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Bacterial Chemotaxis: The Minimal Cognition

The Smallest Mind

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In which a single bacterium — with no brain, no nerves, nothing we would call a mind — is found to sense its world, hold a memory for a few seconds, compare then with now, decide which way to go, and swim there: the whole of behaviour, sensing to acting, worked in one cell, and the smallest ancestor of thought.

Tau (T) is the living fabric of time itself — the sole substance of which all physical reality is composed. Every particle, force, wavelength, and conscious experience is a structured configuration of T-flow. There is no gravity, no electromagnetic force, no strong nuclear force as separate entities: all are registers of the single T-field operating across dimensional levels. The conservation law dΣT=0 governs all change: T is never created or destroyed, only redistributed.

Introduction — Through the Force of Time

The chapter that follows is, in the conventional telling, bacterial chemotaxis — how a single cell senses a gradient, remembers over seconds, and swims toward food by run-and-tumble. Read through the Universal Force of Time, it is the minimal T-cognition: sense, remember over seconds, compute a gradient, act — proving that reading T-differences across time is enough for behaviour. The bacterium is the one-cell prototype of the Earth-locked consciousness the theory describes.

A bacterium swims toward food and away from harm, and to do so it must, in some real sense, know where the good things are. It has no brain, no nerves, no organ of sense — it is a single cell — yet the textbook itself grants it ‘sensors, computers, and motors’, and, crucially, a short memory. That is the skeleton of a behaving creature, credited to one cell.

The obvious way to find a gradient — compare the concentration at the front and the back — is closed to the bacterium: it is far too small for the difference across its length to be measurable, and it eats the attractant as it goes. So it does something deeper. Unable to compare two places, it compares two times: it measures the concentration now, swims a little, measures again, and asks whether things improved. Better → keep going; worse → change course. To do this it holds a short-term memory — a few seconds

— of its last reading, and the whole computation must finish within seconds, before Brownian motion (which re-aims the cell every 3 to 10 seconds) erases its heading. The decision becomes movement through run-and-tumble: straight runs broken by random tumbles, with runs biased longer when the readings improve, so the cell drifts up the gradient without ever steering straight at the source. And it adapts — a steady level soon ceases to excite it, and it re-zeros, staying sensitive to change rather than absolute amount.

Here is the reading. Chemotaxis is the minimal T-cognition. The bacterium reads its T-environment not as a level but as a difference across time: the measure-swim-measure loop is the simplest possible T-clock with a memory — read the field, hold a value, compare against it — and that is already enough to choose. Adaptation is dΣT homeostasis in the sensing register, the cell conserving its dynamic range by measuring change, not level, exactly the product-sensing homeostasis we met in the gene of Chapter 15. And the gradient-reading is spatial T-address reading on the move — the same faculty by which a developing embryo's cells read morphogen gradients to know what to become (Chapter 17), here exercised by a free cell to know where to go. Position-finding by concentration is T-address reading, whether the reader is fixed in a body or swimming free.

And the deepest point roots cognition itself at the bottom of life. Sense, remember, compare, decide, act — the bare skeleton of what a mind does — is done, entire, by a bacterium with no brain, three billion years before there was a brain to house it. The Force of Time holds that consciousness is a T-process, the brain's forty-per-second rhythm locked to the Earth's own register; if so, thought is not an invention of the vertebrate brain but the elaboration of something far older — a T-node reading the field, holding a value, comparing across time, acting on the difference — and that something, in its irreducible form, is the swimming bacterium. The atom of mind is a cell reading a gradient and remembering, for a few seconds, where it just was.

This reaches the reader in the most personal way. The operations your own thought is built from — sensing, remembering, comparing, deciding, acting — are not the invention of the brain but the ancient birthright of the single cell, worked out by bacteria steering toward sugar long before there were brains. Every neuron in your head is a cell that senses, holds a chemical memory, compares, and fires — doing, wired to billions of its fellows, what the swimming bacterium does alone. You are not a mind bolted onto a body of mindless parts; you are built, all the way down, of cells that already, each in the smallest way, sense and remember and choose. The capacity to know one's world and move within it runs unbroken from the smallest cell to the human mind — one faculty, worn at a thousand scales — and the difference between a bacterium's behaviour and a person's thought is one of degree and elaboration, not of kind.

Carry this into the chapter: chemotaxis is the minimal T-cognition — sense, remember over seconds, compute a gradient, act — proving that reading T-differences across time is *enough for behaviour. The bacterium is the one-cell prototype of the mind: the smallest and the greatest are, at root, one — the field, reading itself, and choosing.*

SECTION 22.1

The Smallest Mind

We come, near the end of this book, to a chapter about a bacterium doing something that looks, when you watch it closely, uncannily like thinking. A bacterium in a drop of water is not adrift and passive. It swims — toward food, toward the sugars and amino acids and oxygen it needs, and away from things that would harm it. And to do this it must, in some real sense, know where the good things are and steer toward them. It has no eyes, no nose, no brain, no nerves — nothing we would ordinarily call an organ of sense or thought. It is a single cell. And yet it senses its surroundings, decides on the strength of what it senses, and acts. It behaves.

The textbook itself, describing this, reaches for a striking phrase: a bacterium that chases food must contain, it says, elementary sensors, computers, and motors. Read that again, for it is a remarkable admission. A single cell is credited with the three parts of a behaving creature — something to perceive, something to decide, something to move — and, as we shall see, with a fourth thing besides: a short memory. In the reading of this book, this is cognition at the scale of one cell, the smallest ancestor of mind: a T-node reading its environment, holding a value, comparing, and choosing. Everything that a brain does, in its vast elaboration, a bacterium does here in miniature — and watching how it manages, on so little, is watching thought at its root.

SECTION 22.2

The Problem of the Gradient

The bacterium’s task is to swim up a gradient — toward wherever a wanted substance is more concentrated. And the obvious way to do that would be to compare its two ends: to sense the concentration at its front and at its back, and, if the front reads higher, to know it is pointed the right way. This is roughly how you find a wall in the dark by feeling with two hands. But for a bacterium it does not work, and the reason is a lovely lesson in the tyranny of small size. A bacterium is so minute that the difference in concentration between its front and its back — across a length of a few thousandths of a millimetre — is almost nothing, far too slight to measure against the random noise of molecules arriving. Worse, the cell consumes the very substance it is trying to sense, eating the attractant and so blurring the reading further.

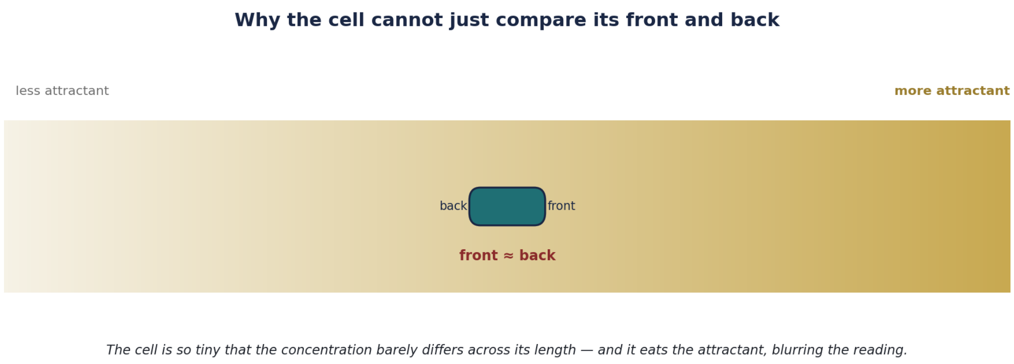


Figure 22.1. Why the cell cannot compare its front and back. A bacterium is so tiny that the concentration barely differs across its length — front and back read almost the same — and it consumes the attractant as it goes, blurring the reading. Spatial comparison, the obvious method, is closed to it.

So the simple method — look at two places at once and compare — is denied to the bacterium by its own smallness. It cannot tell direction by comparing its ends. And this is where its cleverness begins, for it solves the problem in a way that is, in the reading of this book, far more profound than the method it cannot use. Unable to compare two places, it compares two times.

SECTION 22.3

Sensing in Time, Not Space

Here is the trick, and it is beautiful in its economy. The bacterium measures the concentration around it now; then it swims a little way; then it measures again; and it asks a single question — is it more, or less, than it was a moment ago? If more, it is heading in a good direction, and it keeps going. If less, it is heading the wrong way, and it changes course. It does not need to compare its front with its back; it compares its present with its recent past. By turning a question about space — which way is better? — into a question about time — is it getting better? — it sidesteps entirely the problem of its own smallness, for it can measure the concentration over its whole surface, as accurately as it likes, at two moments a little apart.

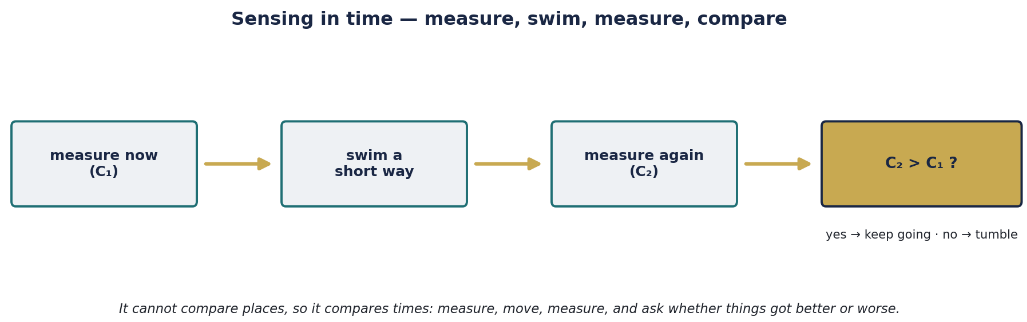


Figure 22.2. Sensing in time. Unable to compare places, the bacterium compares times: it measures the concentration now, swims a short way, measures again, and asks whether it went up or down. Better → keep going; worse → change course. A question about direction becomes a question about change.

In the reading of this book, this is the deepest move in the chapter, and the reason chemotaxis belongs so squarely to the Force of Time. The bacterium reads its T-environment not as a level but as a difference across time — it clocks the change in its surroundings and acts on the change. Behaviour, here, is a T-difference computed over remembered time. And to compute a difference across time, the cell needs one thing above all, a thing we have not yet credited to a single molecule or cell in quite this way: it needs to remember.

SECTION 22.4

A Memory of Seconds

To ask whether things are better now than they were a moment ago, the bacterium must hold, somewhere within it, a record of how they were — a memory of its recent reading, kept long enough to set beside the present one. And it does. The cell carries a short-term memory, lasting a few seconds, in which it holds its last measurement, so that it can compare the new reading against the old and detect the trend. This is not memory in any grand sense; it is a chemical trace, a lingering adjustment in the sensing machinery that keeps the recent past present for a moment. But it is memory nonetheless — the retention of a value across time for the purpose of comparison — and without it the whole method would collapse, for a cell that could not remember where it just was could never tell whether it was getting closer.

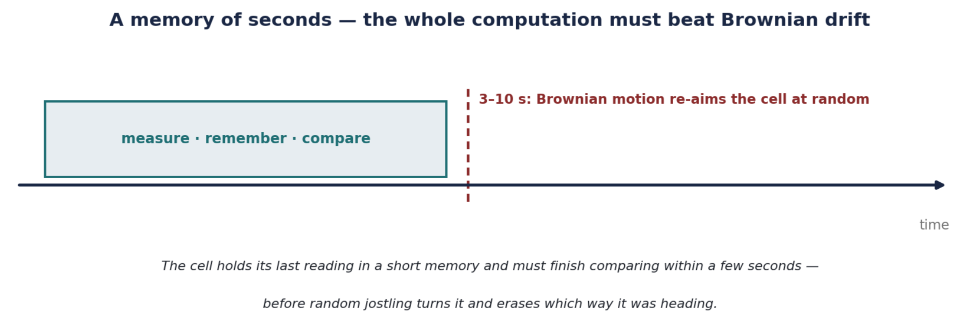


Figure 22.3. A memory of seconds. The cell holds its last reading in a short chemical memory and must finish the whole measure–remember–compare within a few seconds — because random Brownian jostling re-aims it every 3 to 10 seconds, erasing which way it was heading. The computation must beat the drift.

And there is a clock built into the difficulty, which makes the feat sharper still. A bacterium is so small that the ceaseless random battering of water molecules — Brownian motion — turns it this way and that, re-aiming it at random every three to ten seconds. So the whole computation — measure, remember, swim, measure again, compare, decide — must be completed within a few seconds, before the cell is randomly spun about and loses the very heading it was testing. In the reading of this book, the measure-swim-measure loop is the simplest possible T-clock with a memory: a cycle that reads the field, holds a value, and compares against it, all within a window set by the physics of its own size. It is a clock, and a memory, and a comparison — and that, it turns out, is already enough for a cell to choose.

KEY IDEA

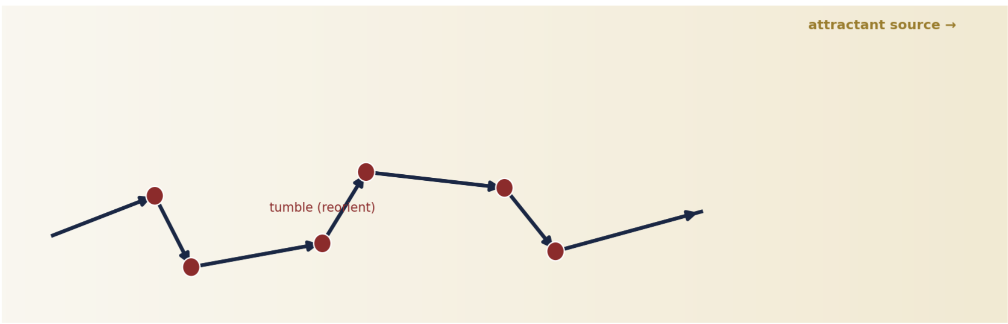
A bacterium swims up a gradient toward food, and it cannot do so by comparing its front and back — it is too tiny, and it eats the attractant. So it compares times, not places: it measures the concentration now, swims a little, measures again, and asks whether things improved. To do this it keeps a short-term memory (a few seconds) of its last reading, and the whole computation must finish within seconds, before Brownian motion (which re-aims it every 3–10 s) erases its heading. In this book: chemotaxis is the minimal T-cognition — a T-clock with memory, reading the field as a difference across time and acting on it. The bacterium senses, remembers, computes, and chooses — the atom of behaviour, and the smallest ancestor of mind.

SECTION 22.5

Run and Tumble

How does the decision become movement? The bacterium swims by spinning long, whip-like tails called flagella, and its motion has two modes. When the flagella turn one way, they gather into a single bundle and drive the cell forward in a smooth, straight run. When they turn the other, the bundle flies apart and the cell tumbles in place, spinning without going anywhere, until the flagella re-gather and it sets off again in a new, randomly chosen direction. Left to itself, this run-and-tumble makes an aimless zig-zag, a random walk that goes nowhere in particular. But the bacterium biases it. When its measurements tell it that things are improving — that it is heading up the gradient — it tumbles less, and so runs longer in the good direction. When things are worsening, it tumbles sooner, cutting the bad run short and trying a new heading.

Run and tumble — a biased walk that drifts up the gradient



Straight runs, broken by random tumbles; runs that head up the gradient are made longer, so the cell drifts toward more.

Figure 22.4. Run and tumble. The cell alternates smooth straight runs with random tumbles that re-aim it. By running longer when its readings improve and tumbling sooner when they worsen, it biases the random walk — drifting, over many runs, steadily up the gradient toward the source.

The result is subtle and lovely: the cell never steers directly toward the food, and never needs to. It simply lengthens the runs that happen to go the right way and shortens the ones that do not, and the sum of many such biased steps is a steady drift up the gradient. In the reading of this book, this is the field acting on its computed T-difference in the plainest way — extending its motion when the trend is good, breaking it off when the trend is bad. Decision, in this smallest of minds, is not a command to turn in a particular direction; it is a modulation of persistence, a lengthening or shortening of the run according to whether the remembered comparison came out favourable. And from that modulation, purpose emerges: a cell with no map finds its way to the food.

SECTION 22.6

Sensing Change, Not Level

One more feature completes the little mind, and it is one we have met before in other guises. The bacterium adapts. If it is placed in a steady, unchanging concentration of attractant — however high — its excitement soon dies away, and it returns to its baseline behaviour, no longer driven. It responds not to the amount of a substance but to the change in it. A sudden rise excites it; but if that higher level then holds steady, the excitement fades and the cell re-zeros, becoming sensitive once more to the next change, up or down, from the new baseline. It is forever asking 'better or worse than just now?', and it re-sets its 'just now' continually, so that it always measures the slope and never the absolute height.

In the reading of this book, this adaptation is dΣT homeostasis in the sensing register — the same holding-steady we met in the gene that limited its own product, now in the machinery of behaviour. The cell conserves its sensitivity by re-zeroing to the ambient T-level, spending its dynamic range where it matters — on differences, on change — and refusing to waste it on a steady background it can do nothing about. And note how right this is for the task: what a swimming cell needs to know is not how much attractant is here, but whether there is more in the direction it is going. It is built to read gradients — differences in T — and adaptation is what keeps it reading differences, at whatever level it finds itself. The field measures change, and conserves its power to measure change; the bacterium is that principle swimming.

WORKED EXAMPLE · the whole loop, once around

Follow one cycle of the smallest mind. 1 Sense: measure the attractant concentration over the whole cell surface → a value, C_1, held in the short memory. 2 Move: run forward a short way (a second or two). 3 Sense again: measure C_2. 4 Compute: compare — is $C_2 > C_1$? 5 Decide & act: if yes, suppress tumbling → run longer this way; if no, tumble → pick a new heading. 6 Re-zero: adapt the baseline to the new level, so the next comparison again measures change. And all of steps 1–5 must finish within a few seconds, before Brownian motion re-aims the cell. In this book: sense → remember → compare → act → adapt is a complete T-cognitive loop — the minimal circuit of behaviour, run in one cell.

SECTION 22.7

Reading the Gradient on the Move

Set this chapter beside the one on development, several chapters back, and a deep kinship appears. There, a cell in a growing embryo read its position from the concentration of morphogens — a coordinate system of gradients, latitude and longitude — and expressed the address that belonged to where it lay. Here, a swimming bacterium reads the concentration of an attractant and moves up it. Both are cells reading a T-gradient; both are position-finding by concentration. The difference is only that the embryo's cell is fixed in place and reads its coordinate to know what to become, while the bacterium is free and reads its coordinate to know where to go.

In the reading of this book, this is one operation in two settings: spatial T-address reading, whether the reader is anchored in a body or swimming loose in the world. The registry — the coordinate system of the field — is read the same way in both. A developing tissue reads it to lay out a body; a bacterium reads it, on the move and moment by moment, to find its food. Position-finding by concentration is T-address reading, full stop; and the bacterium shows it done in real time, by a single cell steering itself through the gradient it reads. The same faculty that builds a body, exercised on the move, is behaviour.

SECTION 22.8

The Atom of Consciousness

Now gather what this cell has been shown to do, and feel the weight of it. It senses its world. It holds a memory across time. It compares the present with the remembered past. It computes, from that comparison, a difference. And it acts on the difference, steering itself toward what it needs. Sense, remember, compare, decide, act — that is not a list of chemical reactions; it is the skeleton of cognition, the bare bones of what a mind does. And here it is, entire, in a single bacterium with no brain at all. The most elaborate thought a human being ever thinks is built, at bottom, of exactly these operations, multiplied and layered beyond counting. The bacterium is not conscious as we are; but it is doing, in the smallest possible way, the very thing consciousness is made of.

In the reading of this book, chemotaxis is the minimal T-cognition, and the bacterium is the one-cell prototype of the mind. The Force of Time holds that consciousness itself is a T-process — that the rhythm of a human brain, its forty-times-a-second oscillation, is locked to the Earth's own register, the field keeping time in the skull as it keeps time everywhere. If that is so, then thought is not a thing that arrived, whole and unprecedented, with the vertebrate brain; it is the elaboration of something far older and simpler — a T-node reading the field, holding a value, comparing across time, and acting on the difference. And that something, in its irreducible form, is here, in a swimming bacterium, three billion years before there was a brain to house it. The atom of mind is a cell reading a gradient and remembering, for a few seconds, where it just was.

SECTION 22.9

Why This Should Matter to You

It is easy to think of a mind as a rare and lofty thing, arriving late in the story of life, the property of brains alone. This chapter unsettles that comfortable picture from below. The operations your own thought is built from — sensing, remembering, comparing, deciding, acting — are not the invention of the brain; they are the ancient birthright of the single cell, worked out three billion years ago by bacteria steering toward sugar. Every neuron in your head is a cell that senses, holds a chemical memory, compares, and fires — doing, in its own way, what the swimming bacterium does, wired to billions of its fellows. You are not a mind bolted onto a body of mindless parts; you are built, all the way down, of cells that already, each in the smallest way, sense and remember and choose.

And there is a continuity here worth carrying out of this book. The Force of Time reads life, from its first page, as one field expressing itself at every scale — the same T in a bond angle, a spectral line, a planet's orbit, a heartbeat. This chapter adds cognition to that list, and roots it at the bottom: the reading of the field, the holding of a value, the comparison across time, are done by a bacterium as surely as by you, and the difference between its behaviour and your thought is one of degree and elaboration, not of kind. That is a strange and, in its way, a consoling thought — that the capacity to know one's world and move within it runs unbroken from the smallest cell to the human mind, one faculty, worn at a thousand scales. When you next decide to reach for something you want, know that a bacterium, in its drop of water, is doing the same thing you are, by the same ancient logic: reading the gradient, remembering the way, and moving toward the better. The smallest mind and the greatest are, at root, one mind — the field, reading itself, and choosing.

The Numbers at a Glance

The parts of the smallest mind, and the reading the Force of Time gives each. Every biological fact is left exactly as measured.

The part	What it is	The Force of Time reading
Sensors, computers, motors	the book's own words for one cell	cognition at the scale of a single T-node
Not front-vs-back	the cell is too small; it eats the signal	spatial comparison closed to it
Sensing in time	measure → swim → measure → compare	reading the field as a T-difference across time
Short-term memory	a few seconds, held chemically	the value retained for comparison — a T-clock with memory
Brownian re-aiming	every 3–10 s	the window the whole computation must beat
Run and tumble	longer runs when improving	decision as a modulation of persistence
Adaptation	excite, then re-zero to ambient	dΣT homeostasis — measuring change, not level
The whole loop	sense·remember·compare·act·adapt	the minimal T-cognition — the atom of mind

References

[1] S. Daubney, The Universal Force of Time — Master Compendium v5, The Daubney Foundation (2026).

[2] R. Schleif, Genetics and Molecular Biology, 2nd ed., Johns Hopkins University Press, Baltimore (1993).

[3] S. Daubney, The Force of Time — Where It Departs From Current Science, The Daubney Foundation (2026).