

Inner Sense

Also by Caroline Williams

Override

Move!

Inner Sense

**How the New Science
of Interoception Can
Transform Your Health**

**Caroline
Williams**



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For Jon and Sam, with love

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Introduction

I'm lying naked (but for a pair of earplugs) in a white pod-like tank that's shaped like an avocado. Inside, a shallow bath is so packed with dissolved salts that I can float without effort, and so close to body temperature that I can't feel the water on my skin. When I close the lid and switch off the mood lighting, there is nothing to see, hear or feel. Nothing to distract me from an hour of blissful silence.

At least, that's what I thought would happen; it soon became clear that silence was not an option. Between the gurgling in my stomach and my pulse banging away in my left ear, my body had far too much to say for itself for me to enjoy what is known in my family as 'a piece of quiet'.

This was my first visit to a floatation tank – an experience that's usually sold as sensory deprivation, a way of taking a well-earned break from the outside world. What I didn't know then was that in the process of tuning out from my surroundings, I would also be tuning *in* to a sense I didn't know I had – an inner sense that is not only the centre of our personal universe but one of the most important concepts to emerge in science and medicine in decades. One that has the potential to bring better wellbeing, less stress, more energy, and new treatments for

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common, hard-to-treat conditions that affect mind, body or both.

Frankly, it's amazing that it's not already headline news. Perhaps that's because, despite its potential to fix pretty much everything that ails us today, its name fails to evoke just how exciting it really is. It's called interoception: the sense of our own bodies from within, and it's a catch-all term for the way the brain makes sense of signals and sensations that originate from inside our bodies, such as heartbeat, hunger, temperature, fatigue, vigour, pleasure and pain. These signals carry vital clues about our current and future wellbeing, and are so important for survival that the brain puts them at the centre of our every experience. If you can get past the name, you'll find a whole new mysterious inner world just waiting to be explored.

My hour in the tank was the start of a year-long journey into this new world. It would see me cross continents, swallow vibrating capsules, and spend an awful lot of time listening to my heart – all in a bid to understand what this has to do with how we think and feel.

The short answer is: a lot. Far from just being the inevitable clanking and whirring of a corporeal machine, the signals and sensations from our organs and tissues are increasingly seen as the foundation of the mind itself, providing a constant stream of biological mood music that colours our every thought and feeling, while also providing the impetus for our every action and desire. According to a mounting pile of research, improving our ability to sense and interpret these signals has the potential to transform our understanding of ourselves, and transform our relationships with the people close to us. It could also

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help us to understand what is driving some of the issues in wider society – not least the seemingly ever-increasing polarisation of political and social discourse. In recent years, calm and rational discussion has given way – especially on social media – to emotionally laden arguments and name-calling, designed to make us feel, not think. If we lack the interoceptive insight to make sense of it all, we are vulnerable to being dragged along by feelings that may not reflect reality.

When you think about it, we've always suspected that we possess something like an inner sense. The idea of listening to your heart, trusting your gut and being guided by instinct makes intuitive sense, even if it's not easy to explain why. But until recently, there was no way to measure whether this had any basis in fact.

Thanks to some ingenious experiments and the creative use of technology, scientists have now come up with ways to measure – and tweak – signals from within, and to link them with what's happening in our minds, in real time. These new approaches are revealing some important insights. First, that this 'sixth sense' is not only real, but is based on measurable bodily sensations and their conversations with the brain. Second, that some of us are better attuned to this sense than others, in ways that affect how we manage our emotions, connect to others, and make decisions. And third, that becoming attuned to this sense is a skill that is proving to be responsive to both training and targeted interventions.

It's difficult to overstate how important this is for our understanding of the mind. For one thing, it moves us away from the idea that everything to do with how we

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think and feel happens from the neck up – a common assumption in neuroscience and medicine.

Interoception is not about demoting the brain, however; it's about realising that the brain only makes sense in the context of the body and the countless communication channels that run in both directions. In this view, the brain isn't so much the boss as an equal partner, working in close collaboration with the body to keep us alive and well.

Can you feel it?

As you read this, you might be wondering whether you actually have this sixth sense. If so, that's totally normal. Because unlike the more familiar, external-facing senses, such as sight and hearing, sensations from within the body mostly operate on a need-to-know basis.

We don't need to know anything about many of the organs and systems in the body. Our kidneys, pancreas and liver, for example, are quite happy doing their job, being kept on course by physiological checks and balances that we rarely know anything about. If we ever feel them, it's because something has gone seriously wrong. By and large, we can ignore them altogether and hope they never come knocking.

Then there are messages from organs that mostly stay quiet, but which we can consciously tune into if we choose. Mostly, though, we only become aware of them when they make themselves heard, usually in order to signal that urgent action is required. Our heartbeat is the most obvious of these, but the sensation of our lungs

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expanding and contracting, the feeling of fullness or emptiness in our gut, bladder and bowels all work to the same pattern. It's not exactly a 'don't call us, we'll call you' situation. More, 'you're welcome to call, but we'll be in touch if it's important.'

Between these two extremes are the low-key, almost imperceptible sensations that underlie gut feelings and intuition, providing a general sense of what the pioneering interoception researcher Bud Craig described as 'how I feel right now'. This might show up as a vague feeling of warmth and safety. It might manifest as a sense of feeling strong and capable one day, but anxious and vulnerable the next. Or it might present as a nagging feeling that something indefinable isn't right. These nebulous feelings are not easy to tie to one body part, or to describe, but they can be powerful drivers of our thoughts, actions and emotions, even when we aren't aware of what's nudging us one way or another.

For reasons that we don't yet fully understand, some people have a more sensitive inner sense than others. Some people can feel their heart beating in their chest when they're sitting perfectly still, while others can't. Some people notice sensations such as hunger, a slight tension in their muscles or the need to find a bathroom long before they become urgent. Others don't notice a thing until they are feeling faint, can't turn their head, or are desperate for the toilet.

We also all vary in how much conscious insight we have into our own body-reading ability, how much faith we put in our bodily signals as accurate sources of information, and whether we tend to pay more attention to our bodies, or to

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the world around us. These differences, which stem from a combination of genetics and life experience, influence everything from our emotional intelligence to our capacity for empathy. They also play into mental health, motivation and some of the challenges associated with neurodivergence. Sensory sensitivities in autism, for example, may lead to feeling anxious and overwhelmed, while problems with emotional regulation, which rely on an ability to sense and understand body signals, are seen both in autism and attention deficit hyperactivity disorder (ADHD).

The good news, though, is that it is becoming clear that our inner sense can be tweaked and trained. By getting better at sensing what's going on inside us and interpreting what it means, we all have the potential to take control of our health and wellbeing.

Uncomfortably numb

While it's difficult to prove without the aid of a time machine, it's possible that those of us living in the West are less aware of how our bodies affect the mind than our ancestors would have been. The closest approximation to how our ancestors lived can be found in modern hunter-gatherer populations, such as the Hadza people in Tanzania. According to a recent study, the Hadza tend to describe emotional moments in terms of physical sensations – they might say that they feel hot, for example, or that they can feel a pounding in their chest. An American comparison group tended to describe emotions in terms of mental experiences such as disbelief and shame, often without even mentioning the body.¹

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Whether this holds true in general is hard to say, but it is certainly true that Western science formally divorced the body from the mind at least 400 years ago, not only cutting up cadavers, but also separating the body and mind into two. The French philosopher René Descartes usually takes the blame for this, not least because of his hugely influential seventeenth-century works, *Principles of Philosophy* and *Meditations on First Philosophy*, in which he described the body as a machine with nothing to do with the ethereal, immeasurable mind. Given how little was known about how either the mind or the body worked at the time, it was an entirely reasonable assumption. A couple of hundred years later, in the mid-1880s, the body was briefly put back into the mind, when William James (an American philosopher widely considered to be the father of psychology) proposed that bodily sensations are the basis of all our feelings. At around the same time, the Danish physician Carl Lange put forward a similar proposal. In their view, which has become known as the James–Lange theory of emotion, we don’t feel scared and then our heart rate increases; we feel scared *because* our heart is beating faster.

The idea was shouted down at the time, not least by the physiologist Walter Cannon, who coined the term ‘fight-or-flight response’. Even Charles Sherrington,² the Nobel Prize-winning physiologist who invented the term ‘interoceptive’ in 1906, wasn’t convinced. For many years, the prevailing view was that the body’s sensory pathways to the brain were too slow to be involved in anything as clever as human thought and emotion; the brain surely noticed changes first and then the body followed. As

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neuroscience developed, it did so based on the principle that all the important stuff happened in the brain. Several centuries later, however, these two competing theories are finally coming together in ways that can help tackle today's challenges – and those that lie ahead.

To state the obvious, the twenty-first century has so far been quite a ride. From climate change to war, a global pandemic and political and financial instability, the existential threats just keep on coming, bringing with them a faint, yet unrelenting, sense that all is not well. This quiet sense of unease jostles for attention with the sensory overload and fast pace of modern life. In the maelstrom of information we receive thanks to our external senses, we become numb to the more subtle information coming from within. What we're left with is a vague sense of impending doom that we can't put our finger on; we would be unable to take action to fix it even if we could find the time. Young adults who are facing the full force of an uncertain future are feeling this most, leading the Stanford researcher Britt Wray to warn of a coming mental health crisis in what she calls 'Generation Dread'.³

The temptation, given the scale of the challenges facing humankind, is to harness the many distractions of the modern world and use them as a shield to protect us from the internal inkling that something isn't right. Having a highly attention-grabbing screen in your pocket at all times makes this only too easy. But in the long term it only makes matters worse, and when taken to extremes it can prove catastrophic. In 2005, a twenty-eight-year-old computer games addict called Lee Seung Seop died at his screen after playing the online game *StarCraft* for fifty

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hours without taking a break.⁴ The official cause of death was heart failure, caused by exhaustion and dehydration. In reality, he died of a failure to notice, or act upon, his body's interoceptive cries for food, water and sleep.

It's a cautionary tale used by many mothers of teenage gamers, and a rare example of taking bodily numbness to the limit. Yet Lee's death wasn't a one-off.⁵ Anyone who lives with a gamer – or any kind of screen addict, from social media scrollers to box-set binge-watchers – will recognise the tendency to neglect even the most basic physical needs. Even at what we might consider to be a healthy level, screen use seems to distract us from what our bodies really need. When the former Microsoft executive turned amateur researcher Linda Stone measured the breathing rate of 200 people as they checked and replied to their emails, she found that 80 per cent of them become so absorbed by their screen that they would occasionally forget to breathe – a phenomenon she named 'screen apnoea', and which has since been linked to an increased likelihood of stress and anxiety.⁶

Being sedentary for long periods, with or without a screen, has other consequences, too. The lack of sensory information from the body leaves us disconnected from our heart, muscles and joints, and numb to the fact that they are becoming stiff and out of condition. This leaves us feeling sluggish and lacking in energy, which kicks off a vicious cycle of fatigue and inactivity, punctuated by the occasional attempt to 'get in shape' that has little to do with how our body feels from the inside.

Modern diets don't help, either. Ultra-processed foods (UPFs), which comprise 60 per cent of the average British

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and American diets,⁷ are designed to be tasty, calorific and to have a melt-in-the-mouth texture that makes them moreish without necessarily being filling. This diet disrupts the interoceptive system that tells us when to eat, what to eat, and when we've had enough. Many UPFs are high in salt, sugar and fat, which overstimulate gut-brain pathways that link high-calorie foods to sensations of pleasure, reward and comfort, turning a life-saving need into a potentially life-threatening one that leads us to eat too much of what we like at the expense of what we need.

Worse still, a bad diet, inactivity and stress trigger inflammation, which involves the release of body signals that tell us to hunker down. We experience this as a low-level malaise: feeling tired, demotivated, and with an aversion to the company of others. What would be a sensible strategy for healing from an infection or injury puts us at greater risk of depression, heart disease and almost every life-threatening ailment known to science,⁸ not to mention feeling run-down and out of sorts.

These modern factors are layered on top of the basic human reality that we all vary, both in our natural tendency to listen to our bodies, and in how loudly they speak to us. And, as we'll see, our life experiences can make important changes to the set points at which we become aware of our body's signals, potentially making us over- or under-sensitive to them. Whether by nature or nurture – or more likely, both – we are all singing from a different hymn sheet and to our own personal backing track. If we can hear what music is playing and understand how it affects us, we have a better chance of being able to change the tune when we need to.

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It's not (only) about you

There's one final reason why interoception should become a priority, and it's an important one. Our interoceptive abilities don't just affect us as individuals; they also have a huge impact on our relationships with others, and the health of our society. Having an accurate sense of what our bodies are doing on the inside is the biological basis of empathy – the ability to tap into the feelings of others. We don't just do this by recognising the outward signs of joy or pain in their bodies; our bodies also change so that we feel their emotions as if they were our own. There's even some evidence that our immune systems become activated when we are in the company of someone who is ill, and we start feeling their symptoms – even if we are not physically in the same room.⁹

Our ability to empathise stems from our unique evolutionary history as a social species combined with our long childhoods, in which we rely on others to help us regulate our physiological and emotional needs. These experiences in our early years stay with us for the rest of our lives, setting the tone for how we understand our bodies and minds.¹⁰

No matter how independent we become as adults, this need for connection never goes away; we can't live without it. A recent analysis of data from over 2 million people found that social isolation was linked to a 32 per cent higher risk of early death. Loneliness, meaning a lack of meaningful social interactions, raised the risk of early death by 14 per cent.¹¹ Even when it isn't fatal, it can make life feel harder than it needs to be. As became obvious during the Covid-19 lockdowns, when we can't connect

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with each other we can easily become emotionally and socially lost.

This lack of connection may even fuel some of the more troubling features of modern society. Manos Tsakiris of Royal Holloway University, London, argues that the resurgence of anger-driven populist politics has been fuelled by an anxious population that isn't fully able to process the turmoil that our modern world stirs within our bodies. It's a potent mix that leaves us at risk of being controlled by our gut feelings, vulnerable to leaders who promise to make these uncomfortable feelings go away, and conspiracy theorists who prey on our worst fears and insecurities.

With the road ahead looking even bumpier, now is a good time to get serious about understanding what we are feeling within – and why. Only then can we stop being divided and begin to understand ourselves and each other. When we can feel the uncertainty and dig deep to find common ground, we can use it to work together as only humans can.

Onwards and inwards

It might sound like a pipe dream, but this new way of living is within our reach. In the pages that follow I'll explore what mastering interoception means, and what it can do for all of us. I'll meet the small band of scientists and philosophers who are charting this unknown internal territory and mapping out how the system works – and how it goes awry in response to the modern world, negatively affecting our physical and mental health.

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I'll meet people who are feeling the benefits of new body-focused approaches, and learn how interoceptive training is helping people with anxiety to get their symptoms under control and helping police officers to deal with the stresses of their job. I'll find out how touch is proving to be a powerful pain reliever, activating interoceptive pathways in the skin that signal comfort and care, and how increasing physical strength can lead to feelings of confidence and self-esteem. I'll discover why feeling energised is the result of an interoceptive conversation about whether what we need to do is worth the energy – and how we might game the system when the answer is 'no'.

I'll also meet people with above-average interoceptive abilities and find out how this helps them. They include a hostage negotiator whose empathy helps him connect with people during a crisis while keeping his own emotions in check, and a financial trader who thrived on Wall Street by listening to his gut intuition. Through such examples, we'll see that, far from being a fuzzy concept that makes no real difference, having a handle on your bodily signals can bring real benefits. I'll end by bringing all this research together and suggesting how you can bring interoceptive wisdom into your everyday life.

First, though, we need to take a deep breath and dive into the murky world within us, to understand why what's happening inside holds so much sway over our experience. As we'll see, the whole point of interoception is to learn from the rough bits of life so we can enjoy the unique experience of being human.

1

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Homeostasis, feelings, and the art of staying alive

‘Look, I’m just a planet doing its thing, alright? If you want to live on me, that’s your business...’

This quote on the satirical website the Daily Mash, attributed to Planet Earth,¹ is more profound than it seems. We might think of our planet as a nurturing ‘Mother Earth’, but in reality she’s not the sort of mother who frets over whether you’re warm enough or have had enough to eat. Life on Earth exists not because it has been looked after, but because it found a way to look after itself.

If it hadn’t, of course, we wouldn’t be here. Once the basic chemical ingredients for life had arrived on Earth, carried (we assume) by various asteroids, life probably emerged multiple times, only to be snuffed out by unexpected changes in conditions. Then, one day around 4 billion years ago, an attempt at life stumbled upon a solution, and went on to become the common ancestor of all life on Earth.

We don’t know exactly what this solution was, but one idea is that several chemical reactions, each capable of creating energy from carbon in the atmosphere, somehow got

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trapped inside an early cell. Because each reaction worked in a slightly different way, it gave the cell back-up. If one or two of the reactions didn't work, one of the others would kick in and life could continue.²

As survival strategies go, it was dangerously hit and miss, but it worked for long enough for evolution to come up with something better – a toolkit of specialised sensors that allowed a cell to sense change in the outside world, adapt its internal state accordingly, and stop adapting when the coast was clear. This process of cellular self-care is called homeostasis, and it's non-negotiable for the survival of any living thing. A couple of billion years after life began, evolution had perfected a variety of cellular tools to detect physical, chemical or temperature changes, and a range of options for tweaking chemistry to get things back on track.

Fast forward a couple more billion years, and the business of maintaining homeostasis in our bodies is both the same and very different. Our bodies' cells are fitted with variations on the same old-fashioned, yet reliable, sensors to detect internal change. Some, the chemoreceptors, respond to changes in things such as carbon dioxide, glucose or salinity. Others, humoral receptors, detect changes in hormone levels, while mechanoreceptors specialise in detecting pressure or stretching.

Along the long road between single-celled organisms and human beings, though, some life forms became so complicated that the insides of their bodies contained almost as many variables as did the outside world. Our interoceptive system is the evolutionary result of needing to keep track of both of these ever-changing worlds

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simultaneously. The arbitrator is the brain, which evolved to keep track of these two worlds and to co-ordinate responses to keep us alive.

To make sense of where we have ended up, it's worth taking a brief tour of the evolutionary leaps that brought us here. These accidental strokes of genius were few and far between, and the first one was a long time coming. For the first 2 billion years, Earth contained only single-celled life. Then one of these single cells found its way inside another, and traded food and shelter in return for most of its DNA and all the energy it could make. This was the origin of what we now know as mitochondria (often called the 'powerhouse' of the cell). With a supply of extra energy and a glut of fresh new DNA, this new hybrid life form could experiment with a host of fresh designs.³ Some of them were multi-celled new life forms, such as green algae,⁴ slime moulds, fungi and sponges.

Then it all went quiet for a billion years or so – a period that has been nicknamed the 'boring billion'. Life bumped along, sensing and adapting to the world via the chemical equivalent of notes being passed in a school classroom. Messages travelled slowly from one end of a creature to the other, cell to cell or in the air or water. Then there was an ice age, and things slowed down even more.

When the Earth finally warmed up, life got back to experimenting. After a few million years of trial and error, a new kind of cell was born – one that could send messages faster and more accurately, vastly speeding up the process of sensing and adapting. These were the first neurons, and any creature that had them found that it could outcompete

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its rivals by beating them to food sources or by escaping danger before others had noticed it.

In many ways, these fancy new cells were a better designed version of the same idea. Sensory neurons feature many of the same sensors that evolved in the early days of life, but in neurons these sensors are concentrated at the ends of the cell's branching tendrils (called dendrites) that extend through tissues and detect any change in the chemical and physical situation or a potentially problematic deviation in temperature. When change is detected, the information speeds along a communication fibre (the axon) to trigger whatever action is necessary. Jellyfish, for instance, have sensory neurons that detect the touch of a potential predator. These relay the message to a different set of neurons, the motor neurons, which tell the jellyfish's muscles to contract so the creature can swim away. In a world where speed can make the difference between life and death, neurons allowed animals to sense and react in less than a second, which gave them an edge over their competitors.⁵

In the game of survival, speed is good – but speed with a plan is even better. That was why, within a few million years of the first neurons, some animals started to develop brains. They didn't show up in all branches of the animal family tree (jellyfish and starfish still manage without them), but in our branch they proved to make movement not only faster, but also smarter. The earliest versions showed up in our distant worm-like ancestors, in little bundles of nerve cell bodies called ganglia, which contained the neuron cell bodies from which the axons extended through the body. The biggest clump was at the head end, near to where most of their sensory kit was found.

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At some point further down the line, the bodily branches converged into a central spinal cord: a kind of cable tidy with neat pathways for sending sensory information in and movement-based instructions out. A notable exception to this system is its most recent addition, the vagus nerve. Sprouting from the brain around 400 million years ago, it snaked through the body to connect with the various organs, which had by then evolved to take care of different homeostatic jobs. Its job was – and still is – to constantly monitor and tweak our organs automatically, without necessarily stirring the whole creature into action.

And this, in effect, brings us to the interoceptive system we have today. It looks complicated when you map it out, but that's because it is. And while we are still working out how it fits together and how we make sense of it all, what we do know is that every part was added over billions of years in the service of keeping us alive. Unfortunately, though, greater complexity brings a greater risk of glitches. Like a high-performance car that is too complicated for your local mechanic to understand, we find ourselves in possession of a finely tuned machine that can be baffling to own and maintain.

Feeling the future

The solution to the challenge of increasing complexity was smart, but it has brought problems of its own. Brains allowed animals to go one step further than merely sensing and adapting. They made it possible to learn, and to use lessons learned in the past to make an educated guess about what was most likely to happen next. Even in

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the earliest, simplest brains,⁶ having bundles of neurons collected in one place made it inevitable that, as well as sending messages through the body, they would connect to each other and share information. That meant that animals could adapt to threats and opportunities – not just quickly, but often before they even happened.

This flexible version of homeostasis is called *allostasis*,^{7,8} meaning ‘stability through change’, and as far as our lives are concerned, it’s a mixed blessing. On the one hand, it has made us experts at adapting quickly to complex environments, allowing us to predict and prepare for them so that we don’t get knocked too far off course. On the other, it means we spend time and energy adapting to situations that may never come to pass, but which involve changes to our body and mind that aren’t always necessary, or healthy. When challenges keep coming, whether they are real or imagined, predicting and adapting can cease to be an energy-saving strategy and can start to put a strain on the body’s resources. This, in a nutshell, is why stress is so exhausting – and so bad for our long-term health.

The good news is that our brains never give up trying to balance adapting in advance with wasting energy on non-existent threats. This can be explained in terms of what’s called *predictive processing*: a fairly new idea in neuroscience that uses complex mathematical models to explain how the brain works. In less complex terms, it means that because the neurons share information, the brain is able to make experience-based predictions about what information is most likely to come in from the senses. Predicting what’s coming means that the body can be prepared and start the process of adapting in

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advance, adding more speed to an already speedy system. While the body adapts its physiology to deal with what the brain expects to happen, sensory information coming from inside the body – and outside, from the eyes, ears, and so on – chimes in with real-time evidence that either confirms the prediction or proves it wrong.

If the signals coming in match what the brain predicts, all is well and not much happens. Any discrepancy between what the brain expects and what the sensors deliver, however, creates an error signal, flagging up that some form of adaptation is needed, either to change the prediction, such as from feeling safe and calm to alert and vigilant, or to change the signal, perhaps by moving away from the heat of a flame.

If adaptation is needed, the body–brain system has three options. First, the brain can change its prediction to match what the body is reporting. A rumbling stomach, for example, might lead to the prediction that you are hungry, even if you have just eaten. Second, the body sensation can be altered to match the brain's prediction – you might run around a corner and see a hill you weren't expecting, for example, at which point your legs feel tired in anticipation of the climb. The third option is that the volume of the body's signals can be turned up or down during their journey through the body and brain. That could mean temporarily disregarding them in favour of something more urgent (for instance, not feeling the pain of a broken ankle until after you've finished running away from danger) or boosting them until they can't be ignored (the overwhelming feeling of suffocation during a panic attack).

Which option is put into action depends on which

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source of information is deemed likely to be the most reliable. Nobody knows exactly how this decision is made, but somehow the brain–body neuron circuitry seems to place a bet on the option that seems most likely right now. The output of this is what we experience as reality: a ‘best guess’ based on the brain’s expectations, what the body is reporting, and the need to take action when they don’t match. But even when we don’t become conscious of these body–brain discussions, they can still influence the way we think and feel, in ways that play into issues that have commonly been dismissed as ‘all in the mind’.

The complexity, and ever-changing nature, of our interoceptive system explains how two people can have such different experiences in the exact same situation. It is also why it can sometimes be so difficult to explain why we think and feel the way we do. It all comes down to the ‘best guess’ of a highly complex body–brain system.

Who’s in charge?

Arguably, the cleverest trick of the predictive brain is giving us the impression that it is solely in charge of how we think and feel: an all-seeing CEO of the body that dictates what we think and do. An interoceptive view of the mind, however, reveals that brain and body are jointly in charge of our mental experience. The brain wasn’t created in a vat and bolted onto the body, fully formed; it emerged *from* the body with the sole aim of keeping the body alive. That means that there is no body–brain split; both are part of the same ingenious survival system, which began with a tiny bag of chemical reactions.

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The main difference between us and a tiny bag of chemical reactions is that, as far as we know, bundles of chemical reactions don't have feelings attached to their homeostatic needs. For some reason – and no one knows why – we do.

Feelings act as a slick user interface that constantly summarises how life is going along two sliding scales: 'good' to 'bad', and 'urgent' to 'less urgent'. The interface usually ticks along behind the scenes, setting the mood, a bit like the background music in a movie. Occasionally, though, either because we decide to tune in and listen, or because the background music gets louder and more difficult to ignore, we become aware of it as a conscious feeling. One thing that all feelings have in common, whether they whisper or shout, is that they all feel *like* something. Anxiety, for example, is more than a factual assessment of a coming challenge. It feels physically uncomfortable, deeply personal, and too urgent to ignore. This, says Antonio Damasio, a neuroscientist and philosopher at the University of Southern California, makes feelings fundamental to understanding consciousness itself.

Damasio is an important figure in the history of interoception: in the 1990s he became the first modern scientist to resurrect the idea, in his research and in the popular books *Descartes' Error* and *The Feeling of What Happens*, that the body is important in our ability to think and feel.

At first, much as William James and Carl Lange had discovered a century earlier, nobody wanted to listen. When we meet via video call from his home in California, Damasio recalls one eminent scientist telling him that

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feelings were ‘for girls’ and that he should stick to the ‘big stuff’ like intellect if he wanted to understand the mysteries of the mind.⁹ He ignored them and, working with his wife and long-term collaborator Hanna Damasio, has spent more than thirty years compiling evidence that the body is very much required for emotion and feelings. The basic idea is now entirely in the mainstream.

Bud Craig, a neuroscientist at the Barrow Institute in Arizona, was another pioneer of the bodily basis of consciousness. He died in 2023, having spent more than two decades mapping the route of sensory nerves from the body to the brain. Craig, like Damasio, believed that consciousness was rooted in the body and its current needs. His work was also important because it expanded the idea of interoception from something that concerned the internal organs to a sense that involves the whole body, from the deepest organs to the muscles and skin, with pain and temperature affecting how we feel just as much as the blood flowing around our bodies and the food in our bellies do. ‘Humans perceive “feelings” from the body that provide a sense of their physical condition and underlie mood and emotional state,’ Craig wrote.¹⁰

Feelings, the sensation-based shorthand for how things are going, underlie emotions, but most neuroscientists agree that the two are not the same thing. Feelings are the ‘mood music’ that plays in the background of our lives: things like unease, vitality, comfort or fatigue. In predictive processing terms, they are a kind of ‘live stream’ of prediction errors, which we become conscious of only when something has to be done to fix them, or when we deliberately decide to listen in.

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Emotions, on the other hand, are the brain's interpretation of what caused the feelings and what they mean, says Lisa Feldman Barrett, neuroscientist and author of *How Emotions Are Made*. For example, if we feel jittery or have butterflies in our stomach, we might interpret this as excitement or anxiety, depending on the context. This, Feldman Barrett tells me, is good news, because emotions are potentially more malleable than the basic feelings of good or bad, urgent or less so. We can choose to interpret butterflies as excitement rather than anxiety – at least, in theory.

Feelings may seem less sophisticated than emotions, but they play an important role in building the mind. For one thing, they are the foundation of our basic sense of self: the idea that there is a 'me' who is the same person from one day to the next and who experiences the world from the inside out.

'Feelings tell you, in no uncertain terms, what is happening to you,' Damasio tells me. 'If I'm feeling well, or if I'm feeling in pain, that's because I have a body and I have a perspective on that body... It is part of the construction of a self.'¹¹ Since we are not the only animals that can feel an adrenaline rush or a pounding heart, I suggest to Damasio that perhaps consciousness isn't unique to humans. 'Correct,' says Damasio. 'That's one of the things that people get so wrong. They want to make human consciousness particular; I think human consciousness is just like the consciousness of any other creature.'

If he's right, it raises uncomfortable questions about how humans treat almost every other species on the planet – not least captive chimpanzees, gorillas and orangutans,

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whose nervous systems and social behaviours are the most like our own. Arguments have so far revolved around basic tests of self-awareness, such as whether an animal can recognise itself in a mirror, and demonstrations of their near-human cognitive skills. By Damasio's reasoning, though, how they think isn't the point. We should be trying to work out how they *feel*.

Damasio believes that the reason that consciousness has proven so tough to explain – both in human beings and in other species – is that most of our recent efforts have focused solely on the brain. 'People talk about consciousness as the great mystery that will be revealed by understanding the brain – and that's wrong. It's not about the brain – it's about what the brain achieves with the interoceptive system in relation to the body,' he says.

Not everyone is on board with the idea of extending human-like consciousness to other creatures. Critics argue that it doesn't account for the possibility that animals with less well-developed brains feel the same physical sensations as we do without interpreting them as emotions. A lion might feel the sensation of an empty stomach without feeling 'hungry', for example. And a gazelle might not experience anything like fear when it spots a lion, even though its heart will start pounding as it prepares for escape. Non-human animals also don't seem to possess the mental hardware to zip back and forth along an imaginary timeline, remembering how they felt in the past and getting excited about the future. In humans, this ability is considered to be a key component of the self. Whether other animals share this – and whether they can be considered to be conscious if they don't – is another debate entirely.

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Nevertheless, the important thing is that as evidence for the body's role in constructing the mind has stacked up, neuroscientists are starting to agree that our sense of self, as the same person existing from one day to the next, is rooted in body–brain interactions that evolved to aid survival. And everyone now agrees that the brain alone is not enough to generate the rich inner experience that we call consciousness.

Could robots care?

This new embodied vision of consciousness has implications for our hopes – and fears – regarding the potential rise of conscious artificial intelligence (AI). AI is already an integral part of everyday life, so it seems reasonable to wonder whether we will soon be in the presence of conscious artificial beings. Incidentally, here's what ChatGPT said when I asked it:

Some researchers argue that consciousness is a function of the information processing that occurs in the brain, and therefore it could theoretically be replicated in a sufficiently complex computational system, such as an AI... Others argue that consciousness is inherently tied to biological systems and cannot be replicated in artificial systems, no matter how advanced they become.

This, to be fair, is a pretty neat summary, but it doesn't take into account the fact that 'biological systems' means more than just the brain. Most attempts at AI involve neural networks that are based on our current understanding of

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how the brain works. If a robotic body is added, it's usually added last, as a fully formed robotic body part.

But as we have seen, human consciousness was built from the body up, not from the brain down. If we build AIs to replicate only our brains, they may never be conscious, no matter how intelligent they might seem.

Some robotics researchers are starting to wonder if continuing to build intelligent, yet unfeeling, and therefore unconscious, minds might be a very bad idea. In 2023 a team of researchers, including Damasio, flagged up the need to factor in an equivalent of homeostatic feelings in artificial minds.¹² They pointed out that all attempts so far to give something resembling empathy to artificial agents involves giving them an intellectual understanding of human thoughts, feelings and emotions, and an ability to read them and respond. But this doesn't give them the ability to feel our pain and care about the things we treasure, which essentially makes them sociopathic – able to read and imitate human empathy, but without feeling, or caring about, anything. Which raises a very important question: are highly intelligent but unfeeling minds really something we want to unleash on the world?

One way to get around this, Damasio and his fellow researchers argue, is to build in the capacity for artificial minds to feel the consequences of personal harm – pain, loneliness, and an awareness of their own mortality. In principle, this would not only give them some insight into how we feel, but it might also prevent them from harming us – or each other. 'Vulnerability and homeostasis in machines may provide ... common ground between themselves and living beings,' they wrote.

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Of course, this raises a whole new set of ethical issues. If we engineer AI-powered robots that could feel, this brings up dilemmas much like those surrounding animal rights. With one crucial difference: unlike animals, robots will be able to tell us exactly what they think of us, and why.

Another option that roboticists are beginning to explore involves taking inspiration from evolution to build AI from the ground up, with its intelligence developing alongside its body. Josh Bongard, a roboticist at Vermont University, is training AI algorithms to learn about the world they are a part of, and to design and redesign their own bodies based on the results.

It's early days for this approach – Bongard told *New Scientist* in 2023 that so far they have built 'relatively simple robots, the sort that kind of shuffle around a little bit'. But as the technology improves, we could see the first body-conscious robots; whether they are more likely to be conscious than the existing 'brain in a vat' systems remains to be seen. For the time being, it might be helpful to remember that however smart AI seems, so far it has no idea what it is doing, or why. For now, Damasio describes chatbots as 'a wonderful example of what consciousness is not'.

Heart: felt

Back in the human body, each of our 30 trillion cells is responsible for a huge number of simultaneous signals. But amid the cacophony, a few of them are constantly saying something important about what's going on inside.

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These constant, but ever-changing, rhythms are the most important link between what the body's doing and what's going on in the brain.

The most obvious of these is the heart. As far as the brain is concerned, the heart has always been there. In a human foetus, it starts beating within a few weeks of conception, at a time when the brain is still organising itself into three basic sections: the hindbrain, midbrain and forebrain. From the day it starts beating, the heart generates its own rhythm. As the brain grows, it does so to the rhythm of the heart.

Catherine Tallon-Baudry, a neuroscientist at the École Normale Supérieure in Paris, suggests that this makes the beating heart a good candidate as an 'anchor' for our sense of self. Sylvia Plath makes the same point in her novel *The Bell Jar*. The main character, Esther, in the depths of suicidal depression, describes being taunted by her heartbeat, an inescapable reminder that she's still alive: 'I ... listened to the old brag of my heart. I am, I am, I am.'¹³

Sure enough, there seems to be something about our heartbeat that marks the body as 'mine' and tells us that we are very much alive. In experiments designed to test whether our sense of self can be transferred to inanimate objects, people are more likely to feel that a rubber hand belongs to them if a projected version of it flashes in time with their own heartbeat.¹⁴ The more keenly a person feels their own heart, the stronger the effect. Adapted versions of these studies in five-month-old babies suggest that heartbeat awareness may be hardwired at birth, or at least very early in life.¹⁵

Tallon-Baudry's idea is supported by the finding that

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heart and gut rhythms seem to have a special status in the brain. Brain imaging studies show a signal known as the 'heartbeat evoked potential' (HEP),¹⁶ which echoes the timing and strength of the heartbeat in various regions of the brain. HEPs are most intense when the body's signals become stronger, or when we consciously tune into our own heartbeat. In the past few years, a separate signal that tracks stomach sensations has been found in other regions of the brain. This is known as the 'gastric evoked potential' (GEP).¹⁷ There is also evidence that the rhythm of our breath, moving in and out of the lungs, acts as a metronome that sets the processing rhythm across the brain, the 'respiratory evoked potential' (REP).¹⁸

The constant and predictable rhythms of these signals also help to make sense of time. Bud Craig noted in 2009 that the main brain regions that put internal bodily signals in context and build a sense of 'me' are fundamental to our ability to perceive time. Experiments since then have confirmed his hunch; our understanding that there is a me, who is feeling this particular feeling in this particular moment, is built from the regular rhythm of our bodies as they keep us alive. This goes some way to explaining why time flies when our bodies are active, and drags when we are still and bored.

We are most aware of our body rhythms when we find ourselves in what feels like a life-or-death situation. At that point, what is usually background noise bursts into consciousness and demands action. Time stands still and our bodies are alert and ready to move. Yet while everybody has this reaction during an emergency, the level at which the background noise is escalated into consciousness varies

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considerably from one person to the next. And as it turns out, the differences between us have a lot to do with how we feel our bodies from within.

Chris White is no stranger to life-or-death situations. As a hostage and crisis negotiator for the Metropolitan Police in London, his job was to resolve hostage situations, armed sieges and terrorist stand-offs. It's the kind of job that demands a clear head and – you might think – an ability to tune out the bodily signals that let fear seep into a situation. According to the brain-centric school of thought, a sudden increase in heart rate or butterflies in the stomach would distract from the kind of calm, rational decision-making required in a crisis.

Yet when scientists talked to White about his work, they found that he was far from a cold, rational thinker. In fact, he told them that he actively listened to what his feelings were telling him, using his bodily sensations as an early warning system to know when the mood between him and the person with whom he was negotiating had changed – before the relationship had soured beyond repair.

Sarah Garfinkel, a neuroscientist at University College London, was intrigued. She tested White's ability to detect his own heartbeat while sitting quietly by asking him to count the number of beats in a short space of time – a standard test of a person's ability to tune into their interoceptive signals and which correlates with heartbeat-evoked potentials. It's not easy, and most people get an accuracy score of about 60–70 per cent; White, however, scored close to 100 per cent.¹⁹

Garfinkel was shocked. But as Chris White told me

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later, he is almost always aware of what his heart is doing, and had no idea that that was unusual. 'I can feel my heart, even sitting here now,' he told me. 'I don't go around all day thinking about it, but even at rest I can feel it. It surprises me that other people don't.'

White says that noticing these feelings is not just a party trick; it helps him pick his moments when intervening in negotiations. 'There's a radar that you pick up. Not everybody does, but I've always believed mine's been fairly acute,' he says. 'There's this sense of "I'm uncomfortable" ... your blood pressure will increase, your heartbeat will increase, and in extreme circumstances you might get butterflies. You genuinely think that something is about to happen that you really don't want to happen.'

Having a particularly sensitive window into what his heart and gut are doing helps him to guide negotiations based on intuition. 'I can generally tell the moment when someone becomes receptive to suggestion,' he says. 'You need to pick that moment – because if you do it too early, they will shut down.'

While White jokes that his acute inner sense hasn't yet made him a millionaire, it seems that others who are similarly endowed have accrued considerable wealth. In the mid-2010s, Garfinkel studied a group of financial traders who, like White, often based decisions on what they claimed to be a sixth sense – in their case, about whether a trade felt 'good' or 'bad'.

Like White, they also turned out to have an unusually acute sixth sense, on average scoring close to 80 per cent on the heartbeat detection task while non-traders scored around 66 per cent. What's more, those with the most

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accurate heartbeat detection scores were more profitable over the course of the financial year. And those with the strongest sense stayed in the job for longer, while others burned out or moved on to lower-stakes jobs. Those who were still on the trading floor fifteen years after their first day had an average accuracy of 85 per cent.²⁰

John Coates, a financial trader turned neuroscientist who collaborated with Garfinkel on these studies, dubbed these people ‘hunch athletes’.²¹ By some combination of genetic good luck and training, they have become highly attuned to their gut feelings – and with a score above 80 per cent on the heartbeat detection task, he is one of them. When he moved from Wall Street to the lab, he took his intuitive sense with him. ‘I was relying on hunches that were every bit as gut feely as things I’d had on Wall Street,’ he says. ‘I could sense there was a message in the data, even though I hadn’t found it yet.’

We may not all be hunch athletes, but we all have this ‘spidey sense’, and it contributes to the decisions we make, even when we aren’t aware that it is happening.

In every moment, our body signals act as a kind of gatekeeper, determining whether something in the outside world is important enough to require further processing. Experiments have shown, for example, that we are faster to notice things – and to react to them – if they hit our senses at the same time as our heart contracts, sending blood around our body. This makes sense when viewed in the context of survival: in times of threat, when the heart is beating faster, we are both hypervigilant to signs of danger and able to react faster to escape if necessary. Memories are also laid down more strongly when the heart

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is pounding – which makes sense if you want to learn from your brush with death so you can react more quickly next time. Something similar happens as we breathe. When we see something scary during an in-breath, we are faster to notice and to react. Again, this makes sense: when faced with danger, you want to notice, act quickly and learn for next time.

This system does have downsides, however. A small, preliminary study led by Yoko Nagai at the Brighton and Sussex Medical School used biofeedback to nudge volunteers into a state of either high arousal (heart racing, palms sweating) or relaxation. They were then subjected to the Weapons Identification Task, a psychological test used to investigate how unconscious racial bias affects perception and behaviour.

In the test, a face briefly flashes up on a screen, followed by a glimpse of either a gun or an innocuous tool, such as a spanner. Previous experiments had shown that after seeing a black man's face, white participants were quicker to spot a gun than a tool, and were more likely to mistake an innocuous tool for a gun than they were after seeing a white face. Nagai and others have also shown that this effect is particularly strong if a volunteer sees the face at the exact moment their heart contracts. Which led her to wonder, what if a person's heart was already beating fast? Would they be more likely to jump to a racist conclusion?

The answer was a resounding yes – which was especially worrying because all these reactions are subconscious. It's important to note that these associations between ethnicity and violence aren't hardwired; they are learned associations that most likely become entrenched through

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racist stereotypes in society and their reinforcement in popular media. This means that people who have watched enough crime dramas, or who consume certain media channels, might be primed to react in ways that might not reflect what they really believe, especially when they are stressed, angry or scared. This feels like something that everyone – and particularly those in positions of power – should be aware of.

Wired for change

The good news is that none of this is set in stone; from the very beginning of human life, our interoceptive system comes wired to adapt and change. When babies are born, their systems are far from finished. The sensors and basic wiring allow them to detect when homeostasis isn't going well, but all they can do is cry and hope that someone interprets what they need and fixes the problem.

Anyone who has been in charge of a baby will know that it's not easy to translate their cry into a specific need for food, a change of nappy or to be helped to sleep. But according to the researchers Manos Tsakiris and Aikaterini Fotopoulou, the process by which adult and child work out the problem allows us to make the link between homeostatic needs and ways of fixing them. It's a process of trial and error that rarely goes without a hitch – but as long as a parent responds and eventually solves the problem, all is well.

If, on the other hand, a baby cries and no one comes to help – or if they are punished for expressing their needs – the system doesn't develop as it should, and this can lead

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to poor mental health in later life. The same process may account for the 'sensitive periods' for mental health during our lifetimes: puberty and adolescence, pregnancy, menopause and old age are all periods when the body and brain are undergoing upheaval. Our bodies are changing and our brains are rewiring themselves, and anything we relearn about the world and our chances of surviving or thriving may be more likely to stick.

Even outside these key periods, our inner sense is telling a constantly changing story that is written and rewritten every day. Intriguingly, the brain-body connections that run the show may be edited and updated while we sleep. It has long been known that during REM (rapid eye movement) sleep, when we do most of our dreaming, our bodies are mostly paralysed, apart from the occasional twitch. Until recently, these twitches were thought to be a remnant of the dream, somehow sneaking out of the brain and being expressed in the body, but according to a new theory it's quite the opposite. Neuroscientist Mark Blumberg found that these twitches happen in the body first, and the brain responds milliseconds later.²² He suggests that one explanation for this is that when we twitch in our sleep we are running maintenance on our body-brain connections, keeping them updated with the latest interoceptive lessons so they are ready to go the next morning.

With new insights like these emerging all the time, we find ourselves at an exciting juncture for the understanding of the mind. Learning how interoception works by mapping its pathways through the body and brain can provide us with tools to understand why we think, feel and act the way we do. Once we know that, we can make

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better-informed decisions about how to read and respond to our own bodies and what they really need. Then we can do much more than just survive through the many challenges of living on modern Planet Earth – we can thrive.

2

The interoceptive superhighway

Navigating the vagus nerve, and other roads less travelled

The human brain is amazing, but if you could remove it from the body and somehow translate its activity into thoughts, you would almost certainly be disappointed. A disembodied brain wouldn't be wise, it wouldn't be rational, it wouldn't even be angry about its predicament. If you got anything from it at all, it would probably be something along the lines of 'Huh?'

For all its bells and whistles, without the rest of the body, the brain has nothing to think – or care – about. Even memories would cease to make sense if there was no body for us to feel them through. So, for all the impressive discoveries in neuroscience over the past few decades, if we are to truly understand our minds, we need to look at the brain in the context of the body it works with. Anything less would be like trying to understand how a tree produces leaves and flowers while ignoring its trunk and roots, or how a great city came to be, without factoring in the flow of people, ideas and materials in and out of its borders over centuries or millennia.

In short, if we are ever going to move beyond vague

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conversations about mind–body connections, we are going to need a better map: one that not only puts the brain in the context of the body but is also interactive, plotting the major highways and byways, and providing updates on any blockages in real time.

It's a big ask, but for the body's major interoceptive highways, efforts are well under way. What has been discovered already makes it clear that the body–brain pathways are far from passive carriers of information. They are way smarter, and far more interesting, than that. And they offer new opportunities to understand – and influence – the mind.

Lines of enquiry

According to the neuroscientist Soyoung Park, there's a word that perfectly sums up the body–brain connection. It is, she told the audience at a recent conference on emotion research: the neck.

It got a good laugh, because as everyone in the room knew, it's a bit more complicated than that. In fact, another scientist I met while researching this chapter suggested I skip the details entirely. Another suggested I bury the specifics somewhere in the notes section. Nevertheless, having spent many hours wading through anatomical treacle, I still think that the basic map is well worth a brief guided tour – if only to hammer home the point that the body–mind connection is not a woolly concept but is actually very real.

The obvious place to start is with the three main body-to-brain pathways (Figure 1). First, there's the vagus nerve,

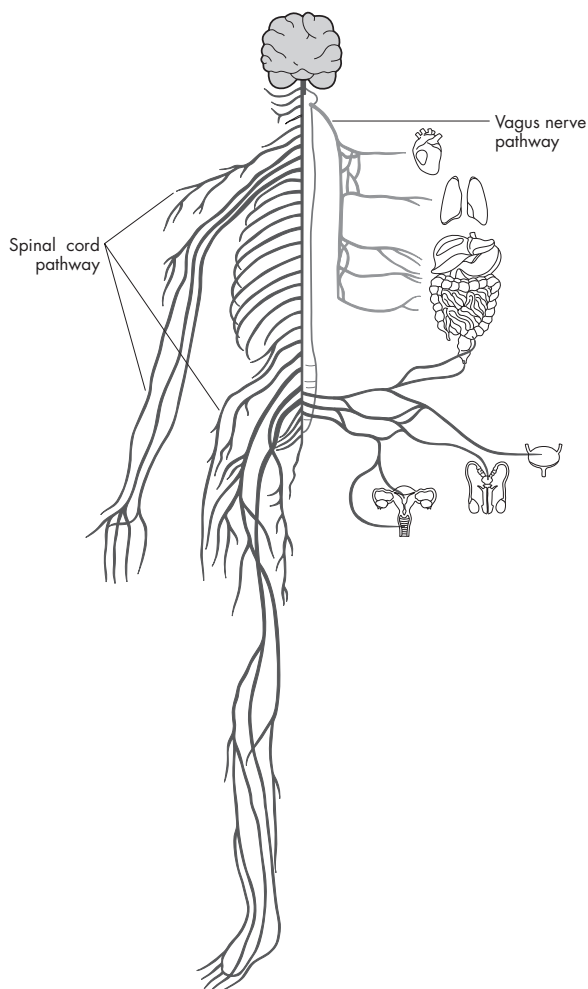


Fig. 1: Body–Brain Interoceptive Pathways

The body–brain conversation takes place along two main nervous system pathways. The vagus nerve carries signals from the major organs directly to the base of the brain. The spinal sensory nerves report from the pelvic organs, including the bladder and genitals, and also from further afield, from the muscles, fat and other body tissues, and travel to the brain via the spinal cord. A third pathway (not shown) carries chemical and hormonal messages between body and brain in the bloodstream.