Friston's theory of everything

*John McCrone**

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*John McCrone is a science writer based in Christchurch, New Zealand
john.mccrone100@gmail.com

For **Friston's free-energy paper** see *Nat Rev Neurosci* 2010; **11:** 127–38

To watch **Friston present me and my Markov blanket** see https://youtu.be/5PHzLvvhj4I

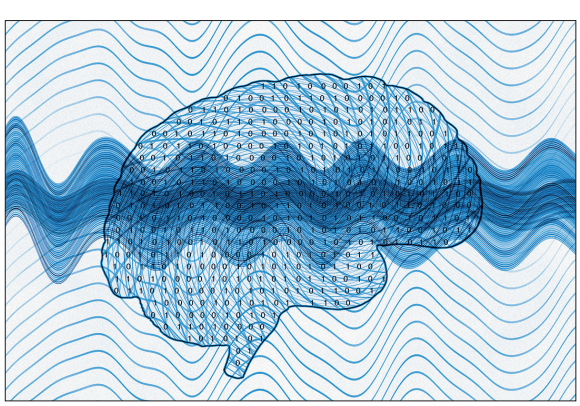
For **Friston's presentation on a unifying theory to unify unifying theories** see https://youtu.be/T711im7ZgmU

It is the obvious question to ask on an anniversary occasion. In 20 years, what breakthroughs have there been about the brain and its functional anatomy? On the whole, few, I would say. Mostly, the past two decades have felt like a filling in of the details. Small discoveries about the brain's cognitive architecture, like the fact there are grid cells in the entorhinal cortex that work alongside the place cells in the hippocampus. But something does impress me, something with admittedly also a personal connection. And that is the continued rise and rise of University College London's Karl Friston and his famously inscrutable Bayesian Brain theory.

You may have heard about this theory as Friston's neurological free-energy principle, his Markov blanket model, his generalised self-evidencing algorithm, or indeed most recently, as his unified theory of unified theories. The name has kept changing as Friston's story has ramped up through its iterations.

I got to know Friston in the early 1990s when I was researching a book—*Going Inside: A Tour Round a Single Moment of Consciousness*—about the hunt for the brain's "neural code". Friston was only a backroom boffin then. The mild-mannered statistics geek at Hammersmith Hospital's pioneering PET neuroimaging laboratory in London. However, all his colleagues made "throbbing brain" motions with their hands when his name was mentioned. And after a few conversations—some on the fire escape he used as an outdoor office where he could sneak a smoke—I could see why.

Yet, I am surprised at how successfully Friston has achieved his mission of the time, which was nothing less than to provide cognitive neuroscience with its own proper mathematical basis by creating a general theory of the brain as a prediction engine. As Friston says, he was really returning the field to its roots in the 1800s, when cognitive science was getting started: the brain as a mix of habits and expectations; Hermann von Helmholtz's treatise on perception; Thomas Bayes' work on probability and structures of belief.



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But the 1950s computer revolution rather hijacked psychology. Alan Turing's theory of universal computation became a compelling mathematical framework for thinking about the brain—the data processing paradigm. Cognition was an input–output process. Sensations arrived and were crunched into perceptual representations, then motor plans: a simple linear digestion of information.

Bayesian Brain theory flips this idea around again so that cognition is a cybernetic or autopoietic loop. The brain instead attempts to predict its inputs. The output kind of comes first. The brain anticipates the likely states of its environment to allow it to react with fast, unthinking, habit. The shortcut basal ganglia level of processing. It is only when there is a significant prediction error—some kind of surprise encountered—that the brain has to stop and attend, and spend time forming a more considered response. So output leads the way. The brain maps the world not as it is, but as it is about to unfold. And more importantly, how it is going to unfold in terms of the actions and intentions we are just about to impose on it. Cognition is embodied or enactive.

Friston's contribution is to have taken this fairly commonsensical view and build it into a mathematical model to rival Turing computation. He has written out the prediction principle in the engineering language of differential equations. Friston's free-energy paper of 2010 now tops 5000 citations. But as a flurry of online presentations during the COVID-19 lockdowns in 2020 and 2021 shows, he is still actively expanding its scope.

These presentations cover the technicalities of Markov blankets and self-evidencing information—the coupling of the way we expect our actions to change the world to the way we then find the world changing the states of our sensory systems. Simply put, if we can turn our heads quickly and feel that it is us who is moving, not the world that is spinning, then we know our brains have got the hang of things. It is forward-modelling our environments in a way such that there is a self as the stable anchoring point of view. We are implementing an information optimisation principle that can be described in the differential equations of a gradient descent algorithm.

Friston is largely a modest person, but he is not afraid to bang the table a little more these days. At the 2021 Brain Connectivity Workshop, Friston asserted he has done nothing less than found a fourth branch of physics. You have Newtonian mechanics, quantum mechanics, and statistical mechanics (that is, thermodynamics), and now you can have Bayesian mechanics—the physics of systems which can exert a predictive control over their worlds. We can debate the truth of this claim. However, I applaud the ambition. Neuroscience establishing its own deep mathematical foundation at last. This is why I pitch the Bayesian Brain as the big thing of the past 20 years.