Quantum Realism Part II. The Observer Reality

Chapter 6. The Mystery of Consciousness

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"I regard consciousness as fundamental. I regard matter as derivative from consciousness. We cannot get behind consciousness. Everything that we talk about, everything that we regard as existing, postulates consciousness." Max Planck (Sullivan, 1931)

Quantum realism is the theory that quantum reality exists and it creates the physical universe as a virtual reality by interacting with itself (Figure 6.1). While previous chapters explained the observed in quantum terms, this chapter addresses the conscious observer. Consciousness is a mystery because nothing in the physical universe explains how we observe. No law of physics requires matter to observe at all and smartphones and driverless cars make complex choices without an "I" experience, so why don't we? *The mystery of consciousness is that a purely physical universe doesn't imply or even allow the observer experience that we all report having.*

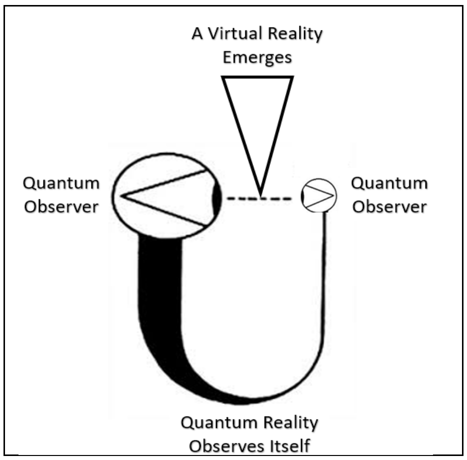

Figure 6.1 A virtual reality emerges as quantum reality observes itself

6.1. WHAT IS CONSCIOUSNESS?

One must define a topic to study it but scientists don't agree on what consciousness is. Some say it doesn't exist, some say it causes everything, while others are in-between. Let us define consciousness as *the ability to observe and experience a physical event,* not just respond to input as a camera might do.

6.1.1. The hard problem

Are you one or many? Most people call themselves *I* not *we,* but if "I" refers to the body, it is a collective of cells that constantly die and are replaced. Skin loses about a million cells a day and it is just one organ. Red blood cells live maybe four months, white blood cells a year or so, skin cells a few weeks and colon cells a few days. Where is the "I" in a bunch of cells that come and go? That some nerves may last a lifetime led one biologist to conclude that *I am my nerves*:

> *"The Astonishing Hypothesis is that 'You', your joys and your sorrows, your memories and your ambitions, your sense of identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules. As Lewis Carroll's Alice might have phrased it: 'You're nothing but a pack of neurons'."* (Crick, 1995)

If so, should I call myself We? If "I" is a medieval error, like that the earth is flat, should we now say *We did this* instead of *I did it?* If you don't want to refer to yourself "We", then welcome to the hard problem of consciousness (Chalmers, 1996), that *we experience life as a single "I" even though we are physically a collection of cells*.

Neurons respond to one light frequency as "red" and another as "blue" but why is red *this* experience and blue *that* one? Nothing in neuroscience requires the processing of different light frequencies to give experiences, so what causes redness and blueness? *The hard problem is that we don't know why sensory input creates an experience as well as a response.*

Imagine a scientist who knew all the facts there are to know about blue from a monochrome screen, such as how neurons analyze blue light frequencies (Jackson, 1982). Yet if she then sees blue for the first time, it's a new experience, so what does she now know that she didn't before? *The hard problem is that the facts of blueness don't explain the experience of seeing blue*.

The Islamic scientist Avicenna proposed a thought experiment: a man floating in a void with no body sensations at all has no awareness of his arms, legs, heart or any other body part but still knows *he exists*. The floating man knows *I am*, even if all inputs stop. *The hard problem is that the observer remains even when nothing is being observed*.

We consider ourselves conscious, and so divide reality into beings that are conscious like us and matter that isn't, but where is the line between? If people are conscious, are dogs, or insects or plants? If I am conscious, is the baby, fetus, or the one cell I grew from also conscious? Dividing reality like this gives an explanatory gap between the matter that makes our body and our experience of it (Levine, 1983). I observe a room of matter but if I am in the room, am I also matter? If what applies to matter also applies to me, am I also a thing?

Conway's free will theorem is that the same rules apply to everything, so either everything is conscious or nothing is (Conway & Koch, 2006). If we are conscious, so is matter, and if matter isn't, then neither are we. That we are conscious but the universe we came from isn't, is illogical. *The hard problem is that no property of matter predicts the observer experience we report*.

After centuries of discussion, the hard problem today is no easier than it ever was:

> *"The question of how matter gives rise to felt experience is one of the most vexing problems we know of."* (Brooks, 2020)

Science still can't explain how we can experience physical events in a body made of matter.

6.1.2. The first fact

The ability to observe refers to the phenomenon of consciousness not a brain function (Block, 1995), so it doesn't require any sense, thought or feeling. Damage to the visual cortex causes blindness but doesn't stop consciousness, as people with *locked in syndrome* are still conscious. People born with no cortex are conscious (Merker, 2007) so it can't depend on a cortical area. No brain area has been identified as the seat of consciousness, because it can persist even when the cerebellum, amygdala, hippocampi or cortex fail. The ability to observe is just there in a way that doesn't require any particular brain function. It can apply to any sense, memory or feeling, so James concluded in 1892 that consciousness is a *fundamental fact*:

> "*The first and foremost concrete fact which everyone will affirm to belongs to his inner experience is the fact that consciousness of some sort goes on*." (James, 2019)

In scientific terms, this fact is *valid* because anyone can confirm that they observe and it is *reliable* because others can repeat the experience. That we each observe differently is irrelevant to the fact that we do observe. Without an observer there is no first person, so we would say "*It is red*" not "*I see red*". To say I see or I hear implies an observer.

We know that we observe phenomena but we assume that it really exists (Kant, 2002). I know that I observe but I assume a physical world out there. I know with absolute certainty that I observe, but everything else is just an assumption, or as science says, a theory.

In physics, both relativity and quantum theory need an observer, one to provide the observer reference frame and the other to trigger a quantum collapse. Science is based on observation, so it is no surprise that the ability to observe is fundamental, as every fact depends on it. In our lives, and in science, the first fact is that we observe because without it, no other facts are possible.

6.1.3. Current theories

The scientific approach to a fact is to explain it, not to ignore or dismiss it, so if consciousness is a valid subject for science, the question raised is:

"Why does conscious experience exist?" (Chalmers, 1996) (p5)

Those who argue that the universe is a machine so consciousness can't exist must also agree that they are also machines, so why should we listen to them? A detailed review of theories on consciousness divides them *exhaustively* into six categories A-F (Chalmers, 2003):

A. *Materialism-A*. Consciousness doesn't exist except as an *imagined* effect of the physical brain (Dennett, 1991). If physical causes explain everything, there is nothing beyond the physical brain that needs explaining, so *the hard problem doesn't exist*.

B. *Materialism-B*. Consciousness exists but is *identical* to certain physical brain states for all practical purposes (Block & Stalnaker, 1999). If consciousness equates to physical states, *the hard problem is solved*.

C. *Materialism-C*. Consciousness exists but is a *physical derivative* of the brain in theory (Nagel, 1974) (Edelman, 2003). If physical causes explain everything, they will one day explain consciousness so *the hard problem will be solved, eventually*.

Theories A-C argue that consciousness arises from a physical process because physical realism is correct. Yet it isn't easy to argue that the observer experience is imaginary (A) or that it equates to matter states (B), so most believers in physical realism are left hoping that a miracle will one-day derive consciousness from matter.

D. *Dualism-D.* Consciousness exists by itself to affect physical events and matter in turn affects consciousness (Stapp, 1993). If consciousness exists as well as matter, *the hard problem is solved*.

E. *Dualism-E.* Consciousness is a brain by-product that helps survival but doesn't affect physical reality (Zizzi, 2003). If consciousness is an epiphenomenon of physical activity, *the hard problem is solved*.

F. *Neutral Monism-F*. If both consciousness and matter derive from a primal cause that is neither, then matter doesn't need to cause consciousness and *the hard problem is solved*.

Theories D-F argue that consciousness is a non-physical reality. Dualism-D lets it affect matter from a non-physical realm, Dualism-E lets it exist but have no effect on matter, and neutral monism-F sees both consciousness and matter as derivative, but as Chalmers notes:

"*No-one has yet developed any sort of detailed theory in this class, and it is not yet clear whether such a theory can be developed.*" (Chalmers, 2003)

Quantum realism is therefore a neutral monism but first, we review physical realism.

6.1.4. Physical realism

The best theory to explain consciousness should be the one that also best explains matter. This is widely thought to be physical realism because the equations of physics predict how matter behaves, but to do so they routinely invoke non-physical causes, like quantum waves.

Consider the question, *is matter a particle or a wave?* Electrons were first seen as particles with mass, charge, and spin, until they were found to be dimensionless points, so how can a particle of no size have mass or charge? How can a particle with no physical extent spin? No-one really knows, so *it's a miracle*.

Physics then described electrons as waves to explain their behavior in atoms, but physical waves vibrate in physical space while the Dirac wave function vibrates electrons in an imaginary plane outside our space. No-one knows how an electron wave can vibrate outside physical space, so *it's another miracle*.

Both views sometimes work, so matter is said to be sometimes a wave and sometimes a particle. This *wave-particle duality* is accepted although particles aren't wave-like nor are waves particle-like. No-one can say how an electron knows to be a particle in space but a wave in an atom, so its yet *another miracle.*

If a miracle is an outcome with no physical basis, physics needs a lot of them to explain the physical world in physical terms, for as Part I established:

- Gravity has to be attributed to graviton particles that have no physical basis at all.
- Light travels at a constant speed with no physical reason to go at just that speed.
- Moving matter changes space and time but has no physical way to do so.
- The vacuum of empty space exerts a pressure that has no physical basis.
- An electron can suddenly appear outside a Gaussian sphere with no physical path.
- An object on a path can be detected without any physical contact at all.
- The physical universe is said to have created itself from nothing, which isn't physical.
- Entangled photons define each other faster than the physical speed of light.
- Most of our galaxy consists of dark matter that has no physical explanation.
- Most of the universe consists of dark energy that has no physical explanation.
- Our universe consists of matter not anti-matter for no known physical reason.
- Quantum waves that aren't physical predict physical event probabilities.

How can a theory based on miracles call itself realistic? Is it realistic that *imaginary waves* cause physical events? Is it realistic that *virtual particles* cause real forces? Is it realistic that particles with *no size* spin? Is it realistic that *massless* gluons create most of a proton's mass? Is it realistic that the future affects the past in delayed-choice experiments? Is it realistic that objects can be detected without physical touching? Physical realism has produced what some now call *fairytale physics* (Baggot, 2013), that predicts what can't be verified and can't explain what can.

Physical realism doesn't deliver but is accepted because the only alternative is thought to be medieval superstition. Physics prefers its new fairytale to the old one, but science shouldn't be about fairytales at all. The fault isn't the equations, because they work, but the fantasy that materialism has spun around them.

Physical realism survives because physicists think that science needs it and scientists think that physics needs it, yet neither is actually true:

a. *Physicists* think that science requires physical causes, but science verifies theories by physical results not causes, and physical realism is just a theory of science.

b. *Scientists* think that physics requires physical causes, but this isn't true either as quantum science predicts physical events from non-physical quantum waves.

The laws of physics work just as well if the quantum world is real, because realism still applies. Neither physics nor science needs physical realism, as the following story illustrates:

> *A father and son would meet to discuss the meaning of life over a meal. Each time they were joined by a third man who ate most of the food, dominated the conversation and left when the bill arrived so he paid nothing. One day the son said "Your friend eats a lot and never pays!" to which the father replied "He's not my friend, I thought he was yours!".*

The third man was accepted by father and son because both thought he was the other's friend. Likewise, physical realism helps neither physics nor science, so both are better off without it. It is an impostor that pontificates but doesn't deliver when the reality check arrives.

6.1.5. Dualism

In 1637, Descartes argued that scientific physicalism and religious idealism are both true, because mind was a substance outside space just as matter was a substance within it. However, two centuries later, Laplace rejected this, arguing that matter alone determined the universe:

> *"We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes."* Laplace, in (Truscott & Emory, 1951) p4.

That physical laws explained everything challenged mind-matter dualism by claiming that science not only didn't need religion, it was better off without it. The case was that all physical events have a physical cause, so the universe is *causally closed.* It is a causal chain with no gaps, like a tube of balls, where pushing one end makes a ball pop out the other end, with no mind or soul needed to make it happen. If all physical facts come from other physical facts, there is no room for mental causes. Causal closure implies that if mind has a physical cause, it is also physical and so not mind, and if not, it can't have a physical effect (Kim, 1999). *Causal closure implies that a non-physical mind can't affect physical events*.

Supporters of dualism sought to demonstrate non-physical causes by paranormal events, like the ability to mentally move objects (telekinesis) or see the unseeable (extra-sensory perception), but attempts to replicate mental powers haven't been definitive (Kelly at al., 2007).

Then just as physicalism was replacing dualism, a new theory, quantum mechanics, concluded that no physical event is 100% certain. In the Stern-Gerlach experiment, silver atoms in a magnetic field go up or down based on a spin that is perfectly random. We can't pre-sort the atoms into those going up or down because they are initially identical, and the spin that moves them up or down in the magnetic field is decided when they observe it, not before. Quantum theory says this happens when the atoms are in the field, just as where a photon hits a screen is decided at the screen. In a mechanical universe, the physical past should entirely define the physical future, but it isn't so in our universe.

When quantum entities interact, they choose their physical future from what is possible and this unpredictability is part of our universe. Quantum theory rejects the idea that the universe is completely physically predictable, and the evidence agrees, so it can't be a big machine.

In quantum theory, when a quantum wave is observed, it randomly actualizes a physical event from one of its lawful possibilities and obliterates the rest. This stops the quantum wave expanding endlessly by restarting it. An observer outside the quantum system ends the chain of quantum events, but there is by definition nothing outside a closed physical universe to do this.

An endless physical chain with no gaps has no way to select one link to be an observation, so it has no way to allow observation or choice. In contrast quantum realism accepts both because it accepts quantum theory entirely. Figure 6.2 compares the reality options:

a. Physical Realism	$P_1 \to P_2 \to P_3 \to P_4 \ldots$
b. Dualism	$M_1 \to M_2 \to M_3 \ldots$ $P_1 \to P_2 \to P_3 \to P_4 \ldots$
c. Quantum Realism	$P_1 \qquad P_2 \ldots$ $Q_1 \to O_1 \to Q_2 \to O_2 \ldots$

Figure 6.2 Reality theories

a. *In physical realism,* a series of physical events (P) lawfully cause each other with no gaps, so there is no observation or choice.

b. *In dualism,* a series of physical events (P) and mental events (M) affect physical events, so there is observation and choice.

c. *In quantum realism,* quantum events (Q) cause observations (O) of physical events (P), so there is both observation and choice. Note that many quantum events produce one physical event.

In Figure 6.2a, each set of physical events causes the next, with no choice or observation possible, so there can be no evolution or observation, yet we know that both occur.

In Figure 6.2b, two causal chains, mental (M) and physical (P), affect not only their realm but also the other, but that mind events cause physical events is both unproven and illogical.

In Figure 6.2c, physical reality (P) arises when quantum waves (Q) interact to allow observation (O), as quantum theory says. Every quantum collapse is then an observation choice.

If quantum waves spread, interact and collapse to give the observations we call the physical world. Quantum realism has no gaps for physical causes just as physical realism had no gaps for mental causes. A physical event is an observed result, not a cause, so it causes nothing. In this view, physical reality is an epiphenomenon that, like a train whistle, appears but doesn't affect the quantum engine driving reality.

If quantum reality creates physical reality, physical laws derive entirely from quantum laws. Physical causality is based on quantum causality, so it is correlation not causality. When a quantum entity picks a physical event from the possibilities it has discovered, it redefines the future timeline. Quantum theory works when physical realism doesn't because it recognizes that quantum events cause the future, not physical events.

6.1.6. Information theories,

Physical reality can't explain consciousness but its information derivative is claimed to do so. Integrated information theory argues that "*consciousness is integrated information*" (Tononi, 2008), generalizing an earlier theory that brain functions like language, vision and hearing deposit information into a global workspace that causes consciousness (Baars, 1988).

Distant brain regions process sight, sound, touch, and smell, then pass the results to areas specializing in memory, emotions, language, planning, and motor responses, but how are global decisions made? Global workspace theory claims that sensory results are put into a common area, for higher functions like memory or language to use. Consciousness then arises when:

> *"… the information has entered into a specific storage area that makes it available to the rest of the brain."* (Dehaene, 2014) p163.

Yet if a specific brain area is critical for consciousness, why hasn't it been found? Workspace theory also suggests that neurons "chat" like little people:

> *"… neural systems do not merely report to their superiors; they also chat among themselves."*(Dehaene, 2014) p176.

Brain science then reduces to neuron sociology (Nunez, 2016) p18, by the analogy of crowd control on the Internet:

> *"… it is helpful to think metaphorically of a theater of mind. In the conscious spotlight on stage – the global workspace – an actor speaks, and his words and gestures are distributed to many unconscious audience members, sitting in the darkened hall. Different listeners understand the performance in different ways. But as the audience claps or boos in response, the actor can change his words, or walk off to yield to the next performer.*" (Baars & Laureys, 2004) p672.

Such analogies are seductive, but that neural areas chat like little people over nerve phone lines, or clap and boo each other as we do online, contradicts information theory. To exchange data like this, the brain would need common protocols, just as the Internet needs these protocol layers to share information:

a. *Data.* Ethernet protocol.

b. *Network.* Internet protocol (IP).

c. *Transport.* Transmission Control Program protocol (TCP).

d. *Application.* Hyper Text Transfer Protocol (http).

The Internet's TCP/IP/http protocols took decades to develop from the original Arpanet, and it was done by a central group the brain just doesn't have. Browsers then need to be updated to work with upgrades, like from IP version 4 to 6, but the brain has no way to do this. And these protocols are just to transmit data packages – to actually see a picture or hear music still needs an application specialized for that data type!

For example, Notepad displays text and Paint displays pictures but loading text into Paint or a picture into Notepad gives nonsense, so even if data was put into a common area, neither could read what the other posted. To do this, Paint would need code to analyze text and Notepad would need code to analyze pictures, which increases program size. And if either application changed the other would have to update its included code to work reliably.

Programs like Word that display text and pictures become huge as a result, and they still can't read zip files, for example. For every brain function to include every other denies the benefits of specialization and updating every area when one changes to share data isn't feasible for the brain. Information science tells us that one can't plug the optic nerve into the auditory cortex and expect information to flow like water.

The auditory area of the brain can no more read smell data than I can read a text in Chinese, so what use is a common stage if neural actors don't use the same language? A global workspace would need a global translator of smells, thoughts, movements, and feelings, which is impossible.

Finally, the Internet shares data so shouldn't it become conscious? Information integration theorists expect it to do so soon (Koch, 2014), despite no evidence at all for this.

Theories of brain data exchange must respect information science, but global workspace theory doesn't, and what won't work for computer networks won't work for brains either. The cartoonish concept of neural areas as little people chatting via a common brain language that isn't possible, merging claps or boos they can't make, on a central stage that doesn't exist, is a fantasy. The brain needs some other way for different regions to share information.

6.1.7. Cognitive theories

We assume realism when we observe that a reality exists out there apart from us. Physical realism calls it physical and quantum realism calls it quantum but, in both cases, sensory events cause nerves to cause observation. If sensory events cause nerve events that cause mental events, one can short-circuit the sequence to argue that mind alone creates observations. This goes against realism, but it is still logical.

Solipsism for example claims that mind alone creates reality, as it does when we dream. This theory is impossible to disprove but it isn't accepted by science because it predicts nothing new and doesn't explain how a mind that can dream arose in the first place.

QBism is a theory of physics that uses this "mind-trick" to dismiss not physical reality, as solipsism does, but quantum reality. It argues that quantum probabilities are degrees of belief about physical outcomes, so quantum waves are just in the mind. Like solipsism, it is impossible to disprove, as one could say gravity is a belief about how matter moves, so it is in the mind too. QBism doesn't do this, as it uses the mind argument selectively to deny quantum reality not physical reality. Like solipsism, QBism has no scientific value because it makes no predictions nor does it explain how a mind with beliefs can exist (McQueen, 2017). That physicists now invoke the mind to deny quantum reality is telling, because *the elephant in the room is that quantum causes can explain what physical causes can't*.

Another cognitive theory of consciousness attributes the mind to complexity, by claiming that brains become conscious in the same way that ants form colonies, because:

> *"... ant colonies are no different from brains in many respects."* (Hofstadter & Dennett, 1981) p181.

The brain is then just a colony of nerves that communicate electrically instead of chemically, as ants do. By this logic, the chemical trails ants lay down are the colony's "language" just as neuron wiring causes our language. Dumb neurons then create consciousness as dumb ants create a colony, so it remains as neurons come and go, just as a colony remains as ants come and go. Crick's "*pack of neurons*" theory is now that we are nothing but a colony of nerves.

The evidence that ant colonies are conscious is weak, as if an ant colony is a being that can communicate, why haven't we learned its language by now, as we did that of the bees? It doesn't help to suggest the same logic applies to countries like Russia or America:

> *"... let us think a bit right now about whether it makes sense to think of 'being' a country. Does a country have thoughts or beliefs?"* (Hofstadter & Dennett, 1981) p192

To say that consciousness is private so countries might be conscious is just a smoke-screen, as no evidence at all suggests that countries are beings. Scientists don't ask others to disprove their speculations but go where the evidence leads. To argue that what appears as a unity might be a being is an appeal to naivety. If that were true, tornadoes might be conscious beings, but they aren't, and neither are ant colonies or countries. When we connect physical parts into a bicycle, it becomes an entity to us but not to itself.

After presenting paradoxical Gestalt patterns and speculating that ant colonies are conscious, the underwhelming conclusion of this theory is that:

> *"Mind is a pattern perceived by a mind."* (Hofstadter & Dennett, 1981) p200.

It isn't hard to see that this statement is circular, because a mind is assumed to perceive a pattern that is then equated to the mind that perceived it. This theory, that mind is a creation of mind, is just another miracle thrown up to maintain physical realism.

6.1.8. Neutral monism

Chalmer's last option is neutral monism, that something more primal than matter or mind is the cause of both, as suggested by Russell in 1921:

> *"The stuff of which the world of our experience is composed is, in my belief, neither mind nor matter, but something more primitive than either. Both mind and matter seem to be composite, and the stuff of which they are compounded lies in a sense between the two, in a sense above them both, like a common ancestor."* (Russell, 2005)

Russell didn't specify a common ancestor for mind and matter, but if quantum reality creates the observer as well as physical events, quantum realism is a neutral monism as Russell proposed.

Consider the premise that every physical event must have an observer. Virtual worlds exist by being observed so if our physical reality is virtual, it should be the same. Quantum theory confirms that physical events require observation, as spreading quantum waves only collapse to a physical event when observed. It follows that an observer is needed for physical events to occur.

We also know that our universe began at a moment in time so without observation, it would have stayed in a quantum superposition. The initial physical events had to be observed to occur. If our universe began as a light plasma that physically collided into basic matter (Chapter 3), the only entities that could observe were photons. The simplest conclusion that lets observation cause the initial physical events is that *photons observed*.

It isn't claimed that photons observe as we do, but that they observe quantum scale events of 10^{-35} meters and 10^{-43} seconds. Such events are incredibly short and brief to us, as they occur more times per second than there have been seconds in our universe. That photons observe seems preposterous but the alternative, that only we observe the universe, is equally so.

To observe so little so briefly seems hardly worth it to us, but *smallism,* that facts about big things come from facts about small things (Coleman, 2006), can apply to observation too. If the observer experience began small, like everything else, then macro-consciousness can derive from micro-consciousness (Chalmers, 1996) (p305). It is possible that photons observe, so who are we to say that they don't when we claim that we do? By Conway's free will theorem, either everything is conscious or nothing is (Koch, 2014), so it is simpler to say that observation always existed than to explain how it began with no precedent.

If observation existed from the start, then photons observe on their scale, but not as we do. To avoid confusion, let us call quantum-scale observations *proto-consciousness,* as Penrose proposed in 1944 (Penrose, 1994), and more recently:

> "*... the elements of proto-consciousness would be intimately tied in with the most primitive Planck level ingredients of space-time geometry, these presumed 'ingredients' being taken to be at the absurdly tiny level of 10^{-35}m and 10^{-43}s, a distance and time some 20 orders of magnitude smaller than those of normal particle-physics scales and their most rapid processes."* (Penrose & Hameroff, 2017) p21.

That consciousness began small answers another question, that if everything is a player in our virtual universe, isn't it boring for some? If one asked for players in a virtual universe like ours, who wants to be a rock on mars, that just sits there for a million years? But a rock is an aggregate of molecules, so it observes on a molecular scale, not a rock scale. On this scale, something new happens every nanosecond, so it isn't boring at all.

This isn't panpsychism, that matter is conscious, because in quantum realism, matter doesn't exist except as a view. Panpsychism assumes that matter exists to have a consciousness property, but if matter itself doesn't exist, it can't have that property. This is possible because previous chapters derived matter properties, like mass, charge, and spin, from quantum reality.

Quantum realism changes the question from how dead matter became able to observe to how proto-observations became human observations. It replaces the explanatory gap between matter and consciousness with an *evolutionary gap,* between what atoms observe and what we do. The conclusion, developed later, is that the ability to observe had to exist from the beginning to cause physical events. Hence, instead of asking how matter acquired consciousness, we now ask how matter observations evolved, which raises the question of how brains evolved?

6.2. EVOLVING A BRAIN

A human brain has more nerves than there are people in the world or devices on the Internet, and it has more connections than the Internet, as one nerve can link to 10,000 others. It also took five hundred million years to evolve, because it had to operate at every step. A bee brain is just a neuron sliver but it lets them fly, form colonies, and even communicate with each other, because brains like ours could only evolve from brains like theirs if they survived. Imagine building a jumbo jet where the first part had to fly and likewise for every part added after that, or writing a program where the first line of code had to work or you didn't get to write the second. *We build information processors but nature had to grow one.*

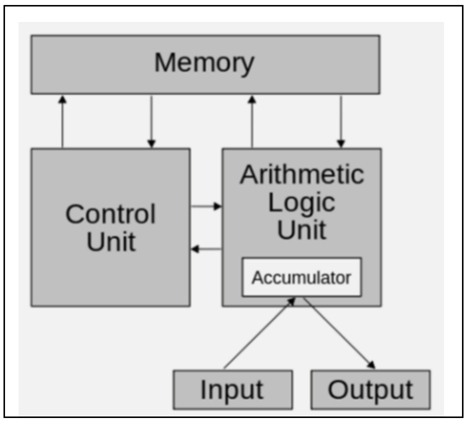

Figure 6.3 Von Neumann Architecture

6.2.1. Growing processing

A transistor can't grow a computer but a cell can grow a brain, so building a processor isn't the same as evolving one. Evolution found a path from a cell to a brain and embryos grow brains by following that path.

Even so, brains and computers have similarities. Both use electricity to power on/off units that process data, so neuron logic gates process data just as computer transistors do (McCulloch & Pitts, 1943). Sensorimotor channels also mirror computer input-output channels so brain-computer theories propose that nerves process the senses to give muscle output as computers process input and output (Churchland & Sejnowski, 1992). Yet the comparison ends there because growing and building processing are different challenges (Whitworth, 2008).

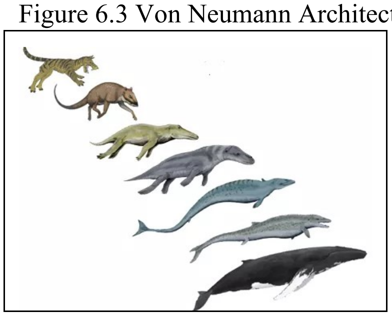

Figure 6.4 Evolution is gradual

We build a computer at leisure then switch it on, but an evolving brain must always be on because life never stops. Our computers use the Von Neumann design, of a central processing unit (CPU) that processes input to give output (Figure 6.3), because it always knows what to do next, but if the CPU fails, everything does. Biological parts fail regularly so a brain that fails when a part does is too fragile to survive in nature. Evolution needed a reliable processor, so brains don't have a central processing unit.

To understand the brain, one must understand evolution. Darwin's natural selection is that traits change gradually over time to select what survives (Figure 6.4). For a brain, this requires variability, change, and survival:

1. *Variability*. Nerve autonomy, the ability to act by internal direction, lets brains vary. If nerves didn't act by their own choice, the brain couldn't evolve, so neural freedom allows evolution while absolute central control denies it, so brains had to *decentralize control*.

2. *Change*. Evolution occurs in a step-wise manner, so brains had to change in the same way. A brain can't string processors together in a series of steps that end up giving value, as programmers do, because each step has to give value. As a result, our brain is layer upon layer, where each layer evolved while the previous one was still operating. Each step has to add value and lead to the next, so it is a *nested hierarchy*.

3. *Survival*. To survive, a brain must add value, say by moving a creature towards light, so a sense like light detection is useless if it isn't acted upon. To survive, a brain must *control the feedback loop* between sensory input and muscle output.

Decentralized control, *nested hierarchies,* and *feedback control,* as evolutionary principles, explain the brain better than any computer analogy.

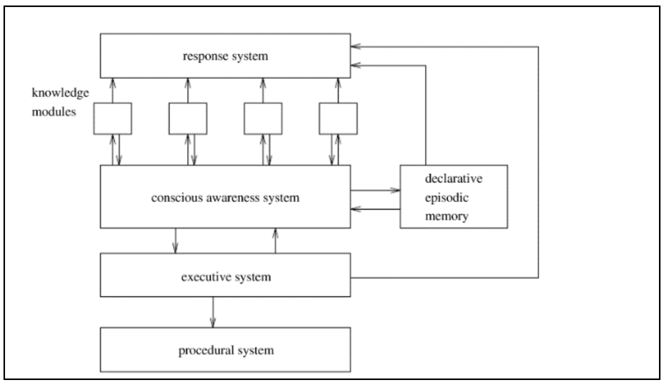

Figure 6.5. Schacter's brain model

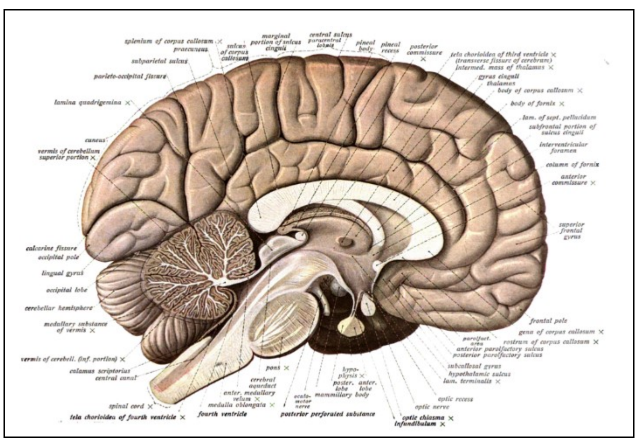
Figure 6.6 The cortex is the folds around the brain

6.2.2. Decentralized control

We like to control things, so our first networks centralized control, until decentralized networks like Ethernet were found to be ten times faster. They also degrade gradually under load, instead of crashing suddenly, as centralized networks do. When the Internet was first proposed, it was expected to fall into chaos without central control, but it was decentralized control that enabled it to survive.

Early brain theories also expected a central executive. In Schacter's model (Figure 6.5), an executive decides what to do after a conscious awareness unit accesses sensory knowledge modules, memory and higher reasoning (Schacter, 1989). The executive was assumed to be in the cortex, a folded layer wrapped around the midbrain and hindbrain (Figure 6.6) that handles voluntary acts, thought, planning, and language.

The cortex is the most advanced part of the brain, but its two hemispheres share the work between them. The left one directs the right side of the body and the right one directs the left. One specializes in language and the other in spatial analysis, but how can *two* hemispheres act as *one* executive?

The answer, revealed by a treatment of epilepsy, is that they don't. In epilepsy, an electrical disturbance in one hemisphere spreads to incapacitate the cortex across an 800 million nerve bridge called the corpus callosum. Cutting it in animals didn't seem to harm them, so surgeons tried the same in epileptics, to stop the epilepsy spreading. The treatment worked but while serious side effects were expected, split-brain patients spoke and acted normally! So little changed that some thought the corpus callosum was just a structural support. Further studies revealed an unexpected result.

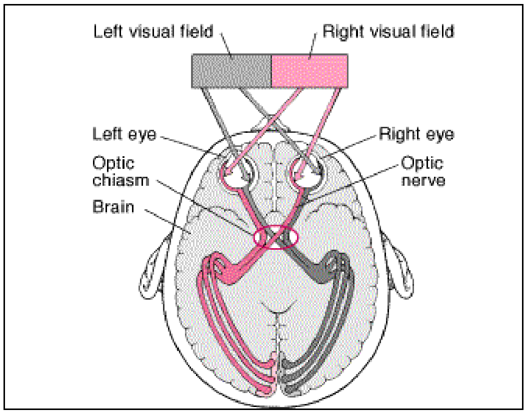

Figure 6.7 How visual processing is shared

Each hemisphere moves the opposite hand but for vision, the left hemisphere inputs the right side of both eyes and the right one gets input from the left side of both eyes (Figure 6.7). In split-brain studies, each eye saw half a split screen, so with the corpus callosum cut, the left hemisphere saw only the claw and the right hemisphere saw only the snow (Figure 6.8).

When subjects were asked to point to a picture that matched what they saw, the right hand picked a chicken but the left hand picked a shovel! The left hemisphere saw a claw, so it used the right hand to point to a chicken, while the right hemisphere saw snow, so it used the left hand to point to a shovel, and neither was aware of the other's choice. Both hemispheres could receive and send data as if each was *a brain in itself,* so there was no central executive.

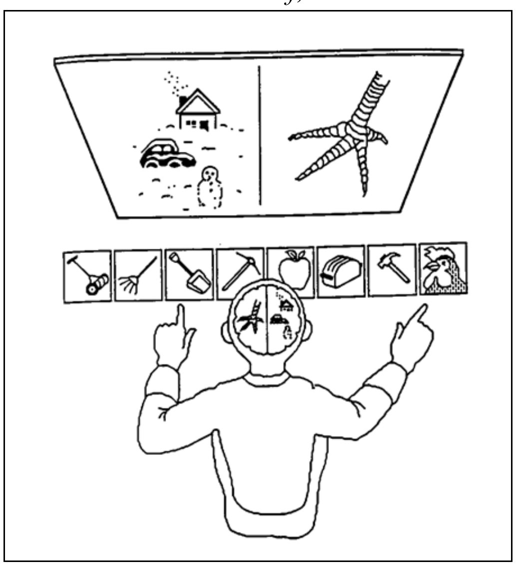

Figure 6.8 A split-brain study setup

When asked why his left hand chose a shovel, a subject said "*you need a shovel to clean up after chickens"*. The verbal left hemisphere had no idea why the shovel was chosen, as it didn't see the snow, but instead of saying I don't know, it made up a story. It tried to interpret events as best it could:

"*These findings all suggest that the interpretive mechanism of the left hemisphere is always hard at work, seeking the meaning of events. It is constantly looking for order and reason, even when there is none - which leads it continually to make mistakes. It tends to overgeneralize, frequently constructing a potential past as opposed to a true one.*" (Gazzaniga, 2002) p30

Interpreter theory is that the cortex, with its language and thought, is more servant than master in the brain. If the brain is a federation of agents (Minsky, 1986), the left cortex is head of human relations not the CEO, as some suggest (Kaku, 2014). It is like a diplomat, whose job is to explain the decisions that others in power make.

Perhaps human intellect expanded when we formed tribes because those who better explain themselves survive to reproduce, as the animal most likely to harm a human is another human. Inventing acceptable reasons after the fact may be the evolutionary basis of our vaunted intellect. Logical thought, building one idea upon another in a rational way to reach an unforeseen conclusion, probably isn't what our intellect originally evolved to do.

The left hemisphere usually specializes in language but the right hemisphere isn't illiterate. One study of a split-brain boy (Wolman, 2012) asked the left hemisphere "*Who is your favorite?*" but flashed "*Who is your favorite girlfriend?*" to the right hemisphere. The left hemisphere made no verbal reply, as didn't see the word *girlfriend,* but a nervous giggle revealed that the right hemisphere understood. The right hemisphere then used the left hand to select scrabble tiles to spell out L-I-Z, a cute girl in his class. The right hemisphere had no vocal control but it could still read and spell. Both hemispheres are conscious in any way you care to define it:

> "*Everything we have seen indicates that that the surgery has left these people with two separate minds, that is, two separate spheres of consciousness. What is experienced in the right hemisphere seems to lie entirely outside the realm of awareness of the left hemisphere. This mental division has been demonstrated in regard to perception, volition, learning and memory."* (Sperry, 1966) p299.

Evolution favors decentralization because then if part of the brain is lost, the rest can carry on. In a famous case, an iron rod pierced the middle and left cortical lobes (Figure 6.9) of a railway worker called Phineas Gage, who shortly after walked off, conscious and speaking. He showed disturbed behavior but lived for 13 more years and died of unknown causes. Now imagine banging a nail through a mother-board! The brain duplicates the cortex for the same reason that planes duplicate critical control units - to increase reliability. This answers Von Neumann's question:

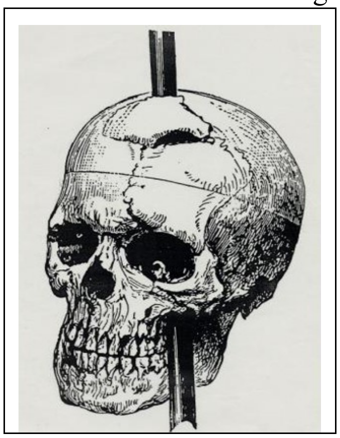

Figure 6.9 Phineas Gage

> "*How could a mechanism composed of some ten billion unreliable components function reliably while computers with ten thousand components regularly fail?*"

As information goes into the brain, it makes sense to peel away the layers of processing to find the "I" from which all proceeds, but doing so reveals no central executive. If the body is a ship run by the brain, it has no "Captain", even at the highest level:

> "*Studies of the structural and functional organization of the brain have shown that this organ is, to a large extent, decentralized, and processes information in parallel in countless sensory and motor subsystems. In short, there is no single homunculus in our brains that controls and manages all these distributed processes.*" (Singer, 2007)

No-one searches the Internet to find its "center", so why expect a brain network to have a center? Neither neuroscience nor information science support the idea that we have one "I":

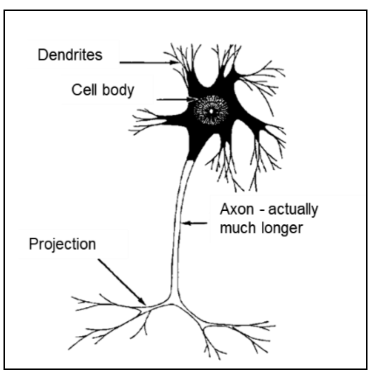

Figure 6.10 A neuron

> "*In contrast to this first-person experience of a unified self, modern neuroscience reveals that each brain has hundreds of parts, each of which has evolved to do specific jobs – some recognize faces, others tell muscles to execute actions, some formulate goals and plans, and yet others store memories for later integration with sensory input and subsequent action.*" (Nunez, 2016) p55.

Some argue that this conflict between the fact that we experience one observer and the fact that the brain has no central control area means one fact is wrong (Dennett, 1991), but science doesn't work by cherry-picking facts. It works by accepting facts, putting questions, and finding answers, so part 6.3 will later ask *how can a decentralized brain can create one observer?*

6.2.3. Nested hierarchies

A neuron is a cell whose body receives electrical input from dendrites and projects electric pulses down an axon to others, as a tree sends water from roots to leaves (Figure 6.10). Dendrites have to pass an input threshold to fire a neuron so input from neurons B and D in Figure 6.11 fire neuron A but B and C don't, as they don't reach its threshold of four. *Neurons selectively pass on electrical impulses*.

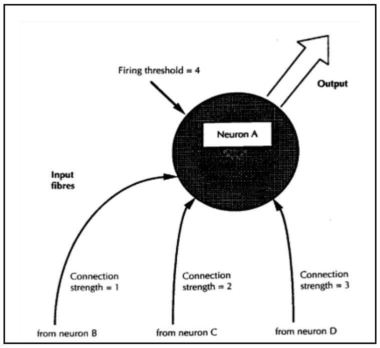

Figure 6.11 Neuron threshold

In embryos, nerves grow out from the brain to form the retina, so light entering the eye touches the brain directly. If the retina was a photoelectric cell, it would pass on pixel data if say 1 is black and 0 is white. It works equally well if 0 is black and 1 is white, as long as the definition is absolute*,* but a designer would have to set that.

Brains had no designer so evolution took both options, as it always does. One type of retinal cell responds to light above the background level and another type responds to light below that level. In Figure 6.12, cell 1 responds to white and cell 2 to black. Instead of defining data absolutely, retinal cells respond relative to background light by interacting to excite or inhibit each other to amplify the borders that later allow object shapes.

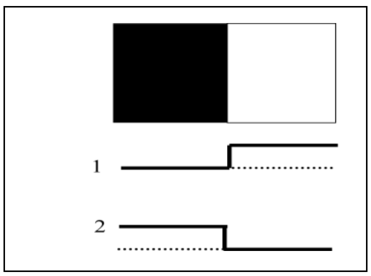

Figure 6.12 Retinal cells respond to black and white

Vision identifies an object by making one side *figure* and the other *ground.* In Figure 6.13, making black the figure just gives blobs but making it background lets you read "MAIL BOX". The brain uses figure-ground context to unravel visual data ambiguity, as one must choose the right figure-ground context to see an object.

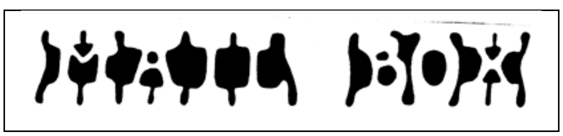

Figure 6.13 Background context defines vision

The human cortex is a nested hierarchy that processes data in six layers labelled I to VI, as lower units feed higher ones. The first step after the nerve is a hundred or so nerves about the thickness of a hair called a *microcolumn*:

> *"… current data on the microcolumn indicate that the neurons within the microcolumn receive common inputs, have common outputs, are interconnected, and may well constitute a fundamental computational unit of the cerebral cortex …"* (Cruz, 2005)

Figure 6.14 Brodmann brain areas

About a hundred microcolumns then form a *cortico-cortical column* that sends axons to nerves nearby. They then form into a *macrocolumn* of about a million nerves, about 3mm wide, with cortical links. Macrocolumns then form about 32 Brodmann areas (Figure 6.14) of maybe a hundred million nerves for functions like language. The cortical processing layers are (Nunez, 2016) p91:

1. *Microcolumns*. A hundred or so nerves about .03mm wide.
2. *Cortico-cortical columns*. A thousand or so nerves about .3mm wide.
3. *Macrocolumns*. A million or so nerves about 3mm wide.

4. *Brain areas*. A hundred million or so nerves of various sizes.

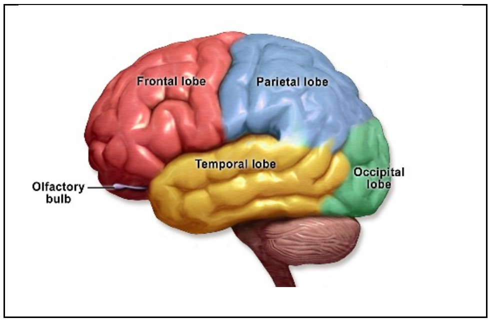

Figure 6.15 The cortex (Blausen.com staff, 2014)

Brain areas then form four *lobes* about 50mm wide separated by deep fissures (Figure 6.15). The occipital lobe handles visual data, the parietal lobe handles body image and space relations, the temporal lobe handles sound and memory and the frontal lobe handles plans and intentions. It can stop other parts doing socially improper acts, so a person with frontal lobe damage may know how to behave but can't stop inappropriate acts like touching. Four lobes together form a hemisphere that with the other is the cortical brain.

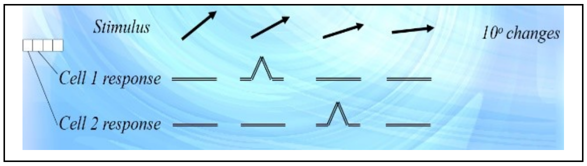

Figure 6.16 Nerves fire for different angles

The visual hierarchy starts when the eye detects photons. This data is then subject to layer upon layer of processing to detect relevant features. For example, some nerves in layer IV fire for different line angles (Figure 6.16) and others for other features.

Figure 6.17 Old or Young?

Scientists estimate that each eye inputs about 8.75 Megabits a second and the brain in total receives over 20 Mbps. As James said in 1892, our first impression was probably information overload:

*"The baby, assailed by eyes, ears, nose, skin, and entrails at once, feels it all as **one great blooming, buzzing confusion**"*

Computers handle information overload by compression that reduces the data in a video but keeps the key features. The brain does the same by reducing sense data to features that represent borders, shapes or objects. When a baby's brain transforms data from millions of optic nerves to see an object is a cup, it handles the world better. *The brain helps us survive by reducing sense data to key features*.

Figure 6.18 Spinning ballerina

Computer processing is mostly linear but brain hierarchies have *bottom-up*, *lateral* and *top-down* links. Sense data flows up and down the processing hierarchy as a two-way flow. Top-down paths predict, interrogate and check lower processing as higher processing "experts" check for consistency or errors (Dehaene, 2014) p139. Bottom-up paths analyze data as computers do, but lateral paths establish context and top-down links can rerun lower processing.

Is Figure 6.17 an old or young lady? If you see a young lady, can you see an old one or the reverse? To do this you must rerun your visual processing. The visual system makes a best guess, but you can ask for a redo because nerves go down as well as up. Lower processing is "*out of sight and out of mind*" but it can be redone by top-down control. All perception is a hypothesis of an ambiguous world.

Subconscious processing might be assumed to be primitive but the spinning ballerina illusion (Figure 6.18) suggests otherwise. Click on the link to see a ballerina spinning but the rotation is ambiguous, so you might see her spin clockwise or anti-clockwise. Try to see her spin the other way. If you can't, pause the video and if you see an extended leg at the front, imagine it at the back, or vice-versa. Restart the video and if she spins the other way, you just reprogrammed some complex unconscious visual processing.

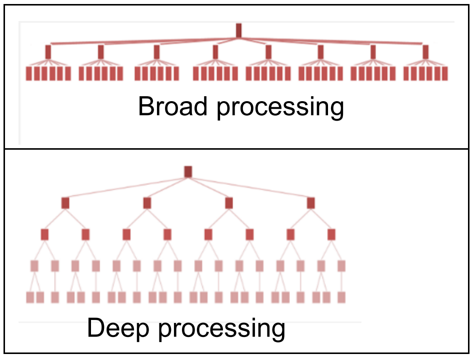

Figure 6.19 Broad vs. deep processing

The optic nerve has about a million axons but the auditory nerve only has about 50,000, so its processing base is narrower than for vision. In Figure 6.19, the same processing resources applied to a narrow base allows deeper processing. There is a trade-off between processing breadth and depth, so if hemispheres of equal capacity specialize, the narrower base of sound can be processed deeper than the broad base of vision. The hemisphere that specializes in sound can develop language because a narrow base allows the deeper processing that language requires. *One hemisphere specializes in the deep processing of language while the other favors the broad processing of spatial analysis.*

6.2.4. Feedback loops

A brain that analyzes input but doesn't control output doesn't help survival. It needs access to both input and output, so that when the eyes see danger, the muscles can run from it. The brain must control the basic feedback loop (Figure 6.20) to evolve, but what initiates this loop? Last century, psychology split into two camps on this issue:

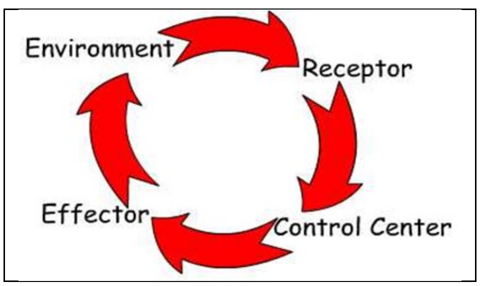

Figure 6.20 The Basic Feedback Loop

a. *Behaviorism* argued that people are machines driven by outside events, so stimuli and responses entirely define the loop and what the brain does.

b. *Constructivism* argued that the brain controls the loop by actively constructing reality, as it can produce more sentences than we could ever learn from stimulus-response associations (Chomsky, 2006).

They differed on what initiated the feedback loop, as behaviorism was input-driven but constructivism was brain-driven (Figure 6.21). Since a circular process can be initiated at any point, today we accept that both can be true. The brain can be driven by outside events but it can also be driven by a brain intent. The second is needed because a brain must initiate the feedback loop to learn or evolve.

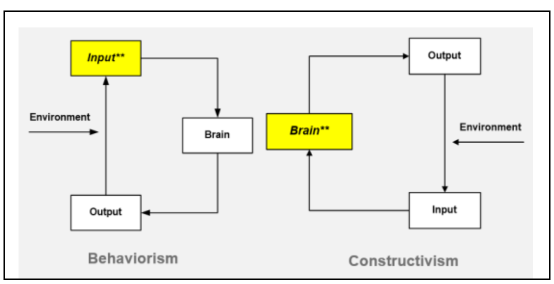

Figure 6.21 Behaviorism vs Constructivism

Yet updating a running system isn't easy. When Microsoft upgraded the DOS operating system to Windows, it just replaced it, making it obsolete along with all the time users spent learning it. If nature worked this way, the mammal brain would make the reptile brain obsolete, losing hundreds of millions of years of evolution! Obviously, that is not efficient.

Three-brain theory

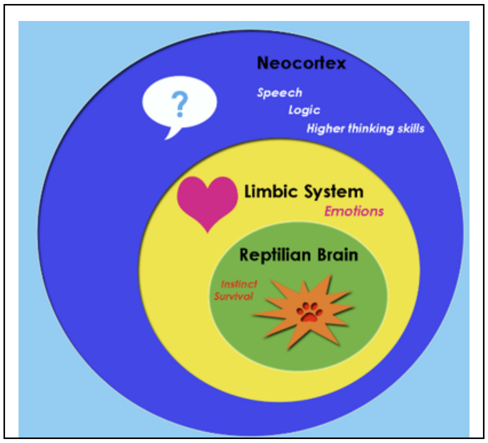

Figure 6.22 The Triune Brain Model

That nature doesn't discard things led an American neuro-physiologist at the National Institute of Mental Health to argue that our brain is a *reptile* brain overlaid by a *mammal* brain overlaid by a *human* brain (MacLean, 1990) (Figure 6.22), where the reptile brain is hind brain structures like the cerebellum, the mammal brain is the mid-brain limbic system, and the human brain is the neocortex of higher thinking. This explained autism as an out-of-control reptile brain, and anxiety as an out-of-control mammal brain. In this view, evolution evolved a reptile brain to handle movement, a mammal brain to handle emotions, and finally a neocortex for human thought. MacLean proposed that the human brain is three brains in one, each overlaying the last.

This model then became a popular way to explain autism and animals. Temple Grandin, an authority on animal psychology, who is autistic, wrote:

> "*To understand why animals seem so different from normal human beings, yet so familiar at the same time, you need to know that the human brain is really three different brains, each one built on top of the previous at three different times in evolutionary history. And here's the really interesting part: each one of those brains has its own kind of intelligence, its own sense of time and space, its own memory, and its own subjectivity. It's almost as if we have three different identities inside our heads, not just one.*" (Johnson & Grandin, 2006).

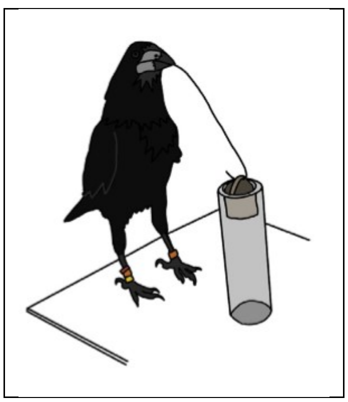

Figure 6.23 Crows use tools

The reception of the three-brain model among neuroscientists wasn't as positive, because evolution doesn't work by adding layers one after another, like geological structures. As one critic put it: Your brain isn't an onion with a tiny reptile inside. Evolution didn't build a reptile brain, then a mammal brain, then a human cortex because it isn't a linear production line. Nor did it add new things without precedent, as bat wings are modified forelimbs that existed before. And even reptiles have a primitive cortex that lets them care for their young and solve problems (Patton, 2008).

Triune theory also didn't account for birds. Over millions of years, reptiles evolved into dinosaurs whose descendants today are birds. Birdbrain is a term of ridicule but they are quite smart, as crows can bend a wire into a hook to get food their beak can't reach (Weir et al., 2002) (Figure 6.23). Children can't use tools like this until about eight and even then, only half succeed (Cutting et al., 2014). Birds like nutcrackers can hide 30,000 seeds over a 200 square mile area and recover them six months later. Birds are more like feathered apes than reptiles, and urban crows are especially smart:

> "*On a university campus in Japan, crows and humans line up patiently, waiting for the traffic to halt. When the lights change, the birds hop in front of the cars and place walnuts, which they picked from the adjoining trees, on the road. After the lights turn green again, the birds fly away and vehicles drive over the nuts, cracking them open. The birds wait patiently with human pedestrians for a red light before retrieving their prize. If the cars miss the nuts, the birds sometimes hop back and put them somewhere else on the road.*" (Earthfire Institute)

Birds share many cognitive abilities with advanced mammals but their brains evolved differently (Jarvis & et al., 2005), as the bird cortex is smooth but the mammal cortex is folded. The current view is that as bird and mammal brains evolved from the basic reptile design, nature tried both options and converged to equivalent functions (Lefebvre et al., 2004). Triune theory doesn't predict this evolution, but an alternative that does is now explored.

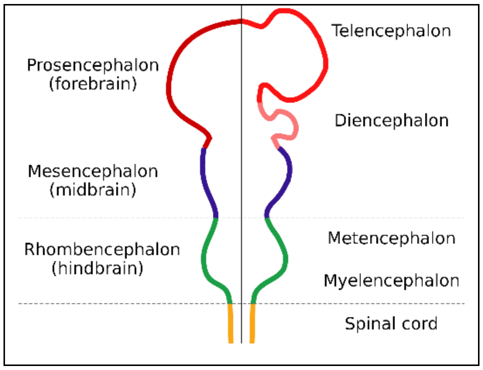

Figure 6.24 Embryo brain divisions

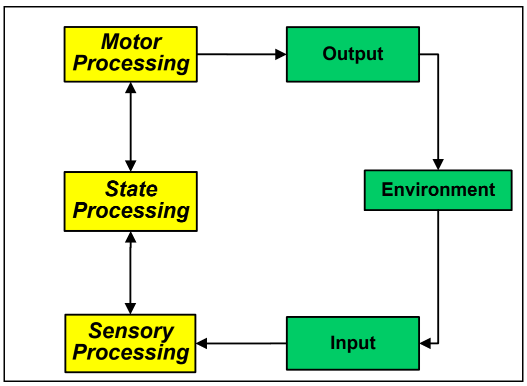

Figure 6.25 Brain processing centers

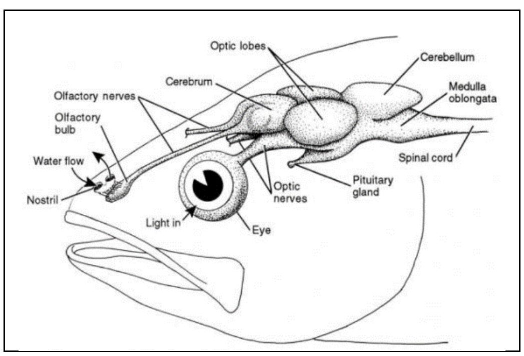

Figure 6.26 The fish brain has three parts

6.2.5. Three-center theory

The human brain grows from a neural tube, whose *forebrain*, *midbrain* and *hindbrain* areas later form the cortex, limbic and cerebellum systems (Figure 6.24). This basic division reflects three basic brain functions:

1. *Input*. What is out there?
2. *State*. What is the body state?
3. *Output*. What actions can be done?

Life involves all three, as animals must sense food or danger, know if the body is hungry or tired, and control actions like biting to survive. The neural tube then evolved to analyze input patterns, evaluate body state, and control muscle schema, and this evolution occurred in parallel not in sequence.

An engineer might design a feedback system to analyze input, assess internal state and direct responses in that order, then integrate them (Figure 6.25), but evolution didn't do that. Given three necessary functions, it developed them all at once in different ways because the brain has no control center.

Three-center theory is that the hindbrain, midbrain, and forebrain evolved as independent feedback control centers for:

1. *Sensory control*: Based on sensory *patterns*.
2. *State control*: Based on body state *feelings*.
3. *Movement control*: Based on muscle *schema*.

How an animal responds depends on which control center drives the feedback loop at a given moment, as an animal with a chance to bite might do so under *movement control*, freeze in place from fear under *state control,* or decide that the threat isn't really dangerous and ignore it under *sensory control*.

The brain evolved motor processing first, perhaps because action is critical to survival.. Single-celled life moved before it saw, and embryo motor nerves develop before sensory ones, so babies kick in the womb before their eyes even start working.

Fish brains have forebrain optical and olfactory areas to process sense data, a midbrain amygdala and pituitary to manage endocrine tasks, and a hindbrain to handle movement (Figure 6.26). All three functions exist, but the cerebellum of fish is far more evolved than its cortex (Montgomery et al., 2012), so it probably controlled the feedback loop using data from the primitive forebrain and midbrain.

In fish, the forebrain area that receives muscle data is next to the area that directs movement, as it is for us, perhaps because it is easier to use the same paths for both, and having sensory and motor areas close to each other improves sensorimotor timing. For us, the motor cortex directs movement but for fish, it is probable that the cerebellum controls the motor cortex, as it projects both excitatory and inhibitory nerves to it (Daskalakis et al., 2004).

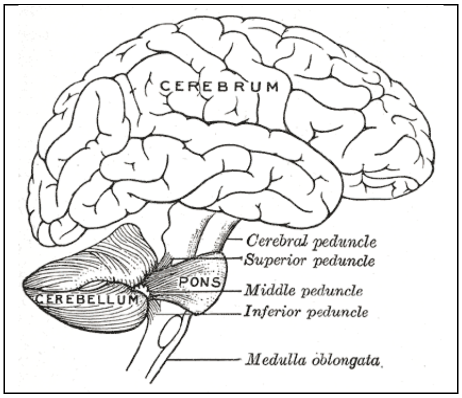

Figure 6.27 The hindbrain

In humans, the hindbrain bulges out from the base of brain as the cerebellum (Figure 6.27). It may be ancient but the cerebellum has more neurons than the rest of the brain put together! Its two cross-linked hemispheres are known to control complex movement and it was certainly the most advanced part of the brain when reptiles ruled the earth. If the hindbrain was the first brain control center to evolve, can it still control the body using primitive links to the early forebrain and midbrain?

In infant swimming, babies instinctively hold their breath underwater thanks to a diving reflex and move their arms and legs in parallel to propel them through the water by an amphibian reflex that flexes same-side hip and knee kicks. These instinctive actions disappear later, as the child learns to swim as people do, by moving limbs alternately. That babies swim as reptiles do but lose the ability after four months suggests that the brain retraces its reptilian ancestry as it matures.

In parasomnia, sleepwalkers can get up, walk, eat, cook dinner or ride a motorbike while asleep and wake up later with no recall. With the cortex and midbrain dormant, the hindbrain moves the body by itself and there is no recall because the midbrain isn't laying down memories. Sleepwalking behavior isn't just reflexes, as cooking a meal is a purposeful act that requires constant situational adaptation. It follows that *the hindbrain can control the body entirely, like a brain in itself, without the cortical intellect or episodic memory*.

Hindbrain control also explains *blindsight,* where people with visual cortex damage report seeing nothing but can still catch a ball or insert an object into a tilted slot whose orientation they say they can't see (Goodale & Milner, 2004). When cortical systems that identify objects fail, the hindbrain can use older subcortical paths to handle spatial location and direct motor acts by implicit perception (Hannula et al., 2005). Primitive circuitry that evolved when the cortex was still in its infancy is used to direct motor output.

When later systems fail, older ones take their place, so aphasic subjects who can't speak due to cortical damage can still swear and sing. Amnesic patients given the same jigsaw every day say: "*I have never seen this before*" but still solve it faster each day. Research confirms that a monkey with no visual cortex can't discern a circle from a triangle but can still move under visual guidance like a normal monkey (Humphrey, 1992). Brain systems that evolved millions of years ago still operate in our brain and can take over if the systems that evolved after them fail.

If the brain was built in a factory, then put to work, the cortex might run the brain but nature didn't have that luxury, as some center had to run the feedback loop at every stage of evolution. In fish, the hindbrain, as the first brain center to evolve, is in control, because the cortex isn't ready yet.

By some estimates, the cerebellum or "little brain" contains about 80% of the nerves of adult brains so despite its ancient origin, its role today isn't just backup. People with cerebellar damage struggle with movement in a wide range of activities, like walking, reaching, speaking, gaze and balance. They have staggered walking, inability to maintain eye-gaze, slurred speech and other features associated with being drunk. What is lost is the ability to relate moment-to-moment muscle actions to sense input, because that is what the hindbrain does.

The cerebellum once acted independently of the cortex that came later, and it still can. For a gymnast to back-flip on a balance beam takes super-fast processing that the cortex just can't do. Even simple tasks like riding a bike are done badly by the cortex until the hindbrain takes over as we automate the task, when the cerebellum develops a schema for it.

Hence, the cortex doesn't *control* the cerebellum, it just triggers it to act. The cerebellum learns a schema, like riding a bike, by itself. When the senses trigger a schema, the cerebellum acts as needed without direction, just as a car's automatic transmission monitors events and changes gear as needed. To ride a bike, we just push off and let our *movement center* take over to handle balance as only it can. It can act by itself because it was once the senior brain system and it retains that ability in us today. Other parts of the brain can interfere with it, but they can't do what it does.

To call the hindbrain primitive because it can't speak is like calling a jet engine primitive because it has no video feed, when given what it does, that's impossible. Just as modern jets have the latest engines, our brain has the latest movement control that evolution can provide. We don't have an old reptile brain but a state-of-the-art movement center. It acts implicitly without fuss, so it's easy to ignore, but the midbrain emotions of the next section are anything but unseen.

6.2.6. The emotional center

Muscle memory is a sensorimotor schema stored in the cerebellum that is activated by sensory triggers, so to know if you know how to ride a bike, you must get on one again. In contrast, midbrain memories let us re-experience past events, like whether we left the stove on. *Episodic memory* provides a past event timeline that can be analyzed to link cause and effect. It allows organisms to survive by emotional learning, of good or bad consequences.

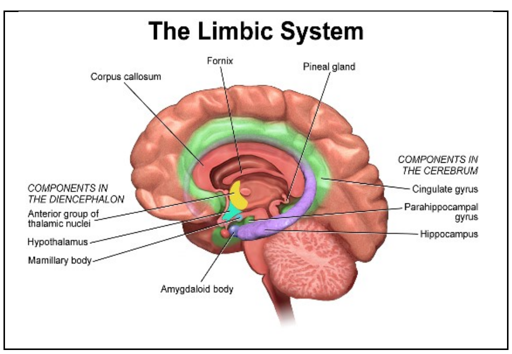

Figure 6.28 The Limbic System (Blausen.com staff, 2014)

The emotional center of the brain is the *limbic system* (Figure 6.28), which includes the:

- *Thalamus*. A relay station to pass on sight, sound, and touch input.
- *Hypothalamus*. Connects to the peripheral nervous system that controls body states.
- *Hippocampus*. Acts to lay down memories.
- *Amygdala*. Analyzes sense and body state input to generate emotions.
- *Cingulate gyrus*. Links to the cerebral cortex.

Hippocampus damage can result in amnesia, the inability to lay down new memories. Cingulate gyrus damage is involved in depression and schizophrenia. Amygdala damage reduces the ability to process emotions in facial expressions and is a neural marker of autism. The hypothalamus links to the peripheral nervous system, a second brain of a 100 million nerves outside the skull that handles body hormones and digestion.

According to three-center theory, *the limbic system is a control center, with its own sensory, visceral and memory input, whose role is to generate emotions that activate body states*.

The amygdala can react to facial data in under a tenth of a second, before cortical awareness, by a subcortical visual path (Adolphs, 2008). Sense data from the thalamus goes direct to the amygdala by a short route and takes a long route via the cortex (Figure 6.29), so the amygdala can initiate emotional responses like sweaty hands, dry mouth and tense muscles before the visual cortex even recognizes what is seen. The thalamus still passes data to the cortex, to allow a better but slower decision. Like the movement center, the emotional center uses links that existed when it evolved, so it can act by visceral and sense links acquired before the cortex began to think.

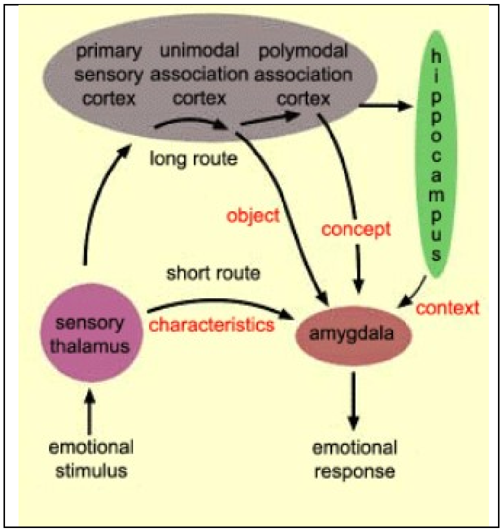

Figure 6.29 Short and long emotion routes

This *emotional center* even has its own ability to process space. While the hindbrain maps the vector data needed to track movement in space, the midbrain maps the locations needed to return to a point in space (O'Keefe & Nadel, 1978). It can compare its own dedicated sensory and visceral input to past memories to generate the appropriate emotion, as it did for millennia in birds and mammals.

An emotion is a neural representation of reality in body terms generated by the limbic system. For example, fear is the experience of increased heart rate, breathing, adrenaline, blood pressure and blood sugar that accompanies a fight or flight response. Over millions of years, this response to threat was passed on because a body prepared for threat survives it better.

The amygdala interprets facial expressions like anger by emotional learning (Hooker et al., 2006) but also responds to any sensed danger, so an odd smell or an insect crawling on the skin can create a fear response that prepares the body for action. Just as the hindbrain represents reality by schema, and the cortex by thoughts, so the midbrain represents reality by emotions.

Fear isn't the only emotion, as limbic states support survival in general. Emotions like lust, anger and greed are now primitive urges to be avoided but even today, anger is useful to fight an enemy, lust helps continue the species and greed ensures that surplus food isn't wasted. Dependence is inappropriate for an adult but it keeps a child by its parents for protection and even laziness has value, as an injured animal should rest and recover. All emotions have survival value in the right situations, as they relate to biological needs.

Emotions, a body state tool kit that can be tailored to situations based on experience, were a big evolutionary advance at the time. All the emotions we now call negative were useful in evolution and still are, if used correctly. A toolkit is only negative if the wrong tool is used, as if a carpenter uses a hammer to shorten a plank not a saw, it isn't the toolkit's fault.

Movement center memory knits sensations into a motor schema but emotional memory lets us base present acts on past experience to allow projection, assessing another's intent based on what I would do. Many birds cache their food to hide it for use later, but when they see another bird watching them hide food, they return later to re-hide it (Clayton et al., 2007). This ability to understand another's intent allows empathy, the ability to feel what another feels, a vital component of the emotion we call *love*.

Doing something is usually better than doing nothing but if a predator is nearby, it's often better to stay still. For the emotional center to respond to threat by keeping still, it must override the tendency to move, so if a mammal sees a predator, the instinct to run away is stopped by the emotion of fear. When fear freezes an animal in its tracks, the amygdala activates its connections to the brainstem and cerebellum (Ressler, 2010). Mammals have this paralysis by fright response but fish don't. An emotional center that can suppress hindbrain movement sets the stage for the evolution of cortical control, in the next section.

6.2.7. The intellectual center

The human cortex handles higher abilities like language that set us apart from other species. While the cerebellum packs 80% of the brain's neurons into 10% of its mass, the cortex needs 80% of the brain's mass to support 20% of its neurons, because they are larger and have more support cells. It is a folded sheet, 2-5mm thick, with six layers, while the midbrain hippocampus only has three layers. It was the last part of the brain to evolve and is the last to mature in children. If other centers ran the feedback loop before it, how can it take control? The answer, it seems, is with difficulty.

Piaget concluded that the human intellect develops in four distinct stages:

1. *Sensorimotor (0 to 2)*: Babies and toddlers think in sensorimotor terms.
2. *Preoperational (2 to 7)*: Children begin to think symbolically and learn language.
3. *Concrete operations (7 to 11)*: Children think logically about concrete events.
4. *Formal operations (12+)*: Abstract thought emerges.

The cortex can't act independently until over 12 years old and it continues to mature into the mid-twenties, as the ability to think increases

In the sensorimotor stage (0 to 2), the moving center controls activities like reaching so it also tries to speak. Hence, language begins as babbling, as babies form sounds to match the speech that they hear in the first year. Babble can sound just like speech, although no words are known yet. The moving center tries to talk as it learns to walk - by just doing it. Before an infant says its first word, at about one year, it knows all the phonemes needed for speech, including intonations. The midbrain isn't mature enough to lay down memories until two or later, so before that we have childhood amnesia, a period we can't remember because the midbrain couldn't lay down long-term memories. The same occurs in animals for the same reason (Feigley & Spear, 1970).

In the preoperational stage (2 to 7), the emotional center increases control of behavior to make us emotional beings who think everyone sees the world as we do. A five-year-old asked what is in a chocolate box will say "chocolates" until shown it contains pencils. If then asked what another child will think is in the box, they say pencils not chocolates. They can't imagine how others see the world yet and so have no empathy.

While the emotional center is in charge, the developing intellect produces egocentric speech, where the child keeps up a running commentary on what they do, even when alone. At first they comment after an action, so a four-year-old child may stroke a teddy bear then say "Good boy", but at five the same child says "Good boy" as they stroke it, and at six they say it first then stroke it. It is as if a part of the brain is first observing what is happening and making after-the-fact comments, then making current comments, and finally predicting what will happen. Egocentric speech is the child's growing intellect expressing itself out-loud to the rest:

> "*One area of the brain and mind may initiate a behavior, which is witnessed or experienced by other (disconnected) brain areas, only as it occurs outside the brain and body.*" (Joseph, 2017a) p442.

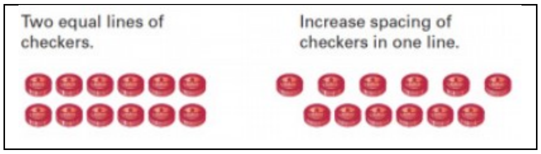

Figure 6.30 Conservation of number

In the concrete operations stage (7 to 11), the intellect learns to apply thought to concrete things. A child under 7 may think that spacing out checkers in a line increases their number, but by 9 they know that number is still conserved (Figure 6.30). Yet they still struggle to reason abstractly.

Not until the *formal operations stage at about twelve* does the intellect manage to think abstract ideas. Prior to this, we learn in a formatory way, by memory associations not logic. Children under 12 can rote learn dates for a history exam but struggle with abstract mathematics. As the intellect matures, it can change from backward thinking to forward thinking*,* from finding reasons to justify conclusions already held to forming new conclusions by analyzing agreed facts.

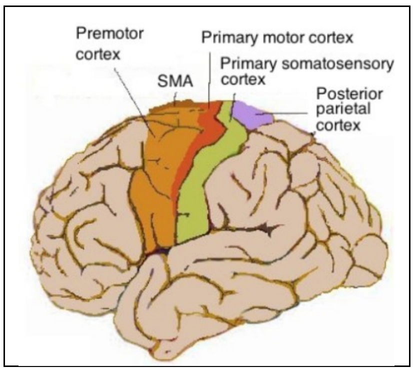

Figure 6.31 The Motor Cortex

Backward thinking is people cherry-picking the Internet for facts to confirm preconceptions while forward thinking is the scientific method. Formal operations let children think scientifically, but it still takes another decade to do it routinely. Western science began when Socrates started to think forwards but two thousand years later, we still struggle to follow his example because thought hurts! For example:

Bob rides his bicycle to pick up his motorbike from the repair shop at 10 mph. How fast must he ride his motorbike back to average 20 mph for the whole trip?

Emotional thinking suggests 30mph but using the intellect shows that is impossible.

Does the cortex control the feedback loop as it matures? It has the nerve links to do so as the sensorimotor cortex (Figure 6.31) maps to body muscles based on importance (Figure 6.32). A voluntary act like raising the hand occurs when the frontal lobe directs the supplementary motor area (SMA) to prepare the movement and tell the motor cortex to do it. The SMA activates even at the thought of moving, long before muscles move (Nachev et al., 2008), suggesting to some that:

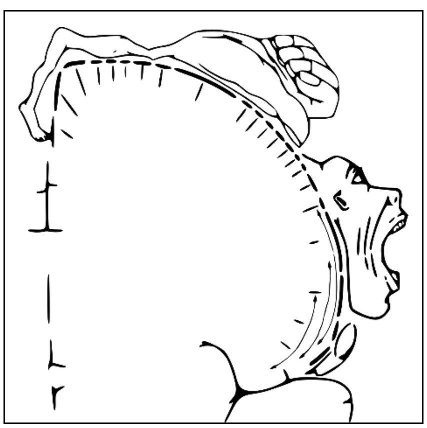

Figure 6.32 The motor cortex map

> "*… the "will" to move begins in the SMA and medial frontal lobes and exerts executive control over the secondary, primary and subcortical motor areas which then perform these "willed" actions.*" (Joseph, 2017b) p151

The author concludes that: "*The frontal lobes serve as the 'Senior Executive' of the brain …*" (Joseph, 2017b) p138, but how can two frontal lobes have one will? The brutal fact of neural science is that multiple systems drive bodily actions:

> "*Figuratively speaking, the skeletomotor output system is akin to a single steering wheel that is controlled by multiple drivers …*" (Morsella et al., 2016) p6.

The frontal lobes can initiate muscle movement but so can other brain centers. The cortex has voluntary muscle control but its ability to coordinate a successful golf swing is close to zero. It also struggles with emotional urges, as when we plan to eat less by dieting, we can deny one cake but to always do so takes more than intellectual "will". Like the triumvirate of Rome, at least two of the three control centers must agree for a long-term plan to work. The ideal for our brain isn't some sort of neural dictatorship but for its centers to *share control in a balanced way*.

6.2.8. Sharing control

The human brain doesn't have an instruction manual but if it did, it might stress that having many ways to control the feedback loop is a feature not a bug. Brains have to analyze sense input, body state and muscle output anyway, so three specialists survive better than one (Figure 6.33). If the brain had only one control center, it would be the hindbrain that matured first not the cortex that came later. This division lets the movement center manage movement details, the emotional center manage feelings, and the intellectual center manage thoughts. But our brains must use the right specialist for the job to succeed.

In Figure 6.33, the forebrain that receives muscle input is next to the motor nerves for those muscles, like a single input-output gate. In fish, the cerebellum used this gate to run the brain-world feedback loop, with data from the still evolving forebrain and midbrain. In birds and mammals, limbic control can override the cerebellum, which still managed fine motor control. In later mammals like us, the neocortex became independent, but its control of emotions and instincts is often quite limited.

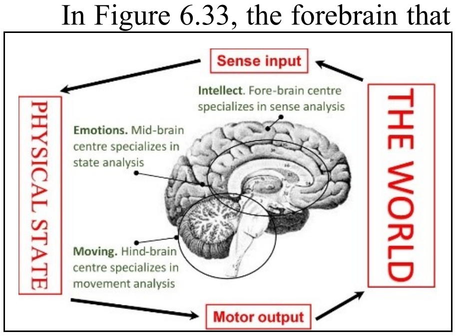

Figure 6.33 Three brain control centers

The result is a brain with not one control-center but three. Each center monitors body and sense input with its own neural connections, and does what it decides is best. Evolution has given us a brain with super-fast movement, powerful emotions, and complex thoughts, because different situations need all three. This isn't easy because the centers can't "talk" to each other as people do. They all speak different "languages" because millions of years of evolution separate them.

For example, people with a spider phobia can discuss their fear intellectually and accept that a little harmless spider isn't a threat. They have all the data needed for a non-fear response, but putting that spider on the table still makes them jump up in fear! The emotional center ignores talk but an actual spider makes it press the red danger button. And if during the conversation an object fell from a shelf above, the moving center might catch it before the intellect can recognize it. Different brain centers are too busy constantly analyzing external events to talk internally.

Each center must learn independently. For example, falling on a hard surface is a common cause of injury in old people. It happens so fast that what the brain does in a fraction of second decides whether we end up injured or just get back up. The intellect is too slow to act in time and an emotional center panic isn't much use, as a muscle spasm can injure bones or joints more than the fall itself. In most cases, its best to relax and let the movement center manage the fall, as parachutists do. This is easy to say but it takes a lot of practice to learn.

The three-in-one answer that evolved from the early forebrain-midbrain-hindbrain division gives us fast responses, powerful emotions, and complex thoughts. The traditional idea of human nature as intellect, emotions and will derives from this early neural division of labor. The three-center approach to the brain can be illustrated by a story:

Once upon a time there were three brothers who flew a tiny plane. Elder brother handled the flight controls, middle brother monitored the cockpit knobs and baby brother looked out the window to see what was out there. Eventually, by delivering goods in the city to earn money, they managed to buy a jet plane for intercity travel that had knobs to automate landing, takeoff, and flight among other things. This meant that middle brother was more often in charge but elder brother still monitored the controls to make fine adjustments and took over in emergencies. Middle brother had a thrust button for more power but he had to use it at the right time. As little brother grew older, he used what he called 'symbols' to record events on bits of paper but the others just used his spotting ability.

Intercity travel made more money, so one day they bought an intercontinental jet with state-of-the-art computer controls. Elder brother preferred his manual controls and middle brother liked his dials and knobs but younger brother preferred the computer screen to paper. It took longer but he could control the plane with it and even send messages to other planes. His older brothers were too busy to talk in flight, so he would demo a new flight technique by computer control and they picked it up if useful.

Their plane was constantly being upgraded. At first, elder brother used a simple dot radar to avoid colliding with other planes. When a radar with pictures instead of dots was installed, he found it too complex for manual flying but middle brother used it to identify friend from foe. When computer radar arrived, the first two found it complex and slow but little brother used it to analyze trends and causes. Over time, the brother's plane dominated the airways because three pilots are better than one if each does what they are good at.

Our brain has three centers just as cars have different gears for different situations, but why do we experience one driver? All that neuroscience knows about the brain, from blindsight to the split-brain, suggests many "I"s not one. Our sense of "I" implies that nerve input goes to a center that then directs all motor nerves, but neuroscience assures us that this isn't so:

"*In contrast to this first-person experience of a unified self, modern neuroscience reveals that each brain has hundreds of parts, each of which has evolved to do specific jobs – some recognize faces, others tell muscles to execute actions, some formulate goals and plans, and yet others store memories for later integration with sensory input and subsequent action.*" (Nunez, 2016) p55.

This issue, of how different brain areas work together, is called the binding problem.

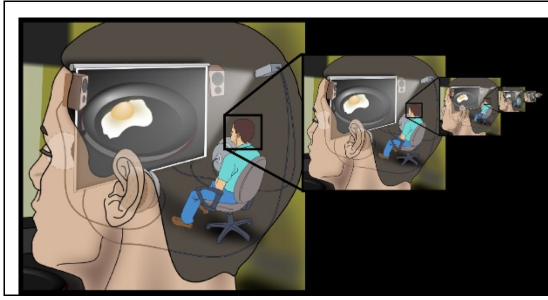

Figure 6.34 The idea of an "internal viewer" generates an infinite regress of internal viewers.

6.2.9. The binding problem

Different brain areas analyze sight, sound, and smell data that other areas use in thoughts, feelings, and actions but how does all this activity bind together in one experience? Descartes explanation was that all sense data clears through the pituitary gland, that passes it to the mind, which is like a little man in the brain watching a movie. Yet by that logic, that little man would need another little man inside his head to also observe, and so on, in an infinite regress (Dennett, 1991) (Figure 6.34). That there is a little man in the brain is illogical, but physical realism isn't much better, as it concludes that each neuron in the brain:

"*… doesn't 'know' it is creating you in the process, but there you are, emerging from its frantic activity almost magically.*" (Hofstadter & Dennett, 1981) p352.

That nerves that can't observe magically act and "*there you are*" is weaker than dualism. The mind-body problem of centuries ago lives on in neuroscience today as the binding problem:

> "*One of the most famous continuing questions in computational neuroscience is called 'The Binding Problem'. In its most general form, 'The Binding Problem' concerns how items that are encoded by distinct brain circuits can be combined for perception, decision, and action.*" (Feldman, 2013) p1.

The binding problem arises because distant processing hierarchies can't just exchange data. They can't "talk", as global workspace theory claims (6.1.6), because when a visual cortex nerve fires to register a line, it doesn't say "*I saw a line*" like a little person. It just fires a yes-no response like any other neuron. To bind that response to another feature like redness needs higher processing in the same hierarchy. At each step in the hierarchy, a nerve can fire to trigger a motor response, but it isn't an experience because the nerve doesn't know why it fired. The six-layered visual cortex can process lines, shapes, colors, and textures but the last nerve to fire in a sequence knows no more than the first. To integrate vision and smell needs a higher area to process both outputs but according to brain studies, this doesn't happen.

Different areas evolved to process sight, smell, sound, thoughts, feelings, touch, and memory but no area evolved to integrate them all. If it had, the brain would be wired like a computer motherboard, with many lines to a central processor, but it isn't. Each brain area is encapsulated, so smell, sight and sound brain areas can't exchange any experiences they have with each other:

> "*Because of the principle of encapsulation, conscious contents cannot influence each other either at the same time nor across time, which counters the everyday notion that one conscious thought can lead to another conscious thought … content generators cannot communicate the content they generate to another content generator. For example, the generator charged with generating the color orange cannot communicate 'orange' to any other content generator because only this generator (a perceptual module) can, in a sense, understand and instantiate 'orange'.*" (Morsella et al., 2016) p12.

And even if higher processing tried to integrate all brain areas, it would be too slow, just as complex thought usually comes up with a witty retort after a conversation is over. Our brain can integrate perceptions with memory to drive motor acts in less than a second but if one hierarchy did this, it would take much longer. The binding problem is that brain activities combine in a way that its wiring doesn't support, so *our unified experience of senses, feelings, thoughts, and actions should be impossible*.

Encapsulation predicts that the hemispheres can't exchange data, so each only sees half the visual field. Yet cutting the nerves between the hemispheres doesn't give a sense of loss:

> *"… despite the dramatic effects of callosotomy, W.J. and other patients never reported feeling anything less than whole. As Gazzaniga wrote many times: the hemispheres didn't miss each other."* (Wolman, 2012).

Why don't split-brain patients know that the corpus callosum is cut? If the optic nerve is cut, we know we are blind, as no data comes from the eyes. If an injury cuts the spinal cord, we know we are paralyzed, as no data comes from the legs. But when the millions of nerves joining the hemispheres are cut, both carry on as before! Why doesn't the verbal hemisphere report a loss of data? If it normally sees the entire field using the other hemisphere, it should report being half blind, but it doesn't. It follows that *it doesn't report any missing data because there is none.*

Instead of data loss, dividing the hemispheres just divides consciousness. One patient couldn't smoke because when the right hand put a lit cigarette in his mouth, the left hand removed it, and another found her left hand slapping her awake if she overslept (Dimond, 1980) p434. Conflicts made simple tasks take longer - one patient found his left hand unbuttoning a shirt as the right tried to button it. Another found that when shopping, one hand put back on the shelf items the other had put in the basket. One patient struggled to walk home as one half of his body tried to visit his ex-wife while the other wanted to walk home. These extraordinary but well documented cases show that cutting the corpus callosum gives two hemispheres with different experiences and opinions about what the body should do.

If the left hemisphere only analyzes data from the left visual field, our experience of a single visual field must arise in some other way. It is now proposed that the hemispheres synchronize their electromagnetic fields into one consciousness by means of the eight million nerves linking them (Pockett, 2017). The answer to the binding problem is then that consciousness causes integration not the reverse, where consciousness is the ability to integrate information to yield adaptive action (Morsella, 2005).

6.3. EVOLVING CONSCIOUSNESS

People have long wondered how physical brains become conscious:

> *"How it is that anything so remarkable as a state of consciousness comes about as a result of irritating nervous tissue, is just as unaccountable as the appearance of the djinn when Aladdin rubbed his lamp in the story."* Thomas Henry Huxley, 1863

But if nerves cause consciousness, and the brain is layer upon layer of neural processing, why doesn't it always happen? If the brain can do many things at once, why are we aware of some neural processes but not others? Why aren't we conscious of the nerves that apply syntax to language, or register balance? And why do nerves in some areas give one consciousness and only one "I"? As it turns out, the need for unified action is an evolutionary demand that begins at the cell level.

6.3.1. Cell unity

A cell has about 42 million protein molecules working together in the most complex system mankind has ever known. It has been called the *third infinity* (Denton, 2020) because it is as far beyond any complexity we know, just as the universe is bigger than we know, and the quantum world is smaller than we know. No machine ever built even approaches a cell's complexity, so the chance that trillions of atoms randomly formed millions of proteins in a primal stew to form a cell is effectively zero.

Evolution needed help, so the emerging field of quantum biology argues that it was a quantum effect (McFadden & Al-Khalili, 2018). Quantum effects like entanglement helped matter, stars and galaxies to evolve but until recently seemed to play no part in life. No-one doubted that quantum weirdness rules the atomic world but quantum entanglements were said to collapse too quickly to affect the macro-world of biology:

> "*On the face of it, quantum effects and living organisms seem to occupy utterly different realms. The former are usually observed only on the nanometer scale, surrounded by hard vacuum, ultra-low temperatures and a tightly controlled laboratory environment. The latter inhabit a macroscopic world that is warm, messy and anything but controlled. A quantum phenomenon such as 'coherence', in which the wave patterns of every part of a system stay in step, wouldn't last a microsecond in the tumultuous realm of the cell. Or so everyone thought. But discoveries in recent years suggest that nature knows a few tricks that physicists don't: coherent quantum processes may well be ubiquitous in the natural world.*" (Ball, 2011) p272

Quantum effects can bypass classical laws, so one expects life to use that power if it can, and it had billions of years to do so. Biologists just had to look to find quantum effects in cells:

> *"…something quantum mechanical is going on inside living cells, whether it's in photosynthesis, whether it's in enzyme catalysis,[16] [17] [18] whether it's in mutations of DNA,[19] [24] even more controversially the way we smell, the theories of olfaction,[25] or magnetoreception, the way certain animals can sense the Earth's magnetic field, the chemical compass that allows them to detect the orientation of the field relies on quantum effects, quantum entanglement.[26] [27] [28]"* (Al-Khalili & Lilliu, 2020)

The best-known example is photosynthesis, the process that sustains complex life on earth. It began over three billion years ago when bacteria harvested the sun's light to create oxygen. Our electric motors are 25% efficient, losing the rest to heat, but low-light bacteria convert 100% of light energy into chemical energy (Magdaong et al., 2014). This energy efficiency is impossible for heat engines, by Carnot's law, but bacteria have evolved a quantum heat engine (Al-Khalili & McFadden, 2014) p310 that can do what classical physics forbids:

> "*natural selection has come up with ways for living systems to naturally exploit quantum phenomena*" (O'Callaghan, 2018).

Photosynthetic bacteria have light receptive molecules called chromophores that absorb light energy and send it to reaction centers that convert it into chemical energy. When a chromophore antennae registers a photon, its energy must pass through the forest of other antennae to reach the nearest reaction center, but:

> "*The problem, of course, is which route this energy transfer should take. If it heads in the wrong direction, randomly hopping from one molecule to the next in the chlorophyll forest, it will eventually lose its energy rather than delivering it to the reaction center.*" (Al-Khalili & McFadden, 2014) p126

A photon pulse decays in nanoseconds so it should often go down a dead-end and die out but instead, nearly every photon arrives at a reaction center. This allows bacteria in the light-starved depths of the sea to survive, but how do they do it?

Studies show that bacteria chromophores vibrate in step to give quantum beats (Engel, 2007) that allow their electromagnetic fields to entangle (Maiuri, 2018). In physics, entanglement is a fragile quantum state that occurs in atoms or near absolute zero, so it should quickly collapse in a warm cell. However, identical matter entities whose quantum fields overlap will entangle (Lo Franco & Compagno, 2016), and densely packed chromophores vibrating in synchrony satisfy this demand, so many receptors entangle into one ensemble.

In physics, entangled photons going in opposite directions look like two photons but are actually one entity (Aspect et al., 1982), so if either interacts, both respond (3.8.5). If entangled photons can go in two ways at once, a photon registered by many entangled chromophore receptors can explore many the paths to a reactor at once. Once received, the energy spreads down all paths like a wave until it collapses at a reaction center. If that doesn't happen in one molecular cycle, the synchrony repeats until it does. The bacterium uses quantum coherence to enhance photosynthesis in a way that supports the known transfer times:

> "*Coherent quantum beats have been observed in most light harvesting systems, where the coherences are stable over a time scale that is commensurate with the relevant energy transfer times.*" (Scholes Group, 2018)

Chromophore molecules vibrating in synchrony let photon energy evolve down many paths simultaneously to find a reaction center before it decays. If light-harvesting bacteria achieved photosynthesis by coherence, all life on earth began with the quantum effect of entanglement.

6.3.2. Orchestrating coherence

Molecules vibrating in exact synchrony maintain a coherence that is usually lost in the molecular bustle of a normal cell. The timing of the synchrony must be almost perfect to produce this quantum effect, so how do photosynthetic bacteria do it?

One theory is that the microtubule cell structure orchestrates it (Penrose & Hameroff, 2017). Microtubules are self-assembling polymers that appeared over a billion years ago and are the skeleton of all cells today. They affect shape, growth, and function. Coherence plays a role in enzyme activity (Frohlich, 1970), and microtubules allow synchronous oscillations that give strong Frohlich coherence at room temperatures (Samsonovich et al., 1992).

If the cell structure oscillates synchronously, molecules in it will do the same, allowing them to superpose, cohere and entangle to act as one. That microtubules can apply quantum effects at cell timescales has led to their study in biological puzzles like smell, protein folding, ion channels, and bird navigation(Gauger, 2011).

Orchestrated coherence theory (Orch OR) argues that brain microtubules unify the brain to make it a quantum computer that processes information in a way that classical processing can't (Penrose & Hameroff, 2017). Critics note that while microtubules enable coherence at cell timescales, the time scale of human consciousness is orders of magnitude greater (Jedlicka, 2017). Microtubules also don't explain why some brain events are conscious and others aren't (Baars & Edelmann, 2012). Comatose brains have as many microtubules as normal ones, so why aren't they conscious? About half the human brain doesn't support consciousness directly but nerves in these regions contain just as many microtubules.

Penrose and Hameroff make a good case for consciousness at the cell scale based on a tubulin decoherence time of 10^{-13} seconds (Tegmark, 2000) but even their 10^{-6} seconds best estimate is too brief for human consciousness (Penrose & Hameroff, 2017) p27. Tubulin-based entanglement may enable cell consciousness but it isn't enough for human consciousness.

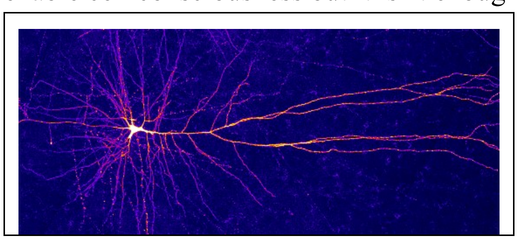

Figure 6.35 Neuron dendrites

6.3.3. Quantum neurons

A neuron is a cell that forms electrical links to other neurons. Neurons in the embryo brain spread like plant roots in a dense mat, to explore every link (Figure 6.35), but only those that are used survive. Neural Darwinism is that neurons compete to survive in the brain, as species do in the world, so unused nerves wither away over time (Edelman, 1987).

A neuron has up to five thousand dendrites (Figure 6.36), so it must find the combinations with others that make it fire as fast as possible, or it won't survive. It isn't easy with so many combinations and noise, random firing not due to signal input, makes it much more difficult.

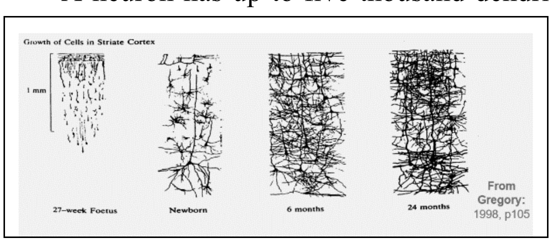

Figure 6.36 Neurons grow links but only the useful ones survive

Neuron tubulins can synchronize adjacent dendrites to reduce signal noise. It has been found that pyramidal dendrites don't spike if their inputs differ, even when either input alone gives a spike (Gidon, 2020). If nearby dendrites agree, they both fire but if not, neither does. The computing result is an XOR gate,[1] a function that classical computing needs two steps to do, not the expected AND/OR gate. Quantum coherence lets nearby dendrites observe signals in a unified way, as they must agree to fire in an XOR operation that reduces signal noise.

Instead of a dumb transistor that just adds inputs, each nerve is a processing network whose dendrite layer purifies the data by inhibiting erratic input (Cepelwicz, 2020). Nerves use molecular quantum effects to enhance their function:

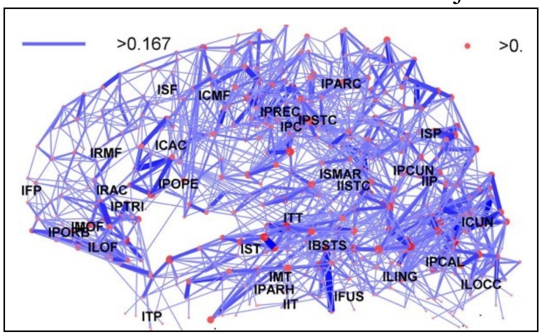

Figure 6.37 Brain neural network

"Physicists thought the bustle of living cells would blot out quantum phenomena. Now they find that cells can nurture these phenomena – and exploit them." (Vedral, 2015).

Some neuroscientists now see the brain as a neural net (Figure 6.37) that can use quantum effects to explore its trillions of links by exponential learning (Yang & Zhang, 2020).

6.3.4. Brain waves

Scientists have long known that nerves create electromagnetic pulses that electrodes on the scalp detect as brain waves. They include alpha-beta waves at 8-38Hz, the theta waves of sleep at 3-8Hz, and gamma waves of intense focus at 38-42Hz, but their general role is unknown.

Nerves must synchronize their firing to produce brain waves. In cat brain studies, cortical neurons synchronize their fire at a high degree of precision to produce beta-gamma waves (Gray, 1989) and they relate to the binding problem because studies:

> *"… have demonstrated that response synchronization is a ubiquitous phenomenon in cortical networks and is likely to serve a variety of different functions in addition to feature binding at early levels of sensory processing."* (Uhlhaas, 2009) p1.

Nearly all neural areas in the brain beat in synchrony, which isn't easy given nerve synapse, conductance, and propagation time delays. That even distant cortical neural areas achieve zero-phase synchrony, to beat almost perfectly in time, is an extraordinary feat:

> *"Early studies showed that zero-phase lag synchronization can occur even between distant neuronal assemblies,… This is particularly relevant as the conduction delays in the cortex make the occurrence of zero-phase lag synchronization difficult to accomplish."* (Uhlhaas, 2009) p3.

Entrainment was discovered when Huygens found that pendulums set in motion would all synchronize by the next day. It occurs because out-of-phase oscillations exchange energy that drops to zero when they vibrate in phase. In the same way, playing a note on a violin makes the violin next to it play that note without touching it, by resonance. Neuronal entrainment that creates resonances is ubiquitous in a wide variety of brains (Lakatos, 2019).

The encapsulation principle, that different hierarchies don't exchange data, means that nerves between them don't transmit content data. When a nerve in the visual cortex fires to register a line angle, it doesn't encode a message like "*I saw a 10° angle at location x,y,z*", it just fires. If a camp surrounded by beacon lights sees that one is lit, it means an enemy is coming that way and likewise

[1] An eXclusive OR operation compares two input bits and generates zero if the bits are the same and one if the bits are different. The XOR logic is widely used in cryptography.

when a nerve fires, its location implies the rest. In computing, the simplest signal is a ping, like a ping test that sends a no-content message to see if a web site still works. Encapsulation suggests that signals between distant brain areas are just pings, that carry no information content at all!

If distant nerve signals are just pings, there is no information to compete for consciousness (Baars, 1988), or to broadcast a global ignition that causes consciousness (Dehaene, 2014). Nerves constantly send signals between areas but this "chatter" doesn't exchange data. Instead, it just establishes the phase synchronies that give the brain waves we register.

The brain is a neural oscillator network that explores a vast domain of resonances. Models of oscillator networks with delayed links show that low frequency hubs can enable higher frequency synchronies (Vlasov & Bifone, 2017), so slow brain waves help faster ones keep time. The brain evolved many long-range and precise lag-free synchronies so it must serve a key function, and the exquisite time sensitivity of neural spikes implies that timing is critical. The neural synchrony evidence is so compelling that some suggest it is an information code, but there is no evidence for that (Uhlhaas, 2009). Others link synchrony to consciousness to conclude that:

> "*The central issue is how coherent, informational activity in multiple cortical areas is welded into a seamless unity that becomes aware of itself.*" (John, 2005) p160.

It is now proposed that consciousness relates directly to brain-generated neural synchronies.

6.3.5. Consciousness by synchrony

The idea that neural synchrony causes consciousness is over two decades old (Crick & Kock, 1990). The neural binding hypothesis is that when nerves bind together by synchrony, if some represent a trunk and others its leaves, they represent a tree when they fire together. Evidence that neural synchronies correlate with consciousness includes that they:

a. *Accompany face recognition*. Face recognition occurs when distant nerves synchronize with no phase lag (Rodriguez et al., 1999).

b. *Don't depend on firing rate*. Studies of the visual cortex find that the:
   > "*… selection of responses for further processing is associated with enhanced synchronization rather than increased firing.*" (Singer, 1999) p62.

   This suggests that synchrony causes observation rather than the number of nerves firing.

c. *Represent odors*. Different smells produced odor-specific synchronies in locust olfactory nerves that differed for different smells but not for the same smell (Laurent et al., 1996), suggesting that the observation of odors depends on nerve synchrony.

d. *Are transient*. Neural synchronies can be brief and hard to detect (Singer et al., 1997), just as conscious observations are fleeting moments.

e. *Accompany cognitions*. Beta/gamma brain waves correlate with cognitive functions like attention, memory, sensory integration and motor coordination (Uhlhaas, 2009) p8, so synchrony is related to higher cognitive functions.

Studies from insects, cats, monkeys, and humans agree that:

> "*… synchronization affects communication between neural groups.*" (Fries, 2015) p220.

The result is a mood of optimism that consciousness is coming within the realm of science:

> "*Beliefs about the basis of subjective experience have slowly evolved, from mystical notions of the soul and a disembodied mind to acceptance of the proposal that consciousness must derive from neurobiological processes.*" (John, 2005) p143.

Critics of consciousness by synchrony theory note that unconscious insects, anaesthetized animals, and subcortical structures also have synchronies, so why aren't they also conscious? This assumes that only humans are conscious but if consciousness is any ability to observe, then anaesthetized animals, insects, and primitive brain areas have less consciousness not none at all. If our consciousness began at the cell level, even insects are conscious on their scale.

Brain synchronies also build-up in a time-frame that reflects the chronology of a conscious experience (John, 2005):

1. *50 milliseconds*: *P1 waves* occur as nerve synchronies in primary sensory cortex areas that register input features.
2. *130 milliseconds*: *N1 wave* synchronies link the cortex to the thalamus/limbic system.
3. *210 milliseconds*: *P2 waves* link higher cortex layers to the thalamus/limbic system.
4. *300 milliseconds*: *Sustained P300 gamma oscillations* synchronize the frontal and parietal lobes with zero-delay in what is considered the basis of human perception itself.

Sense input triggers local synchronies in sensory areas, then long-range synchronies add emotions, memory, and language to give a global conscious experience. There is agreement that neural synchrony relates to consciousness, but how it does so is unclear.

6.3.6. Field theories of consciousness

If the brain is a network of oscillators, a nerve is more like a Wi-Fi device than a transistor chip. Brain areas aren't just wired together, they resonate together, suggesting that consciousness arises in the brain's electromagnetic field. Conscious electromagnetic field information (CEMI) theory suggests that:

> *"… the brain's EM (electromagnetic) field is the physical substrate of consciousness."* (McFadden, 2020) p5.

This doesn't mean the brain isn't an information processor. Its nerves identify lines in a picture, so a some nerve must fire "*Yes*" to recognize a face, the so-called Jennifer Aniston neuron (Quiroga et al., 2005), but one nerve firing isn't "information integration", as it can:

> *"… only encode a single firing rate that cannot represent anything more than a tiny fraction of the information present in a conscious percept."* (McFadden, 2020) p3.

McFadden argues that data processing can't integrate information but an electromagnetic field can. Nerves affect the brain's electromagnetic field like pebbles dropped on a pond, to spread ripples that interfere or combine into one result. That the mind is in the field solves the mind-body problem at a stroke, as then consciousness is unified because:

> *"… EM fields are always unified, there is only ever one EM field in the brain.*" (Ibid, p6).

CEMI theory also predicts that:

> *"… conventional computers, despite their undoubted computational skills, have not exhibited the slightest spark of consciousness, nor any signs of the general intelligence endowed by conscious minds."* (McFadden, 2020) p9.

But if electromagnetic fields are conscious, why isn't a toaster conscious? CEMI theory argues that when the brain's electromagnetic field encodes data, like a thought, it is consciousness. We download data from the brain's electromagnetic field as we download songs from a Wi-Fi field, and a toaster can't do that.

However, the field can't be both the observer and the data observed. If the data is in the field, then the brain needs a receiver to download it, just as a smartphone is needed to download songs from a Wi-Fi field. Data encoded by a field needs a receiver to download and decode it (Pockett, 2014) but the brain doesn't have a central receiver, just as it doesn't have a central processing unit.

On the other hand, if the observer is in the field, then what is it observing? It can't observe itself, as observer and observed can't be the same entity.

Pockett and McFadden also both assume that the brain's electromagnetic field is physical:

"... matter is not the only kind of physical entity. Electromagnetism is also an undeniable part of the physical world." (Pockett, 2017).

And:

"... consciousness is rooted in an entirely physical, measurable and artificially malleable physical structure and is amenable to experimental testing." (McFadden, 2020) p11.

Yet light waves aren't physical because they travel in a vacuum, which physical waves can't do. And they vibrate in an *imaginary plane* that is outside physical space, which a physical wave also can't do. The electromagnetic field of light is measurable, but it isn't physical. Indeed, if it were, no observer would be possible because one physical event can't observe another. Given these inconsistencies, another explanation for the relation between brain waves and consciousness is needed.

6.3.7. The entangled observer

A quantum entity, like a photon or electron, is observed when something else, like a screen, interacts with it. Until then, it is a spreading wave that doesn't observe itself or anything else. Only when another quantum wave interacts with it, can it collapse to restart at a point in a physical event. In quantum theory, a physical event is quantum entities observing each other. And the event location is chosen from the possibilities regardless of prior events. It follows that all physical events involve observation and choice.

When quantum entities restart in a physical event, something remarkable occurs: they entangle into a single ensemble that spreads from the event point. When two photons entangle, the spreading ensemble instantly knows if it is involved in a physical event, regardless of physical distance (QR3.8.5). When a physical event occurs to an entangled ensemble, all the entities involved observe it, even if they then disentangle. This isn't information exchange but it has the same effect, that distant participants obtain the same physical information.

It follows that when synchrony entangles nerves into an ensemble that observes a data point in the brain's electromagnetic field, they all get the same information, whether they created it or not. The same logic applies to the choice of the point observed. In simple terms, distant nerve areas can share data by forming a quantum entity that observes and chooses. Applying Penrose's logic to nerves, if tubulins can synchronize cell molecules to observe as one, brains can synchronize nerves to do the same. A quantum effect therefore underlies the observer we call "I".

It isn't proposed that all brain nerves synchronize, but that some do, to solve local problems, followed by a cascade from microcolumns to macrocolumns and so on, up to a global observer. Nor do all nerves need to synchronize perfectly, as only some need to do so to achieve the effect. If nerves that wire together fire together, then nerves that fire together observe together. Consciousness then arises when nerve synchronies cascade into a global observer.

When we watch a movie, sight and sound seem like one experience because entangled visual and auditory nerves make one observation. Bottom-up sensory analysis would process vision or sound alternatively but we observe both at once and can attend either. How attention occurs isn't known but where observation occurs alters the observation. An electromagnetic field is stronger closer to its source, so attending the sound of a movie may be choosing to observe close to the auditory area. Or I could attend to a thought or feeling by choosing to observe closer to that brain function. The brain has no wiring switch to do what attention does, so this theory explains what others can't.

If a single neuron opens a small observation window on physical reality, then many neurons entangled open a bigger window. The brain solved the binding problem by forming layer upon layer of neural synchronies to enable a global observation, hence:

a. *Consciousness takes time*. A global neural synchrony takes time to build up.

b. C*onsciousness scales*. Synchrony enables consciousness at multiple scales of the brain.

c. *Consciousness cascades*. Small-scale synchronies lead to large-scale synchronies.

The following sections give more details.

6.3.8. Consciousness takes time

Using electrodes to stimulate cortex locations in awake subjects having neurosurgery can give a body sensation, so a left-cortex point might give a brief right-hand tingle that subjects report about 500ms later (Libet, 2005), so is consciousness just an effect? In general:

> *"How are nerve cell activities in the brain related to conscious subjective experience and to unconscious mental functions?"* (Libet, 2005) p32.

To find out, subjects were asked to flick a wrist when they felt like it. The EEG showed a movement readiness potential in the prefrontal cortex about 200ms before subjects reported their intention to act. Conventional science took this to mean that consciousness is like a king who thinks he rules but his advisors do everything. Thus, even if consciousness exists, it does nothing:

> *"A systematic exploration suggests that every cortical site holds its own knowledge. Consider the insula, a deep sheath of cortex that is buried beneath the frontal and temporal lobes. Stimulating it can have a diversity of unpleasant effects, including a sensation of suffocation, burning, stinging, tingling, warmth, nausea or falling. Move the electrode to a location farther below the surface of the cortex, the subthalamic nucleus, and the same electrical pulse may induce an immediate state of depression, complete with crying and sobbing, monotone voice, miserable body posture, and glum thoughts. Stimulating parts of the parietal lobe may cause a feeling of vertigo and even the bizarre out of body experience of levitating to the ceiling and looking down on one's own body.*
>
> *If you had any lingering doubts that your mental life arises entirely from the activity of the brain, these examples should lift them."* (Dehaene, 2014) p153.

These results don't mean what Dehaene thinks they do, that our mental life arises entirely from the brain, because none of the nerve regions stimulated are capable of observing anything. Explaining how a movie gets onto a screen doesn't explain how it is observed. It is true that:

> *"… a whole array of mental processes can be launched without consciousness…"* (Ibid, p86)

But to say that global consciousness does nothing because some brain parts can act without it is like saying that the sun does nothing because I can switch on a light at night. It is true that parts of the brain can react to stimuli in 200ms, before the 500ms it takes to be fully conscious, but this just implies degrees of consciousness, not that global consciousness does nothing at all.

The relation between consciousness and the brain is like a viewer watching a TV. Nothing can be seen until the TV is turned on but even so, a TV can't view itself. If physical realism (PR) is that

TVs exist without viewers, then viewer realism (VR) is that viewers also exist. One can imagine a conversation between these two points of view as follows:

VR: *A TV can't view itself, so there must be a viewer out there*.

PR: *Not at all. When the TV is turned on, we just imagine that someone is viewing it*.

VR: *But a network of TVs that no-one watched would be pointless!*

PR: *Exactly! It's all pointless, that's why it doesn't matter what we show*.

VR: *But we can talk to viewers watching TV by long-distance phone calls*.

PR: *Yes, but they are also imaginary. It's all fake.*

VR: *How do TV channels change if there are no viewers?*

PR: *The remote control changes the channels randomly. Who knows, maybe a fly sits on it?*

VR: *So how do you know that viewers don't change the channel?*

PR: *We did an experiment. We asked a "viewer" to call us when he changed channels and the remote control came out of standby a second before his call arrived. Hence, he didn't do it.*

VR: *But how long does it take a long-range phone call to arrive?*

PR: *About a second*.

VR: *So that's not really conclusive, is it?*

PR: *Its near enough. Machinery does everything, viewers don't exist*.

VR: *But you watch TV so you're a viewer too, does that mean you don't exist?*

PR: *Don't be ridiculous, of course I exist*.

Libet's flawed experiment led many to think that the brain is merely a meat machine, just as nineteenth century science thought the universe was a clockwork machine, until quantum theory proved it isn't. This desire of scientists to prove they have no choice should be a subject of study:

> *"… why are so many intellectuals so intent on proving that they have no free will? (As the philosopher Alfred North Whitehead pointed out ironically, 'Scientists animated by the purpose of proving themselves purposeless constitute an interesting subject for study.')"* (Taylor, 2019)

Evolution doesn't do pointless. The long and short-range nerve synchronies found in every brain wouldn't have evolved if they did nothing. It takes effort to be conscious like us, as brain waves take time to form. That these synchronies correlate with consciousness suggests that the latter has an evolutionary benefit. It is now proposed that it is to unify observation, whether at the cell or human scale.

6.3.9. Consciousness scales

The multiscale conjecture is that consciousness builds up at many temporal and spatial scales in the brain (Nunez, 2016) p326, so:

> *"Consciousness does not work like a light switch that just goes on and off. Rather it is more like a light with variable brightness controlled by a dimmer switch."* (Nunez, 2016) p98.

The electromagnetic field of a nerve is extremely local so it fades after a millimeter or so, but tubulins could synchronize a microcolumn 1/300thmm wide to give P1 waves that occur 50ms after stimulus. This scale of observation might be a fleeting registration of borders.

Synchronizing a microcolumn amplifies its electromagnetic field, increasing its strength and range. This lets cortico-cortical columns of about 10,000 neurons synchronize, perhaps using thalamic beats and cortico-cortical links, to give N1 waves about 130ms after stimulus (John, 2005) p159. An observation at this scale might be a brief registration of features like shape.

Synchronized macrocolumns of about a million neurons can arise in the same way, to give P2 waves about 210ms after stimulus. The observation at this scale might be of a visual object.

The synchrony cascade doesn't stop there, as macrocolumns can form into areas. The primary visual area V1 at the back of the brain maps shapes in space, then shares its results with nearby V2, V3, V4, V5 and V6 areas that handle relative movement.

Finally, the distant brain areas responsible for memory and planning join the synchrony to form a global observation, based on the same principles. The evidence that synchrony enables consciousness is strong.

When subjects were asked to recognize images, electrodes in the occipitotemporal cortex, hippocampus and prefrontal cortex showed a steady beta synchrony, significantly higher than when they didn't recognize it (Sehatpour et al., 2008). When input reaches higher visual areas, a remarkable thing happens: sub-millisecond synchronies link distant brain areas as the image is recognized. Distant areas use re-entrant circuits and self-perpetuating loops to set up rhythmic synchronies of amazing precision, that integrate information in some way:

> *"We believe that the brain integrates functional modules by bringing neural oscillations in those modules into synchrony. Neurons oscillating in synchrony can communicate their information and influence each other's activities much more effectively than can those oscillating asynchronously."*(Ward, 2007) p325.

In a study of monkeys presented with two stimuli, one of which was relevant, both stimuli produced a V1 response, but only the attended one gave a V4 area gamma synchrony (Bosman et al., 2012). A similar result was found for auditory streams presented simultaneously - only the attended stream synchronized the higher auditory area, leading the authors to suggest a top-down synchrony filter for auditory attention (Lakatos et al., 2013). Human studies of binocular rivalry give each eye a different image but the brain sees one or the other, not a mix of both. Neuromagnetic measurements of rivalry find the hemisphere with better local synchrony predicts the image that is consciously perceived (Tononi, 1998).

In masking studies, where a word is only seen half the time, long-distant gamma synchrony between occipital, parietal and frontal areas occur if the word is seen but not if it isn't (Melloni et al., 2007). Both cases gave gamma oscillations but phase-locked synchrony between distant areas and the hemispheres only occurred for the visible case and shortly after this transient synchrony, the p300 correlate of consciousness occurred. Evidence from animal and human studies suggests that neural synchrony enables the conscious observation that binds areas:

> *"We propose that this transient synchronization might enhance the saliency of the activation patterns not only allowing the contents to get access to consciousness but also triggering a cascade of processes such as perceptual stabilization, maintenance in working memory, and generalizations of expectations, all aspects intimately related with conscious awareness."* (Uhlhaas, 2009) p11.

Why do nerves send the same signal hundreds of times a second in synchronized volleys? It can't be to exchange information, because we neither act nor perceive in hundredths of a second. but constant pings can build larger synchronies from smaller ones, in a cascade of consciousness.

6.3.10. Consciousness cascades

Brain synchronies develop in a sequence, from tiny nerve clusters to brain-wide synchronies. Microcolumns must synchronize first, to get the strength to merge into cortical columns, that then synchronize into macrocolumns. The constant pings of interneurons and the thalamic beat then help distant nerve areas to lock in phase in a global synchrony that allows consciousness.

We tune violins by varying notes slightly to achieve resonance, so a brain is like an orchestra tuning different instruments to the same frequency, except that nerves tune to obtain the same phase. This entangles them into a quantum entity that can collapse at a point in their field in an observation.

If a local synchrony that gives a small observation is maintained by constant pings, it can merge with others into a bigger observation, by the same process. This takes time to achieve, so nerves constantly ping to allow observations that can synchronize further. The cascade culminates when distant brain areas of language, meaning, and memory merge into a global synchrony that integrates the decentralized brain in a single observation that is what I attend to.

To recap, a photon wave collapsing at a screen point essentially chooses to observe there. When many nerves synchronize, their entangled field collapses to observe represents some neural combination. The microcolumn result is a flicker of an observation, but if it repeats, instead of collapsing alone it entangles with others that are doing the same. Constant neural volleys sustain lower synchronies until they cohere into bigger ones, and the process repeats until it gives a global observation. The global ignition that correlates with consciousness is a series of observer choices that end in what we experience.

This cascade allows negotiation between higher and lower units. A result that doesn't work at a high level can be repeated until it does, so an ambiguous figure seen one way can be redone differently. Computers struggle with low-level ambiguity but a brain based on choices at every level can ask for a rerun with different choices. Top-down links also let the global observer prime lower neural units to act alone, allowing instinctive response times as low as a tenth of a second.

Nerves that entangle by synchrony observe together so they are observer gates not transistor gates. Each observation is a choice*,* and lower choices precede higher ones, up to a global observer who also chooses what to observe. The choice of what we attend to isn't defined by sense input nor is it entirely free, as the options available at the top level depend on choices made lower down. This isn't a machine where each cog drives the next but a choice hierarchy*,* where lower choices define higher ones. The cause of human behavior, in brain terms, is choices all the way down, so the social norm of people being responsible for their own actions has a neural base.

Consciousness is like a spotlight that begins as millions of barely discernible point flickers that blink at different times. Eventually they become area flashes that wink separately until they also synchronize into a coherent beam directed at a target, which is our attention. It takes about half-a-second for the spotlight to power up, as each synchrony leads to the next..

This explains how we see one visual field when each hemisphere only sees half of it. Each hemisphere doesn't send data to the other hemisphere to unify the visual field. This is impossible by encapsulation and inefficient. Instead, callosal nerves synchronize the hemispheres into one observer that sees what both do.

This explains why beta-gamma waves stop under anesthesia and consciousness doesn't return until they do (John et al., 2001). The anesthetic makes us unconscious by interfering with brain synchrony. Only when and brain waves return, and the uncoupled hemispheres recouple, does conscious vision also return. What observes the full visual field isn't either hemisphere but their quantum entanglement.

6.3.11. The silicon chip speculation

A classic brain information theory argument is the silicon chip speculation, that replacing every neuron in the brain with an equivalent silicon chip wouldn't alter consciousness:

> "*… imagine that one of your neurons is replaced by a silicon chip prosthesis that has the exact same input/output profile as the neuron it replaces. At the core of this thought experiment is the presumption that such a replacement would be unnoticeable to you or to anyone observing your behavior. Presumably, you would continue to experience pain even though the physical realization of those mental events includes a silicon chip where an organic neuron used to be. Now imagine that, one by one, the rest of your neurons are swapped for silicon prostheses. Presumably there would be no change in your mental life even though your brain, which was once made of lipid and protein neurons, is now entirely composed of silicon neuronoids.*" (Mandik, 2004).

No evidence supports this speculation except the belief that brains are biological computers. That the brain equates to a set of wired chips isn't supported by neuroscience, as transistors are insulated from electromagnetic fields while neurons broadcast them, as brainwaves show.

Replacing a neuron with a chip might duplicate its wiring but not its broadcast field, so just as replacing a cellphone antenna with a computer would diminish a network, replacing neurons with chips would reduce the brainwaves that correlate with consciousness. If consciousness derives from nerve entanglements, the end result of the silicon experiment would be a brain with no more consciousness than a computer. The silicon chip speculation is science fiction posing as science fact, like the singularity prediction, that computers will soon become conscious (Kurzweil, 1999), as neither have any basis in evidence.

A related claim is that if we could copy matter atom-for-atom, copying the brain would copy its consciousness. If the physical world is all there is, physically identical brains are the same in everything, but if one "me" tends the garden while another cooks a meal, how can one I experience two events? If my copy went to work while "I" lay in the sun, I have no knowledge of a day at work, so my "copy" didn't replace me at all. It follows that physically copying a brain creates another self, not a new myself. Identical twins are, initially at least, largely identical, but they are different beings with different choices and lives.

Given a physical copy, Chalmers argues that the original is conscious but the copy is a zombie, while for Dennett, both are zombies imagining they are conscious. In quantum realism, two identical brains would generate two conscious beings that independently choose. Splitting one brain into two hemispheres gives two I's that can come into conflict so why wouldn't a perfect copy be the same? This clearly isn't beneficial so if I made a perfect copy of myself that was also conscious, who is to say it wouldn't decide to kill me? The brain evolved to unify consciousness, not to divide it, for a reason.

6.3.12. The nature of consciousness

The cascade theory of human consciousness answers common questions about it as follows:

1. *What is consciousness?* Let consciousness be the ability to observe a physical event. In our case, distant brain areas analyze different senses yet give one multi-sense observation. If nerves work as computers do, how can a brain with no central control form one observation? Millions of years ago, nature found a way, to entangle nerves by synchrony into one observer, because forming one observer is as important as analyzing the senses. Even in the womb, some nerves process data while others generate brain waves. When a baby looks at you intently, it may be forming the observer as well as the observed. Human consciousness is the brain's ability to entangle nerves into an I to observe the world that sense nerves register.

2. *What causes consciousness?* The primal cause is that quantum entities can observe physical events, but human observation requires a bigger observer. It requires a cascade of brain synchronies for our consciousness to emerge from the electromagnetic field.
3. *Is consciousness physical?* Every physical event is an observation result so what observes it can't also be physical, as that would be circular. If consciousness was physical, we could put it in a bottle, but what creates the bottle can't be contained in it. If a non-physical electromagnetic field underlies consciousness, then the observer isn't physical either.
4. *Is consciousness continuous?* A physical observation is an event not a thing, so observations are intermittent not continuous, but the being that experiences can constantly exist.
5. *What does consciousness do?* Consciousness enables a single being that can observe and choose, whether at the cell or human scale. Acquiring consciousness allows a complex brain to act as an entity. We take ourselves for granted, but imagine an online game whose players asked "*What does the player do?*" Some might say the player observes and chooses but those who see only the game see no "players" in it, so conclude they don't exist. They say: "*If players exist, point to them in the game!*" This can't be done, yet the game only exists for its players. In essence, consciousness provides the players in the game of physical reality.
6. *Why is consciousness singular?* Brain areas act in parallel but can only form one synchrony at a time, to give one global experience at a time. Consciousness is singular because the brain-wide resonance that creates it is singular.
7. *Why does the conscious experience never fail?* Brain states that give new smells or feelings are experienced with no more effort than familiar ones. How does consciousness know what experience to generate each time, without fail? If the cascade of consciousness builds up from individual nerve observations, the experience is built from scratch each time. Consciousness never fails because every experience is generated from the ground up.
8. *Can consciousness change?* Consciousness based on neural synchrony can grow or shrink as nerves join or leave the ensemble, so "I" take a while to fully emerge after sleeping. If consciousness increases as nerves synchronize better, one can be more or less conscious over a day or lifetime. Consciousness can also reduce by dissociation, when the unitary self falls apart, as seen in multiple personality cases.
9. *Can consciousness observe itself?* An observation is an observer-observed interaction where the observer isn't the observed, so to observe itself an entity has to divide into observing and observed parts. Brains do this when the intellect observes the emotions, as interpreter theory proposes, but consciousness as an entanglement can't split into parts. Yet somehow, our ability to observe includes knowing that we observe. The Gnostic saying "*Know Thyself*" is explored further in Chapter 7.

If consciousness sets us apart in the animal kingdom, how then did it evolve?

6.3.13. The evolution of consciousness

The three great mysteries of science are how the universe, life and consciousness began. If a quantum event began the universe, a quantum effect began cells, and the ability to observe is a quantum property, then quantum reality could explain all three:

1. The universe began when quantum reality split into server and client (2.4.2).
2. Life began when tubulins entangled cell molecules to allow unified choices (6.3.7).
3. Consciousness always existed, so it evolved from the quantum scale (6.1.8).

There is little doubt that we and everything around us evolved from a first event billions of years ago, so the universe, life, and our consciousness are connected. The common thread is that evolution increased observation because it favors survival. If the first light became matter, matter became life, and life became us, our bodies link back to the first event. No plan was needed because, by the quantum law of all action, anything possible will eventually happen (3.6.3). Light became matter and matter became life because it is possible not because the universe is finely tuned (4.8.2). It took a long time to increase observation.

In nature, big things come from small, so our bodies grew from a cell smaller than a full stop, and bacteria we can't see evolved into us. It follows that consciousness grew in the same way. Evolution and growth are step-wise sequences, so humans aren't a realm apart from animals, and life isn't a realm apart from matter. By Conway's Free Will theorem (Conway & Koch, 2006), consciousness is all or none, so it couldn't not exist then exist. It didn't suddenly begin at a past moment, so even trilobites in the primeval seas observed (Figure 6.38). The ability to observe can then be traced back to the first event as follows:

Figure 6.38 Even Trilobites observed

Planck time is the shortest possible physical time. An observation on this scale occurs more times a second than there have been seconds in our universe. Planck time can represent *photon scale observations*.

A yoctosecond (ys) is a trillion-trillionth of a second. A top quark's lifetime is estimated at half a ys, bosons have lifetimes in *ys,* and quark plasma light pulses are a few ys, so this timescale may represent *basic matter observations*.

A zeptosecond (zs) is a billion-trillionth of a second and the shortest time measured so far. Physicists estimate a few hundred *zs* for the two atoms of a hydrogen molecule to photoionize (Grundmann et al., 2020), so this timescale may represent *atomic observations*.

An attosecond (as) is a million-trillionth of a second. Ultrafast x-ray sources with *as* time resolution reveal bromine molecule vibronic structures (Kobayashi et al., 2020), so this timescale may represent *molecular observations*.

A femtosecond (fs) is a thousand-trillionth of a second or 0.000000000000001second. It is to a second as a second is to about 32 million years. High-energy *fs* scale X-rays that probe complex protein molecules in light harvesting bacteria respond to light in the order of one *fs* (Rathbone et al., 2018) p1433*,* so this timescale may represent *macromolecule observations*.

A picosecond (ps) is a trillionth of a second or a million-millionth of a second. Estimates of coherence times for cells range from 100*fs* to 1 *ps* (Rathbone et al., 2018) p1447, so this timescale may represent *simple cell observations*.

A nanosecond (ns) is a billionth of a second. This is a big number as it takes 95 years to count to a billion. Nanosecond pulsed electric fields elicit various responses in human and other cells (Koga et al., 2019), so this timescale may represent *complex cell observations.*

A microsecond (μs) is a millionth of a second. Bacteria existed three billion years ago but the leap to multi-cell life was only 800 million years ago, when cell walls used ion channels that act in microseconds (Minor, 2010) p201, faster than any nerve, to let simple animals with no nerves move towards the algae they feed on (Smith et al., 2019). Microsecond pulsed electric fields of ten *μs* can double the growth of mushrooms exposed to them (Edwards, 2010), so this timescale may represent *multicell observations*.

A millisecond (ms) is a thousandth of a second. In larger animals, electro-chemical nerves replaced chemical signals. Jellyfish nerves are all over their body but oysters have a neuro-endocrine center (Liu et al., 2016). Worms and slugs have ten-thousand nerves in a chord, and crabs and insects have a hundred-thousand nerve chord. A honeybee with nearly a million nerves can fly, navigate, and communicate where pollen is. These brains are fast, as an insect startle response can be less than *5ms* (Sourakov, 2011) and a praying mantis can evade a bat attack in *8ms* (Triblehorn & Yager, 2005), so this timescale may represent *instinctive brain observations*.

A centisecond (cs) is a hundredth of a second. Frogs and reptiles have brains with tens of millions of nerves that pass data from one nerve to the next. It takes at least a *cs* for a signal to travel a meter of nerve, so a cerebellum-based brain can respond in hundredths of a second. Tadpole startle responses occur within *1-2cs* (Yamashita et al., 2000) and our blink responses take 3-4 *cs*, so this timescale may represent *one-center brain observations*.

A decisecond (ds) is a tenth of a second. Bird and small mammal brains are about ten times larger than same-size frogs or reptiles due to midbrain and neocortex increases. Two-center brains require thalamic coherence that takes two-tenths of a second to occur, so a rats reaction time is about *2-3ds* (Blokland, 1998). In 100m races, responses under a tenth of a second are considered a false start because elite sprinters take 1.2-1.6 tenths of a second to begin to move (Tønnessen et al., 2013), so this timescale may represent *two-center brain observations*.

The speed of thought seems to be about a second. Lower brain areas respond faster but if brain-wide consciousness takes about half-a-second, human thought will take longer. Lower brain areas respond faster but brain-wide consciousness takes about half-a-second, so human thought will take longer. We blink in hundredths of a second and change highway lanes in tenths of a second, but it takes about a second to mentally rotate an 80° shape (Harris et al., 2000), or a 3D shape (Shepard & Metzler, 1988), or do mental arithmetic (Han et al., 2016), so this timescale may represent *three-center brain observations*.

Table 6.1 shows how consciousness, the ability to observe, evolved from photons to us, so the consciousness of a fly differs from ours in scale not in kind. Simpler entities observe faster so it's hard to swat a fly that sees 250 frames a second to our 60 because, we move in slow motion compared to it. The same applies to distance, as I see a chair that it doesn't because it sees less. Other animals have better senses but none can observe the galaxy as we do. Working back through evolution, consciousness was always there, just on a lesser scale.

Table 6.1 The Evolution of Consciousness

Observer	Time Scale		Examples
Light	Planck time	~10^{-44} seconds	Photon
Basic matter	Yoctosecond	10^{-24} seconds	Electrons, quarks, neutrinos
Atoms	Zeptosecond	10^{-21} seconds	Periodic table atoms.
Molecules	Attosecond	10^{-18} seconds	Oxygen, carbon dioxide …
Macromolecules	Femtosecond	10^{-15} seconds	DNA, RNA, mtDNA
Simple cells	Picosecond	10^{-12} seconds	Bacteria and organelles
Complex single cells	Nanosecond	10^{-9} seconds	Paramecium, amoeba
Multicell life	Microsecond	10^{-6} seconds	Placozoa, algae, fungi
Instinctive brains	Millisecond	10^{-3} seconds	Fish, insects, crabs
One-center brains	Centisecond	10^{-2} seconds	Reptiles, amphibia

Two-center brains	Decisecond	10^{-1} seconds	Mammals, birds
Three-center brains	Seconds	Seconds	Humans

For evolution to increase consciousness it must increase survival. Eyes and wings help survival but what does consciousness do? The benefit proposed is unity. That a house divided against itself cannot stand applies as much to cells and brains as it does to societies. The brain's binding problem was how to get trillions of nerves to act as one and a cell's trillions of molecules have the same problem. Every composite entity has this problem - how to get its parts to work together not against each other. The benefit of unity is universal, and quantum entanglement allows it.

Unification by entanglement began with matter,as an electron is entangled photons that survive as an entity (4.3.1), atomic nuclei survive as entangled quark strings (4.6.1), and molecules survive because entanglement lets them form physically incompatible structures (3.8.1). Matter evolved by entanglement, by letting new combinations unify to be stable, and thus survive.

Unity benefits cells too, as photosynthesis works better if receptor molecules work as one, as they did when tubulin structures synchronized and entangled them. How quantum entanglement works is unclear but the benefit of unity is clear. It makes cells more than a bunch of molecules, just as it made us more than a bunch of nerve cells. For example, *S. Roeselii* is a trumpet-shaped single cell animal that attaches to sea rocks to feed on passing rotifers. When stimulated by an irritant, it tries various options, in order, before finally deciding to relocate elsewhere (Dexter et al., 2019) (Figure 6.39):

> "*They do the simple things first, but if you keep stimulating, they 'decide' to try something else. S. roeselii has no brain, but there seems to be some mechanism that, in effect, lets it 'change its mind' once it feels like the irritation has gone on too long.*"

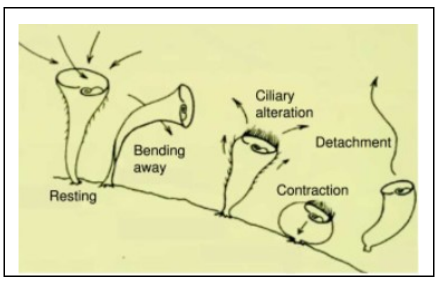

Figure 6.39 S. Roeselii responses

How can a cell with no brain do that? The answer proposed is that cell unity allowed cell choices that help survival. Quantum entanglement helped every step of evolution by letting complex entities make unified choices. The increase in consciousness shown in Table 6.1 is thus no accident, because the unity that consciousness provides benefits survival.

Each of us is a walking, talking, thinking complex of 30 trillion cells that grew from one cell by a path that evolution discovered. We see ourselves as uniquely conscious, but evolution doesn't do unique. We are only conscious because countless life forms before us found ways to become more so. The vast tree that bore us stretches as far as we can see and more, but how does it exist?

6.3.14. What exists?

Theories about what exists can be derived from three simple questions:

1. ***Does anything exist out there?***

   Yes. *Realism:* Something that exists out there apart from our observation of it, so we see a common reality because there is one.

   No. *Solipsism:* The world out there is created entirely by our mind, so each person constructs their own version of it, just as in a dream.

2. ***Does matter exist by itself alone?***

Yes. *Physicalism:* Matter is an objective substance that exists whether we observe it or not.

No. *Idealism:* Matter is the thought of a non-physical mind, like a shadow of reality.

3. ***Does the observer exist apart from matter*?**

Yes. *Dualism:* Mind is a non-physical substance that exists in a mental realm just as matter exists in the physical realm.

No. *Physical realism:* All reality is just matter interacting with matter, so the observer must be either a physical result, a physical combination, a physical property, or just an illusion.

Each theory struggles with different facts. *Solipsism* struggles to explain why we all dream the same lawful reality, which leaves *realism,* that there is a common reality out there. *Physicalism* has a vanishing matter problem, as when examined closely, matter becomes virtual particles or quantum waves that aren't physical at all. An embarrassing fact of physics is that 96% of the universe is dark matter and energy with no known material cause. *Idealism* has a manifestation problem, as what does a non-physical mind do that matter doesn't do already? *Dualism* has the problem that different realms of existence have no basis upon which to interact.

Current science embraces physical realism, that only matter exists, but if it were so, detecting an object without physical interaction would be impossible, yet it happens (3.8.4). Nor can this theory explain observation, as no physical mechanism exists that lets dead matter observe:

"*It is well recognized in the West that physicalism … has no adequate account (and many would say no account at all) of how consciousness could arise from the activities of non-conscious physical matter."* (Velmans, 2021) p25

As Russell concluded after many years:

"… we cannot say that 'matter is the cause of our sensations' " (Russell, 1927) p290.

He therefore suggested *neutral monism*, that matter and mind arise from something else, but neither he nor James (James, 1904) could specify what it was. Figure 6.40 shows the main reality theories at the beginning of last century. What exists (solid lines) was thought to be a substance that was either matter, or mind, or both, or neither.

A century later, theories are more complex but not a lot has changed. Physical realism now uses panpsychism, that matter observes, to make consciousness fully physical (Strawson, 2008). Dualism has become property dualism, that some matter can be conscious (Chalmers, 1996) p165. Idealism now includes cosmopsychism, that a great mind dissociated into human beings (Kastrup, 2019). Dual-aspect monism merges idealism and physicalism by making mental and physical inseparable aspects of an unknowable primal reality (Vimal, 2018). Mind and matter are then complementary just as electricity and magnetism are in physics (Velmans, 2021) p192, but aspects whose union is impossible can't be complementary. Arguing that because an electron can be a wave and a particle, we can be a mind and a brain, is using one miracle to justify another.

Dual substances, dual properties and dual aspects explain how atoms can be conscious but not how we are. Mass and charge add when matter aggregates but if consciousness did that, the moon would be more conscious than us. Dual-aspect monism concludes that "*'I' and 'Self" and 'me' are all plural terms (like the crew of the USS Enterprise.*" (Benovsky, 2016) p348, but this contradicts the first fact, that at each moment we experience one observer not many.

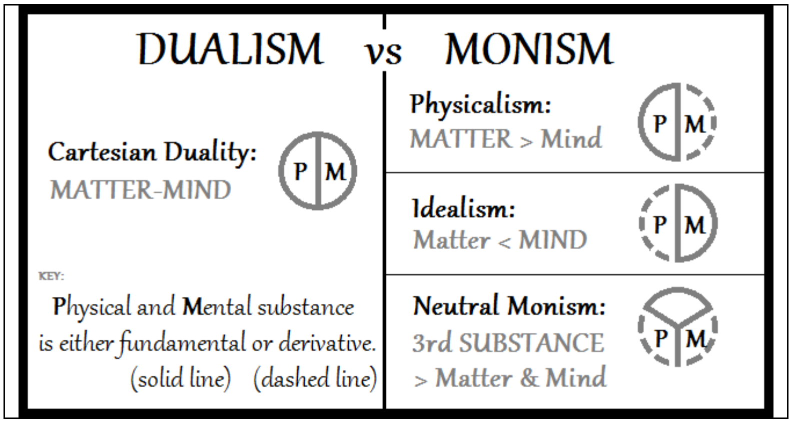

Figure 6.40 Theories of Reality

More complexity didn't solve the core problems: that dual realities can't co-exist, that dead matter can't observe and that atoms can't combine consciousness. The naïve belief that only matter exists is false, by the previous chapters. The dualism that observer and observed are both substances is also false. And no-one believes in solipsism, that only they exist, either. This leaves neutral monism, that the observer and the observed don't exist by themselves, but are both caused by some other reality.

Quantum realism proposes that quantum reality exists, as quantum theory describes it. Hence, it is all around us but physical events just represent it, so realism is true. Hence, quantum laws everywhere create universal physical laws, so lawfulness is true. Hence, there are no particles, only quantum waves that look like particles when observed, so matter disappears when examined. And if quantum reality causes all physical events, it made the galaxies and so doesn't have a manifestation problem.

Future generations may mock physical realism as a naïve belief in what doesn't exist, just as we now mock fairies (Kastrup, 2020), because that a matter universe made itself from nothing is magical thinking. That quantum reality causes mind and matter isn't dualism because there is only one source. That atoms are conscious doesn't explain how we are, but if they entangle to increase the observer, our consciousness can evolve from what came before.

Some say that what can't be seen can't exist but that isn't true, as unseen programs create the images that gamers see. If a gamer in a dungeon clicks on a door to reveal a monster image, was the monster lurking there beforehand? Obviously not, as that a dungeon of monsters exists in our laptop when we aren't using it is absurd. A generated experience isn't a permanent thing, so only what creates the monster image needs to constantly exist on the laptop.

If the physical world is a virtual reality, the same logic applies. We see tables and chairs not the quantum waves that generate them, and thinking they always exist is like thinking your laptop contains a dungeon of monsters. We see events not things, but if matter can't observe, what exactly is observing?

6.3.15. What observes?

Observation occurs when a quantum wave collapses in a physical event that restarts it again. Quantum theory needs observation to trigger physical events, so the first to observe our universe was its first creation – light. Observation occurred before matter or information existed, so they couldn't cause it. If quantum theory is true, then observation is fundamental to our universe.

A photon of light also chooses where it hits a screen from its wave distribution. Physics calls it random, as if it had no value, but if this choice also underlies our attention, it is worth having. If we choose, why can't a photon? Rather than explain when choice began, it is simpler to say that photons choose on an infinitesimal scale, so choice is also fundamental to our universe.

Light is a stream of photon quanta, but what makes a quantum unit? Physical waves that spread and dissolve back into the sea aren't units but photon waves are because they spread and restart. A photon wave that can spread over a galaxy then restart at a point is an *entity*.

What then *is* a photon? Quantum waves that collapse and disappear before a physical event can't decide where the wave restarts, so something else must do that. And if the speed of light doesn't fade, something else must generate its waves. Let us call that something else being, where an entity's being is how it exists. If a photon's being generates its quantum waves and chooses where they restart, it can also observe physical events, as they can't observe each other. If a photon's being chooses and observes, then being is what observes and chooses, a definition that also works for human beings.

A photon is immortal because, like the phoenix, it rises again from the ashes of its collapse, but if what observes in us ends when the brain dies, we aren't. Yet if the photon is an infinitesimal being, all later beings could derive from this primal ground by entanglement.

In this view, our universe began when a quantum entity passed its activity to others to make a single photon in a unit of space. The "big bang" that followed was a blast of light that continued until expanding space stopped it. Quantum realism proposes that this "rip" was a *server-client relation*, a computing term for one source activating another. For example, when a laptop prints a document, it is a server that makes its client printer print pages. It is also a server to its client screen. If a photon is a server manifesting waves on a client network, the wave can be restarted, just as a laptop reboot can restart a screen that hangs. This division separated quantum reality into:

1. *Server entities,* that generate quantum waves and restart them, and a
2. *Client network,* where quantum waves lawfully interact in physical events.

This isn't dualism, that two realities exist, because one reality divided into server and client. We call it being and manifestation, where being is what exists and manifestation is what is observed. Quantum reality divided into manifestation and being, where this division operates as follows:

1. Server entities generate quantum waves that spread on the client network.
2. Quantum waves interact to overload a client node in a physical event.
3. The physical event restarts the quantum entities involved at the same point.
4. Restarting at the same point entangles them to share information in an observation.
5. What is observed is generated, so it is virtual.

For example, when electrons meet, their quantum waves overlap until an overload restarts and entangles them as an entity that spreads waves again until another physical event disentangles them. Being the same entity lets them observe each other at that moment, so observation has a quantum origin. Countless quantum events cause each physical event, so it is just a snapshot of reality, like a camera that takes a photo every million years or so.

Figure 6.41 expands Wheeler's universal eye to include the observer. It divides quantum reality into server and client, which for us is being and manifestation. The realm of manifestation is the client network that we call physical space. The realm of being is what generates and restarts quantum waves, and where observation and choice occur.

Initially, tiny physical events gave tiny observations but over time the universe (U in the figure) observed more by finding entanglements that survived. Most entanglements collapse quickly but some survived as electrons, quarks, atoms, molecules, and macro-molecules like RNA. Each step in the evolution of matter increased the beings that observed.

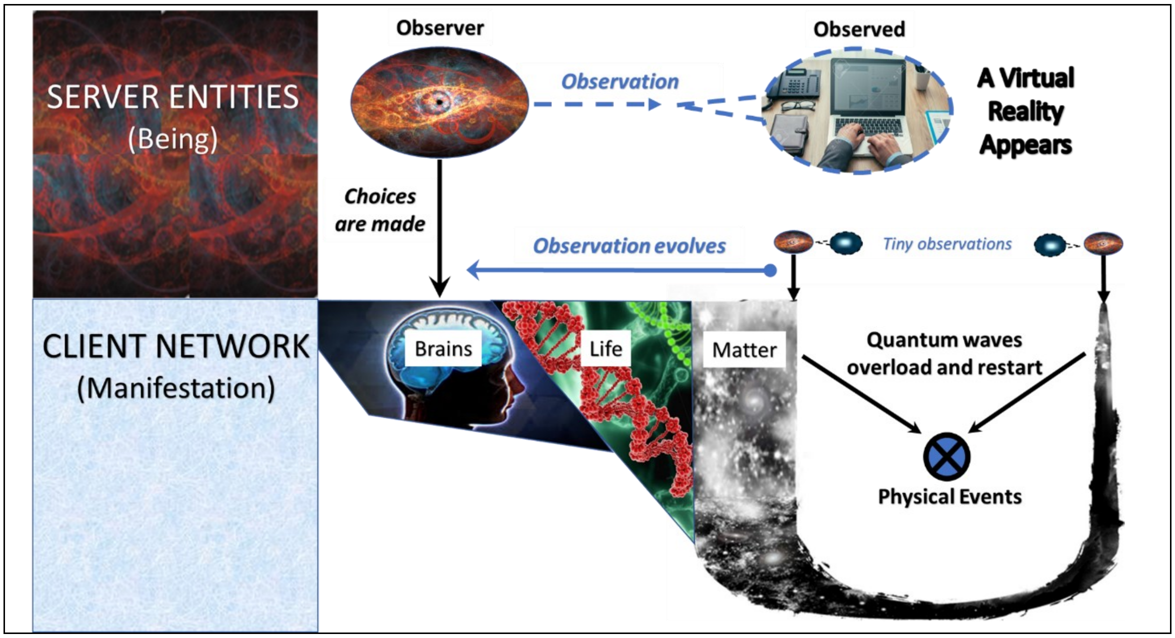

Figure 6.41 Quantum reality observes itself as a virtual reality

When the vibrations of tubulins kept entanglements going longer, millions of molecules were able to form a cell that can observe and choose as one. Simple cells led to complex cells, then plants, until animal brains managed to cascade synchronies, to increase observation still further. The result was sentient beings like us, that can think about the world and experience it as beings.

Evolution expanded the left of the U in Figure 6.41. Part of a universe of light became matter, some matter became life, and some life became sentient. Most of the universe isn't sentient, but the trend to observe more is clear. It drives matter to become life and life to become sentient. And now, billions of years later, we can see the scale of what is going on (Figure 6.42). We are beings that observe other being's manifestations by means of our own, but *where* is the observer that does that?

Figure 6.42 Our view of the universe today, where each dot is a galaxy

6.3.16. Where is the observer?

The question *where does observation occur?* seems simple but it isn't. Dualism locates it outside physical reality but can't explain how that is possible. Dual aspect monism locates a pain at the point where it occurs (Velmans, 2021), but phantom limb pains have no such point. Physical realism locates it in the brain but can't say what nerves observe, because if physical events are an unbroken causal chain, making any event an observation breaks the chain. Nerves busy with physical acts can't also observe them, so physical events can't observe other physical events. That a physical thing can't observe as we do is even a mathematical theorem (Reason, 2018), so:

> *"The materialistic theory is a logical blunder, because it is based on a confusion between the object and subject. It asserts that matter is objective, but at the same time tries to show that it is also the cause of the subject, which it can never be. 'A' can never become 'non-A'."* (Abhedananda, 1905) p22

If observation is a server-client effect, a server can't exist on its client network lest an event there gives an infinite loop. A server entity observing client events must exist outside its client space, which is our space. By the nature of observation, observer and observed are *A and non-A,* so a subject can never be an object.

It follows that the subject observing is outside physical space, just as we observe a snow scene in a glass globe from the outside it. One can tap a point to see a scene but can no more enter the globe than we can enter a screen. The observed location isn't the observer location, just as players see a dungeon while sitting in a chair. We see a world of physical events following each other in a lawful way, never doubting that we exist in it, but the logic of quantum realism is that it couldn't possibly be so.

We create virtual worlds for observers that exist, but our universe evolved both observer and observed from the quantum scale. The game Civilization lets a village grow to rule the world but the player leaves as still a citizen. In contrast, in our universe, both observer and observed increase by evolution. Quantum reality made not only a manifest world, but also the beings that observe it.

Virtual games exist for their players not themselves so the goal of Civilization isn't to rule a virtual earth nor is the aim of Warcraft to conquer orcs. The aim is the player experience not the game result, just as we don't care if a virtual plane crashes in a simulator as long as the pilot learns. A virtual universe that exists for itself alone is utterly pointless unless the observer benefits. If our universe is a virtual reality that increases the ability to observe, which is consciousness, then it has an observer benefit.

If our universe exists to benefit beings not things, we are at best an experiment of consciousness and at worst, too smart for our own good, and about to become extinct. It only took six million years for a chimp-like creature to become human so if we fail, something else will come along in what, for the universe, isn't even a heartbeat. Long before the first human, cells were evolving, and long before the first cell, matter was evolving, so we probably aren't the only experiment in progress.

The next chapter considers whether some among us long ago realized by intuition what is here deduced by science – that physical reality isn't what it seems, that it depends on something outside itself, and that what is manifest exists for the benefit what is not.

6.1. ACKNOWLEDGEMENTS

Especial thanks to Celso Antonio Almeida, Ramón Pérez Montero, and Steve Alvarez for ongoing advice.

6.2. DISCUSSION QUESTIONS

The following questions are addressed in this chapter. They are better discussed in a group to allow a variety of opinions to emerge. The relevant section link is given after each question:

1. What part of you experiences your life? (6.1.1)
2. What would you say to someone who denies that they observe the physical world? (6.1.2)
3. Which Chalmers consciousness category does quantum realism belong to? (6.1.3)
4. Is physical realism a realistic theory of what physical particles actually do? (6.1.4)
5. If quantum reality creates the physical world as a virtual reality, what does the physical world cause? (6.1.5)
6. Why can't text programs process picture files or vice-versa? (6.1.6)
7. What problem faces theories that say the mind causes things? (6.1.7)
8. Why isn't quantum realism the same as panpsychism, that all matter is conscious? (6.1.8)
9. How does growing an information processor differ from building one? (6.2.1)
10. What does split-brain research suggest about what controls the brain? (6.2.2)
11. What does the spinning ballerina illusion tell us about visual processing? (6.2.3)
12. Did evolution build three brains one after the other, each making the last obsolete? (6.2.4)
13. Why is the evolutionary "old" cerebellum still state-of-the-art? (6.2.5)
14. What are emotions and why were they important in brain evolution? (6.2.6)
15. Why was the intellect the last part of the brain to evolve and is the last to mature? (6.2.7)
16. Why does the brain have three centers of feedback control not just one? (6.2.8)
17. What is the effect of cutting the nerves that connect the hemispheres? (6.2.9)
18. How do photosynthetic bacteria harvest every photon of light they receive? (6.3.1)
19. What causes the molecules in a cell to vibrate in synchrony? (6.3.2)
20. How do nerve dendrites check they are receiving error-free data? (6.3.3)
21. What causes brain waves? (6.3.4)
22. What neurological process is consciousness now believed to derive from? (6.3.5)
23. If consciousness arises in the electromagnetic field, what does that explain about it? (6.3.6)
24. How do entangled entities share information? (6.3.7)
25. Why does consciousness take time to arise? (6.3.8)
26. When different images are presented to each eye, why do we see only one image? (6.3.9)
27. Why is what you observe always a choice? (6.3.10)
28. What would happen if silicon chips replaced all the nerves in the brain? (6.3.11)

29. Nerves evolved to process sensory data but why did they evolve brain waves? (6.3.12)
30. If the body has about 30 trillion cells, can we know what they are conscious of? (6.3.13)
31. What is fundamental, mind or matter? (Is it mind, matter, both, or neither?) (6.3.14)
32. Is dividing reality into being and manifestation the same as mind-matter dualism? (6.3.15)
33. Why does quantum realism conclude that the observer is outside physical space? (6.3.16)

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