all animals fro ageing and dying. Natural selection is adept at solving problems, right? Yet death is the bigge problem of all, surely. So why is death so prevalent in the animal kingdom? he wondered. Why hasn it been whittled into shape by natural selection, as one might expect?

Medawar was the first to appreciate that the answer lay in probability. He realised that, even witho considering ageing, there is a statistical likelihood of death for any creature at any given moment. A animals will die eventually; that's 100 per cent likely. Some animals might die when still relativel small and young, when they become easy prey for something else. Some species might be more like to die once mature and in competition for mating resources (like nests) or searching for mates. We a have a chance of death, and this probability changes during our lifetime. In humans, statistically, on we reach 30 years of age our chance of dying doubles approximately once every eight years. It's simple as that. It may seem obvious to us now, but in 1951 this idea of probability was an importa insight. Medawar understood that for every second that a bacterium swims in a pool of water, f instance, there is a probability of death that glows like a neon sign above its head. The give bacterium may die through predation, cosmic radiation or misadventure, and plenty else. It could besieged by virus particles. Squashed or dehydrated into oblivion. Every day that a bacterium lives is rolling the dice, unaware that one day its numbers will come in. And they *will* come in eventuall no matter how expertly that bacterium piddles about in that particular puddle of water. Natur selection, Medawar realised, simply favours the animals that get on with the business of reproducti before their chances of dying increase. An organism in that puddle that breeds every two days, f instance, will far outcompete an organism that breeds every two weeks or two years. Simply, ge pools become flush with those best primed for reproducing before the statistical chances of dea increase.

At its most simple, Medawar's idea was that natural selection didn't sort out senescence because was drawn to the battleground of life; it was drawn to sex. The only language of transmission it kno is through reproduction. And those sexy genes, high on life and sex, think nothing about solving t problems of old age. They think only of carrying on. As ageing individuals we, according to Medawa have been left high and dry by our genes' insatiable desire to spread at all costs before death gets u

In nature, when death doesn't get animals early, the lucky few that remain will see senescence expos itself to pick them off anyway. And that googly-eyed rockfish, kept safe in its tank, is just that. Lik us, it lives a different kind of life. One, on the whole, without predators. Medawar's idea was a catch one. It influenced a generation of scientists with it, but doubts still remain about whether, and to wh degree, his idea works in the real world. Could senescence really be as simple as Medawar describe Could the signs of ageing really just be the result of sloppy maintenance that can't be fixed by a unthinking selection machine obsessed with sex and cutting-edge replication? We still can't be totall sure.

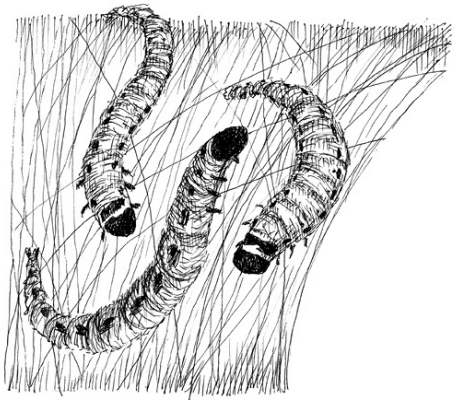
In 1966, the evolutionary biologist George C. Williams offered up another way in which senescen may appear naturally in a way that is similarly unfixable by natural selection. He proposed somethin called 'pleiotropy' – a situation where the flipping of genes on and off can cause multiple, seeming unrelated traits to expose themselves, either instantly or later in life. To Williams, the problems of ol age come about as side-effects of things that help animals have better sex earlier in life. Williams example was to imagine a hypothetical gene that alters calcium metabolism in a way that bo strengthens bones in youth and occludes arteries in old age. In this situation, natural selection wou be drawn to maintaining the healthy strong bones of fertile youth – those genes would sprea regardless of the consequences later in life. In many ways Williams's view works in the same way a Medawar's. Sexy genes spread better than genes for healthier arteries in old age, which barely sprea at all because of the fertility drop that occurs with ageing. Natural selection can barely touch th diseases of old age, let alone try to fix them, and so these diseases remain. 'Reproduction is th beginning of death,' wrote James Joyce. And so it is. Sex and death really are two sides of the sam coin.

And so the googly-eyed rockfish lives out its life. Its wonky eye is an expression of a fleet of gen obsessed with sex, which barely gave a nod to trying to fix a common disease of old age. Stare close enough and you will see yourself reflected in that googly eye. The universe has given you a statistic chance of death, and natural selection has acted accordingly on your growth rate, your bra development and your puberty. Each is programmed with sex in mind, not cosy senescence.

Does this make you feel small and helpless and a bit insignificant? I confess that exploring all of th does make me feel a little helpless about ageing. But don't feel too glum, because there is a silv lining and it comes down to a simple observation in nature. It may not *always* be this way for u Many populations of a given species appear to evolve longer lifespans quite quickly in evolutiona terms, particularly in habitats that lack predators. Give an opossum an island habitat with few predators, and a couple of thousand years later the opossums will live twice as long, ageing at half th rate of their mainland competitors. Their lifespans change. Brook trout offer an even more spectacul example: their introduction into cold, nutrient-poor waters in California's Sierra Nevada has seen the populations quadruple in lifespan. Where once they lived six years, now they can expect to live for 2 with the only apparent catch being a delay in sexual maturation. Fiddle with the statistical chances death and animals evolve, not within millions of generations, but hundreds. The writing is on the wa Senescence isn't a phenomenon etched in stone. Senescence is fluid. Natural selection, if needed, ca pull the strings of ageing, which means that there may be a genetic component to ageing. The broo trout and the opossums offer us a startling revelation: diseases of old age – *all of them* – might b something we can delay. And by fiddling with genes, we may discover that they can be delaye greatly. Perhaps immeasurably.

The study of ageing really is far from a scientific backwater; it is recruiting geneticists, zoologist biochemists, molecular scientists and physicists. They are queueing up, eager to weigh in with the

own given insights. And why? Because they are drawn, like so many humans before them, to th
prospect of immortality. But this time it’s real.



CHAPTER THREE

Fear and Loathing in Birchwood

‘Anyone want a dead magpie?’ her message on Twitter had read. My eyes lit up. Me, I thought. I wa
a dead magpie. That’s *exactly* what I want. I really did. Genuinely, I really did want a dead bird. I ha
quite wanted a dead magpie or crow as part of some initial research I was undertaking on how corvi
(the family which includes crows, jackdaws, magpies and jays) respond when finding dead membe
of their own species. My plan was simple: I would get my hands on a dead magpie or crow or jackda
and rest this corpse gently in the middle of my local corvid haunt, a spinney in a nearby field in whi
a jackdaw colony rubs up against small flocks of crows and magpies. What would they do when
placed the magpie on the floor? How would they behave? Would they inspect it? Become anxious?
was interested. Sure, it wasn’t exactly a randomised controlled trial at this point but it was a start,
thought. I had to have this dead magpie. I *had* to have it. I’d *travel* for this dead magpie. So that
exactly what I did. I travelled to Birchwood to meet Alison Atkin, bone expert, archaeologist and sel
anointed ‘deathsplainer’.

Birchwood is near Warrington, which is midway between Liverpool and Manchester. I had neve
travelled to Birchwood before. I like going to new places – it was quite exciting. As the train pulled
it looked a clean, ordered place. Birchwood is what we in Britain call a ‘new town’ – a place witho
historical infrastructure, where county planners in the 1970s could work unimpeded by irregul
angles laid down by the Victorians. So Birchwood is a place where everything sits at 90 degrees, ar
into which paving slabs are perfectly flush up against each other, which makes the place look ver
neat and tidy and organised. There are cycleways and pedestrian zones in Birchwood. Lots
seventies-style flats and other rectangle-shaped objects. And tree-lined avenues, which is somethi
you don’t often get in Britain, given that trees take up space and space is at a premium in many par
of this relatively tiny island.

I walked along the station not knowing quite what to expect from Alison. Would she be like th
people at Death Salon? Would there be the same air of mortician chic in her? Would she approve o
what I planned to do with her dead magpie? I really didn’t know because our correspondence hadn
been particularly detailed up to this point. In fact it wasn’t detailed at all. It was: ‘Who wants a dea
bird?’ [PAUSE] ‘Me.’ And that had been pretty much it. We’d arranged it all, in fact, via Twitter.