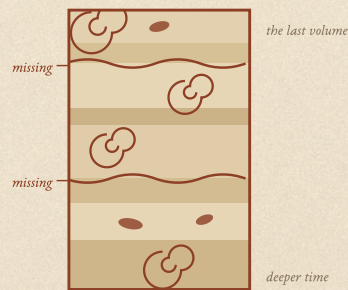


MY OWN READING OF DARWIN · IN EIGHT PARTS

ON THE ORIGIN OF SPECIES

By Means of Natural Selection

Charles Darwin, 1859 — first edition



PART SIX OF EIGHT

The Broken Record

*Chapter IX: The Imperfection of the Geological Record
+ Chapter X: The Geological Succession of Organic Beings*

*“Of this history we possess the last volume alone...
only here and there a short chapter has been preserved;
and of each page, only here and there a few lines.”*

Darwin, Chapter IX

READ AND EXPLAINED BY LOVEPREET SINGH

I read the whole book myself. This is what I understood,
written the way I'd explain it to a friend.

I

The cheque comes due

In Part Four, Darwin was asked where all the transitional fossils were. He said the record was far worse than anyone realised, promised to prove it, and changed the subject. Here he has to pay.

This is the moment I was most curious about when I got here, because in Part Four Darwin does something that looked, on the page, like a dodge.

Faced with the obvious question — if life shades gradually from one form into another, where are the countless in-between creatures in the rocks? — he gave half an answer, said the geological record was much more incomplete than geologists assumed, and told the reader he'd demonstrate it later.

Now it's later.

TWO CHAPTERS, PULLING IN OPPOSITE DIRECTIONS

Chapter 9 is defensive. It is Darwin explaining, at length, why the evidence he needs mostly doesn't exist — and it is a far better chapter than that sounds, because he doesn't just assert it. He walks through the actual physical process of making a fossil and shows how nearly every step throws almost everything away.

Chapter 10 goes on the attack. Whatever is missing, the fossils we *do* have are not scattered at random. They fall into five clear patterns, and every one of those patterns is exactly what a branching family tree buried in mud would look like — and awkward to explain any other way.

Chapter 9 is the excuse. Chapter 10 is the evidence. Chapter 10 is the better chapter.

One thing to hold in mind before we start

Darwin is writing without dates. He has no way to say how old any rock is in years — radioactive dating was still half a century away. He can say one layer is above another and therefore younger, and that's all.

So when he needs to argue that geological time is unimaginably long, he has to improvise. And that improvisation, as we'll see in a moment, got him publicly humiliated.

II

On the Imperfection of the Geological Record

Why almost nothing that ever lived left a trace, and why the traces that survive have enormous unwritten gaps between them.

Denudation means wearing away — rock removed by rain, rivers, frost and sea. Darwin uses it constantly, because what gets removed is as important as what gets laid down.

First he has to make you feel how long geological time is

Everything in the theory depends on there having been enough time. So Darwin tries to give the reader a number, and he does it by measuring erosion.

He takes a stretch of southern England called the Weald — a broad valley between two ranges of chalk hills. Geologists agreed that the chalk once arched right over the whole valley and has since been worn away. So: estimate how fast sea cliffs retreat, work out how much rock is missing, divide one by the other.

His answer, printed in the first edition, is 306,662,400 years, or as he puts it, say three hundred million.

AND HE GOT TAKEN APART FOR IT

The arithmetic was shaky and the assumptions were guesses, and critics said so loudly. Darwin was mortified. He cut the calculation down in the second edition and removed it entirely by the third.

Then it got worse. William Thomson — later Lord Kelvin, the most respected physicist in Britain — calculated from the rate at which a molten earth would cool that the planet could be at most a few tens of millions of years old. Far too short for Darwin. It was the most serious scientific attack the theory faced in his lifetime, and Darwin had no answer to it. He called it one of his sorest troubles.

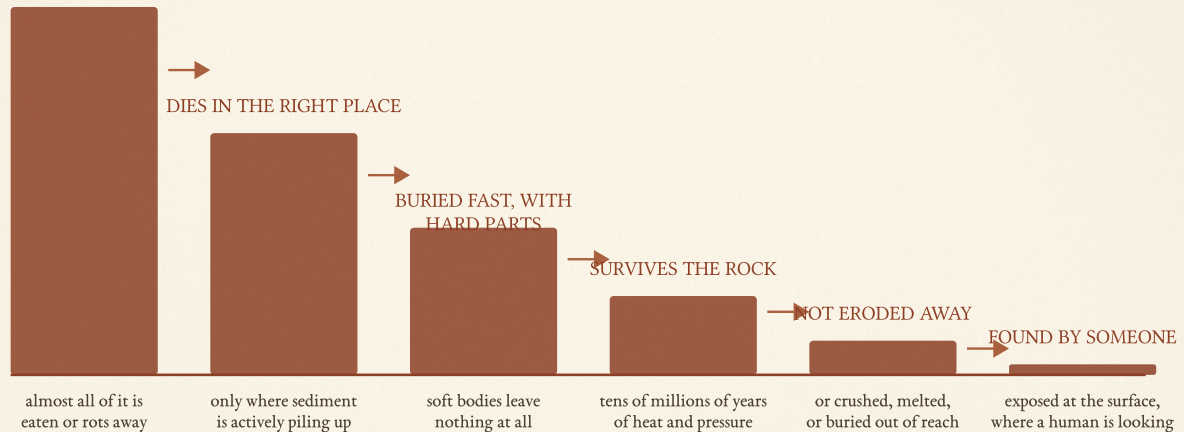
Kelvin was wrong. His physics was impeccable and he was missing one fact nobody would discover until 1896: radioactivity, which keeps the earth's interior warm and wrecks the cooling calculation entirely. The earth is about 4.5 *billion* years old.

So Darwin lost the argument publicly, was proved right posthumously, and his own number — three hundred million years for one English valley — is still far too big. He was wrong in both directions at once, and right about the thing that mattered: there has been plenty of time.

Then: what it actually takes to become a fossil

This is the strongest part of the chapter, and it's strong because it's concrete. Darwin walks through the physical process, and at every step almost everything is lost.

EVERYTHING THAT LIVES



Six filters in a row. The bar on the right is not drawn small for effect.

FIGURE 21 Darwin's point, laid out as a sequence of filters. Each one removes the overwhelming majority of what reaches it, and they multiply. Fossilisation isn't rare — it is astronomically unlikely, and we should be startled we have anything at all.

And the pages are only written some of the time

Here is the insight in Chapter 9 that I'd never thought about, and it's the one that does the real work.

Sediment only piles up where the ground is sinking. If a seabed is subsiding, layer after layer accumulates and anything that dies there gets buried and kept. If the land is instead rising, the opposite happens: rain and rivers and sea strip material *off*, and any record that was there is destroyed.

So the rock record is not a continuous diary with some pages missing. It is a diary that was *only written during certain periods at all* — and during the periods in between, somebody was tearing out and burning the pages that already existed.

IN DARWIN'S OWN WORDS

"I am convinced that all our ancient formations, which are rich in fossils, have thus been formed during subsidence... Thus the geological record will almost necessarily be rendered intermittent."

WHAT HE MEANS — The fossil-rich rock layers only formed while the ground was sinking. So the record has to come in disconnected episodes, with unrecorded time between them.

Which means two layers sitting directly on top of each other, apparently continuous, can be separated by an unimaginable span of time in which everything changed and nothing was recorded. You turn one page and a

million years have gone by.

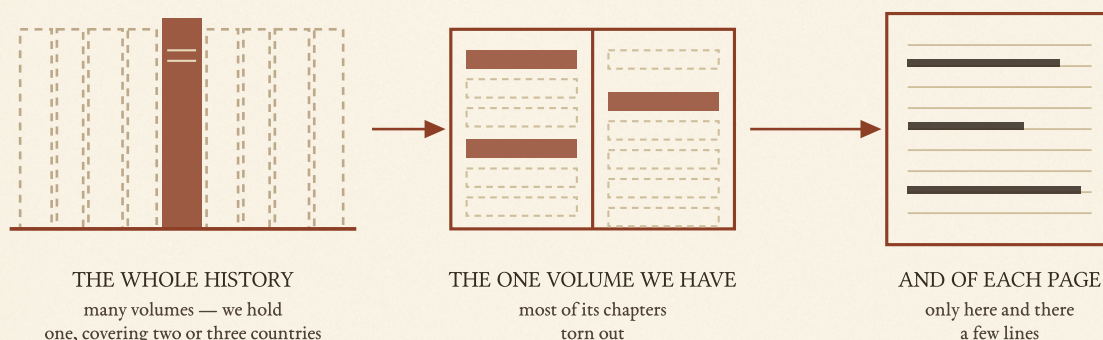
The image he leaves you with

Darwin ends the chapter with the best metaphor in the book, borrowed and improved from his old mentor Lyell.

THE PASSAGE EVERYBODY REMEMBERS

“I look at the natural geological record, as a history of the world imperfectly kept, and written in a changing dialect; of this history we possess the last volume alone, relating only to two or three countries. Of this volume, only here and there a short chapter has been preserved; and of each page, only here and there a few lines.”

WHAT HE MEANS — Imagine a complete history of the world in many volumes. We have one volume, covering a couple of countries. Most of its chapters are torn out. On the pages that remain, most of the lines are blank. And it’s written in a language that keeps changing.



Given all that, the surprise isn't that intermediates are rare. It is that we have any.

FIGURE 22 Darwin's metaphor drawn out. Solid marks are what survives; dashed outlines are what has been lost at each level. This is his answer to "where are the missing links?" — almost everything is missing, including most of the things nobody is arguing about.

The one he could not answer

And then, to his credit, Darwin puts up his hands.

In the oldest rocks known to contain fossils at all, complex animals — trilobites and the rest — appear suddenly, fully formed, in variety, with *nothing whatsoever* beneath them. No simpler ancestors, no long

build-up. On Darwin's theory there should be an enormous span of earlier life below that layer, and in 1859 there was a blank.

DARWIN CONCEDED

"The case at present must remain inexplicable; and may be truly urged as a valid argument against the views here entertained."

WHAT HE MEANS — I cannot explain this. And it is a fair argument against me. *Urged* here means "pressed as an objection."

That is a remarkable sentence to publish about your own life's work. He offers a guess — that the earlier rocks exist but have been destroyed or lie undiscovered — and openly labels it a guess.

HIS GUESS WAS RIGHT, AND IT TOOK A CENTURY

There *is* a vast record below that layer. It was found piece by piece through the twentieth century: strange soft-bodied creatures now called the Ediacaran fauna, microscopic fossils, and mats of bacteria that go back around three and a half billion years.

The reason it looked blank is close to what Darwin suspected, with one addition he couldn't have guessed: hard parts — shells, carapaces, bones — only became widespread at roughly that moment. Before it, almost everything alive was soft, and soft things almost never fossilise. The sudden appearance was largely the sudden appearance of things that *could* be preserved.

The event is real, and it is still called the Cambrian explosion. It just took twenty million years or so and had three billion years of history behind it.

SECTION THREE · CHAPTER X OF THE BOOK

III

On the Geological Succession of Organic Beings

Chapter 9 explained what is missing. This chapter asks what shape the surviving fragments make — and the answer is five patterns that are very hard to get any other way.

Having spent a chapter apologising for his evidence, Darwin now turns round and points out something that should have been obvious to everyone and somehow wasn't.

The record is full of holes. Fine. But the fragments are not arranged at random. They fall into definite patterns, and none of those patterns had to be true. Each one is a bet the theory places, and each one could have come out the other way.

Pattern one: species come and go one at a time

New forms don't arrive in batches. They appear singly, at intervals, spread through the layers, and they vanish the same way — separately, at their own times.

If life had been created in episodes, you would expect clusters: a layer with a great many new arrivals all at once, then nothing, then another burst. What you actually see is a steady trickle. That is what a branching tree looks like from underneath.

He adds that different groups run at different speeds. Some change fast; others barely change for enormous stretches — there are shellfish and cephalopods that look much the same in very old rocks as they do alive today. Nothing in the theory requires a constant rate, and the rates aren't constant.

Pattern two: once a species is gone, it never comes back

This is the one I'd put money on if I had to pick the single strongest fact in the chapter.

IN DARWIN'S OWN WORDS

"When a species has once disappeared from the face of the earth, we have reason to believe that the same identical form never reappears."

WHAT HE MEANS — Once a species is extinct, that exact species is never found again in any later rock. Not once, anywhere.

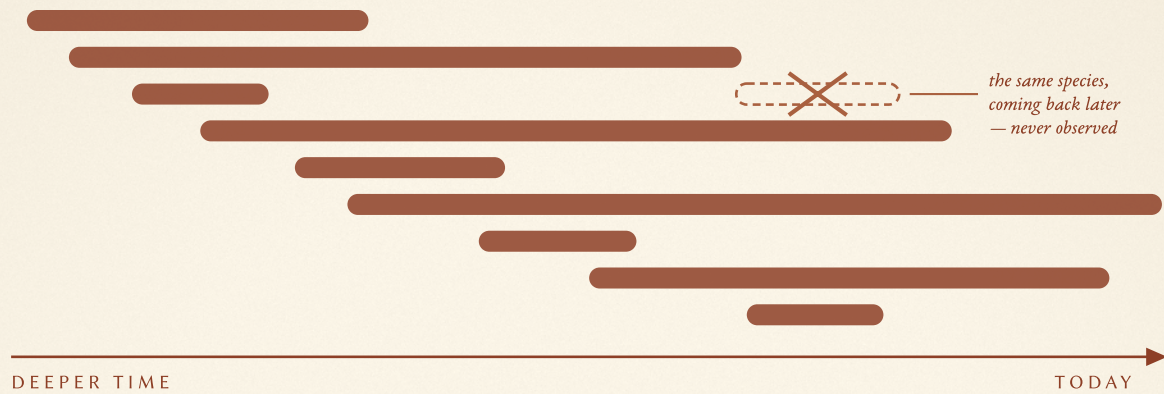


FIGURE 23 *Every species is a single continuous run through time. In 165 years of digging, nobody has found a species that died out and later returned — and a single clear case would be a serious problem for descent with modification.*

Ask why that should be so.

If species are created, there is no obvious reason the same one couldn't be created again when the same conditions came round. Climates repeat. Habitats repeat. Yet the species never do.

On Darwin's account it's not a rule anyone imposed — it's a consequence. A species is the end of one specific, unrepeatable chain of ancestors. Cut the chain and that exact combination is gone for good. You could re-evolve something similar; you cannot re-evolve *that*.

And notice the shape of the claim. It is a prohibition. One well-documented counterexample anywhere in the world's rocks would break it. There isn't one.

Pattern three: extinction is quiet, and rarity comes first

Species don't usually vanish in one dramatic stroke. They get rare, and stay rare, and then they're gone. Darwin found this written in the more recent rock layers repeatedly: *rarity precedes extinction*.

That fits what Part 3 established. Extinction isn't bad luck arriving from outside — it's the slow losing end of competition, mostly against relatives who are doing the same job slightly better.

A LINE WORTH KEEPING

"We need not marvel at extinction; if we must marvel, let it be at our presumption in imagining for a moment that we understand the many complex contingencies, on which the existence of each species depends."

WHAT HE MEANS — Don't be amazed that things go extinct. Be amazed at our nerve in thinking we understand all the delicate conditions a species needs in order to keep existing at all.

An aside: the things that barely changed at all

Darwin coins a phrase in this chapter that has outlived almost everything else he wrote, and people use it now without knowing where it came from: living fossil.

He means a creature alive today that looks much as its relatives did in very old rock. He points at a brachiopod called *Lingula*, which turns up in some of the oldest fossil beds and is still sitting in the mud of tidal flats now, and at the pearly nautilus.

People sometimes throw these at evolution as if they were a problem — if everything is evolving, why hasn't that? But it isn't a problem, it's the theory working. Selection has no drive to change anything. It changes things when conditions change or competitors appear. A creature in a stable, low-competition situation, already well fitted to it, will be held *steady* by exactly the same process that transforms everything else.

Darwin points out these tend to be forms living in confined or isolated situations, where they have faced less severe competition. Nothing has pushed them, so nothing has moved.

It's the same lesson as species F on the diagram in Part Three — the line that runs straight up for fourteen thousand generations without altering. Staying the same is a result, not an exemption.

Pattern four: extinct forms sit between living groups

When you dig up something old, it very often doesn't fit neatly into a modern group. It sits between two of them, sharing features with both, closing a gap that looks unbridgeable among living animals.

This is Part Three's tree again, seen from a different angle. The gaps between modern groups exist because the connecting branches died. Dig into the past and you start hitting those branches — not always the exact joins, but forms that bring separated groups measurably closer together.

Once more, it's a prediction that could fail. Extinct animals could have been *more* distinct from each other than living ones are, each in its own isolated box. They aren't.

AND THE CHANGES LINE UP ACROSS THE WHOLE WORLD

One more observation, which Darwin treats almost in passing and which is stranger than it first looks.

When the forms of life change, they change *in step* across enormous distances. Rock layers from Europe, North America and South America can be matched up by the fossils in them, because the same broad turnovers show up in all of them at roughly the same points. Geologists rely on this constantly — it is how they correlate rocks on different continents.

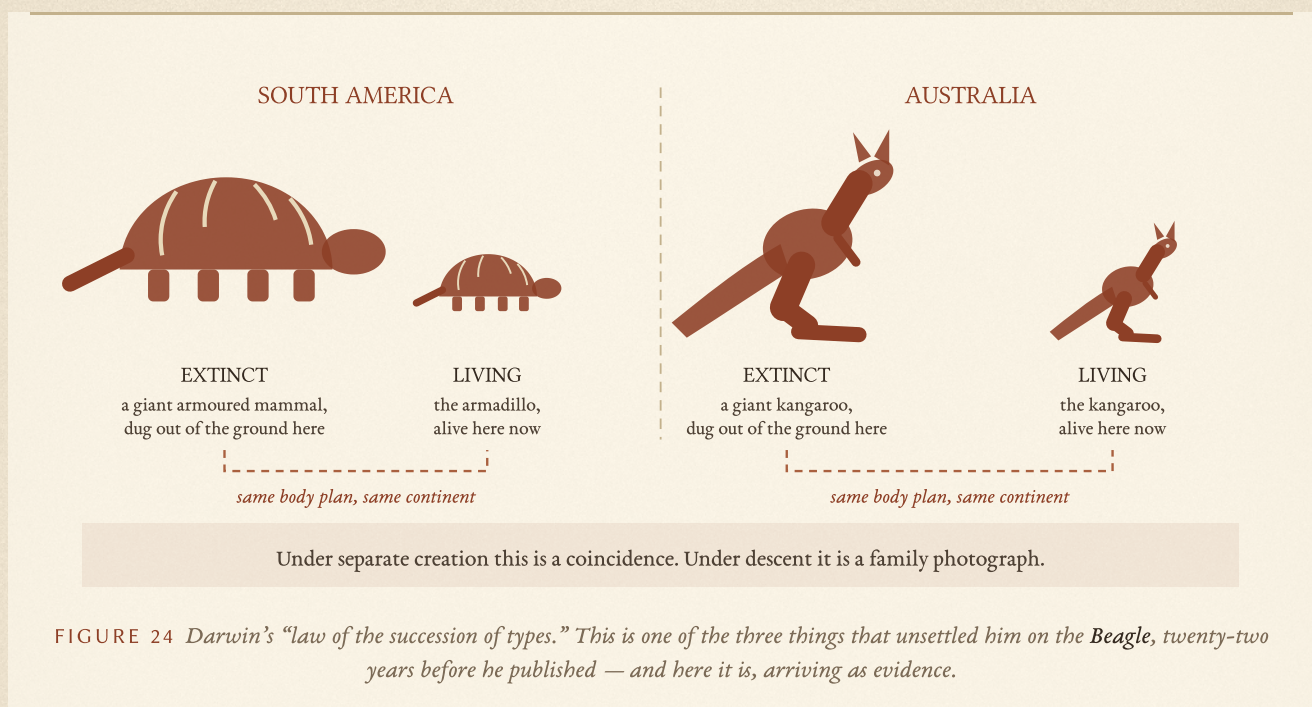
Under separate creation there is no reason for that. Why should the creatures of Britain be replaced at the same moment as the creatures of Argentina?

Under Darwin's account it follows from something he established back in Part Three: the winners spread. A form that gains an advantage doesn't stay put — it expands, displacing relatives as it goes, until it is stopped by a barrier. Wide, slow, worldwide replacement is what dominance looks like from a great distance.

Pattern five: the dead and the living of a continent match

And here the book comes full circle, back to a young man on a ship in Part One.

Dig in South America and you pull out gigantic extinct armoured mammals — and living armadillos are walking around on top of them. Dig in Australia and you find extinct marsupials, in a continent whose living mammals are almost all marsupials. Each region's fossils look like that region's current inhabitants, blown up or shrunk or altered, but unmistakably the same family.



IN DARWIN'S OWN WORDS

"This wonderful relationship in the same continent between the dead and the living..."

WHAT HE MEANS — The extinct animals of a place look like the living animals of that same place, and that is remarkable and needs explaining.

He says he doesn't doubt it will eventually shed more light on how living things appear and disappear than any other class of facts. And under his theory it isn't remarkable at all — it's inheritance. The animals of a region descend from the earlier animals of that same region, which is why they look like family. Because they are.

MY TAKE — COUNT HOW MANY BETS ARE ON THE TABLE

Look at what Chapter 10 has quietly done. It has made five separate claims about what the rocks must contain, every one of which could have come out differently:

Species should appear one at a time, not in batches. Once gone, they should never return. Extinction should be gradual, with rarity first. Extinct forms should sit between living groups, not outside them. And the fossils of a region should resemble that region's living inhabitants.

Any one of those failing would have been serious trouble. All five hold, in rocks Darwin never saw, on continents he never visited, dug up by people who were often trying to prove him wrong.

Chapter 9 asks you to excuse the evidence he lacks. Chapter 10 is him quietly collecting.

SECTION FOUR

IV

The scorecard

One chapter of excuses that turned out to be true, and one chapter of predictions that all came in.

WHAT DARWIN GOT RIGHT

- The record really is that bad. We can now put numbers on it, and they are worse than he guessed. A vanishing fraction of species that have ever existed are known from fossils at all — and whole environments, like tropical forest floors, preserve almost nothing.
- Deposition really is intermittent. Geologists have a word for the surfaces where time is missing — *unconformities* — and some of them swallow hundreds of millions of years between one layer and the layer resting on it.
- There really was a long history before the Cambrian. He said the rocks must exist and we hadn't found them. They do, and we have.
- All five patterns in Chapter 10 hold. Including the strict one — no species has ever been found to return after extinction.

WHAT HE GOT WRONG

- The Weald calculation. Bad arithmetic on bad assumptions. He was right to withdraw it.

- He over-committed to gradualism. Darwin needed slow, steady, uniform change and read every jump in the record as a gap in preservation. Some of those jumps are real. Sudden mass extinctions have hit the planet repeatedly — the one that ended the dinosaurs was caused by an asteroid, an idea that would have appalled him. And some lineages do sit almost unchanged for long stretches and then shift quickly.
- None of that breaks the theory. It means the tempo varies more than he wanted it to.

THE THING HE NEVER HAD

Darwin could not date anything. Not one rock, not one fossil, not one event — only *older than* and *younger than*. Every argument in these two chapters is made without a single reliable number, which is why the Weald guess was so exposed and why Kelvin's physics hurt so much.

Radioactive dating arrived in the twentieth century and settled all of it at once. It gave geology the numbers Darwin was reduced to guessing at, and the numbers were far more generous than he ever dared claim.

THE ONE-LINE VERSION

Chapter 9 says: *don't judge the tree by the handful of leaves that survived.*

Chapter 10 says: *and look at how the surviving leaves are arranged.*

REFERENCE

Every hard word in this part

Same rule as always — explained the way I'd explain it to a ten-year-old.

Geological Record

Everything the rocks preserve about the past — layers, fossils, the lot. Darwin's whole argument in Chapter 9 is that it is a wreck of a document.

Formation

A distinct body of rock laid down in one episode. Two formations can sit directly on top of one another with an unrecorded eternity in between.

Denudation

Wearing away. Rain, rivers, frost and sea stripping rock off the land. Darwin used it to estimate the age of the Weald, and got badly burned.

Subsidence

Ground sinking. Darwin's key insight: fossil-rich layers only build up while the ground is sinking. When it rises instead, the record is destroyed rather than written.

Strata

Rock layers. Lower is older, higher is younger — which is the only kind of dating Darwin had.

Unconformity

Not Darwin's word, but his idea. A surface in the rock where time is simply missing — sometimes hundreds of millions of years, between one layer and the next one lying on it.

Palaeontology

The study of fossils. Darwin calls our collections of them "poor," which was generous.

Silurian (*now Cambrian*)

The oldest fossil-bearing rocks known in 1859, where complex animals appear suddenly with nothing beneath. Darwin admitted he could not explain it and that it counted against him.

Ediacaran

The strange soft-bodied life found in the twentieth century in rocks *below* the Cambrian — exactly the earlier history Darwin insisted must be there.

Succession of Types

The rule that a continent's extinct animals resemble its living ones. Giant armoured mammals under South America's armadillos; extinct marsupials under Australia's.

Living Fossil

Darwin's phrase, coined in this book. A form that has changed very little over enormous spans of time — because its conditions barely changed either.

Radiometric Dating

Measuring a rock's age from the steady decay of radioactive atoms inside it. It arrived after Darwin's death, gave geology real numbers for the first time, and destroyed the physics objection that had troubled him most.

Lines worth remembering

If you forget everything else from Part Six, keep these eight.

-
- 1 Six filters stand between an animal and a fossil, and each one throws away nearly everything. The surprise isn't that intermediates are rare — it's that anything survives.
 - 2 Rock only records while the ground is sinking. When it rises, the record is destroyed. So the diary was only written some of the time, and burnt the rest.
 - 3 The last volume, most chapters torn out, and on each surviving page only a few lines. That's Darwin's answer to "where are the missing links?"
 - 4 He admitted in print that the sudden appearance of Cambrian life could fairly be urged against him. He guessed the earlier record existed and hadn't been found. He was right.
 - 5 Species appear one at a time, not in batches — which is what a branching tree looks like from underneath, and not what episodes of creation would look like.
 - 6 No species has ever come back. A species is one unrepeatable chain of ancestors; cut it and that exact combination is gone. One counterexample would break the theory.
 - 7 Extinct forms sit *between* living groups, closing gaps rather than widening them. These are the dead branches of the tree from Part Three.
 - 8 Each continent's fossils look like that continent's living animals. A coincidence under creation; a family photograph under descent.
-

Part Six on one page

Tear this out. It's the whole thing in ninety seconds.

THE DEBT BEING PAID

In Chapter 6 Darwin was asked where the transitional fossils were, said the record was far worse than anyone realised, and promised to prove it. Chapter 9 is the proof. Chapter 10 is the counter-attack.

CHAPTER 9 — WHY THE RECORD IS SO BAD

Six filters stand between a living animal and a fossil in a museum: it must die where sediment is piling up, be buried fast, have hard parts, survive tens of millions of years of heat and pressure, escape erosion, and finally be exposed where somebody is looking. Each removes nearly everything, and they multiply.

The deeper point: rock only accumulates while the ground is sinking. When land rises, the record is stripped away instead. So the record isn't a diary with pages missing — it was only written during some periods at all, and destroyed during the others.

His image: a history of the world imperfectly kept, of which we hold the last volume alone, most chapters torn out, and on each page only here and there a few lines.

WHAT HE ADMITTED HE COULDN'T EXPLAIN

Complex animals appear suddenly in the oldest fossil-bearing rocks with nothing beneath them. Darwin wrote that the case “must remain inexplicable; and may be truly urged as a valid argument against the views here entertained,” guessed the earlier rocks existed undiscovered — and was right. A three-billion-year record below the Cambrian was found in the twentieth century.

CHAPTER 10 — THE FIVE PATTERNS

1. Species appear and vanish one at a time, at their own rates — never in batches.
2. Once extinct, a species never reappears. Not once, anywhere, ever.
3. Extinction is gradual; rarity comes first.
4. Extinct forms sit between living groups, closing gaps.
5. Each continent's fossils resemble that continent's living animals.

Every one of those could have come out differently. All five held, in rocks Darwin never saw.

WHERE HE LOST, AND WON LATER

He estimated 306 million years for the erosion of one English valley, was mocked, and withdrew it. Lord Kelvin then used cooling physics to argue the earth was far too young for evolution, and Darwin had no reply — because radioactivity, which breaks Kelvin's sums, wasn't discovered until 1896. The earth is 4.5 billion years old. There was always plenty of time.

Part Seven

Chapters 11 & 12: Geographical Distribution

Part Six looked down, into the rock. Part Seven looks out, across the map — and asks a question so ordinary that nobody had thought to find it strange: why does anything live where it lives?

Two chapters, and they are among the most enjoyable in the book, because this is Darwin's home ground. He spent five years sailing round the world looking at exactly this.

The puzzles he sets are lovely. Two regions with identical climates — same temperature, same rainfall, same soil — are stocked with completely unrelated animals and plants. Meanwhile a mountain range or a stretch of sea separates two areas with quite different climates whose inhabitants are near-identical. Climate plainly isn't doing the work. Barriers are.

Then the islands, which are where the argument becomes unanswerable. Oceanic islands have far fewer species than mainlands of the same size. They have *no* native land mammals, and *no* frogs or toads — though both do perfectly well when humans bring them. But they are full of birds, bats, insects and plants. And the species they do have look like those of the nearest mainland, however different that mainland's climate happens to be.

Every one of those facts is inexplicable if creatures were put where they best fit. All of them follow immediately if life had to *get there* — and Darwin, being Darwin, spent years in his kitchen floating seeds in salt water and feeding them to ducks to find out exactly how far things can travel.



End of Part Six of Eight · *The Broken Record*

My own reading of Darwin — Lovepreet Singh