

Can the line between Science and Metaphysics move?

- 1.1. By performing experiments, we can only access relations: we measure lengths and masses by comparing them with other lengths and masses designated arbitrarily as units, we count what goes into an interaction and what goes out, and we express the results numerically.
- 1.2. When developing theories, we organize these relational patterns into structures. We postulate *dynamical laws* to describe how structures change, extending the structures across time.
- 1.3. We try to guess what structure matches the relations obtained from experiments, then we derive new relations from the structure, and we make new experiments to verify these predictions. When a theoretical model fails, ideally, we discard it and try a new one.
- 1.4. Since any consistent set of propositions about the world can be modeled mathematically, the matured products of Science are mathematical structures. Any *mathematical structure*, no matter how complicated, consists of relations¹.
- 1.5. Science seems blind to the nature of the things in relation, to the *stuff-in-itself*. This focus on measurable relations and structure, is its tremendous power, which gave us the Theory of Relativity, Gauge Theory, and Quantum Physics.
- 1.6. Since all we can measure are relations, many scientists think the nature of things is irrelevant, that discussing it is unscientific, or that it should, at best, be left to *Metaphysics*.
- 1.7. Science can, in principle, say everything about the structure of the living beings, how they evolved, how the environment pressured them and selected only those lucky enough to adapt by pure accident, about the structure of your brain, and perhaps even how your mind works.
- 1.8. But can Science say anything about your private experiences, your feelings, your qualia, the *hard problem of consciousness* [3], or about what makes you feel alive, about what it's like to be sentient, or even simply about what it's like to be? For a long time, we were either told "some day, Science will answer these questions", or "this is Metaphysics, not Science!".
- 1.9. Let's play by these rules and see where they lead us. Let's put our own sentient experience aside for a moment, and follow *Structure-only Science*, cold and blind to experience as it is. Let's take it for its word and see if we can push it into a contradiction, forcing it to reveal its own limits, by using its own methods.
- 1.10. And, after pushing Structure-only Science beyond its breaking point, by its own methods, let's restore the wholeness of Science, by its own methods again, allowing it to deal with sentience and the experience of being. Let's make Metaphysics falsifiable, let's make it part of Science.

Is everything reducible to the quantum structures?

- 2.1. According to Quantum Physics, the state of the world is encoded in a vector, the *state vector*. All possible state vectors form a high-dimensional vector space. The values of the physical properties can be decoded from the state vector by using linear operators called *observables*.
- 2.2. All possible values² of the observables representing the coordinates of the particles (plus some other degrees of freedom) form a high-dimensional space named the *configuration space*. The state vector can be expressed as a *wavefunction*, a function that takes a complex value at each point of the configuration space, propagating like a wave. These values are the components of the state vector in the position basis³. The way it propagates is encoded in a linear operator called *Hamiltonian*.
- 2.3. Everything there is to know about the external reality is encoded in the patterns of the wavefunction. Alternatively, they are encoded entirely in the state vector and the quantum observables. These data encode all other observables and all structures in the world, including space and the decomposition into subsystems (*eg.* elementary particles).
- 2.4. If Structure-only Science provides a complete description of reality, by reproducing or simulating the relations from a world it should be possible to obtain an identical world. Everything there is to know about reality, including life and your sentient experience, should be reducible to the quantum structures.

2.5. If Structure-only Quantum Physics seems to provide a complete description of reality, this is because we map, in our minds, the observables to the *physical meanings* they represent. This map tells us which observable corresponds to a position, momentum, or another physical property, and it allows us to group the observables into commuting algebras to identify the subsystems [24].

2.6. However, the labels assigning physical meaning to observables are not part of the structure itself. If we delete the labels and try to reattach them to the observables, we can do it in infinitely many ways, even if we try to obtain the same structures and the same relations between observables. Without the labels we can't decode the world from the structures.

2.7. Each way to label the observables by their physical meanings decodes, from the same state vector, a completely different physical reality, even with different dynamical laws. But even the relabelings that preserve the dynamical law decode infinitely many different physical realities.

2.8. Some physicists hope that we can infer the physical meaning of the observable, or a preferred basis with a special physical meaning, from the relations only. But there are infinitely many possible relabelings that preserve the relations. These possible relabelings form an n^2 -dimensional space if the vector space of states is n -dimensional (and, from what we know, $n = ?$). And among these, the possible relabelings that preserve the relations and the dynamical law form a subspace having between n and n^2 dimensions⁴.

2.9. Therefore, there is no way to extract a complete description of reality from the structure alone. We need a map between structures and their physical meaning, and this is not part of the structures. The map exists only as labels in our minds.

2.10. Being unaware of this makes us believe that everything is reducible to the structure.

Are you just structure?

3.1. Why can the observers know the map between physical properties and the observables representing them? The observers are part of the world they're trying to describe. For example, they measure the positions of the objects compared to their own perceived position.

3.2. This makes us hope that we can find the map associating meaning to observables within the structure of the brains of the subsystems that have the same structure as an observer.

3.3. But how can we identify such *observer-like structures*, without knowing what physical meaning is associated to the observables in the first place?

3.4. For any two possible states of the world, no matter how distinct physically, there are symmetry transformations of the quantum structure turning one into the other⁵. That is, the structures of any possible state of the world can be relabeled like the structures of any other possible state of the world, no matter how different. Structure-only Science won't see any difference.

3.5. Consider a world in which you think you know the value of a physical property of an object. The observables can be relabeled in infinitely many ways to get worlds containing systems having the same structure as you^{3.4}, including your brain's structure with the record of knowing that property, but in which that property has a different value.

3.6. Even if we restrict the relabelings to those preserving all relations, including the form of the dynamical law, there are symmetry transformations mapping a world in which a measurement obtains an outcome into one in which it has another outcome⁶.

3.7. If you would be reducible to the structure, since these observer-like structures are identical, you could be any one of them, randomly. Since you can't know which one you are, but their external worlds are different, you can't know the values of the physical properties in the external world. Then everything you think you know about the world would amount to a random guess.

3.8. But you know many things about the external world, it's an *empirical* fact. Therefore, either you are impossibly lucky by pure accident, or you can't be a random observer-like structure.

3.9. If they have your structure, but you can't be one of them, it follows empirically that structure is not enough. Most of the other observer-like structures are *philosophical zombies* [13].

3.10. This falsifies the hypothesis that you are wholly reducible to structure. You are also the stuff-in-itself that gives physical meaning to observables, constructing the physical reality by allowing some observer-like structures to be and experience the world, while leaving other observer-like structures as zombies.

Can Structure-only Science be saved?

4.1. One may hope that the properties of matter break somehow the symmetry of the structure, avoiding the conclusion of Section ?3. But if only the structure of matter matters, and not its nature, matter can't break the symmetry of its own structure. Calling the stuff-in-itself "matter" or "physical" doesn't make go away the logical conclusion that it has to have sentential powers.

4.2. One may hope that some sub-structure of the world, for example space itself, breaks the symmetry of the vector space of states and gives it a unique physical meaning. But this would imply that its nature is more fundamental than that of other structures. Along with observables labeled as positions, other observables satisfying the same relations exist, highlighting other degrees of freedom as spatial⁷. None are more fundamental than the others, because once some exist, the others exist at once, and to Structure-only Science they are all the same.

4.3. One may try to replace the labeling with additional structure, but more structure means more degrees of freedom, hence more ambiguity. Then, to attach meaning to the new structures, we will need additional labels that are not part of the structure.

4.4. One may hope that, by adding more variables to the structure, its symmetry breaks, resulting in a unique physical meaning. But more variables mean more degrees of freedom, hence more structure, more freedom to choose the labels, and therefore introduce even more structural ambiguity.

4.5. One may hope that "the physical meaning emerges" due to *decoherence*¹¹ or *mutual information* or any other criterion thought to select a preferred basis and break the symmetry. But if these criteria are purely relational or structural, this doesn't help, because the same criteria are equally satisfied in infinitely many bases. In addition, these proposals already assume the existence of a preferred decomposition of the world into subsystems, which has the same ambiguity⁸.

4.6. One may hope that the role of the environment in selecting observers forces somehow the symmetry breaking that may avoid the conclusion of Section ?3. But, at any instant, along with the observer-like structures shaped by the environment, infinitely many other observer-like structures exist, unaffected by this selection.

4.7. One may hope that natural selection might somehow select only the observer-like structures that know their environment. While the role of natural selection is extremely important, it is insufficient here, because the other bases equally exist, and so, along with the naturally selected observers, the isomorphic but zombie observer-like structures equally exist.

4.8. One may hope that the probability measure over the isomorphic observer-like structures dampens the chance of being one of those who don't know the properties of their environment. But the probability measure is uniform, because with a basis in which we consider our observer-like structures, all other bases equally exist, along with the zombie observer-like structures.

4.9. So one can't get symmetry to be broken by relational means alone and avoid the conclusions of Section ?3, no matter what structure-only conditions one imposes. Symmetry in, symmetry out.

4.10. The only way to break the symmetry comes from the stuff-in-itself. The stuff-in-itself affects the physical world without affecting its causal structure, but by endowing it with meaning through sentient beings like you.

Do observers measure reality or do they paint it?

5.1. Nowhere did we invoke the quantum measurement problem to infer the fundamental role of the observers in Section 3. But what we found offers a new solution to the measurement problem.

5.2. Unlike Classical Physics, in Quantum Physics there are incompatible observables. Two observables are *incompatible* if they can't have definite values simultaneously. For example, the position and the momentum of the same particle are incompatible observables.

5.3. Among all observables, only some manifest directly at the *macro level* of reality. These observables are compatible, behaving much like the observables of Classical Physics.

5.4. The set of compatible macro observables provides a low-resolution picture of reality. For the smaller scales we need higher and higher-resolution descriptions. The full-resolution needed for the *micro level* is given by the state vector and all of the observables^{2,3}.

5.5. A *measurement* is a way to record the value of an observable of a subsystem in the value of a *pointer observable* of another system, at the macro level. When either one of two incompatible observables can be measured, such a measurement is a *quantum measurement*.

5.6. Quantum Physics seems to predict that quantum measurements result in a superposition of different outcomes. The *measurement problem* is that we never observe such a superposition.

5.7. The mainstream solution of the measurement problem is to postulate that the state vector of the observed system jumps (collapses) during measurement, yielding a definite outcome instead of a superposition. This *ad hoc* solution violates the Schrodinger equation and conservation laws. Other proposals interpret the superposition of different outcomes as parallel worlds, or postulate point-particles guided nonlocally by the wavefunction, or spontaneous nonlocal collapse *etc.* Each proposal has advantages and disadvantages.

5.8. Another proposal relies on the fact that the observed values were indefinite before the measurement⁹, proposing that the state of the observed system was in fact indefinite. After the measurement, the state is defined “retroactively”. This *retrocausality* can also be understood as fine-tuning the past state so that all future measurements will yield definite outcomes. To allow successive measurements of incompatible observables of the same system, the states of the systems interacting with the observed system also have to be fine tuned. This can avoid collapse, nonlocality, and parallel worlds^{5,7}. But such a *superdeterministic* fine tuning has to be done at the big bang, for all particles, so it seems wildly conspiratorial.

5.9. But the realization that endowing the observables with physical meaning involves the observer suggests another way to solve the measurement problem: the assignment of physical meaning to the measured observable is indefinite until the measurement, when it becomes definite. The state vector is never collapsed, but the physical meanings of its observables are partially indefinite until the measurement¹⁰. This avoids collapse, nonlocality, parallel worlds, *and* conspiracy.

5.10. As they observe new degrees of freedom of the structure of the world, the observers gradually bring into being their physical meaning, making it climb up from the micro to the macro level.

Why do we say “I’m sentient”?

6.1. The necessity of an unambiguous map between physical properties and the observables representing them revealed that the stuff-in-itself endows with being only some observer-like structures, making them into sentient observers and conveying physical meaning to the observables.

6.2. The stuff-in-itself grounds your sentient experience of the physical properties, without doing the same for the infinitely many other observer-like structures having the same structure.

6.3. While you and your mind have a structure, you are more than that. If only the structure of the stuff-in-itself would matter, you would know nothing about the external world, you would not even be. The stuff-in-itself grounds your existence, consciousness, and sentient experience.

6.4. So can your mind be just a computation [21]? Computation is based on a very low-resolution set of compatible observables representing the data. The meaning of the data is our own convention. Without

the possibility to freely change the convention, there would be no computational universality and no programmable computers [5]. Because a computation needs a convention from an external designer, it's not an intrinsic property of the computer, while you are sentient by yourself, intrinsically. Moreover, the physical meaning of the observables representing data is irrelevant for the computation, while your mind is more than its structure.

6.5. *Functionalism* models of the mind [16] rely purely on structure as well, on the causal relations. *Integrated Information Theory* is also purely structural [23]. We can even hope that the brain's structure down to its finest resolution is enough to yield consciousness. But other observer-like structures can have the same structure and be zombies, so any structural model is insufficient.

6.6. The stuff-in-itself can endow structure with sentience only if sentience is part of its nature.

6.7. But if you say "I am sentient", do you say it *because* you're sentient? A zombie with the same structure as you would claim to be sentient just like you do, by purely causal but insentient means, and not because it's sentient. What's the difference between your claim and the zombie's?

6.8. To say "I am sentient" *because* you're sentient, the nature of the stuff-in-itself has to be able to causally affect the world. But causality is relational, it's a property of the structure. How can causality be both purely structural, but also be affected by the nature of the stuff-in-itself?

6.9. During a quantum measurement, physical meaning is created, "coloring" the relational structure without collapsing it 5.9-5.10. Thus, the stuff-in-itself can affect the physical reality without breaking the purely structural causal relations, but by endowing them with physical meaning.

6.10. Then, you say "I am sentient" *because* you're sentient. Not from breaking the causal chain, neither from purely structural causal relations, but from coloring these causal relations with physical meaning without changing their structural relations.

What breathes life into the equations?

7.1. We've seen that the stuff-in-itself endows the observables with physical meaning 2.9 and a definite value 5.9-5.10 by endowing the observer's structure with sentience 3.7-3.10. The final pointer, at the end of any observation, is raw, unprocessed sentient experience 5.10. It is the pointer of the pointer, the eye of the eye, the ear of the ear, the being of your being.

7.2. Then, if from the physical meaning given to the structure's observed degrees of freedom we infer retroactively the meaning of the structure's past states, this appears *as if* the past state of the world was fine-tuned specifically to evolve into the observed state 5.8.

7.3. The observed systems behave *as if* their goal always was to put the pointer in a definite state, or rather to create new definite sentient experiences 7.1. This may seem like a fluke or a fine-tuning conspiracy 5.8, but it doesn't break the causal chain and it doesn't affect the past, it rather "colors" the structure with meaning without changing it 5.9-5.10.

7.4. As quantum systems interact, they measure each other 11, and this may lead to superpositions. If superpositions can be resolved by creating experiences, there is a smallest scale where this happens. These tiny experiences build up into more and more complex systems that convert more and more quantum measurements into sentient experiences, *as if* against all odds.

7.5. What we know as life forms are more complex systems able to create sentient experiences, but also to process them, to convert them into coarser, diluted sentient experiences able to represent and properly interact with the world at the macro level to sustain themselves.

7.6. Then, the empirical refutation of Structure-only Science 3.7-3.10 leads naturally to the prediction that living forms aggregate many tiny measuring devices. That cells are tiny quantum labs seeking new sentient experiences by quantum measurements, that perception, decision-making, accessing memory, the triggers of sensory experience, reaction, or action initiated by living forms, involve instantiation of new meaning by quantum measurements.

7.7. Evidence already exists for quantum effects in biological systems [1, 19, 8]: quantum tunneling in enzymatic reactions [15, 20] and DNA mutations [17], maintaining and using coherence [22], and quantum effects in avian magnetoreception [9]. But more can be done to identify such key processes in the cells and test the prediction that they involve measurements to harness quantum resources to create sentient experiences. If the brain does quantum computations, it may use nuclear spins as in Fisher's proposal [7], or microtubules to orchestrate it, as in the Penrose-Hameroff Orch-OR proposal [11]. But mind isn't reducible to a computation, classical or quantum^{6.4}, and based on our results, we predict that the brain uses quantum computing and measurements to orchestrate the creation of refined integrated experiences and meanings.

7.8. When you quiet your mind and notice thoughts and experiences arising like bubbles as if from nowhere, it is like observing the trace of a particle in a bubble chamber. It's a quantum measurement of the depths of your consciousness. You use private quantum measurements to create spontaneous ideas and free decisions^{6.9-6.10} by initializing with meaning previously indefinite degrees of freedom. This is how you create ideas and make free choices, as if they were always in your own nature. This is becoming.

7.9. Therefore, your very experience of meaning, qualia, freedom of choice, and becoming, already testifies that quantum measurements are inherent parts of your brain's functionality.

7.10. To summarize, Sections 7.1-7.3 rely purely on mathematical proof and draws the conclusion from experience. Once this is understood, the first place where hypothesis comes in^{5.9} becomes natural, and it resolves the measurement problem while avoiding the drawbacks of the previous proposals, and entails naturally an answer to the main question about sentient agency^{6.7}. These findings make testable predictions: life should involve quantum measurements at all levels^{7.6-7.9}. Life and the quantum are two sides of the same coin, the sentential powers of the stuff-in-itself.