The Embodiment of Mind

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Introduction

The word 'mind' is a loose one with many applications in use. As I use it here, I am restricting it to one definition in *Webster's Third International Dictionary*: 'Mind – the sum total of the conscious states of an individual.' I want to suggest a way of looking at consciousness in tune with, and responsive to, a statement on the subject by the American philosopher Willard van Orman Quine [1]. With his usual ironic candor, Quine said,

> I have been accused of denying consciousness, but I am not conscious of have done so. Consciousness is to me a mystery, and not one to be dismissed. We know what it is like to be conscious, but not how to put it into satisfactory scientific terms. Whatever it precisely may be, consciousness is a state of the body, a state of nerves.
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> The line I am urging as today's conventional wisdom is not a denial of consciousness. It is often called, with more reason, a repudiation of mind. It is called a repudiation of mind as a second substance, over and above body. It can be described less harshly as an identification of mind with some of the faculties, states, and activities of the body. Mental states and events are a special subclass of the states and events of the human or animal body.

Philosophers have wrestled with the so-called mind-body problem for millennia. Their efforts to explore how consciousness arises were intensified following René Descartes' espousal of dualism. The notion that there are two substances – extended substances (*res extensa*), which are susceptible to physics, and thinking substances (*res cogitans*), which are unavailable to physics – still haunts us. This substance dualism forced confrontation with a key question: how could the mind arise in the material order? Attempts to answer this question have ranged widely. In addition to

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the various forms of dualism, a few proposals we might mention are panpsychism (consciousness inheres in all matter in varying degrees), mind-body identity (the mind is nothing but the operation of neurons in the brain), and, more recently, the proposal that the understanding of quantum gravity will ultimately reveal the nature of consciousness [2]. There are many more proposals, but aside from the extremes of idealism espoused by Bishop Berkeley and Georg Hegel, they all wrestle with one question: how can we explain consciousness in bodily terms?

Attempts to answer this question often begin by examining the features of consciousness to generate a number of more pointed questions. I shall follow that path here. But I don't wish to consider the subject from a philosophical point of view. Rather, I will describe a theory of consciousness based on some significant advances in neuroscience.

Features of Consciousness

Consciousness is a process, not a thing. We experience it as an ongoing series of myriad states, each different but at the same time each unitary. In other words, we do not experience 'just this pencil' or 'just the colour red.' Instead, within a period I have called the remembered present [3], consciousness consists of combinations of external perceptions and various feelings that may include vision, hearing, smell, and other senses such as proprioception, as well as imagery, memory, mood, and emotion. The combinations in which these may participate are usually not fragmented, but instead form a whole 'scene.' Consciousness has the property of intentionality or 'aboutness' – it usually refers to objects, events, images, or ideas, but it doesn't exhaust the characteristics of the objects toward which it is directed. Furthermore, consciousness is qualitative, subjective, and therefore, to a large degree, private. Its details and actual feel are not obviously accessible to others as they are to the conscious individual who has wide-ranging first-person access to ongoing phenomenal experience.

This brief summary prompts me to single out three challenging questions: (1) How can the qualitative features of consciousness be reconciled with the activity of the material body and brain (the qualia question)? (2) Does the conscious process itself have effects? In other words, is the process of consciousness causal (the question of mental causation)? (3) How can conscious activity refer to, or be about, objects, even those that have no existence, such as unicorns (the intentionality question)?

Body, Brain and Environment – The Scientific Approach

There is a voluminous body of philosophical thought that attempts to answer these questions. The efforts of nineteenth century scientists in this regard were relatively sketchy. But a new turn dating from the 1950s has invigorated the scientific approach to consciousness [4]. Neuroscientific investigation has uncovered a rich store of anatomical, physiological, chemical, and behavioural information about our brains. It has become possible to lay the groundwork for a biologically based theory of consciousness, and I believe we are now in a position to reduce Quine's mystery. In this brief essay, I want to lay out some thoughts that bear directly on the nature of consciousness, as well as on how we know, how we discover and create, and how we search for truth. There is nature, and there is human nature. How do they intersect?

In the first place, we must recognize that consciousness is experienced in terms of a triadic relationship among the brain, the body, and the environment. Of course, the brain is the organ we wish to examine. But the brain is embodied, and the body and brain are embedded in the world. They act in the world and are acted upon by it.

We know that the vertebrate species, and specifically in humans, the development of the brain (for instance, the organization of its sensory maps) depends on how our eyes, ears, and limbs receive sensory input from the environment. Change the sequence of actions and inputs to the brains, and the boundaries and response properties of brain maps change, even in adult life. Moreover, we sense our whole body (proprioception) and our limbs (kinaesthesia), as well as our balance (vestibular function), and this tells us *how* we are interacting, consciously or not. We also know that damage to the brain – for example, from strokes involving the cerebral cortex – can radically change how we consciously 'sense' the world and interpret our bodies. Finally, through memory acting in certain sleep states, the brain can give rise to dreams in which our body seems to carry out actions of an unusual kind. The dreams of REM sleep, however fantastic, are in fact conscious states.

Neurology Essential for Consciousness

What can we say about the brain structures whose interactions are responsible for such states? One such interactive structure is the cerebral cortex [5]. Most people are familiar with the cerebral cortex as the wrinkled mantle seen in pictures of the human brain. It is a thin six-layered structure, which, if unfolded, would be about the size of a large table napkin and about as thick. It contains approximately 30 billion neurons or nerve cells, and one million billion synapses connecting them. Moreover, its regions receive inputs from other parts of the brain and send outputs to other portions of the central nervous system such as the spinal cord. There are cortical regions receiving signals from sensory receptors that are functionally segregated for vision, hearing, touch, and smell, for example. There are other cortical regions, more frontally located, which interact mainly with each other and with more posterior regions. There are also regions concerned with movement, for example, the so-called motor cortex.

A key feature of the cortex is that it has many massively parallel nerve fibres connecting its various regions to each other. These cortico-cortical tracts mediate the interactions that are critical for binding and coordinating different cortical activities.

Another structure that is critical for consciousness is the thalamus. This is a relatively small, centrally located collection of so-called nuclei that mediate inputs to, and outputs from, various regions of the cortex. For example, the thalamus processes inputs coming from the eyes via the optic nerves and sends fibres called axons to a posterior cortical region called V1. V1, in turn, sends reciprocal fibres back to the thalamus. Similar thalamo-cortical and cortico-thalamic connections exist for all other senses except for smell; each sense is mediated by a specific thalamic nucleus.

It is known that strokes damaging a cortical area such as V1 lead to blindness. Similar losses of function in other regions can lead to paralysis, loss of speech function (aphasia), and even more bizarre syndromes in which, for example, a patient pays attention only to the right half of his perceptual world (hemineglect). Damage to particular portions of the cortex can thus lead to changes in the contents of consciousness.

The thalamus projects fibres from certain of its nuclei in a diffuse fashion to widespread cortical areas. Damage to these nuclei of the thalamus can have even more devastating effects than cortical strokes, including the complete and permanent loss of consciousness, in what has been called a persistent vegetative state. These thalamic nuclei thus appear to be necessary to set the threshold for the activity of the cortical neurons underlying conscious responses.

The thalamocortical system is essential for the integration of brain action across a widely distributed set of brain regions. It is a highly active and dynamic system – and its complex activity, in stimulating and coordinating dispersed populations of neural groups, has led to its designation as a dynamic core. The dynamic core is essential for consciousness and for conscious learning [6]. Interactions mainly within the core itself lead to integration of signals, but it also has connections to subcortical regions that are critical for nonconscious activities. It is these regions that enable you, for example, to ride a bicycle without conscious attention after having consciously learned how.

The structures I have mentioned thus far function dynamically by strengthening or weakening the synapses that interconnect them. These changes result in the activation of particular pathways after signals are received from the body, the world, and the brain itself. These dynamics allow the development of perceptual categories in the short term and memory in the long term.

In addition to changes that result from and accompany an individual's behaviour, the brain also has inherited value systems selected for and shaped during evolution that constrain particular behaviours. These systems consist of variously located groups of neurons that send ascending axons diffusely into various brain areas. For example, the locus coeruleus consist of several thousand neurons on each side of the brain stem, sending fibres up to the higher brains. Like a leaky garden hose, the fibres release noradrenaline when a salient signal, such as a loud noise, is received. This substance modulates or changes the responses of neurons by changing their thresholds of activity.

Another important value system is known as the dopaminergic system. In situations of reward learning, neurons in this system release dopamine. This compound modulates the response threshold of large numbers of target neurons – for example, those in the cerebral cortex. Without such a value system, the brain would not function efficiently to relate behaviour to the need for survival, i.e. to assure adaptive bodily behaviour. Notice that ‘value’ as I discuss it here is not ‘category’. While value systems constrain rewards or punishments, an individual’s behaviour, learning, perception of objects and events, and memory all derive from actions that occur during that individual’s lifetime by means of ongoing selections from the brain’s vast neuronal repertoires.

A word about the vastness of these repertoires may be in order. Taken together with the intricacy of brain anatomy, the dynamics of synaptic change can give rise to a huge number of possible functional circuits. For example, synaptic change acting on the million billion synapses of the cerebral cortex can provide hyperastronomical numbers of circuits subject to selection during behaviour.

The Need for a Brain Theory

The background for a theory of consciousness that I have presented so far puts a strong emphasis not just on the action of brain regions but also on their interaction. Some scientists have been tempted to speculate in the opposite direction, claiming that there are ‘consciousness neurons’ or ‘consciousness areas’ in the brain. It seems to me more fruitful to ask about the interactions among brain regions that are essential for consciousness.

To explain consciousness in biological terms requires a theory of brain action and a linked theory of consciousness, and both must be framed within an evolutionary perspective. To put these theories in such a perspective, it is useful to distinguish between primary consciousness and higher-order consciousness [3]. Primary consciousness (as seen, for example, in monkeys and dogs) is awareness of the present scene. It has no explicit conscious awareness of being conscious, little or no conscious narrative concept of the past and future, and no explicit awareness of a socially constructed self. Higher-order consciousness, which yields these concepts, depends on primary consciousness, but includes semantic capabilities that are possessed by apes, such as chimpanzees, and, in their highest reaches, by humans who have true language.

To simplify matters, let us focus on the evolutionary emergence of primary consciousness. Why do I insist that we base our explanation on an underlying brain theory? One reason stems from the idea that the neural structures underlying consciousness must integrate an enormous variety of inputs and actions. A parsimonious hypothesis assumes that the mechanism of integration of this great diversity of inputs and outputs is central and not multifarious. A contrasting hypothesis would require separate mechanisms for each conscious state – perception, image, feeling, emotion, etc.

What kind of theory can account for the unity in diversity of these states? I have suggested elsewhere that such a theory must rest on Darwin's idea of population thinking applied to individual vertebrate brains. The resultant theory, Neural Darwinism, or the theory of neuronal group selection (TNGS), states that the brain is a selectional system, unlike an instructional system such as a computer [5]. In a selectional system, a repertoire of diverse elements preexists, and inputs then choose the elements that match those inputs. The enormous diversity in the microscopic anatomy of the brain is created by a selectional rule during the brain's development: neurons that fire together wire together. This rule acts epigenetically, i.e. it does not depend primarily on genes. Overlapping this developmental selection is experiential selection: even after brain anatomy is developed, the connection strengths at the so-called synapses change as the result of an individual's experience. This alters the dynamic signalling across neuronal pathways. By these means, vast – indeed, hyperastronomical – repertoires of circuits, consisting of neuronal groups or populations, are created, upon which further selection can occur and upon which memory is based. As a result, no two brains are identical in their fine details.

The existence of these repertoires is essential as a basis for the selection of circuits leading to behaviour. However, their existence cannot in itself account for the integration of the brain's responses in space and time. For this, a specific anatomically based dynamic feature of higher brains had to evolve. This critical feature is re-entry: the recursive signalling between brain regions and maps across massively parallel arrangements of neural fibres called axons. Re-entrant activity synchronizes and coordinates the activity of the brain regions linked by these axonal fibres. An outstanding example of such parallel connections is the so-called corpus callosum. This tract consists of millions of axons going in both directions to connect the right and left cerebral cortices. Re-entrant activity across such a structure will change with behaviour and also act to integrate and synchronize the dynamic activity of firing neurons. This integrative synchronization allows various brain maps to coordinate their activity by selection. No superordinate or executive area is required. This means that different maps of the brain can be functionally segregated – e.g., for sight, audition, touch, etc. – but, nonetheless, can become integrated, as reflected in the unitary scene of primary consciousness.

What might be useful at this point is an image or metaphor to capture how the re-entrant thalamocortical system – the dynamic core – binds or integrates the complex activities of the various functionally segregated areas of the cortex in a manner consistent with the unitary scenes of primary consciousness. One such image is that of a densely coupled mass of numerous springs. Disturbance within one region of such a structure will be propagated through the whole structure, but certain of its distributed vibrational states will be integrated and favoured over others. Less dense and looser coupling to other springs would correspond to interactions of the core with subcortical brain structures. The main point here is that the myriad interactions in such a densely connected mass will yield certain favoured states, integrating various local changes in a more coherent fashion. This is, of course, only a gross mechanical analogy, but I hope it will help provide a grasp of the subtle electrochemical interactions of core neurons mediated by re-entry that can yield such a great variety of distinct states.

Re-entry is the central organizing principle in selectionistic vertebrate brains. It is of some interest that the underlying structures necessary for dynamic re-entry appear to be missing from insect brains. For our purposes, re-entry will turn out to provide an essential basis for evolutionary emergence of consciousness. The implication is clear: animals lacking wide-scale re-entrant activity are not expected to be conscious as we are.

A Biological Theory of Consciousness

We are now in a position to relate these observations of anatomy and neural dynamics to an analysis of consciousness. As I have suggested, a theory of consciousness based on interactions of the brain, body and environment must be grounded in an evolutionary framework [6]. According to the extended TNGS, primary consciousness first appeared several hundred million years ago at the time of the emergence of birds and mammals from their therapsid reptile ancestors. At these junctures, there appears to have been a large increase in the number and types of thalamic nuclei. Even more to the point, new and massive re-entrant connectivity appeared among cortical regions responsible for perceptual categorization, and more anterior brain regions mediating value-category memory. This is the memory enabled by selective synaptic plasticity, which is constrained overall by value-system responses to reward or to a lack of reward. The integration achieved by this re-entrant system, including the widely distributed thalamic connections, gave rise to unitary conscious or phenomenal experience.

Now we must confront an issue laboured over by students of the mind-body problem. How can one relate the integrated firing of the dynamic core to the subjective experience of qualia? The term ‘qualia’ has been applied narrowly to the warmness of warmth, the greenness of green, etc. In view of the present theory, all conscious experiences – especially the various integrated unitary experiences accompanying core states – are qualia. How can they be explained in neural terms?

The answer harks back to evolution. According to the theory, animals possessing a dynamic core are able to discriminate and distinguish among the myriad interactions of different perceptions, memories, and emotional states [7]. This enormous enhancement of discriminatory capability is of obvious adaptive advantage. Animals lacking a dynamic core can make relatively few discriminations. In contrast, animals possessing primary consciousness can rehearse, plan, and generally increase their chances of survival through their ability to make the vast numbers of discriminations necessary for the planning of behaviour.

This provides a key answer to our question concerning the relationship of neural states to qualia. Qualia *are* the discriminations afforded by the various core states. Thus, although each core state is unitary, reflecting integration of its activity, it changes or differentiates to a new state over fractions of a second, depending on outer and inner circumstances and signals. Still, you might ask: how can we connect neural activity to qualitative experience? The answer is that particular dynamic core states faithfully *entail* particular combinations of discriminations or qualia. Core states do not cause qualia any more than the structure of haemoglobin in your blood causes its characteristic spectrum – the quantum mechanical structure *entails* this spectrum. In this view, conscious states are not causal. The underlying brain and core activity is both causal and faithful. This reconciles the theory with physics – no readjustments for spooky forces need to be made to the laws of thermodynamics to account for consciousness.

What I have not emphasized is the relationship of this model of consciousness to the subjective self. Briefly, this relationship depends on the value systems – the agencies of the brain controlling endocrine and movement responses as well as emotions [7]. In the re-entrant interactions of the core, the earliest and most inherent activities of these systems often supersede other inputs. There is, in foetuses as well as in babies and adults, constant proprioceptive and kinaesthetic input to the core from the body and limbs. It is inevitable that elements of self-reference arise under these circumstances.

This account provides a background for certain features of higher-order consciousness present in humans. With the emergence of higher-order consciousness, through the evolution of larger brains with a new set of re-entrant connections allowing semantic exchange, a socially defined self could appear. Narration of the past and extensive planning of future scenarios became possible. So arose the consciousness of being conscious.

Some find it a retreat to an abhorrent epiphenomenalism to assume that consciousness is not itself causal. But upon reflection, one sees that core processes are faithful ones – so much so that we can speak *as if* our discriminations or qualia are causal. Besides the fidelity of the proposed mechanism, we may point out its universality: all discriminations – whether sensory, abstract, emotional, or fantasy-ridden – are integrated by the same re-entrant mechanisms operating in the thalamocortical core. This lays the burden of differences among qualia on their prior neural origins in regions sending inputs to the core. Qualia are different because the neural receptors and circuits for each differ. Touch receptors and circuits differ from visual receptors and circuits, as do neural circuits governing hormonal and movement responses. Each quale is distinguished by its position within the universe of other qualia, and there is, in general, no place for isolated qualia, except perhaps in the linguistic references of philosophers.

We may now encapsulate the picture put forth here.

According to Neural Darwinism, the brain is a selectional system, not an instructional one. As such, it contains vast repertoires of neurons and their connections, giving rise to enormous numbers of dynamic states. Behaviour is the result of selection from these diverse states. While the brain responds epigenetically to signals from the body and the world, both in development and in behaviour, it also has inherited constraints. These include not only morphological and functional aspects of the body, but also the operation of the brain's value systems.

Such structures and systems were selected during evolutionary time. It is the interplay between evolutionary selection and somatic selection that leads to adaptive behaviour.

To provide for this behaviour, the combinatorial richness and uniqueness of each human brain are coordinated and integrated by the dynamic process of re-entry. Indeed, it was the evolution of new re-entrant circuitry in the dynamic thalamocortical core that allowed the emergence of the myriad discriminations among successive integrated states, which comprise the process of primary consciousness. The rich combinations of qualia constituting phenomenal experience are precisely these discriminations, which are faithfully entailed by core activity. The possession of primary consciousness allows for the planning of behaviour, conferring adaptive advantages on the vertebrate species having this capability.

It is the activity of neuronal groups in the re-entrant dynamic core that is causal, for it provides the means for planning adaptive responses. Consciousness as a phenomenal process cannot be causal in the physical world, which is causally closed to anything but the interactions of matter-energy. Nonetheless, speaking as if conscious states are causal usually mirrors the truly causal core states.

Inasmuch as the set of historic selective events accompanying each individual's development is a function of the unique triadic interactions of body, brain and world, no two selves or sets of brain sets are identical. The privacy and subjectivity of conscious states and selves are an obligate outcome of body-brain interactions. In hominine evolution, a more sophisticated self emerged as a result of social interactions facilitated by the appearance of new re-entrant core circuits that permitted the emergence of higher-order consciousness and, ultimately, language. As powerful as this system of higher-order consciousness is, it still depends critically on the operation of primary consciousness. In any event, the proposed re-entrant core mechanism is universal, i.e., it applies to all mental states, whether they concern emotions or abstract thoughts.

As a result of higher-order consciousness enhanced by language, humans have concepts of the past, the future, and social identity. These enormously important capabilities derive from the activity of the re-entrant dynamic core responding to a multiplicity of inputs from the body and the world, as well as the brain's use of linguistic tokens. The embodiment of mind that results is certainly one of the most remarkable consequences of natural selection.

These considerations provide provisional answers to both the qualia question and the question of mental causation. In this brief compass, I cannot delve deeply into the intentionality question [8]. But the framework I have described posits that consciousness requires re-entry between systems of perceptual categorization and systems of memory. Perceptual systems, by their nature, depend upon interactions between the brain and signals from the body and the world. In one sense they are systems of referral. Moreover, memory systems allow the brain to speak to itself, providing a means for referral to what have been called 'inexistent objects', such as unicorns or zombies. With the emergence of higher-order consciousness and language, intentionality achieves a range that is, for all intents and purposes, limitless.

Significance

I have described a theory, the testing of which will depend on two factors. The first is the self-consistency of its underlying concepts. The second is the provision of support by experimental means. Clearly, it is important to search for neural correlates of conscious processes. There is already evidence that re-entry plays a role in a person's becoming aware of an object [9]. What is required additionally is evidence of how the re-entrant activity of the dynamic core changes when a person goes from an unconscious state to a conscious one. And, of course, we should welcome a variety of experiments exploring neural correlates of consciousness in the hope that some unforeseen correlation will either support or change our theoretical views.

For the present, it is useful to ask what consequences this theory would have, if we assume it is correct. If the theory holds up, we would no longer have to consider dualism, panpsychism, mysterianism, or spooky forces as explanations of our phenomenal experience. We would have a better view of our place in the world order. Indeed, we would finally be able to corroborate Darwin's view that the brain and mind of man are the outcome of natural selection.

Clearly such a theory, linking body, brain, and environment in terms of conscious responses, would, if correct, be of great use in gaining an understanding of psychiatric and neuropsychological syndromes and diseases. Even in the normal sphere, such a theory might give us a better picture of the bases of human illusions, useful and otherwise.

Tangent to these matters, such a brain-based theory might allow us to obtain a clearer understanding of the connection between the objective descriptions of hard science and the subjective, normative issues that arise in ethics and aesthetics. Theory pursued in this fashion might avoid silly reductionism while helping to undo the divorce between science and the humanities.

Quine, with whose quote this essay began, suggested that epistemology, the theory of knowledge, be naturalized by linking it to empirical science, particularly psychology [10]. His proposal encompassed physics, but restricted itself to sensory receptors, a position he justified by claiming that one could, by this restriction, maintain the extensionality of physics. His position, unfortunately, was allied to philosophical behaviourism, and to that extent it skirted the important issue of consciousness. The present excursions, if validated, are more expansive – they would allow the formulation of a biologically based epistemology, which would include the analysis of intentionality. While remaining consistent with physics, this would represent an accounting of knowledge in terms that relate truth to opinion and belief, as well as thought to emotion. Such an accounting would include aspects of brain-based subjectivity in its analysis of human knowledge. Intrinsic to such a study would be the understanding that knowledge, conscious or unconscious, depends on action in the world.

Finally, one must seriously consider the future possibility of an artificial embodiment of mind: we may someday be able to construct a conscious artefact. Brain-based devices capable of acting in the environment and able to develop conditioned responses and autonomously locate targets already exist [11]. Nonetheless, we are still very far from realizing a conscious artefact. To be sure that we had achieved this would require, I believe, that such a device have the ability to report its phenomenal states while we measured its neural and bodily performance. Would such a device sense the world in ways we cannot imagine? Only the receipt of extraterrestrial messages would exceed this enterprise in excitement.

In the meantime, we can take comfort in the fact that such a device, which will not have our body, will neither destroy nor challenge the uniqueness of our phenomenal experience.

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