

Here Comes the Sun-The Extraordinary Journey from Light to Vision

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Submission: September 13, 2026; **Published:** September 30, 2026

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Abstract

Life on Earth exists within a continuous flow of energy, much of it originating in the Sun. Over billions of years, living systems evolved not only to capture this energy but also to use light as a source of information about the world. This paper follows that journey—from the generation of energy within the Sun, through the emergence and evolution of life, to the absorption of a photon in the human retina and the neural activity that follows. It ends where another journey begins: with the birth of a child, opening its eyes to the world for the first time.

Keywords: Sun; Photon; Evolution; Chemiosmosis; Oxidative Phosphorylation; Phototransduction; Vision; Consciousness; Birth

Part I-Light

I am driving to work. It is a cold, foggy winter morning, and the Sun sits low on the horizon. Surprisingly, I can see it entirely, its usual brilliance muted by clouds, and it seems a small orb strangely similar to the Moon. Of course, they are nothing alike. The Sun, at nearly 1.4 million kilometers across, is roughly 400 times the Moon's diameter. But it is also about 400 times farther away, a strange coincidence that makes them appear almost exactly the same size in the sky [1]. This is what makes a total solar eclipse possible, but it will not last forever. As the Moon slowly recedes from Earth, it will appear smaller, and the similarity will gradually wane [2].

But for now, it lingers.

And I pause.

My hand rests by the window, and sunlight gently reflects off my skin. I wonder about that light. I realize that a little over eight minutes earlier, it was leaving the Sun's surface. It seems unbelievable that, in such a short time, it has travelled nearly 150 million kilometers. Some of it has reached my hand. Some has entered my eyes. Almost all of it, however, has missed the Earth entirely and continues outward, unseen, through the vastness of space.

Eight Minutes Earlier

Light leaves the Sun as electromagnetic radiation. It can be

described as waves of oscillating electric and magnetic fields travelling through space at a staggering speed of nearly 300,000 kilometers per second.

In quantum terms, that same radiation can be described as photons, discrete packets of electromagnetic energy. The energy of each photon depends on its frequency, and therefore its wavelength: shorter-wavelength ultraviolet photons carry more energy than those of visible light, while longer-wavelength infrared photons carry less. There is nothing fundamentally special about the narrow band we call visible light. It is simply the part of this spectrum that our eyes have evolved to detect [3].

As they reach me now, reflected from my hand, these photons have been travelling for only a little over eight minutes. But the energy they carry has a much older history. Its journey began long before it escaped from the Sun's surface.

Inside the Sun

The Sun is composed predominantly of hydrogen. At its core, enormous temperature and pressure allow these nuclei to fuse, forming helium. In the process, a small amount of mass—about 0.7% of the total involved—is converted into energy. It might not seem like much, but according to Einstein's familiar equation ($E=mc^2$), this tiny loss produces an extraordinary amount of energy. Every second, the Sun converts about 600 million tonnes of hydrogen into helium, with about 4 million tonnes becoming

energy—roughly equivalent in mass to two-thirds of the Great Pyramid of Giza [4].

The Sun has been doing this for billions of years.

From the core, that energy begins a remarkably slow journey toward the surface. Deep within the Sun, it moves through countless interactions with surrounding matter, repeatedly absorbed, scattered, and re-emitted along the way. Farther out, energy is increasingly carried by convection, as hotter plasma rises and cooler plasma sinks, creating enormous circulating currents that carry energy toward the photosphere. Together, these processes mean that energy generated in the core may take tens of thousands, perhaps hundreds of thousands, of years to reach the surface [5].

Only then can it escape into space as electromagnetic radiation.

Before the Sun

But the story of light reaching my hand did not begin with the Sun.

Although the Sun formed about 4.6 billion years ago from the gravitational collapse of an enormous cloud of gas and dust, much of its hydrogen originated in the earliest moments of the Universe after the Big Bang, almost 13.8 billion years ago. Other, heavier elements—including carbon, nitrogen, oxygen, phosphorus, sulfur, iron, and magnesium—were forged by earlier generations of stars that shone and died and scattered their debris into space long before our Sun even existed [6].

Both the Earth and the Sun therefore share an enormous cosmic inheritance.

As indeed do we.

The calcium in our bones, the iron in our blood, the oxygen we breathe, and the carbon from which life is constructed all have histories that extend far beyond the cradle of the Solar System.

Into the Dark

From its surface, the Sun radiates energy outward in all directions. A joule is a relatively small unit of energy—roughly comparable to the mechanical work of a single human heartbeat. The Sun's photosphere releases about 63 million joules every second from each square meter of its surface, amounting to an almost unimaginable torrent of energy pouring continuously into space [7].

Most of this will never be seen. It may travel enormous distances without ever encountering another planet, a grain of dust, or anything else, simply continuing outward through the apparent darkness of space. What reaches us, almost 150 million kilometers away, is only a tiny fraction of what left the Sun. Nothing has been used up along the way. Individual photons have not gradually tired or lost their energy simply because they have

travelled farther. Rather, the radiation has become increasingly diffuse as it spreads across an ever-expanding area.

Yet the tiny portion that reaches Earth is enormous on a human scale—thousands of times greater than humanity's current power consumption. About 30% is reflected back into space, while much of the remainder is absorbed by the atmosphere, land, and oceans, warming the planet and driving many of its physical processes [8,9].

For billions of years, the Earth has existed within this ongoing flow of energy from the Sun. On the young Earth, this combined with energy from within the planet itself, driving a dynamic interplay of heat, water, minerals, and chemistry.

Eventually, within this continuing flux of energy and matter, life arose.

Part II-Life

In the flow

Life is governed by many things: environment, biology, and, more fundamentally, universal physical laws. Some of these laws may seem like chapters from an old physics textbook, yet they remain fundamental to the organization and persistence of all life.

One of these is the second law of thermodynamics, which states that when left to itself, an isolated system tends toward increasing entropy: energy becomes progressively more dispersed and less available to perform useful work. For example, differences in temperature and chemical concentration tend to even out over time, gradients dissipate, organized processes cease and structures eventually break down [10].

At first, life might seem strangely at odds with this law. Living organisms are extraordinarily good at holding themselves together. They build cells, maintain membranes, repair damage, reproduce, and preserve extraordinarily complex molecular structures, sometimes for decades. It can almost seem as though life has somehow been excused.

But life does not exist as an isolated system.

It exists within the much larger system of the Earth, which itself lies within a continuous flow of energy. Electromagnetic radiation arrives predominantly from the Sun, while heat from within the planet drives geological activity. Solar energy is absorbed and transformed by the atmosphere, oceans, land, and living organisms before ultimately being radiated back into space, primarily as infrared radiation.

Within this ongoing flow, pockets of organization can arise and persist even as overall entropy increases. A whirlpool provides a simple analogy. It appears as an organized structure within a flowing river, even though the individual water molecules that make it up are continually changing. Remove the conditions that sustain it, and the whirlpool disappears.

Life is, of course, vastly more complex, but the underlying principle remains similar. Living systems persist because they maintain their organization through continuous flows of energy and matter [10]. The young Earth was awash in such flows. On the ocean floor, seawater seeped through cracks in the crust, heated up, became enriched with dissolved minerals, and then returned to the ocean through hydrothermal vents. Here, warm, mineral-rich fluids met the cooler waters of the surrounding ocean, creating environments where increasingly complex chemical processes could occur.

This was not yet life. But it brought together many of the ingredients from which biology could eventually emerge. Molecules formed and broke apart, reacted with one another, and encountered natural mineral structures that offered something increasingly important: barriers and spaces where reactants could accumulate rather than simply dispersing into the vastness of the ocean [11].

In some such systems, differences in acidity meant that the concentration of hydrogen ions, or protons, was higher on one side of a mineral barrier than on the other, creating a gradient. Like water held behind a dam, this separation represented a store of potential energy that could be used to do work. As protons moved down the gradient toward equilibrium, some of that energy could, in principle, be harnessed to drive other chemical reactions [11].

This principle is at the heart of life today.

From charge to life

Life appears to have become established remarkably early in Earth's history, by at least 3.5-3.7 billion years ago [12]. We do not know where or exactly how the transition from chemistry to biology occurred. Hydrothermal environments are one possibility [11]. But somewhere on the young Earth, within ongoing flows of energy and matter, chemistry began to acquire the characteristics we now associate with life.

One of the most fundamental of these was the distinction between inside and outside.

A boundary.

We have already encountered natural mineral barriers that can separate one chemical environment from another. Biology would later develop something similar with membranes. Simple fatty molecules in water can spontaneously arrange themselves into membrane-like structures, with water-attracting portions facing outward and water-repelling portions tucked inward. Some can close upon themselves to form tiny vesicles, creating a separate internal environment [13].

We should not imagine that one of these vesicles suddenly became alive. The transition from chemistry to biology was almost certainly a series of steps, though the precise sequence

remains uncertain. But compartmentalization changed what chemistry could do. Molecules could be kept together. Differences in chemical composition could be maintained between the inside and the outside world. Reaction products could remain near the reactions that produced them, allowing increasingly interconnected chemical systems to develop [13].

A defining property of emerging life was the ability to capture energy from the surroundings and make it available to the chemical reactions that sustained it. The earliest cellular organisms were probably simple prokaryotic cells—single-celled organisms without a nucleus or the complex internal structures that would characterize later eukaryotic life forms. In a world with essentially no free oxygen, they relied on chemical reactions involving substances already present in their surroundings. Hydrogen, sulfur compounds, and reduced forms of iron were among the substances that could donate electrons in these reactions, while other compounds acted as electron acceptors. When electrons are transferred from a suitable donor to an acceptor where they occupy a lower-energy, more stable state, energy can be released. The cell can capture some of this energy and use it to drive other processes [11].

A crucial development was the ability to harness some of this energy to move protons across the cell membrane, creating the gradient we have already encountered. When protons flowed back down this gradient, they passed through ATP synthase, a tiny molecular machine embedded in the membrane. Some of the potential energy stored in the gradient could then be captured to synthesize ATP, which in turn could be used to power chemical reactions elsewhere in the cell [14]. Life had learned to create for itself something the physical world had already provided: a store of potential energy held across a boundary. It used energy to create and maintain a gradient, then captured some of that energy as the gradient dissipated. The tendency toward increasing entropy had not been overcome. Life had simply found a way to work within it.

This use of a proton gradient to drive ATP production is known as chemiosmosis. It would become one of the most enduring mechanisms in the history of life [14].

Enlightened

For early life, however, the chemical energy available depended on the substances present in its surroundings. This could be limiting. Then some organisms gained access to an energy source that had been pouring across the Earth long before life began.

Sunlight.

The key was the evolution of pigments—molecules that absorb photons. When a photon of the appropriate wavelength strikes such a molecule, its energy can excite an electron to a higher-energy state. That electron can then be transferred to an acceptor, initiating a series of electron transfers. As the electrons

subsequently move toward lower-energy states, some of their energy can be captured and used to drive chemical reactions, including the establishment of the proton gradients that support chemiosmosis [15]. The earliest forms of photosynthesis were likely very different from those familiar to us today. They did not release oxygen. That came later, when some microorganisms evolved the ability to extract electrons from water, releasing oxygen as a by-product. This form of oxygenic photosynthesis would become characteristic of the cyanobacterial lineage [15].

Over time, the oxygen released through photosynthesis began to accumulate in the atmosphere. By around 2.4 billion years ago, during what is known as the Great Oxidation Event, its growing presence began to profoundly alter the planet's chemistry [16]. Oxygen was not a source of energy, but it was an exceptionally effective electron acceptor. Organisms that were able to use oxygen as the final acceptor in the electron-transfer reactions we have already encountered could extract far more usable energy from organic molecules. This was aerobic respiration.

The energetic possibilities available to life had changed dramatically.

Empowered

By roughly two billion years ago, prokaryotic cells had already evolved sophisticated mechanisms for extracting energy from their surroundings. Greater size could offer advantages, including more internal space for increasingly complex cellular machinery. But it also created a problem. Much of the membrane-based machinery of respiration operated across the cell membrane. Because a cell's volume increases more rapidly than its surface area as it grows, a larger cell—with greater energetic needs—has progressively less external membrane relative to the volume of cytoplasm it must support.

Then something audacious happened.

An ancestral archaeal host entered into a relationship with a bacterium capable of aerobic respiration. Rather than being destroyed, the bacterium survived within the host, bringing its energy-producing machinery inside the cell. This partnership, known as endosymbiosis, was one of the major transitions in the history of life [17].

The host cell's energetic architecture changed profoundly. Energy production was no longer confined to its cell membrane. The respiratory membranes of the bacterial partner now provided additional internal surface area for electron transport, proton gradients, and ATP production. This coupling of electron transport to ATP production via chemiosmosis is known as oxidative phosphorylation.

The host was transformed.

And empowered.

This greatly expanded energetic capacity may have helped overcome some of the constraints associated with increasing cell size, supporting larger cells, more extensive genomes, internal compartments, elaborate cytoskeletons, and increasingly complex systems of cellular regulation [18]. Over evolutionary time, descendants of this bacterial partner became the mitochondria still found in nearly all eukaryotic cells today. Their numbers vary widely—from relatively few to many thousands—depending on each cell's energy demands [17].

Whether mitochondria were the sole driver of increasing cellular complexity or one of several developments that made it possible remains debated. What is clear is that this partnership became extraordinarily successful and was fundamental to the evolution and diversification of eukaryotic life, from which complex multicellular organisms would eventually arise [17,18].

Life had emerged from its surroundings.

It had learned to use the environment around it.

Now it needed to know what was there.

Part III- Sensing

Learning to sense the world

Throughout this long evolutionary history, the Sun continued to shape the world in which life evolved. Solar radiation warmed the land and oceans and helped drive winds, currents, rainfall, and climate. As the Earth rotated, light and darkness alternated predictably, while its orbit and axial tilt produced longer seasonal changes in day length and temperature.

Life therefore evolved within a dynamic environment continually shaped by the flow of solar energy. From its earliest beginnings, conditions outside a cell could determine whether it survived. Chemical sensing was one of the earliest ways life gathered information about these conditions. The surrounding water, for example, might contain nutrients or harmful substances; it might be more acidic or more alkaline, warmer or colder, rich in one chemical and depleted in another. An organism that can detect such differences and respond effectively is more likely to survive.

But how?

Molecules in the environment can encounter receptor proteins on the cell membrane. When an appropriate molecule binds to one of these receptors, it can change the protein's shape, which in turn may initiate chemical signals within the cell that alter its metabolism or behaviour. By responding to changes in the concentration of particular substances, for example, a bacterium can bias its movement toward favourable conditions or away from harmful ones. It does not need to know what lies ahead in any conscious sense. Its molecular machinery simply links environmental information to an appropriate biological response [19].

One that works.

One that keeps it alive.

Over evolutionary time, receptor systems became increasingly sophisticated. In eukaryotic organisms, one important family of molecular receptors is the G-protein-coupled receptors, or GPCRs. Today, members of this family still detect an extraordinary range of signals, including odours, tastes, hormones, and neurotransmitters.

Among this ancient family of receptors, however, are proteins that evolved to detect something very different from the chemicals surrounding them.

Not just a molecule or a chemical.

Something much less tangible.

A photon.

Learning to see

The evolutionary story that would eventually lead to vision began long before there were eyes. Central to that story are proteins called opsins. They belong to the much older family of G-protein-coupled receptors we have already encountered, but with an important difference. Each opsin is associated with a small, light-sensitive molecule called retinal, which is derived from vitamin A. When retinal absorbs the energy of a photon of the appropriate wavelength, it changes shape. This, in turn, alters the surrounding opsin protein, triggering a signalling cascade, much as other receptors do in response to chemical or molecular signals [20].

This was not the first-time life had learned to use light. Photosynthetic organisms had already evolved ways to capture the energy carried by photons and use it to drive chemical reactions. But something different was happening now. Light was no longer just an energy source. It could provide information about the world beyond the organism.

Sensitivity to light offered something chemical sensing generally could not. Chemical signals were usually local, carried by molecules that diffused or were transported through the organism's immediate surroundings. Light, however, could travel much greater distances, arriving directly from a source or reflected from objects elsewhere in the environment. Life now had access to information about a world extending far beyond its immediate surroundings.

There was still no image and certainly no eye.

The organization of light-sensitive cells into an eyespot allowed changes in light intensity to be detected. The organism could now distinguish light from darkness—simple information, but enough to alter its behaviour in potentially useful ways.

A further advantage arose when these clusters of photoreceptive cells became recessed into a shallow depression. Here, the surrounding ridge of tissue allowed light from some directions to reach the receptors while blocking it from others, providing a primitive form of directional sensing. As the depth increased and the opening narrowed, these structures acquired characteristics similar to a pinhole camera: light arriving from different directions fell on different parts of the light-sensitive surface, providing increasingly precise information about where the light was coming from and allowing the organism to respond accordingly [21].

By the early Cambrian, about 540 million years ago, sophisticated eyes had already evolved in some animals. This was not the result of a single, inevitable progression toward the modern human eye. Light-sensitive structures evolved repeatedly across different branches of life, yielding an extraordinary variety of solutions to the specific worlds in which organisms needed to survive: simple photoreceptive patches, cup and pinhole eyes, compound eyes, and the camera-like eyes of vertebrates and cephalopods [21].

In some lineages, transparent tissues evolved to refract and focus incoming light, forming lenses and producing increasingly detailed images. Some visual systems became highly sensitive to colour, while others favored greater sensitivity in dim light. In some animals, particularly predators, forward-facing eyes produced overlapping visual fields that helped depth perception, while laterally placed eyes provided a much wider view of their surroundings. The wavelengths an organism can detect also differ according to the light-sensitive pigments it possesses. Many birds, insects, and fish, for example, can detect ultraviolet wavelengths, while some animals can detect properties of light, such as polarization, to which we are effectively blind.

The same physical world can therefore provide very different visual information to different organisms. No visual system captures everything. Each is sensitive to some features of the environment while remaining insensitive to others. A bee, a bird, and a human may look toward the same flower, illuminated by the same Sun, yet each may see it differently. What can be seen depends not only on the world and the light within it, but also on the organism doing the seeing.

Vision, in all these forms, was a profound evolutionary innovation. It allowed organisms to gather information about the world at a distance. A predator could detect prey before reaching it. Prey could respond to an approaching threat. Obstacles, shelter, and potential mates could influence behaviour before physical contact occurred. As visually guided behaviour became more effective, it also placed evolutionary pressure on other organisms, favoring adaptations such as improved camouflage, armour, speed, and concealment.

Vision may not by itself have caused the extraordinary diversification of animal life since the Cambrian period, but it may have intensified the ecological interactions and evolutionary pressures through which that diversification unfolded. But this was only part of the challenge. As visual systems became more sophisticated, organisms also needed increasingly effective ways to process the growing stream of information they provided—to map spatial relationships, integrate different features of the visual scene, and translate them into appropriate behaviour. Nervous systems capable of integrating vision and coordinating progressively more complex responses therefore became increasingly advantageous.

Part IV-Living

Inner and outer worlds

I look again at my hand. It rests gently on the steering wheel. Sunlight falls on its surface. Some is absorbed, and some is reflected. Much of the latter will pass me by unnoticed.

To me, it seems the simplest thing imaginable. I open my eyes, and there is my hand.

Just as it should be.

But there is so much more to it than that.

Visual processing occurs remarkably quickly. So quickly, in fact, that the few hundred milliseconds during which light reaching the eye is transformed into conscious visual experience seem, to us, immediate [22].

But a lot happens in that time.

Photons entering my eye are refracted and focused onto the retina, where some are absorbed by the retinal molecules we encountered earlier. Retinal changes shape, altering its associated opsin and initiating the cascade of phototransduction [20]. For those photons, a journey that began deep within the Sun and continued for a little over eight minutes across space to Earth, has come to an end. The photons have been absorbed. What continues is no longer light but electrochemical signalling within the nervous system.

The photon is gone.

No light travels along the optic nerve. No image of my hand appears in the visual cortex to be viewed again as though on a screen. Instead, neural signals pass through pathways of increasingly complex processing, where information about contrast, colour, shape, position, and movement are extracted and integrated [23].

And somehow, from all of this, a world appears.

Light that life had once learned to capture as energy eventually became part of the means by which a world could be experienced.

Just how this happens is difficult to say.

You would be forgiven for thinking we simply see what is out there, as if looking through a window. I know I do. I can see the Sun on the horizon, the road stretching out ahead of me, and my hand resting, as it was before, on the steering wheel.

Yet none of these things themselves has entered my brain. There is no little Sun, road, or hand inside my head, nor is an image somehow projected outward onto an invisible screen in front of me. The things I see may indeed exist outside me, but my experience of them must somehow be contained within the activity of my brain.

It hardly seems possible.

The philosopher Ludwig Wittgenstein captured something of this paradox—the distinction between how the world appears to us and our understanding of how that appearance arises. He asked why people once found it so natural to believe that the Sun moved around the Earth. The answer was that it simply looked that way: we remain still while the Sun rises in the east, crosses the sky, and sets on the opposite horizon. But how, Wittgenstein asked, would it look if the Earth were rotating instead? [24]

The answer is simple.

It would look just the same.

Discovering the mechanism behind what we see may therefore transform our understanding of how it happens without necessarily changing the experience itself. Knowing that it is the Earth that turns does not stop the Sun from appearing to rise, cross the sky, and set.

Knowledge changes the explanation, but not the experience.

Finding Us

Precisely how neural activity becomes subjective experience remains one of the great unanswered questions of consciousness.

Yet we know the brain can generate extraordinarily convincing perceptual experiences. It does so every night when we dream. With our eyes closed, we may see people, places, movement, colour and space. They seem to surround and involve us, and for as long as the dream remains, can seem entirely real.

So, we know such an experience is possible

And we know it can happen in our heads.

The neuroscientist Anil Seth has described waking perception as a controlled hallucination. He does not mean that the world outside us is imaginary. Rather, the brain continually infers the causes of the sensory signals it receives, combining incoming information with expectations derived from previous experience and the evolved organization of the perceptual system itself. This aligns with the broader idea of top-down processing, in which

perception is influenced by what the brain already brings to it—prior knowledge, expectations, associations, and memories. The brain does not simply receive sensory signals and reproduce them. It uses what it already knows to infer what those signals are most likely to represent [25,26].

The title of this paper offers a simple example of how readily what we perceive can become entwined with what we already know. For many readers, Here Comes the Sun will bring to mind George Harrison and the Beatles, perhaps the melody itself or memories associated with the song and the culture of the late 1960s and early 1970s. None of this is present on the page. The title provides a signal, but what it evokes depends on what the reader already knows. Different histories will produce different responses; for some, it may evoke nothing at all.

What the brain brings to perception includes not only what we have acquired during our own lives but also predispositions whose origins may reach deep into our evolutionary past. Because perception draws upon these existing resources, the incoming information need not always be complete. Remarkably little visual information can sometimes be enough for something familiar to appear—for instance, a few lines on a page can become a tree rather than simply marks on paper. Two dark spots above a line can be enough for a face to appear, just as we can easily see faces in passing clouds, the front of a car, the windows of a house, or the patterns of grain on a wooden wall.

What we experience is therefore neither a photograph of the world nor an invention independent of it. It is the brain's continuously updated interpretation of the world most likely to have produced the sensory information it receives [25,26].

And the result is so convincingly real that we experience it without question.

1.1. What about me?

As I sit here, looking out the car window, I do not simply see the Sun slowly rising above the horizon.

I see more than that.

I see it from somewhere.

I seem to be behind my eyes, looking out upon a world that surrounds me. Things appear before me, sounds come from around me, I sit on a seat beneath me, and my feet touch the floor. Yet if the brain constructs the experienced world, might it also construct the position from which that world appears to be experienced? [27]

A woman once described an extraordinary experience during childbirth:

"I remember when my world changed forever. I experienced something miraculous. During labour, I noticed the world around

me shift. The lights seemed dimmer, and the room fell silent. I was conscious, but it felt different. An incredible calm settled over me. I could feel everything: the bed, the people around me, my breath and heartbeat. Time stood still. I was no longer connected to anything. I was distant, in a place I had never been before. I felt like I was floating without boundaries. It was so calm and peaceful. I remember looking down as I hovered over my body, watching myself from above as if I were both here and below me. I felt loved. Fearless. I had never felt anything like this before."

—Anonymous birth account.

We might reasonably ask whether such an experience accurately reflected reality. She was not, after all, literally hovering above the bed, though to her it was compellingly real. Can we regard it as yet another construction of the brain—an experience that felt entirely convincing despite placing her somewhere she was not?

I think we can.

And if the brain can construct an alternative perspective with such conviction, perhaps the more fundamental question is why we are so certain that our ordinary sense of perspective is different. The apparently self-evident sense that I am somewhere behind my eyes, looking out at the world, must also arise somehow from the activity of my brain [27].

Might this too be part of what Anil Seth calls our controlled hallucination?

I encounter a simple analogy of this almost every time I park the car.

Cameras mounted at the front, rear, and sides show me what lies around the vehicle. But the display also shows me something quite different: a bird's-eye view in which I appear to be looking directly down from somewhere above the car.

Of course, there is no camera up there.

The view is constructed by combining information from the other cameras. From several separate perspectives, the computer creates a new, coherent viewpoint from a position where no camera actually exists. A brain is not a collection of cameras, and an out-of-body experience is far more complex than an image on a parking display. Yet the example highlights something that might otherwise be easy to overlook: a coherent and convincing viewpoint can be constructed even when there is nothing at the position from which that viewpoint appears [27].

Our ordinary experience of self is remarkably stable. Perhaps what makes it seem so unquestionably real is that it is so extraordinarily consistent. It accompanies us through almost every waking moment. It is the perspective we have learned to call normal. It is centered on the body, typically experienced as coming from somewhere behind our eyes, and is integrated with

information from vision, touch, balance, proprioception, and the position of our limbs.

Yet this sense of being here is almost certainly something the brain constructs.

As is, it seems, the entire world we experience.

Conclusion

We have followed the light a long way, from the Sun, across the darkness of space, into the chemistry and experience of life. Solar energy helped shape the environment in which life arose. Living organisms later evolved ways to capture light as an energy source and, eventually, to extract information about the world from it. Eyes and nervous systems evolved to gather and process that information.

And somewhere within those pathways, seeing became experience.

But here our understanding reaches a boundary.

We do not know why any of it should become a subjective experience. Why should electrochemical activity be accompanied by the experience of colour? Why should particular patterns of neural activity give rise to the warmth of bright sunshine, the blueness of the sky, or the sight of my own hand resting on the steering wheel?

We simply know they do.

The Sun is now above the horizon. It has been shining for more than four and a half billion years. In the brief time it takes my brain to process what I see, the light that passes me by unseen is already 60,000 kilometers away—a distance equivalent to circling the Earth one and a half times.

A distance that would surely have gotten me to work by now.

I'm late.

There are things to do.

In the birthing suite, a baby will soon be born.

A pregnancy is almost at an end, but its story began long before that. The atoms from which this new life has been assembled have histories that reach back far beyond the Earth itself. The biology that organized them has been evolving for billions of years, much of it within a world continually shaped and sustained by the Sun's energy.

During these past nine months, the products of that history have been assembled anew. Eyes have formed. Retinal molecules and opsins have been produced. Neural pathways have developed according to patterns shaped over an immense evolutionary history, ready to receive and process the information that light will bring.

Soon, those little eyes will open.

And somewhere amid all that activity, a world will appear.

Anew.

Real.

I look at my hand again.

And smile.

It is extraordinary.

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DOI: [10.19080/JOJPH.2026.11.555802](https://doi.org/10.19080/JOJPH.2026.11.555802)

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