ChatGPT

White Paper 2: The Negentropic Bridge from Quantum Potential to Classical Reality

Introduction

In the early 20th century, physics shattered the clockwork certainty of the Victorian universe. Where classical science envisioned a **deterministic** reality – in which perfect knowledge of initial conditions would yield a perfectly predictable future – **quantum mechanics** introduced fundamental **uncertainty**. Subatomic particles could no longer be pinned down with arbitrary precision; instead they existed as *probability clouds* and superpositions of multiple states. This raised a profound question: **How does the blurry, probabilistic quantum world give rise to the crisp, concrete reality we experience?** In this white paper, we explore a unifying principle called **informational proximity** to explain how quantum potentials resolve into classical actuality. We will develop this concept in depth and show how *negentropy* (negative entropy, or information) provides a bridge from microscopic uncertainty to macroscopic order. Along the way, we integrate rigorous mathematical insight with metaphors, historical context, and philosophical reflections – from Schrödinger's famous cat-in-a-box paradox to modern neuroscience principles like **Friston's Free Energy**. Our journey will take us from the quantum realm through decoherence and classical emergence, into the dynamics of life and mind – where perception and cognition actively shape reality by collapsing uncertainties. We will consider **informational gradients** that drive attention, the imaginative rotations of thought, and how the **act of observation itself – through gaining information – can be seen as bringing the world into concrete being**. Finally, we delve into the implications for subjective experience, tackling the *hard problem of consciousness* and the perennial mystery of **free will**. By weaving together threads from physics, information theory, biology, and cognitive science, this paper aims to present a richly layered understanding of how **negentropy** and **informational proximity** clarify the emergence of the classical world from quantum possibility, and how our minds – as *negentropic agents* – participate in the unfolding of reality as experienced.

Quantum Uncertainty and the Emergence of Classical Determinism

At the quantum scale, nature behaves in ways that defy our classical intuitions. **Heisenberg's uncertainty principle** formalized the idea that certain pairs of properties (like position and momentum) cannot both be known to arbitrary precision – the act of measuring one blurs our knowledge of the other. Moreover, quantum theory tells us that particles exist in **superpositions** of states until measured. In stark contrast, the **classical world** of everyday experience appears deterministic and well-defined: a baseball follows a single trajectory, a cat is either alive *or* dead – never a mysterious blend of both. Reconciling these views is not just a matter of experimental accuracy, but a deep conceptual puzzle. As the *Information Philosopher* succinctly states: *"There is only one world – it is a quantum world – but epistemically our experience with large objects inclines us to see it as deterministic"*. In other words, fundamentally the universe may be indeterministic and probabilistic, but as objects grow larger and interactions multiply, the myriad microscopic uncertainties average out or become hidden beneath our observational threshold. This averaging – analogous to the law of large numbers in probability – makes large-scale behavior **"adequately deterministic"** in practice, even if at base it's rooted in quantum chance.

Historically, thinkers like **Laplace** imagined a demon that, knowing all particle positions and velocities, could compute the future with certainty – a vision of **classical determinism**. Quantum mechanics undermined this vision by revealing that such exact initial data is in principle unattainable (and perhaps meaningless) due to inherent uncertainty. Even if one could gather complete information about a system, *quantum indeterminism* implies the future isn't strictly determined – there's a built-in **element of chance**. Some prominent physicists (including Einstein) resisted this indeterminacy, famously insisting that "God does not play dice." Yet experiments (from the verification of Heisenberg's relations to Bell tests on entanglement) have overwhelmingly confirmed that chance is real in the physical fabric of the world. As philosopher-psychologist William James put it, **chance** provides "elbow room" for novelty and freedom; and indeed modern physics shows that the world *"remains chaotic and random at the atomic scale"*.

Still, if the microscopic world is ruled by probabilities, why do we perceive a stable, law-abiding macroscopic world? **Niels Bohr** offered one early hint with his *Correspondence Principle*: quantum behavior must merge into classical behavior for large quantum numbers – for example, the discrete quantum jumps in atoms should smoothly approximate the classical orbits when scales get large. In essence, quantum effects "wash out" when viewed at a coarse scale. Similarly, if an object's **de Broglie wavelength** (a measure of its quantum "spread") is tiny compared to the scale of observation, wave-like behavior (diffraction, superposition effects) becomes negligible. For everyday objects with huge masses and many atoms, the quantum uncertainties in position or momentum are incredibly small fractions of the whole – far below the **resolution** of any measuring device or our senses. Thus, a thrown baseball does not appear in a delocalized cloud; its uncertainty in position might be on the order of 10^-30 meters, utterly negligible. **Classical determinism emerges as an *effective description***: like a zoomed-out photograph hides the graininess of the pixels, the macro-world hides quantum fuzziness under layers of statistical regularity. The *quantum-to-classical transition* is often described as taking the limit of Planck's constant h going to zero (though h itself is fixed, the ratio h/m for large mass m becomes effectively zero). When quantum fluctuations fall below detection limits, events appear continuous and determined.

However, a mere averaging story is not the full resolution of the puzzle. The more vexing issue is the **measurement problem**: *How and when do quantum possibilities reduce to a single observed reality?* If a nucleus has a 50% chance to decay in an hour, quantum theory (by its standard interpretation) says it will be in a **superposition** of "decayed" and "not decayed" states at the hour's end. If that nucleus is tied to a macroscopic event – say, the triggering of poison that endangers a cat – does the **cat** also enter a superposition of alive and dead? It seems absurd, yet this is precisely the scenario **Erwin Schrödinger** highlighted in 1935.

Schrödinger's Cat: A Paradox of Quantum and Classical Worlds

*Schrödinger's cat – a thought experiment illustrating quantum superposition and collapse. A cat is sealed in a box with a vial of poison that will be released if a radioactive atom decays. Quantum theory suggests that after some time the atom is in a superposition of "decayed" and "not decayed" – and thus the cat's fate is entangled with both outcomes, seemingly alive and dead at once. Only upon observation is the ambiguity resolved, and we find a cat that is either alive or dead. Schrödinger posed this scenario to dramatize the question: when and how does quantum indeterminacy give way to the single definite outcomes we see?***

This famous **thought experiment** brings the measurement problem into sharp focus. As long as the box is closed (unobserved), the quantum description would treat the cat's state as a *superposition* of two drastically different realities. Yet, in practice, when we open the box we **never** see a half-alive/half-dead cat; we see a definite outcome. The paradox forces us to ask: *at what point does the quantum wavefunction "collapse" to a single outcome?* Is it when the geiger counter triggers, when the poison is released, when the cat's neurons register death – or only when a conscious experimenter lifts the lid and **perceives** the result? This is essentially **Wigner's friend** scenario – the ambiguity of when an observation counts as a "measurement."

Schrödinger's cat was originally devised as a critique of the Copenhagen interpretation, which vaguely asserts that quantum systems don't have definite properties until measured. Schrödinger and Einstein found this unsatisfying: it implied that reality somehow depends on an observer. Einstein in particular worried that quantum mechanics might be incomplete – as expressed in the EPR paper (Einstein-Podolsky-Rosen, 1935) which argued that the theory's "lack of separability" for entangled particles suggested something was missing. Schrödinger's feline paradox turned that abstract debate into a vivid image that captured public imagination. It dramatizes the question posed in many physics textbooks: *"How does the quantum description of reality – with superpositions and probability waves – give rise to the solid, everyday reality we perceive?"*. In other words, **what physically constitutes a 'measurement' and causes the wave function to collapse into a definite state?**.

Multiple interpretations of quantum mechanics offer different answers. The Copenhagen interpretation simply accepts collapse as a primitive concept linked to observation (without specifying what qualifies as an observer). The **Many-Worlds interpretation** sidesteps collapse altogether: both cat states persist, but in non-communicating branches of the universe – so the experimenter finds the cat alive in one branch and dead in another, and neither branch can interact. Other interpretations invoke **objective collapse** mechanisms (where physics itself causes collapse when systems reach a certain size or complexity), or **pilot-wave** theories (which restore determinism at the expense of nonlocal hidden variables). Each approach has its merits and issues, but most strive to **explain the emergence of the one classical reality we see, from the underlying quantum formalism**.

A central theme common to many explanations is the role of the **environment** and **information**. While Schrödinger's isolated cat seems to hover in limbo, a real cat is never truly isolated from its surroundings. In practice, even before the box is opened, countless air molecules, photons, and thermal vibrations are interacting with the cat (and the poison, detector, etc.). These interactions can effectively **monitor** the system's state. If the radioactive atom decays and releases poison, that will alter the temperature, produce airborne molecules, perhaps change the cat's movement or sounds – in short, it leaves myriad **traces** in the environment. Each trace carries a bit of information: for instance, an air molecule that collides with a decayed poison molecule now carries away a tiny momentum change that (in principle) encodes the event. When many such degrees of freedom become entangled with the quantum system, the **superposition's coherence** is lost from the perspective of any local observer. This process is known as **quantum decoherence**.

Decoherence and Classical Emergence

Decoherence theory provides a quantitative account of how classical behavior emerges in an open quantum system. When a quantum system (like Schrödinger's cat scenario or any microscopic object) interacts with a large environment, the environment effectively performs continual measurements. The would-be superposition becomes **entangled** with distinct states of the environment (e.g. one where poison molecules are spread vs one where they are contained). The result is that the **system's reduced state** (the state we'd assign to the cat alone, ignoring the environment) no longer shows interference between the superposed components – the cross-terms ("alive" with "dead") in the cat's density matrix rapidly vanish. The system **decoheres** into a mixture of “cat alive” *or* “cat dead” relative to the environment. To any observer entangled with (or part of) that environment, it appears as if the wavefunction has randomly collapsed to a definite outcome. In essence, the environment has **“measured”** the cat. Crucially, this does not require a conscious observer; even inanimate surroundings – air molecules, photons, a Geiger counter – can carry away information that resolves a superposition.

Physicist **Wojciech Zurek** and others introduced the idea of **environment-induced superselection** (often whimsically termed *“einselection”*). Certain preferred states (called **pointer states**) are robust against entangling with the environment and thus tend to be the outcomes that persist. For example, in a position measurement, localized states of the particle become pointer states because any spread-out superposition would quickly become inconsistent with environment interactions (like scattering photons). The environment, in effect, “chooses” a basis in which quantum states get decohered (superselected). This explains why, despite the myriad ways a wavefunction could in principle collapse, we consistently see outcomes in sensible classical terms (a definite position, a dead *or* alive cat, etc.). From this perspective, **wavefunction collapse is not a mysterious abrupt process, but an emergent *illusion***: the appearance of collapse reflects our ignorance of the environment’s degrees of freedom which have siphoned off the quantum phase information.

An important point in decoherence is that while it explains why we don’t observe superpositions of macroscopically distinct states, it **does not by itself select a single outcome** – it produces a stable mixture or branching of reality. If one insists on a single outcome, one must still invoke some interpretation (like “Many-Worlds” accepts all branches as real, whereas Copenhagen says the observer’s knowledge jumps to one branch). But pragmatically, once decoherence happens, the branches are effectively non-interacting, and each looks classical. The **creation of records** or **irreversible information** during decoherence marks the **quantum-to-classical transition** [1] . As one source puts it: *“The creation of irreversible new information also marks the transition between the quantum world and the ‘adequately deterministic’ classical world”* [1] . Once the outcome is recorded in a macroscopic way (e.g. millions of molecules have different positions in one scenario vs the other), you cannot erase or “un-entangle” that information easily; the alternatives might as well belong to separate worlds.

Thus, **information is the key**. The classical world emerges when information about a quantum system becomes **dispersed in the environment** in such a way that it’s effectively irreversible and broadly accessible. We can even quantify this: for a pure quantum superposition, the entropy is zero (since the system is in a definite pure state, albeit superposed), but when entangled with an environment, the system alone is described by a mixed state with **entropy**. This entropy increase in the system corresponds to losing information about relative phase – essentially the environment has *gained* that information. The environment is like a **witness** to what happened, holding many redundant copies of the outcome (as in Zurek’s **Quantum Darwinism** scenario, where environment fragments broadcast the state of the system). When many independent fragments of the environment carry the same information (e.g. countless photons scattered off an object all encode its position), observers can **indirectly** measure the system by sampling the environment – and they will all agree on the observed state. That is how objectivity arises from quantum ambiguity: the state becomes a *fact* in the environment that no longer suffers quantum indeterminacy.

In summary, **decoherence** bridges quantum and classical by **entangling** systems with their environments and thereby **delocalizing information**. The once-coherent superposition **“branches”** into decohered alternatives, which are *informationally separate*. The effect is that a cat is either alive or dead relative to any given observer who has the slightest interaction with the cat’s environment. Schrödinger’s cat, for all practical purposes, was never in a bizarre limbo once decoherence via air and thermal photons did its work almost instantaneously. The seeming paradox is resolved not by magic, but by recognizing the **informational exchange** with the surroundings.

This understanding shifts the emphasis from **"wavefunction collapse"** as a physical force, to **information flow and correlation** as the drivers of classical reality. It suggests that the *boundary* between quantum and classical is not a fixed demarcation but a continuum governed by how much information has been shared or **which degrees of freedom have become correlated**. A small, isolated quantum system (e.g. an electron in a vacuum) retains its quantum character. But let that electron interact with a measuring apparatus or stray into air, and information about its position or momentum leaks into the environment – it now behaves classically from our vantage, as if its wavefunction collapsed. This perspective naturally leads us to articulate the notion of **informational proximity**: the idea that when two systems exchange information or become correlated (i.e. "close" in an informational sense), their states mutually constrain each other, reducing uncertainty.

Informational Proximity: Information as the Catalyst of Collapse

Informational proximity can be thought of as the *degree of informational connectedness or correlation between systems*. When a quantum system is **informationally distant** from any observer or environment – meaning no information about its state is leaking out – it can maintain its quantum superposition freely. But when another system (be it an apparatus, environment, or conscious observer) comes into **informational contact**, the distance closes: bits of information are exchanged, and the state of the quantum system becomes entangled with and **known to** the other system. In this closeness, the hazy cloud of possibilities condenses into a sharper reality. **Collapse of uncertainty is essentially the establishment of information**.

Imagine two systems separated by a great informational gulf, like two strangers with no knowledge of each other. Each can exist in many uncertain states relative to the other. Now imagine bringing them into interaction – say, a photon from one strikes the other. That interaction creates **correlation**: the photon's state now carries information about the other system (perhaps about its position or energy). They have become less like strangers and more like acquaintances exchanging data. With enough such interactions, the systems become strongly correlated; their states are entwined by shared information. At the extreme of informational proximity, one system's state might be almost entirely known given the state of the other (think of two gears locked in sync – knowing one's position tells you the other's). In quantum terms, as information flows in, the **entropy (uncertainty) of the system's state relative to the observer decreases**. When informational proximity is maximal (short of total mutual determinism), the uncertainty is minimized – the observer has effectively "collapsed" the system's state by learning about it.

We can formalize this in terms of **mutual information**. If S is the quantum system and E the environment (or an observer's measuring device), their mutual information $I(S:E)$ measures how much knowledge of one reduces uncertainty about the other. Initially, $I(S:E) = 0$ if they are independent. As interactions occur, $I(S:E)$ grows – reflecting that E now contains information about S. In decoherence, for instance, the environment E gains enough information to distinguish the previously superposed states of S. When $I(S:E)$ approaches the entropy of S (the maximum correlation), the environment has learned everything it can about the system's pointer state. At that point the system's reduced state (from perspective of environment or observers coupled to it) is essentially definite – "collapsed". In a very real sense, *acquiring one bit of information about a quantum system's state corresponds to eliminating one bit of* *entropy (uncertainty) from that system*. It's a tradeoff: the entropy doesn't vanish but is exported to the environment (which in turn usually dumps it as heat or noise). **Leon Brillouin**, one of the pioneers of information theory and thermodynamics, articulated this tradeoff clearly: *"Every observation… is made at the expense of a certain amount of negative entropy (negentropy) taken from the surroundings."*. In other words, to obtain information (negentropy) about a system, the observer or apparatus must expend energy and increase entropy elsewhere. This is precisely how **Maxwell's demon** paradox was resolved: the demon can reduce entropy in a gas by gaining information about molecules, but the act of acquiring and erasing that information necessarily raises entropy in its environment, preserving the Second Law overall. The demon's **"torchlight"** must shine into the dark box to see fast molecules, thereby flooding the box with negentropy (light of low entropy) that later increases entropy when absorbed. What the demon illustrates metaphorically is that *information is physical*: closing informational distance has thermodynamic consequences.

Bridging this back to quantum measurement: when an apparatus measures a qubit, the apparatus must gain one qubit of information, and by Brillouin's principle it must expend at least an equivalent negentropy from its own free energy reservoir. The act of measurement correlates apparatus and qubit, reducing the qubit's entropy (from maximal superposition uncertainty to near-zero since the outcome is known) while increasing entropy in the joint apparatus-environment. A **high informational proximity** thus **forces the selection** of a definite outcome – the so-called "collapse" – because only definite outcomes can be consistently recorded in a classical memory (which the apparatus effectively is). If the apparatus tried to record a superposition, it would itself enter a superposed (and unstable) state. Stable records require that the possible outcomes decohere into distinct, non-interfering states of the apparatus. Hence informational proximity – making information *proximate* or available to other degrees of freedom – is the *cause*, and collapse (or decoherence) the **effect**.

We can think of **negentropy** (order, information) as a kind of "glue" that locks down one reality out of many. When a system is left to itself (maximum entropy from an external viewpoint), it can wander a superposition of many states. But when an **informational constraint** is applied – i.e. when we know something about it or it is correlated with something else – its freedom reduces. Gaining one bit of information is like narrowing the system to one of two possibilities. The extreme case: if we have enough information to predict the system's behavior with certainty (from our chosen observational basis), the system will appear to behave classically and deterministically. Indeed, a fully **deterministic classical trajectory** can be seen as one where at each moment, all relevant information is already known, so no surprises occur – essentially zero entropy from the observer's standpoint. *"Classical reality" can be viewed as the limit of infinite informational proximity.* Conversely, when informational proximity is low (a system is isolated and uncorrelated), its evolution appears reversible, spread-out, and nondeterministic to outsiders.

To summarize this principle: **a quantum system's potentialities become actualities in direct proportion to the information about them that enters the wider world**. By sharing information, systems reduce their mutual entropy and thereby constrain each other's states to particular combinations consistent with that information. This is how *informational proximity* bridges the gap from quantum possibility to classical reality: it is the *exchange of information* – the establishment of correlation – that selects a specific outcome and embeds it in the fabric of the larger world. Classical reality is, in a sense, the **network of mutual information** linking countless particles and fields into a coherent tapestry, where each part informs and constrains the others. The quantum fuzziness gets woven into a tight classical fabric by this sharing of bits.

This perspective prompts us to rethink what an **"observer"** really is. Not necessarily a conscious mind, but any system that *registers information*. A photographic plate observing electrons in a double-slit experiment is an "observer" because the electron's position gets imprinted as grain marks (information in the plate). Once those marks are made, the interference pattern is destroyed – the electron had to "choose" a slit, because the plate obtained that bit of which-slit information. Likewise, our conscious observation is a sophisticated example of information registration, with the key difference that it comes along with *experience*.

Having established how information underlies the transition from quantum to classical, we now turn to the realm of **life and mind** – where negentropy and information processing are central. Living systems are not passive observers; they are active participants in shaping reality. They *gather* information, *process* it with remarkable efficiency, and *use* it to maintain their internal order against the tide of entropy. Nowhere is the dance of entropy and information more evident than in biology and cognition. In the next sections, we will explore how **negentropy is the lifeblood of living systems**, how the brain implements an information-driven prediction machine guided by what Karl Friston calls the **Free Energy Principle**, and how our perceptual apparatus creates a stable, classical world from a barrage of ambiguous signals – effectively performing continuous "collapse" through active interpretation. This will set the stage to discuss how these processes relate to subjective consciousness and free will.

Negentropy, Life, and the Free Energy Principle

In 1944, in his famous book *What is Life?*, **Erwin Schrödinger** made a provocative observation: living organisms seem to **resist the Second Law of Thermodynamics** – they maintain and even increase local order despite the universal tendency toward disorder (entropy). He introduced the concept of **negative entropy** (which he nicknamed "negentropy") to describe what organisms feed upon. *"How does the living organism avoid decay?*" Schrödinger asked. His answer: *"By consuming negentropy."* In more concrete terms, organisms import organized energy (food, sunlight) and export entropy (waste heat) to keep their internal state highly ordered. Life is like a tiny **eddy** in the entropy cascade – a vortex that locally reverses the flow of disorder by pumping out entropy to the environment, creating a pocket of order within. As one commentary colorfully summarized: *living matter, Canute-like, for its lifetime, reverses the cosmic tide towards disorder*. (The reference is to King Canute, who in legend commanded the sea to halt – a metaphor for life's defiance of entropy's tide).

The **key to negentropy is homeostasis**. This insight comes from 19th-century physiologist Claude Bernard, who noted that higher organisms maintain a stable internal milieu (body temperature, chemical balance, etc.) despite changes in the external environment. Homeostasis is essentially an information-driven balancing act: sensors detect deviations, control mechanisms act to correct them. It is a prime example of using information (feedback) to maintain order. A thermostat in a room is a simple homeostatic device – it measures temperature and activates heating or cooling to hold the temperature near a setpoint. Organisms have countless such feedback loops. **Homeostasis and its more dynamic cousin allostasis** (achieving stability through change) **"resist the forces of entropy"** to keep the system within viable bounds. Every boundary of an organism – cell membranes, skin, even the ephemeral boundary between self and environment – serves to locally segregate and regulate information and energy flow. In doing so, living systems continuously **import negentropy**. For instance, plants absorb highly ordered energy from sunlight (low entropy photons) and create sugars – storing negentropy in chemical form. Animals eat those sugars (or plants) and use the free energy to build complex structures (proteins, DNA) and to perform work, all the while dumping low-grade heat to the surroundings.

From a thermodynamic perspective, **life is an island of negentropy** sustained by a constant throughput of energy. But how exactly do organisms *use* negentropy to such stunning effect – building the intricate architecture of cells, the ultra-low-entropy information molecule DNA (which can preserve a high-fidelity blueprint for millions of years), and the highly ordered firing patterns in a brain? The answer lies in the **processing of information**. Organisms don't just passively receive negentropy; they actively **organize it**, channeling it into functional structure. This is where **cognition** enters the picture.

The brain is often dubbed an "entropy pump" or an "inference engine." The emerging view in neuroscience, crystallized by **Karl Friston's Free Energy Principle (FEP)**, is that the brain's overarching function is to minimize surprise – effectively to minimize entropy in its internal states by improving its predictions about the world. Friston's theory is steeped in both information theory and thermodynamics, hence the name "free energy," which in this context relates to information (technically a variational free energy bound on surprise). Friston was inspired by predecessors including Schrödinger himself, Hermann von Helmholtz (who saw perception as unconscious inference), Claude Shannon (information theory), and the tradition of cybernetics and control theory. His stroke of insight was to see that *the same negentropic, homeostatic principle that keeps the body in balance might also explain the brain's cognitive function*. The brain, in Friston's words, **"counteracts entropy"** to maintain the organism's integrity and goals. It does so by constantly aligning its internal models (beliefs about the world) with the incoming sensory data, in order to reduce the *mismatch* between expectation and reality.

Let's break down the Free Energy Principle in simpler terms. The brain faces an inferential challenge: it must figure out the hidden causes of its sensory inputs. At any given moment, a flood of signals bombard our senses – photons on the retina, pressure waves in the ear, chemicals in the nose, etc. These signals are *ambiguous* and noisy on their own (high entropy). Yet we reliably make sense of them: we see a coherent world of objects, hear meaningful sounds (like speech or music), and so forth. According to FEP, the brain achieves this by operating as a **Bayesian prediction machine**. It carries an internal **model** (a set of hypotheses) about the causes of sensations, built from prior experience. It continuously *predicts* what it should be sensing and compares this to actual input. The difference – the **prediction error** or "surprise" – is then used to update the model (learning) or, interestingly, to drive actions that change the sensory input to better match the prediction (active control). The brain's imperative is to **minimize prediction error** over time. By doing so, it minimizes the *uncertainty* (surprisal) it experiences. In information terms, surprise is just the negative log probability of an event – high surprise means "I didn't expect that." The brain tries to engineer a situation where, as much as possible, it *did* expect what's happening, i.e. it's not surprised.

To connect this to negentropy: **surprise or prediction error can be seen as a form of entropy (uncertainty) the brain wants to reduce**. Friston's *free energy* is essentially an upper bound on surprise – a measure that the brain can calculate and minimize. When the brain improves its model such that it accurately anticipates sensory inputs, it has effectively gained information (negentropy) about its environment and itself. A perfectly predictable sensation would carry no surprise, implying the brain's model already contained that information (maximally ordered knowledge). The brain's quest to reduce prediction error is thus a quest to accumulate negentropy in its models – to build structure in its understanding. This is reminiscent of the slogan from the Fristonian model: *"the brain's aim is constantly to reduce informational entropy and maximize meaning."*. Indeed, as one paper puts it, the brain filters the torrent of sensory data for *"the 'meaning' of its sensations, attending only to those that are relevant... and especially to input that is anomalous or novel."*. Noise – being patternless and high entropy – is ignored, whereas structured signals (like language, which is highly ordered and thus negentropic) carry meaning and are preferentially processed.

The Free Energy Principle provides a unifying framework: *Perception, learning, and action* all emerge as processes to **minimize free energy (surprise)**. In perception, the brain revises its *beliefs* (neural parameters) to better predict sensory input – this is akin to performing Bayesian inference (updating a prior with evidence). In action, the brain can also minimize surprise by changing the world state to better fit its predictions (e.g. if I predict that my hand will grasp an apple, I can reduce the surprise of not having the apple in hand by reaching out and *grasping it*, making the prediction come true). This two-way street – either change your mind or change the world – optimizes alignment between inside and outside. Both routes increase information overlap between brain and environment, effectively increasing their mutual information and reducing entropy. This casts the organism as an **active agent** of negentropy: it doesn't just passively receive data; it probes, tests hypotheses, and seeks out informative stimuli (or avoids overly surprising, potentially dangerous ones), all in service of keeping its internal state within tight bounds.

Mathematically, the Free Energy Principle relates to well-known quantities: it formalizes how **variational free energy** (a construct borrowed from statistical mechanics) is minimized when the brain's internal model (the "recognition density") approximates the true environmental causes. In doing so, the Kullback-Leibler divergence (information distance) between the brain's expectations and reality is minimized. In less technical terms, *the brain becomes an increasingly faithful mirror of causal structure in the world*, which is another way of saying it gains knowledge (negentropy). It also resonates with the principle of **maximum entropy** in statistical physics (choose the least-informative distribution consistent with constraints) but inverted: the brain is continually imposing *informational constraints* (its learned models) on incoming data to reduce entropy in its representation.

A beautiful consequence of FEP is that it ties life and cognition to fundamental physical principles. Some have gone so far as to call it a potential "Theory of Everything" for biology, since it says any system that manages to exist as an independent entity must obey a form of this principle (otherwise it would dissolve under entropy). There is debate and some skepticism about such grand claims, but at the very least, FEP provides a powerful metaphor: *living organisms are prediction-error-minimizing machines that harvest negentropy*. They maintain their **Markov blankets** – the informational boundaries that separate them from the environment – by constantly exchanging signals across that boundary in a way that keeps internal entropy low. If they did not, random environmental fluctuations would perturb them towards disorganization and death.

In practical terms, **Friston's principle recapitulates Schrödinger's insight**: the brain (and body) keep entropy at bay by being proactive. As the Cambridge psychiatrist Philip Gerrans summarized, *"the brain's job is to counteract entropy and maintain internal stability on behalf of the organism"*. It does so by a sort of perpetual information warfare against uncertainty – a continual filtering, learning, and acting to secure its niche. The reward for success is **homeostatic balance** (no surprise, no excessive physiological stress) and effective function; the penalty for failure is surprise, which can signal danger or prediction breakdown. Emotions even emerge from this dynamic: **free energy is aversive – it feels like mental pain – whereas reducing free energy (resolving uncertainty) is rewarding**. This aligns with our intuitions: we dislike being confused (high uncertainty) and we feel satisfaction when things make sense or when we gain knowledge.

Thus, **negentropy is not just an abstract thermodynamic quantity; it is deeply woven into the fabric of life and mind**. A living cell's molecular engines (like the ATP synthase in mitochondria) literally convert negentropy into useful work. A brain's neural networks convert sensory entropy into meaningful information (percepts, concepts) by sculpting neural connectivity (synapses) to reflect statistical regularities of the world. In doing so, the brain builds an **internal model** – effectively a compressive encoding of the environment that captures its key structures (and compression is all about removing entropy by exploiting patterns). As Gregory Bateson quipped, information is **"a difference that makes a difference"**; the brain strives to latch onto the differences in sensory input that *matter*, that carry structure (like the letter "X" in Scrabble conveys more information than "E" because it's rarer). It discards random noise that carries no actionable difference (hence white noise is experienced as meaningless hiss, whereas a voice or melody stands out as *negentropic* signal).

Having explored how organisms, especially brains, are engines of negentropy and information, we are prepared to examine how **cognition and perception** specifically create the *experienced* classical world. Our senses and brain together form a **perceptual apparatus** that acts as a bridge from raw physical signals to the rich, structured world of our awareness. This bridge operates by leveraging limited **resolution** and targeted **attention** – effectively simplifying and collapsing the torrent of sensory possibilities into a coherent, stable picture. We shall see that the very limitations of our perception (its finite granularity and scope) are what allow a stable classical reality to emerge for us. By filtering out quantum-level noise and by focusing on macro-scale structure, our cognition ensures that we perceive a world of objects and causes, not quantum wavefunctions. In the next section, we delve into **cognitive resolution** and how **perception at the classical limit** is achieved.

Cognitive Resolution: Perception at the Classical Limit

Human perception is remarkably **granular and coarse-grained**. We do not directly see individual photons or air molecules; instead, we see averaged quantities like brightness and color, we hear aggregated vibrations as tones, and we feel collections of molecules as a continuous texture or temperature. This limited **sensory resolution** is not a flaw but a feature that has evolved – it allows us to filter out irrelevant micro-variations and focus on stable patterns relevant to survival. In essence, our perceptual system performs an automatic **coarse-graining of reality**, very much analogous to how macroscopic measurements average over microscopic states. By doing so, it naturally yields a **classical picture** of the world.

Recall the observation from earlier: a macroscopic object's quantum uncertainties are typically far too small to notice. Our senses amplify this effect. For example, the eye's retina has photoreceptor cells that catch individual photons, but the signals are pooled and processed by neural circuits such that what reaches conscious vision is an integration over many photons – enough that statistical fluctuations (shot noise) are suppressed under normal lighting. Only under extreme low-light conditions might one occasionally experience the randomness of single-photon detection (as faint twinkles in the dark). Similarly, our tactile sense cannot feel atomic-scale jitters; it responds to collective pressure over many receptors. By having a **limited sensitivity and bandwidth**, perception inherently filters out quantum-level phenomena. As the *Information Philosopher* noted, *"macroscopic objects are quantum objects, but the uncertainty in their properties is not detectable by our instruments"*, so *"the classical laws appear to apply perfectly"*. Our brain and senses *are* such instruments – evolved to ignore microscopic uncertainty and treat things as having definite positions, shapes, and trajectories whenever possible.

This cognitive coarse-graining aligns with the concept of **adequate determinism**. The world we perceive is "adequately deterministic" – planets follow orbits, rocks fall predictably, and cats in boxes are either alive or dead, with such reliability that we base our lives on these expectations. Small random deviations exist, but they fall below our threshold of notice or significance. When uncertainties occasionally *do* impinge on our scale – say, the chaotic flutter of a leaf in the breeze or the random crackle of a Geiger counter – we interpret them as *random noise on a stable background*, not a fundamental breakdown of causality. In our mental model, we distinguish signal from noise, the former we attribute to concrete causes and the latter we often relegate to "chance." This mindset itself is a manifestation of how our cognition erects a mostly deterministic classical narrative on top of an indeterministic substrate.

Attention further refines this process. Our brain does not process every bit of sensory data uniformly; it **selects**. We deploy attention to particular aspects of the environment, effectively increasing the *resolution* or *gain* on those aspects while ignoring others. Attention is often drawn to **surprising, novel, or salient** stimuli – an evolutionary strategy to detect the unexpected (which could be threat or opportunity). In doing so, attention is following an **informational gradient**: it moves from areas of lower information (predictable, boring background) toward areas of higher information (where something deviates from expectations). This is precisely what the free energy principle would predict – we sample where prediction error is high so we can resolve it. Psychologically, when something "catches your eye," it is typically because it was statistically improbable given the context (hence informative). By reallocating processing resources to that stimulus, the brain attempts to quickly reduce the uncertainty it poses (figure out what it is, why it's there). This is an active **collapse of ambiguity** in the perceptual field. For example, if you hear a faint rustle in the bushes (unexpected noise), your attention zooms in; you might turn your head (action to get more sensory data) and visually inspect. In so doing, you convert a vague possibility ("Maybe something is there?") into a concrete perception ("Ah, it's just the wind moving leaves" or "It's a cat"). The process of attending and resolving the source is essentially a microcosm of the measurement process: by focusing, you **increase informational proximity** to the stimulus – more photons from that location hit your fovea, more auditory neurons lock onto that frequency – and soon the uncertainty collapses into a recognized object or event.

Neuroscience shows that attention can be modeled as tuning the "precision" of certain sensory channels (like increasing the signal-to-noise ratio for expected inputs). This selective enhancement is like steepening the informational gradient: the brain makes it easier to extract clear information from the attended source, effectively speeding up the reduction of entropy. In a way, attention is **directed negentropy** – a beam of mental energy that decreases uncertainty where it is pointed, much as a flashlight (to reuse Brillouin's demon's analogy) locally reduces darkness (uncertainty about what's there) at the cost of expending battery energy (increasing entropy elsewhere). The spotlight of attention brings clarity (order) to whatever falls within its beam.

Our cognitive limitations also manifest in phenomena like **change blindness** – we can miss even large changes in a scene if our attention isn't directed properly. This indicates the brain does not build a fully detailed, high-resolution model of the entire visual field at all times – that would be inefficient and unnecessary. Instead, it holds a **sparse sketch** plus focused high-resolution patches at points of interest. This strategy itself is a kind of controlled negentropy allocation: we *spend* our limited processing bits where they matter most for the task at hand. The rest remains in a low-information state until needed.

Another way our perception "chooses" reality is through **multistable illusions** (like the Necker cube or Rubin's vase/face illusion). In such cases, the sensory input is consistent with more than one plausible interpretation (multiple "stable" states of perception). Our mind will settle on one interpretation at a time – you either see the vase or the two faces, but not both simultaneously. After a while, it may spontaneously flip to the other interpretation. This is analogous to a small-scale, entirely cognitive collapse of a superposition of perceptual hypotheses. Both interpretations are in some sense present (the brain's visual areas oscillate between two attractor states), but awareness snaps to one, giving a definite experience. We can't see an ambiguous figure as both things at once, just as in quantum measurement we don't perceive a superposition outcome even if, theoretically, the wavefunction had multiple components. The cause in perception is the brain's constraint of **consistency** – it enforces that at any given moment, there is a single coherent interpretation of the scene in consciousness (even if lower levels briefly entertain mixtures). This coherence reflects the brain's bias towards **order and simplicity**: it picks one stable gestalt to avoid the "entropy" of indecision or confusion. The result is a phenomenological collapse: out of many potential qualia, one is realized.

Imagination adds another layer to this. We are not purely passive receivers of sensory information; we actively generate mental representations. Consider the act of **mental rotation** or what we can term "imaginal rotations." This refers to our ability to manipulate mental images as if they were physical objects. In classic experiments by Shepard and Metzler (1971), subjects were shown two 3D shapes and asked whether one is a rotated version of the other. The response times increased linearly with the angular difference between the shapes, as if people were *literally mentally rotating* one shape until it aligned with the other [2] [3]. These findings strongly suggest that the brain uses an analogical, spatial representation in imagination, not just abstract reasoning. Essentially, the mind can simulate an alternate state of the world internally. This ability has huge implications: it means we can **reduce uncertainty by internal trial and error** without physically acting. For example, if you're trying to fit a new couch through a door, you might mentally simulate different angles rather than actually wrestling the couch repeatedly. Imagination thus creates an **informational virtual space** where possibilities can be explored safely and efficiently.

From the perspective of informational proximity, imagination is a way of bringing hypothetical states *informationally closer* to current knowledge. By simulating the outcome of an action or the appearance of an object from another angle, the brain is effectively generating information that it doesn't currently have from the senses but can infer from memory and reasoning. This fills in gaps and helps collapse uncertainty about what would happen *if*. Athletes use mental practice to improve performance – the imagined movements share neural circuits with actual movements, tightening the brain's predictions. Likewise, scientific creativity often involves thought experiments – Einstein imagining riding on a beam of light – which are essentially pushing the mind into a hypothetical scenario to glean insights (information) that inform real-world expectations. Imagination leverages stored negentropy (knowledge of how things work) to project possible states and then inspects them for consistency or desirability. It's an internalized form of experiment, cheaper than real experiments in terms of energy and risk.

Crucially, imagination and attention work together. We direct our "mind's eye" (attentional resources) to aspects of an imagined scenario just as we would to the external world. The brain may even blur the line between perceiving and imagining: similar neural networks activate when seeing an object and when vividly imagining it. This has led to theories that **perception itself is a controlled hallucination** – as the predictive coding framework suggests, the brain is always generating predictions (hallucinations) and sensory data just corrects those predictions. In that light, what we call reality is the brain's best guess, sharpened by just enough sensory evidence to keep it tied down. Too little sensory constraint (like in sensory deprivation or certain drug states) and the brain's intrinsic activity may run free, producing full hallucinations (unrestrained predictions). Too much constraint (like an overwhelming unfamiliar stimulus) and the brain scrambles to fit a model, resulting in confusion until learning occurs. Normally, there's a balance: the brain's internal model (negentropic structure) molds our perception, while the senses ensure we don't drift into fantasy, by providing error signals that yank perceptions back to what's externally consistent. In this interplay, **the world we experience is partly a *construction* (informed by memory and expectation) and**

partly a *discovery* (driven by sensory data), with attention mediating where construction vs. discovery dominates.

Let's illustrate with a familiar example: reading. When you read a sentence, you are not scrutinizing each letter; your eyes jump in saccades and your brain predicts many words from context. You can read words even with jumbled letters (as long as first and last letters are correct) because your cognition fills in likely letters. You might not notice a typo if it doesn't violate your expectation strongly. In essence, you hallucinate the correct spelling via top-down expectation and only if there's a glaring error (bottom-up surprise) do you become aware and actually analyze each letter. This shows how perception is **actively confirming predictions** rather than passively absorbing data. Through such mechanisms, cognition assures that our experience of reality is stable, continuous, and meaningful – it spackles over gaps and erases noise.

So far, we have seen that our cognitive apparatus ensures that the **world as experienced** is a highly ordered, low-entropy interpretation of incoming data. We've likened this to how decoherence enforces classicality in physics – in both cases, underlying uncertainty is projected into definite states by coupling to a larger system (environment or brain's knowledge). At this point, we can appreciate a profound unity: **the emergence of classical determinism in the physical world and the creation of a stable perceived reality in the mind are parallel processes governed by the flow of information (negentropy).** In the physical case, it's the environment's information that selects outcomes; in the mental case, it's the brain's internal information (plus continuous sensory updates) that selects an interpretation of the world.

With this understanding, we venture into the final frontier: **subjective experience itself**. It's one thing to have a functional description of how information shapes reality, but why and how do we *feel* anything as a result? Why is there a first-person perspective at all – the domain of qualia and consciousness – when we could, in principle, imagine a very sophisticated philosophical zombie that processes information and acts adaptively with no inner life? This is the famously thorny *hard problem of consciousness*. Furthermore, do our information-driven models leave any room for **free will**? If our choices are the result of neurons firing according to predictive algorithms or random quantum states decohering in our brains, where is *volition*? In the final section, we will connect our informational perspective to these existential questions. We will examine how **consciousness might be related to the collapse of uncertainty** and what freedom means in a world governed by entropy and information.

Subjective Experience and Free Will in an Informational Universe

Our journey so far has painted a picture of reality as an interplay between entropy and information, chance and constraint. We've described how the physical world's ambiguity is tamed by informational exchanges and how the brain mirrors this by shaping a coherent perceptual reality. Yet, an explanatory gap remains: *why does information processing feel like something from the inside?* This is the essence of the **hard problem of consciousness** – explaining why certain physical processes (like brain activity) have an associated subjective experience. While a complete solution to this problem remains elusive (and is beyond the scope of any single theory here), our negentropic framework offers some tantalizing clues and directions.

One possibility is that **consciousness is deeply linked to information integration**. The brain doesn't just process information in isolated streams; it binds them together into a unified experience. Neuroscientist Giulio Tononi's **Integrated Information Theory (IIT)** posits that consciousness corresponds to the amount of *integrated information* (denoted as Φ) in a system. In plain terms, for a system to have subjective experience, it must be a single entity with a repertoire of highly differentiated states that are also highly interdependent (integrated). The human brain, with its billions of neurons forming a complex web of connections, is posited to have a high Φ value – meaning it's a single system that encodes a vast amount of information not decomposable into independent parts. This aligns with our narrative: the brain at any moment holds a **complex state of negentropy** (low entropy, high information structure) that represents both our perception of the external world and our internal milieu. Consciousness could be the "feel" of that state from the inside – the **qualia** being specific informational states or transitions.

In an informational universe, one might speculate that whenever information becomes self-referential and richly integrated, it develops a point of view. This is admittedly speculative, but consider: our brain models not just the outer world but also the self within it. We have information about our own body, our own thoughts (to some extent), and we can even reflect on our reflections – a recursive loop. Perhaps *subjectivity* arises precisely in such self-referential informational loops, where the system perceives its own state as part of the world. This could resonate with the idea that consciousness is an emergent property of certain complex, negentropic systems that can model themselves. In that sense, consciousness might be the ultimate **collapse of uncertainty**, where a system not only reduces external entropy but also illuminates itself – achieving a kind of "self-measurement." Philosopher Thomas Metzinger suggests there is a *transparent self-model* in the brain that we don't recognize as a model; we just experience it as "I." When the brain's informational processes become sufficiently proximate to themselves – when the informational distance between representer and represented closes – the result may be the immediate presence we call conscious experience.

Another intriguing angle is the role of **quantum processes in consciousness**. This is controversial, but worth noting given our theme. One theory by Roger Penrose and Stuart Hameroff (Orch-OR, Orchestrated Objective Reduction) proposes that microtubules in neurons could support delicate quantum states that collapse in a controlled way, somehow correlating with moments of conscious awareness. They argue that each collapse (objective reduction) might be linked to a conscious "moment," injecting a non-computable element into brain processing that could be tied to **free will**. In essence, they bring the collapse of the wavefunction (quantum uncertainty resolving) into the neuron as a causal factor for decisions. If such ideas were true (the jury is still out, and many neuroscientists remain skeptical), it would mean that **conscious free will operates at the edge of informational uncertainty**, at the bridge between quantum possibilities and classical neural actions. Each conscious choice could literally be the selection of one reality out of a quantum superposition, steered by an interplay of mass-protein states in microtubules and fundamental spacetime thresholds. This is a bold and speculative vision, but it poetically fits our narrative: our minds might be exploiting quantum negentropy (temporal non-locality and genuine indeterminism) to produce meaningful, volitional acts that are not mere algorithmic outputs.

Even setting aside specific quantum brain theories, our informational framework naturally accommodates a form of **free will** that is neither absolute nor illusory, but emergent and context-dependent. Classical physics seemed to doom free will – if the universe were a deterministic machine, then every choice we make was set in motion at the Big Bang, and our feeling of choosing is just ignorance of prior causes. Quantum physics, by introducing true randomness, undercuts strict determinism, but randomness by itself is not *will* – a random choice is the opposite of an intentional one. The challenge has been: how to reconcile *neither* strict determinism *nor* pure randomness with the notion of agency?

Our exploration suggests an answer: **self-organizing negentropic systems (like brains) exploit indeterminism while harnessing structure to produce choice**. In other words, the brain is not a simple billiard ball system nor a quantum roulette; it's a complex adaptive system that can amplify minute fluctuations in a controlled way, funneling them through the constraints of goals, values, and learned information. *Free will, in this view, is the capacity of an information-driven system to make decisions that are neither predetermined nor acausal, but rather self-determined.* The system's *self* – encoded in its integrated information, memories, desires – provides a boundary condition that shapes outcomes without rigidly fixing them. The ever-present stochasticity in neural processes (from ion channel noise to potentially even quantum noise) ensures that behavior is not absolutely pre-scripted; there is always a distribution of possible actions. But the brain's negentropic models (its predictions, plans, and preferences) bias this distribution heavily towards certain outcomes – those that serve its perceived goals or make sense in light of its prior knowledge. Thus, when *I* make a decision, it is neither arbitrary nor pre-ordained by external factors alone: it's constrained by my character and reasoning (informational structure), yet flexible enough to be *adaptive* and *creative* because it's not purely mechanistic.

This aligns with the perspective from **information philosophy**: *"the classical problem of reconciling free will with physical determinism is now seen to be the wrong problem. The real problem is reconciling free will with indeterminism."*. They point out that while the atomic world is fundamentally undetermined, macroscopic structures (including organisms) have found ways to **overcome chaotic randomness and create stable, information-rich structures** [4] . Life's creativity – evolution itself – leveraged random mutations (quantum accidents in DNA) filtered by selection to produce organisms of great complexity and apparent purpose. Similarly, one might say each individual leverages micro-level unpredictability filtered through their mind's value structure to produce *willful actions*. We are, in a sense, **self-programming beings**: not free from causality, but *free to set our own goals* (within biological and physical limits) and to pursue them in ways not strictly imposed from outside. The "freedom" here is the wriggle room provided by indeterminism, elevated and directed by knowledge (negentropy). As one analogy: think of improvisational jazz. The musicians have a guiding structure (key, tempo, theme) but within that, they spontaneously create. Their choices are not random (they follow aesthetic intent and skill) yet not pre-scripted. Likewise, our **will** operates within the constraints of who we are (which is an accumulation of negentropy/information and physical structure) but is not a playback of a fixed script.

Crucially, **free will might also involve the ability to *not* act on impulse – to negate or veto**. Neuroscience experiments by Benjamin Libet famously found that a readiness potential in the brain precedes conscious awareness of a decision to move by a fraction of a second. Some interpret this as conscious will being an illusion (the unconscious brain "decided" and then the conscious mind only later thinks it decided). However, Libet himself noted that subjects seemed to have the ability to veto a pending action in the last moments ("free won't"). This suggests consciousness might play a role in inhibiting or permitting actions initiated by subpersonal processes, rather than initiating every action from scratch. In terms of information, the conscious self – loaded with integrated knowledge of long-term goals and social rules – can suppress a prepotent response that would be counter to those goals. For instance, your reflex might be to respond angrily to an insult (subcortical systems may start a cascade to shout), but your conscious self might quash that impulse upon reflection. That veto is an exercise of free will, aligning action with higher-order information (values, plans) rather than immediate deterministic reaction.

Ultimately, our framework sees **negentropy (information)** as the enabler of freedom: the more information an agent has about the world and itself, the more it can anticipate consequences and thus choose among alternatives. A simple organism with little information (only reflexes) has effectively no freedom – it reacts deterministically or randomly. A highly informed, self-aware organism can foresee outcomes and steer between them – it has a larger **space of possibilities** it can navigate. Free will, then, is not absolute freedom from cause, but the *freedom of a system to utilize cause and chance to pursue its own* *informatically defined objectives*. We are free because we are **participatory agents in the cosmos's unfolding**, not just passive pieces. In John Wheeler's words, *"this is a participatory universe"*, where *"all things physical are information-theoretic in origin"*. We, as observers and choosers, are part of the mechanism by which reality comes into being. Wheeler's aphorism **"it from bit"** captures this: every "it" (entity, event) fundamentally comes from a "bit" of information – a distinction made, an observation noted. And because we are information processors par excellence, our observations and decisions (our extracted and enacted bits) literally shape which branch of reality is realized out of the many possible.

The implications of this worldview are profound. It suggests a cosmos in which **meaning and matter are intertwined**. The growth of negentropy – whether in the formation of stars and planets, or in the evolution of life and intelligence – is not an incidental byproduct but central to the story of the universe. Each new layer of informational complexity (atoms forming molecules, molecules forming cells, cells forming brains, brains forming societies and knowledge systems) adds new degrees of freedom and new modes of influencing outcomes. With humans (and potentially other intelligent life), the universe achieves a form of self-reflection and deliberate creativity. We collapse quantum wavefunctions in our labs and daily life; we collapse conceptual uncertainties in our thoughts; we invent tools and arts, thereby imposing novel order on the world. In doing so, we *increase the negentropy* locally – building cities, technologies, libraries of knowledge – even as we must pay an entropy cost (using energy, producing waste heat). There is an almost moral or existential dimension: as beings of negentropy, our role could be seen as *local entropy fighters*, islands of order that temporarily hold back the night of chaos. We cannot violate the Second Law globally, but we can carve out niches of increasing complexity and order, for a while.

Subjective experience is the bright flame accompanying this process, perhaps an emergent glow whenever information is organized in the special way brains do. And **free will** is the ability of these flames to dance in novel patterns, not entirely dictated by the fuel or the drafts, but shaped by an internal spark. In a way, life and mind are the universe's method of exploring possibility spaces that raw physics alone might take eons to stumble upon.

To be clear, much remains mysterious. We have not answered exactly how or why *this* particular integrated information yields the redness of red or the pain of pain. But our narrative reinforces that whatever consciousness is, it is intimately bound up with *information flow and collapse*. Perhaps consciousness *just is* what it's like to be a system that's actively minimizing its entropy relative to the world – *what it's like to be a negentropic eddy in the river of increasing entropy*. And perhaps free will is what it *feels like* for such a system to harness genuine causal ambiguity (like quantum indeterminism or chaotic dynamics) in the service of its own internally defined ends.

Conclusion

We have journeyed from the subatomic realm to the mind's inner workings, guided by a unifying idea: **informational proximity** – the closeness or coupling in terms of information – explains how the nebulous **quantum potential** we cannot directly see turns into the concrete **classical reality** we do see. In the quantum world, particles exist in blurred overlaps of possibility; in the classical world, those possibilities narrow to a single actuality. The narrowing, we argued, is driven by **information exchange**: as soon as a particle interacts with something else, it sheds some ambiguity, aligning with a definite state relative to that something. Entanglement and environment-induced decoherence show us that the act of recording information (even if by an unconscious environment) is tantamount to choosing a reality. The coin of this process is **negentropy** – each bit of information gained about a system reduces its entropy, sculpting order out of chaos. Thus the **bridge from quantum to classical is built on information**: every classical fact is like a hardened cement that was once wet quantum possibilities, solidified by the drying agent of information flow.

Climbing up from physics to life, we found the same principles at play in new forms. **Living systems** persist by continuously taking in negentropy (through food, sunlight) and expelling entropy, a process tightly controlled by informational feedback loops (homeostasis). The **brain**, the most complex negentropic structure we know, uses a strategy of **predictive coding** to stay one step ahead of entropy – it models its world and acts to minimize surprises. The **Free Energy Principle** gave us a rigorous lens: it is mathematically mandated (in theory) that any system which maintains its order must act as if it's minimizing a free-energy information metric. This throws a bridge between **biology and physics**: just as a rock finds a minimal energy state when it settles at the bottom of a hill (principle of least action), a brain finds a minimal "surprisal" state by adjusting to its environment. The difference is, the rock's principle is passive and without awareness, whereas the brain's is active and accompanied by awareness.

Crucially, our exploration emphasized the role of **cognition and perception in shaping reality as experienced**. We saw that our perceptual apparatus filters and resolves the world, akin to a measuring instrument that enforces classicality. The brain's limited resolution washes out quantum randomness and amplifies stable patterns. Our **attention** zeroes in on the unexpected and unresolved, collapsing ambiguities into knowledge. Our **imagination** rotates and explores possible states, effectively performing internal experiments to guide external actions. In short, **the mind is a co-author of the reality it experiences**: not in the solipsistic sense of creating the physical world from nothing, but in the participatory sense that it selects, interprets, and even intervenes in outcomes. Every observation we make and every action we take is a moment where the space of possibilities is narrowed. When you decide to measure one property of a system, you necessarily blur out another (by uncertainty relations) – you've shaped reality's course. When you decide a course for your life, you collapse myriad alternate paths into the one you enact.

It is awe-inspiring to recognize that, in this view, **conscious observers are not just insignificant bystanders in the cosmos but fundamental agents of its unfolding**. Each sentient being is a locus where entropy is locally beaten back, where information grows, and where new causal chains originate. We are **localized negentropy engines** – each of us is an improbable pocket of order that has learned to perpetuate and extend that order. With our technology and culture (both embodiments of information), we have magnified our reach: we can affect the environment on planetary scales, for better or worse. In doing so, we literally rearrange the classical world; and as our measurements delve into the quantum realm (think of particle colliders or quantum computing experiments), we even directly shape quantum outcomes.

Looking back at Schrödinger's cat, we might say: the cat was never *both alive and dead for itself* – if it had consciousness, from its frame it always experienced one outcome (assuming any collapse or decoherence had happened from its perspective). It's only an outside perspective lacking information that describes it as a superposition. This underscores that **information is relative**: what looks like a superposition to an ignorant observer is in fact a definite reality to an informed one. Reality thus **unfolds in layers**, depending on informational vantage. Our Negentropic Series argument is that one can **peel away those layers by increasing informational proximity** – by entangling with the system of interest – until at the limit, the phenomenon is fully observed and becomes an objective fact in our classical world. Conversely, uncertainty reigns where information does not reach.

In closing, we return to John Wheeler's evocative phrase: *"It from bit."* Everything we call a thing, an event, an object ("it") arises from acts of discernment, choices, bits of information. And we live in a **"participatory universe"** – meaning that by our observations and actions (our bits), we participate in the very existence of the "its." The classical reality, with its moons, apples, and cats, exists as it does because countless interactions (measurements in a broad sense) have woven a stable consensus of information. The quantum substrate provides the potential, the canvas of possibility; information provides the outline that becomes the drawing.

Our consciousness, riding atop this vast informational edifice, experiences a world of its own making and not of its own making – a paradoxical duality. We did not create the sun or the stars, but by observing them, by understanding them, we have *brought them into our experiential reality*, given them meaning and context that did not exist before minds. The **negentropy of cognition** is arguably as significant a cosmic development as the negentropy of stars (which create elements) or of DNA (which creates organisms). With cognition, the universe gained eyes to see itself and a will to influence itself.

Free will, then, might be seen as the universe's way of introducing *choice* into its course – not magic, not violation of physics, but an outcome of the complexity physics allowed. Just as random quantum fluctuations were essential for the richness of evolution (introducing variation and novelty), informed choices by intelligent agents add a new layer of "variation" – directed variation, intentional action – which can steer outcomes in non-random but also non-predetermined ways. We are both bound by natural laws and, within those bounds, able to create new patterns (art, science, ethical decisions) that are not compelled by mere survival or chemistry but by *ideas*. Ideas themselves are structures of negentropy that can propagate (memes, knowledge) and alter the world physically (when implemented as technology or behavior).

In sum, **informational proximity and negentropy provide a conceptual arc that links the microworld to the human world**. They explain how definite reality emerges from possibility, how life and mind sustain themselves and make sense of things, and they hint at how mind might affect matter in turn. By expanding on these connections, we get not only explanatory power but a sense of *wonder*: we come to see ourselves – conscious, choosing beings – as integral threads in the grand tapestry of reality, a tapestry woven from the interplay of entropy and information. The hard problem of consciousness and the riddle of free will are not solved in a fell swoop here, but they are contextualized: consciousness is the flower of a negentropic process billions of years in the making, and free will is the fruit of that flower – the ability of the universe, through us, to reflect and act upon itself.

The **Negentropic Series** will continue to probe these themes, but with this White Paper, we have established a foundation. Classical determinism is an emergent property – *a shadow cast by deeper informational processes*. Quantum uncertainty, far from being an abstract quirk, is the wellspring of both randomness and flexibility that make novelty possible. Informational proximity is the bridge that solidifies one path out of many. Friston's principle shows that even in the wilds of biology, there is a drive to tame surprise – nature abhors an information vacuum much as it abhors an energy vacuum. And the human mind stands as a testament to how sublime the results of negentropy can be: it can question its own existence and, as we have done here, trace the **arc from atom to awareness**.

To close with a poetic reflection: We exist in the **interface between the quantum and the classical**, between chaos and order, between ignorance and knowledge. In that interface, *information is alchemy*. It transforms the possible into the actual. It is the **negentropic force** that carves out oases of meaning in a desert of chance. And each of us, by the simple act of observing, thinking, and choosing, is practicing this quiet alchemy – turning bits into its, and in so doing, participating in the perpetual dawn of reality.

References (selected and cited in text):

- Schrödinger, E. (1944). *What is Life?* (introducing negentropy in organisms).
- Zurek, W. (2003). *Decoherence, einselection, and the quantum origins of the classical*. Rev. Mod. Phys. 75, 715-775. (on decoherence and pointer states).
- Zeh, H. D. (1970). *On the interpretation of measurement in quantum theory*. Foundations of Physics, 1(1), 69-76. (early decoherence theory).
- Brillouin, L. (1956). *Science and Information Theory*. (coining “Negentropy Principle of Information”).
- Friston, K. (2010). *The free-energy principle: a unified brain theory?* Nature Reviews Neuroscience, 11(2), 127-138. (overview of FEP and brain).
- Gerrans, P. (2020). *Friston’s Free Energy Principle and psychology*. (discusses negentropy, homeostasis in FEP context).
- Shepard, R. & Metzler, J. (1971). *Mental rotation of three-dimensional objects*. Science, 171(3972), 701-703. (classic study on imaginal rotation showing linear increase in time with angle) [2] .
- Wheeler, J. A. (1990). *Information, physics, quantum: The search for links*. *Proceedings III International Symposium on Foundations of Quantum Mechanics*. (Wheeler’s “It from Bit” and participatory universe).
- Tononi, G. (2008). *Consciousness as Integrated Information: a provisional manifesto*. Biol. Bull. 215, 216-242. (Integrated Information Theory, Φ).
- Hameroff, S., & Penrose, R. (2014). *Consciousness in the universe: A review of the 'Orch OR' theory*. Physics of Life Reviews, 11(1), 39-78. (quantum collapse in microtubules tied to consciousness and free will).

---

[1] The Quantum to Classical Transition
https://www.informationphilosopher.com/introduction/physics/quantum_to_classical.html

[2] [3] Mental Imagery > Mental Rotation (Stanford Encyclopedia of Philosophy/Summer 2020 Edition)
https://plato.stanford.edu/archIves/sum2020/entries/mental-imagery/mental-rotation.html

[4] The Physics of Free Will
https://www.informationphilosopher.com/freedom/physics/