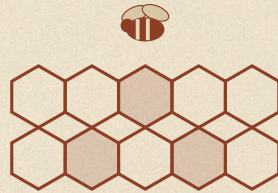


MY OWN READING OF DARWIN · IN EIGHT PARTS

ON THE ORIGIN OF SPECIES

By Means of Natural Selection

Charles Darwin, 1859 — first edition



PART FIVE OF EIGHT

The Two Hard Cases

Chapter VII: Instinct +

Chapter VIII: Hybridism

*“One special difficulty, which at first appeared to me
insuperable, and actually fatal to my whole theory.”*

Darwin, Chapter VII, on the sterile worker bee

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

Two debts come due

Darwin listed four difficulties in Chapter 6 and answered two of them on the spot. These are the two he put off — and he put them off because they are harder.

Back in Part Four, Darwin lined up the objections to his own theory. Where are the transitional forms? How do you get a bat, or an eye? He dealt with both. Then he named two more and said, honestly, that each needed a chapter of its own.

THE TWO UNPAID DEBTS

Can instinct be built by natural selection? A bird that has never seen a nest builds the right nest. A bee builds a mathematically optimal cell. These aren't body parts — they're *behaviours*. How does a behaviour get inherited, and how could a blind process design one?

Why are hybrids sterile? Varieties of one species interbreed freely and their young are fertile. Different species usually can't interbreed at all, and when they can, the offspring — a mule, say — is a dead end. That looks like a genuine hard line drawn through nature, exactly where Darwin claims there is none.

These two chapters feel nothing like each other

Chapter 7 is a delight. It is the most enthusiastic writing in the book, and also the most disturbing. Darwin is plainly having a wonderful time with bees and ants, and then he walks you into some genuinely grim material about slavery and infanticide in the insect world and doesn't flinch. It also contains the one problem he says nearly killed his theory outright.

Chapter 8 is a slog. It is dense, technical, full of other people's breeding experiments, and it is the chapter his opponents cared about most. Because in 1859, hybrid sterility was the single strongest argument that species are real, fixed, separately created things.

I'll go slowly through Chapter 8's argument, because it's clever and it's buried under a mountain of pollen data.

II

Instinct

How a bee inherits geometry it was never taught, why some ants keep slaves, and the one problem Darwin says almost destroyed his whole theory.

An instinct is a behaviour an animal performs correctly the first time, without being shown, without understanding why.

Darwin refuses to define instinct properly, and he's right to. Instead he describes it, and his description is the clearest thing anyone has written on the subject.

IN DARWIN'S OWN WORDS

"An action, which we ourselves should require experience to enable us to perform, when performed by an animal, more especially by a very young one, without any experience, and when performed by many individuals in the same way, without their knowing for what purpose it is performed, is usually said to be instinctive."

WHAT HE MEANS — If *we* would have to learn it, and an animal does it straight off, and every member of the species does it the same way, and none of them knows why — that's an instinct.

Three things in there are doing work. *Without any experience* — so it isn't learned. *Many individuals in the same way* — so it isn't personality. *Without knowing what for* — so it isn't reasoning.

And Darwin is careful to separate instinct from habit. A habit is picked up during a lifetime, and lifetime habits are not the raw material here. What he needs is behaviour that is *born in* and therefore inheritable.

The easy part: we have already done this ourselves

Before the hard cases, Darwin makes the same move he made in Chapter 1 — go and look at what breeders have already achieved without meaning to.

- A pointer freezes and points at game. Nobody teaches a puppy this; you can watch it happen the first time it smells a bird.
- A retriever carries the bird back instead of eating it, which is a genuinely strange thing for a predator to do.
- A sheepdog circles a flock rather than attacking it — hunting behaviour with the kill removed.

- A tumbler pigeon flips backwards in mid-air. For no reason. It just does.

These are inherited behaviours, they vary between individuals, and humans amplified them by breeding from the dogs that did them best. If behaviour can be shaped by a few centuries of careless human selection, the question isn't whether instincts can be built. It's whether the *hard* ones can.

So Darwin goes and picks the three hardest he can find.

Hard case one: the cuckoo

The European cuckoo lays its eggs in other birds' nests and abandons them. The foster parents raise the chick. And the young cuckoo, blind and naked and only hours old, heaves its foster-siblings over the edge of the nest to die.

It is a horrible thing to read about and it looks impossible to build gradually. What use is half of that?

Darwin's answer is the same as always: go and find the gradation. The American cuckoo builds its own nest and raises its own young — but it *occasionally* lays an egg in another bird's nest as well. That's the first rung, and it pays for itself immediately: a bird that offloads one egg has one fewer mouth to feed and one extra chance of a surviving chick.

Do that more often, and more reliably, over enough generations, and you arrive at a bird that has stopped building nests altogether.

Hard case two: ants that keep slaves

Some ant species raid the nests of other ants, carry off the pupae, and put the resulting adults to work. Darwin studied two of them and the contrast between them is the whole argument.

FORMICA SANGUINEA

Keeps fewer slaves. Still forages, still decides when the colony moves, still does its own work alongside them.

Would survive, more awkwardly, without them.

FORMICA RUFESCENS

Utterly dependent. Cannot forage, cannot build, cannot even feed itself.

Darwin: without its slaves the species would be extinct within a single year.

Two species, one habit, caught at two different distances along the same road.

That gap is the point. There is no need to explain how a fully dependent slave-maker appeared from nothing, because a partly dependent one is right there in the same wood. Each step — carry off a pupa, let it work, rely on it a little more — is useful on its own and leads to the next.

A NOTE ON THE WORD

Darwin uses “slave-making” because that was the standard entomological term of his day, and it still is. It describes ants stealing the young of other ant species. It is worth saying plainly that he is not drawing any analogy to human beings — Darwin came from a family of committed abolitionists and was appalled by slavery all his life.

Hard case three: the honeycomb

This is the one Darwin clearly loves, and it’s the hardest, because it isn’t just complicated — it’s *mathematically optimal*.

IN DARWIN’S OWN WORDS

“He must be a dull man who can examine the exquisite structure of a comb, so beautifully adapted to its end, without enthusiastic admiration.”

WHAT HE MEANS — If you can look at a honeycomb properly and not be amazed, something is wrong with you.

Here is what a bee does. It builds cells in hexagons, packed with no gaps, sharing every wall, with the back of each cell folded into a three-sided pyramid that meshes with the cells on the other side of the comb. The result uses the smallest possible quantity of wax for the largest possible storage. Mathematicians had to work to prove this was optimal. The bee has never met a mathematician.

And wax is expensive — a bee has to eat a great deal of honey to make a little of it — so the saving is real and worth having.

DARWIN'S ANSWER, PART ONE: THE GRADATION

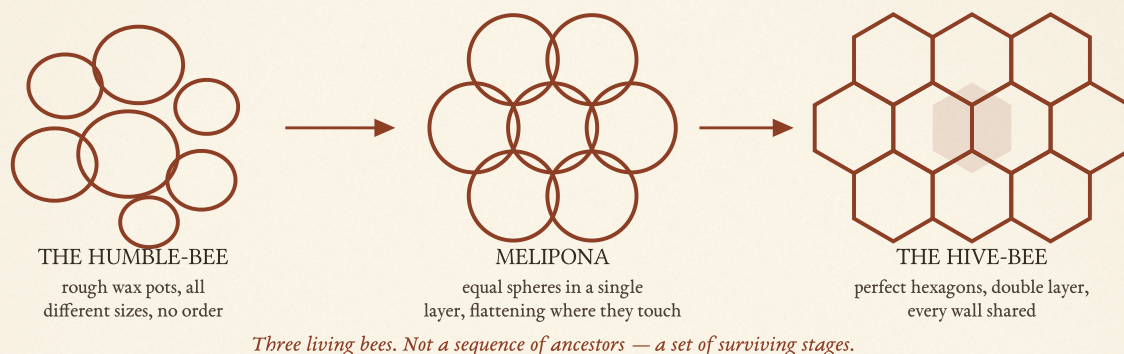


FIGURE 17 *Darwin's ladder for the honeycomb. The middle rung is the one that matters: **Melipona** already builds equal spheres in a layer, which is most of the way there without any geometry being involved.*

DARWIN'S ANSWER, PART TWO: THE BEE IS NOT DOING GEOMETRY

This is the beautiful bit, and it's the reason the chapter works.

Darwin's claim is that a bee does not measure angles, and does not need to. It follows two simple rules: excavate a rough sphere, and stay a fixed distance from your neighbours. When neighbouring spheres run into each other, the bees gnaw the wax away at the meeting surface, and what is left is a flat wall.

Do that with equal spheres at equal spacing and the flat walls have no choice about where to be. Six neighbours, six flat walls, a hexagon. Nobody decided on a hexagon. It is what falls out.

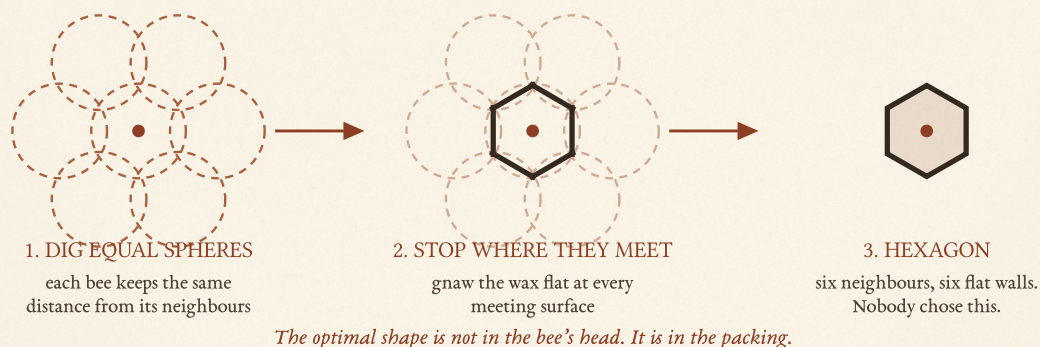


FIGURE 18 *Where the hexagon actually comes from. Two dumb rules, followed by a lot of bees at once, and the geometry appears by itself. This is Darwin's method in miniature: replace a designer with a procedure.*

He did not leave this as an argument. He ran experiments — feeding bees wax coloured with vermilion so he could trace exactly which bee had worked where, and giving them ridged and flattened wax plates to build against, to see what they did with the wrong starting conditions.

WHY I THINK THIS IS THE BEST SECTION IN THE BOOK

It's the same trick as the whole theory, shrunk down to something you can hold in your hand.

A honeycomb looks like it needs a designer, because the outcome is optimal and the builder plainly doesn't understand geometry. Darwin's answer is not "bees are cleverer than you think." It is: the cleverness isn't in the bee. It's in what happens when a simple rule is applied over and over by a lot of individuals.

Swap bees for organisms and wax for generations and you have Chapter 4.

The difficulty that nearly ended it

And then, in the middle of a chapter full of enthusiasm, Darwin stops and says he has to deal with something that once looked like the end of everything.

THE MOST ALARMING SENTENCE DARWIN EVER WROTE ABOUT HIS OWN WORK

"One special difficulty, which at first appeared to me insuperable, and actually fatal to my whole theory. I allude to the neuters or sterile females in insect-communities."

WHAT HE MEANS — There is one thing that looked, for a while, like it destroyed everything I've written. It's the sterile workers in ant and bee colonies.

Take a second to see why this is so bad for him.

A worker bee is sterile. She will never lay an egg. She leaves no descendants at all. And yet she is exquisitely equipped for her job — pollen baskets on her legs, wax glands in her abdomen, a barbed sting, and the entire comb-building instinct.

Now run natural selection on that. Selection works because individuals with useful variations leave more offspring, and those offspring inherit the variation. A worker leaves *zero* offspring. So there is no way for "slightly better worker" to be passed on. The machinery has nothing to grip.

Worse, in some ants there are two or three different worker castes in the same nest — small workers and huge-jawed soldiers — all sterile, all different, all beautifully suited to their role. If selection can't reach one sterile caste, it certainly can't build three.

DARWIN'S ANSWER, WHICH TOOK HIM A LONG TIME TO FIND

His solution is one line, and it's a genuine conceptual leap: selection can act on the family, not only on the individual.

The worker doesn't need to breed. Her *parents* breed. And the queen and drone that produced a batch of unusually good workers end up with a colony that stores more honey, defends itself better and survives the winter — and that colony sends out more new queens next year. Those new queens carry the same instructions that made good workers.

The trait travels through the fertile relatives. The worker is a dead end who improves everybody else's odds.

Darwin illustrates it with the least glamorous example imaginable, and it's perfect:

IN DARWIN'S OWN WORDS

"A well-flavoured vegetable is cooked, and the individual is destroyed; but the horticulturist sows seeds of the same stock."

WHAT HE MEANS — You can't breed from the tastiest carrot, because you ate it. But you plant seed from the same family and get tasty carrots again. Selection worked perfectly well on an individual that left no offspring, because its relatives carried the same thing.

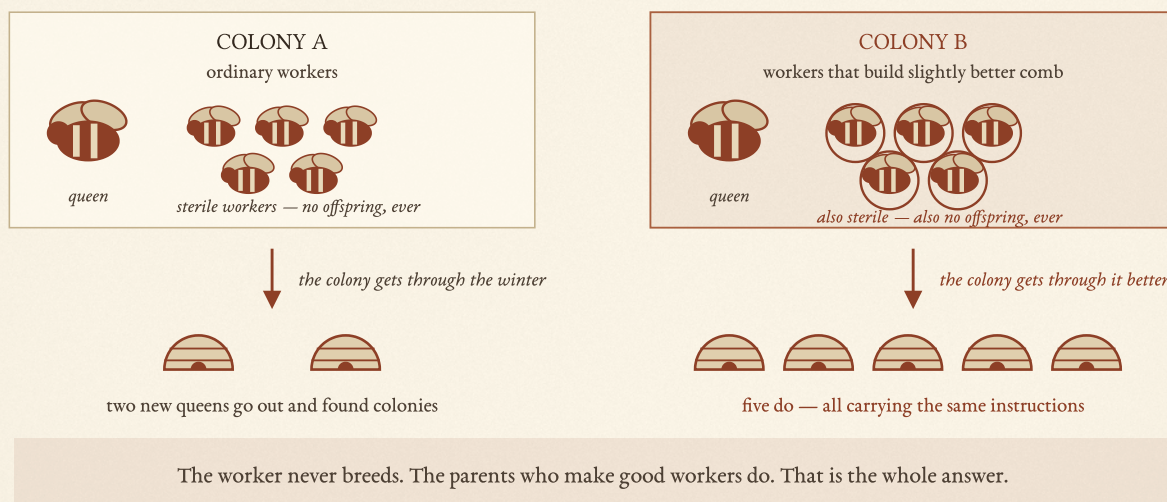


FIGURE 19 Selection reaching an individual that cannot reproduce. Nothing has to pass *through* the worker — the trait travels in her fertile relatives, and the colonies that produce better workers send out more queens.

A HUNDRED AND FIVE YEARS EARLY

Darwin has no genetics, no idea why bees and ants in particular should have evolved sterile castes so often, and no way to put numbers on any of it. He works it out from first principles and one carrot.

In 1964 a young biologist named W. D. Hamilton turned this into proper mathematics — kin selection. A gene that makes you help a relative can spread, if the help to the relative outweighs the cost to you, in proportion to how closely related you are. Since your relatives carry copies of the same gene, helping them *is* a way of getting the gene into the next generation.

It also explained the puzzle Darwin couldn't even see: bees, wasps and ants have an unusual system of inheritance that makes sisters extraordinarily closely related to one another — which is precisely why sterile sisterhoods keep appearing in that group and almost nowhere else.

And instincts are not perfect either

Darwin closes the chapter the same way he closed Chapter 6, and it's the same move: if instincts were designed, they should be flawless. They aren't.

Bees make mistakes and waste wax. Ants make errors of judgement. Instincts misfire routinely when conditions shift even slightly — the machinery was tuned to circumstances that may no longer apply.

And he adds one more test of the same kind he used for organs: no instinct has ever been found that exists purely for the benefit of another species. Instincts help their owner or their owner's family. If one turned up that served somebody else at its owner's expense, the theory would have a serious problem. None has.

SECTION THREE · CHAPTER VIII OF THE BOOK

III

Hybridism

The strongest single argument against Darwin in 1859, and his patient dismantling of it. Dry going, and the reasoning at the centre is the sharpest in the book.

A hybrid is the offspring of two different species. A mule — horse crossed with donkey — is the famous one, and mules cannot have foals.

Here is the objection, and in 1859 it had real force.

Two varieties of one species breed together perfectly happily, and their young breed on for ever. Two different species usually can't breed at all — and on the rare occasions they can, the offspring is a dead end.

So there *is* a line. It isn't a matter of opinion or filing convention. It is a hard biological wall, it falls exactly where naturalists say species boundaries are, and it looks for all the world like something put there on purpose to keep the created kinds from running together.

Darwin has spent seven chapters arguing that species are only well-marked varieties. This chapter has to remove the wall, and he does it in three moves.

Move one: separate the two things everyone runs together

People say “species are sterile together” as if it were one fact. It's two, and they don't behave the same way.

- The difficulty of the first cross. Getting any offspring at all. Both parents are perfectly fertile with their own kind; they just won't take with each other.
- The sterility of the hybrid. The cross works, you get a healthy animal — and *that* animal can't breed. A mule is strong, long-lived, and a dead end.

They are different problems with different causes, and they don't track each other. Some pairs cross with great difficulty and yet the few offspring produced are fertile. Others cross easily and produce entirely sterile young. If a designer had installed one barrier, you would not expect it to come apart into two pieces that disagree.

Move two: show that it is a slope, not a wall

Then Darwin does the thing he always does, and buries the reader in other people's data — decades of plant-crossing experiments by two hybridisers named Kölreuter and Gärtner, who between them crossed thousands of plant pairs and wrote down every result.

And the results do not form two groups. They form a smear.

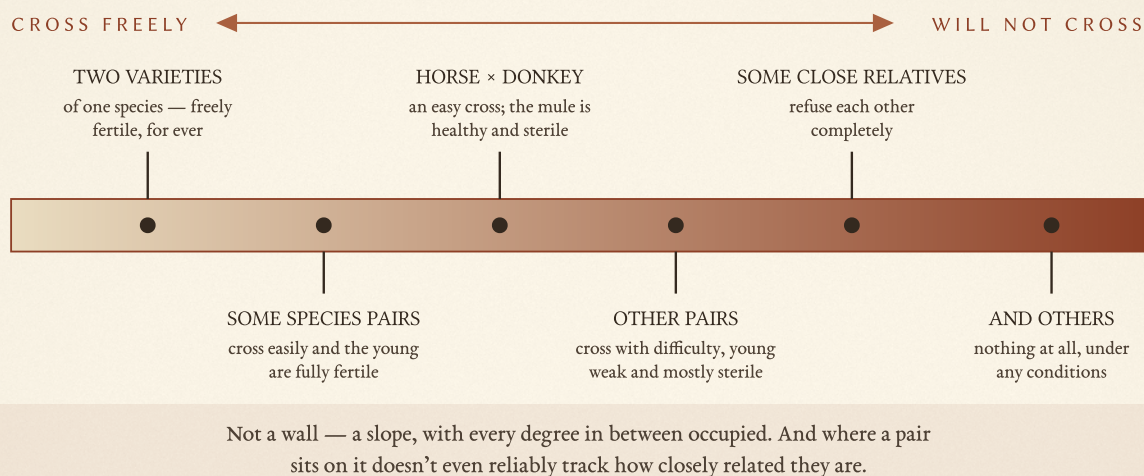


FIGURE 20 *What the hybridisers actually found. If sterility were a boundary marker installed at the species line, it would be present or absent. Instead it comes in every possible degree, and in the wrong order.*

He adds a detail that I think is the quiet killer. Reciprocal crosses often give completely different results. Put species A's pollen on species B and you get seed; put B's pollen on A and you get nothing. Same two species, opposite outcomes depending on which way round you do it.

A barrier installed to keep two kinds apart would not work in one direction and fail in the other. That is not a wall. That is two machines that no longer quite fit together, and the misfit happens to be worse one way round than the other.

Move three: selection cannot have built it

This is the argument I keep coming back to, because it is a genuinely elegant piece of reasoning and it takes about three sentences.

THE CORE OF THE CHAPTER

“The sterility of hybrids could not possibly be of any advantage to them, and therefore could not have been acquired by the continued preservation of successive profitable degrees of sterility.”

WHAT HE MEANS — Being sterile never helps the individual who is sterile. So there is no way natural selection could have built it up step by step.

Follow it slowly, because it does something unusual.

Natural selection accumulates traits that lead to more surviving offspring. A tendency towards sterility leads to *fewer* offspring — in the limit, none. So any such tendency deletes itself immediately. Selection

cannot build sterility. It is the one thing the mechanism is structurally incapable of producing.

Now notice who that argument hurts.

MY TAKE — DARWIN ARGUES AGAINST HIS OWN MECHANISM, AND WINS

He has just proved that *his own theory cannot explain hybrid sterility*. On the face of it that's a devastating admission.

But look at what it forces. Sterility exists. Selection can't have made it. So it cannot be a purpose-built barrier at all — not by selection, and, he implies without ever saying it, not by anything else that had a reason.

What's left is that it is a side effect. Two populations drift apart for long enough, each accumulating changes in its own reproductive machinery for its own local reasons, and eventually the two sets of machinery no longer mesh. Nobody built the incompatibility. It is what you get when two things that used to be one thing stop being maintained together.

That is why sterility comes in every degree, why it doesn't track relatedness cleanly, and why it works one way round and not the other. Side effects are messy. Barriers are not.

THE GRAFTING ANALOGY

To make the point land, Darwin reaches for something nobody has any strong feelings about: grafting.

Gardeners know that some plants can be grafted onto each other and some can't, and the pattern is patchy and unpredictable. Nobody has ever suggested that the Creator specially designed which pear will take on which quince in order to keep the fruit trees from mingling. Everyone accepts it as an incidental consequence of the two plants' growth differing.

Crossing, says Darwin, is the same kind of fact. We only treat it as profound because we have decided in advance that species are special.

AND VARIETIES ARE NOT ALWAYS FERTILE TOGETHER EITHER

The final brick. If the rule is "varieties fertile, species sterile," then any case of two *varieties* showing reduced fertility breaks the rule. Darwin collects them. They are not common, but they exist — and one is enough, because the claim was that the line is absolute.

THE LAST LINE OF CHAPTER 8

"The facts briefly given in this chapter do not seem to me opposed to, but even rather to support the view, that there is no fundamental distinction between species and varieties."

WHAT HE MEANS — The strongest evidence against me turns out, looked at properly, to be evidence for me.

IV

What happened to these two arguments

One was vindicated with mathematics a century later. The other was vindicated and then corrected in an interesting way.

INSTINCT: DARWIN WAS RIGHT, AND IT TOOK 105 YEARS TO PROVE

His family-selection answer sat there as a plausible hand-wave for a very long time. Then Hamilton did the algebra in 1964 and turned it into a rule you can apply: a gene for helping relatives spreads when the benefit to the relative, discounted by how closely related you are, exceeds the cost to yourself.

Sterile castes stopped being a difficulty and became one of the strongest confirmations of the whole framework — because the theory predicts *where* you should find them, and that's where they are.

HYBRIDISM: RIGHT ABOUT THE MECHANISM, INCOMPLETE ABOUT THE STORY

Darwin's central claim has held up completely. Hybrid sterility is a by-product, not a purpose. We can now say what the by-product is made of: two separated populations each accumulate changes that work fine at home, and when the two sets are finally combined in one hybrid body, some of them contradict each other. Neither change was ever a problem on its own. The incompatibility only exists in the mixture.

That is exactly the shape of explanation Darwin reached for without being able to name a single component of it.

WHERE HE WAS PARTLY WRONG — AND IT'S INTERESTING

Darwin argued selection cannot build barriers between species, because sterility never benefits the individual who has it. That's true as far as it goes.

But there's a route he missed. Suppose two species already produce feeble or sterile hybrids. Any individual that wastes its breeding season on the *wrong* species has thrown away its whole reproductive life. So selection now favours anything that helps you avoid the mistake — a different courtship song, a different flowering time, a stronger preference for your own kind.

Selection can't make you sterile with the other species. It can absolutely make you stop trying. The barrier gets reinforced from the outside, and biologists call it exactly that: reinforcement.

Darwin's logic was sound; he just stopped one step short of the loophole.

AND THE SPECIES LINE IS BLURRIER THAN EVEN DARWIN CLAIMED

He would have enjoyed knowing how thoroughly the boundary has since dissolved. Some species hybridise freely and productively in the wild. Some populations form a chain around a mountain range or a continent, each neighbouring pair interbreeding happily, until the two ends of the chain meet again and cannot. And it turns out that ancient humans interbred with at least two other human species — most people alive today carry a small amount of Neanderthal in them.

“Species” remains what Darwin said it was in Chapter 2: a convenience label, arbitrarily given, extremely useful, and not a fact about the world.

REFERENCE

Every hard word in this part

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

Instinct

A behaviour performed correctly first time, without being taught, the same way by every member of a species, none of whom knows why. Darwin declines to define it more tightly than that, and he’s wise not to.

Habit

Something picked up during a lifetime. Darwin is careful to keep this separate from instinct — habits die with the individual, so they are no use to his argument.

Neuter (*sterile caste*)

A worker bee or ant. Female, fully equipped for her job, and permanently unable to reproduce. The thing Darwin called insuperable and actually fatal to his theory.

Family Selection

Darwin’s answer to the sterile worker: selection can act on a whole family rather than one individual. The parents that produce good workers leave more descendants, so the trait travels through the fertile relatives.

Caste

A distinct kind of worker within one colony — small foragers and huge-jawed soldiers in the same ant nest, all sterile, all sisters. Two or three castes made Darwin’s problem several times worse.

Melipona

A stingless bee whose comb is the crucial middle rung: equal spheres packed in a single layer, already flattening where they touch. Most of the way to a hexagon without any geometry.

Kin Selection

The modern version, worked out by W. D. Hamilton in 1964. Helping a relative can pay, because relatives carry copies of the same instructions. Darwin’s carrot, with the algebra filled in.

Brood Parasite

An animal that gets somebody else to raise its young. The cuckoo is the famous one. Darwin's answer is the American cuckoo, which does it occasionally rather than always.

Hybrid

The offspring of two different species. A mule is a hybrid of horse and donkey — healthy, strong, and unable to have foals of its own.

Mongrel

Darwin's word for the offspring of two *varieties* of the same species, as opposed to a hybrid from two species. Usually fully fertile — which is exactly the contrast Chapter 8 has to explain away.

First Cross

The initial mating between two species. Its difficulty is a separate question from whether the resulting hybrid can breed, and the two don't track each other.

Reciprocal Cross

Doing the same cross both ways round — A's pollen on B, then B's on A. These often give completely different results, which is very hard to explain if sterility is a deliberate barrier.

Incidental

A side effect. Darwin's single most important word in Chapter 8: sterility isn't a purpose, it's a consequence of other changes nobody was aiming at.

Ring Species

A chain of populations circling a mountain or a coastline, each neighbouring pair interbreeding happily — until the two ends of the ring meet and cannot. A species boundary you can walk around the outside of.

Reinforcement

The modern addition Darwin missed. Once hybrids are feeble, selection favours anything that stops you wasting a breeding season on the wrong species — a different song, a different season. The barrier gets strengthened from outside.

Lines worth remembering

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

-
- 1 Behaviours are inherited and variable, and we have already reshaped them ourselves — a pointer points without being taught, and nobody designed that on purpose.

 - 2 For every impossible-looking instinct there is a species doing a milder version. The American cuckoo dumps an egg *occasionally*; one ant keeps slaves without depending on them.

 - 3 The bee isn't doing geometry. Dig equal spheres, keep your distance, gnaw flat where you meet — the hexagon falls out of the packing on its own.

 - 4 That is the whole book in miniature: the cleverness isn't in the builder, it's in what a simple rule produces when it runs everywhere at once.

 - 5 A sterile worker leaves no offspring, so selection has nothing to grip. Darwin's answer: it grips the family instead. You ate the best carrot, and you sow seed from the same stock.

 - 6 Hybrid sterility isn't a wall, it's a slope — every degree occupied, and not even in the right order by relatedness.

 - 7 Selection cannot build sterility, because sterility deletes itself. So sterility was never a barrier *for* anything. It is a side effect of two machines drifting out of alignment.

 - 8 The strongest argument against Darwin in 1859 — that species are sealed off from one another — turned out, examined closely, to be an argument for him.
-

Part Five on one page

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

THE TWO DEBTS

Chapter 6 named four difficulties and answered two. These are the other two: can natural selection build an instinct, and why are hybrids sterile if species are only well-marked varieties?

CHAPTER 7 — INSTINCT

An instinct is a behaviour done right first time, by everyone, without knowing why. Breeders have already reshaped them — pointers point, retrievers retrieve, tumbler pigeons tumble. For the hard cases Darwin finds the gradation every time: the American cuckoo dumps an egg *occasionally*; *Formica sanguinea* keeps slaves but doesn't depend on them while *F. rufescens* would be extinct in a year without them.

THE HONEYCOMB, AND WHY IT ISN'T GEOMETRY

Hexagonal cells use the least wax for the most storage — provably optimal. Darwin's answer: the bee follows two dumb rules. Dig a rough sphere; stay a fixed distance from your neighbours. Gnaw the wax flat where spheres meet and the hexagon appears by itself. The gradation is alive today: the humble-bee's rough pots, *Melipona*'s equal spheres in a layer, the hive-bee's perfect comb.

THE DIFFICULTY THAT NEARLY KILLED THE THEORY

A worker bee is sterile. She leaves no offspring, so a "better worker" trait has no way to be passed on — and yet workers are exquisitely equipped, in several distinct castes. Darwin's answer: selection acts on the family, not only the individual. The parents that produce good workers found more colonies. His image: you cook the best-flavoured vegetable, destroying it, then sow seed from the same stock. Hamilton turned this into kin selection in 1964.

CHAPTER 8 — HYBRIDISM

Separate two things people merge: the difficulty of the *first cross*, and the sterility of the *hybrid*. They don't track each other. Across thousands of recorded crosses, sterility comes in every possible degree — a slope, not a wall — and doesn't reliably follow relatedness. Reciprocal crosses often work one way round and fail the other.

THE ARGUMENT AT THE CENTRE

Sterility never benefits the individual who has it, so natural selection cannot possibly have built it. Therefore it was never a purpose-built barrier at all. It is *incidental* — the side effect of two populations drifting apart until their reproductive machinery no longer meshes. Nobody thinks God designed which pear grafts onto which quince; this is the same kind of fact.

THE VERDICT

The strongest argument against Darwin in 1859 turns out, examined properly, to support him: there is no fundamental distinction between species and varieties.

Part Six

Chapter 9: On the Imperfection of the Geological Record · Chapter 10: On the Geological Succession of Organic Beings

Back in Part Four, Darwin wrote a cheque he couldn't cash. Asked where all the transitional forms were, he said the fossil record was far more incomplete than anyone realised, promised to prove it, and moved on. Part Six is where he has to pay.

Chapter 9 is his defence of the evidence he doesn't have, and it is a much better chapter than that description suggests. He goes through exactly how a fossil gets made and how many things have to go right — the animal must die in the right place, be buried fast, escape being eaten and crushed and dissolved, sit in rock that survives millions of years of weathering, and then happen to be exposed at the surface somewhere a human being is looking. Each step throws away almost everything.

His verdict is one of the best images in the book: the geological record is a history of the world, imperfectly kept, of which we possess the last volume alone — and of that volume, only here and there a short chapter, and of each page, only a few scattered lines.

Chapter 10 turns from what's missing to what is actually there, and it is the stronger chapter. Whatever the gaps, the fossils that *have* been found appear in a definite order. Species come and go one at a time, never reappear once gone, and the ones found together in a layer resemble each other more than they resemble those from distant layers. Extinct forms in a region look like the living forms of that same region.

None of that has to be true. It is exactly what a branching family tree buried in sediment would look like, and it is very hard to explain any other way.



End of Part Five of Eight · *The Two Hard Cases*

My own reading of Darwin — Lovepreet Singh