Antonio Damasio & Hanna Damasio

Minding the body

We spend a good part of our lives attending to the sights and sounds of the world outside of us, oblivious to the fact that we (mentally speaking) exist in our bodies, and that our bodies exist in our minds.[1] This neglect is both good and bad: good when it allows us to let our own physical suffering go undetected, bad when it screens us from the biological roots of our selves. Be that as it may, the body does come to mind, in no uncertain terms, when injury or disease breaks down its integrity and causes pain. The body also comes to mind, somewhat less demandingly, in moments of joy, when physical lightness and ease of function inevitably make us aware of the body.

What we would like to address in this essay, however, is not the obvious fact that the state of our bodies can be conveyed to our minds, but rather the neurological mechanisms that enable this spectacular phenomenon. How can the body, with its myriad physical compartments and complicated operations, show up in our minds and be felt?

The most common perspective on this question assumes that there is a 'mind-body problem,' which is best resolved using the tools of analytic philosophy. Our perspective here, however, is more restricted, focusing instead on the biological scaffolding without which the body certainly cannot be present in the mind. We are convinced, incidentally, that this perspective and its facts are relevant to the mind-body problem and go a long way toward solving it. Elsewhere we have addressed the connection,[2] but

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2 See Antonio Damasio, *The Feeling of What Happens* (New York: Harcourt, 1999), for an overview of the argument.

here we simply wish to discuss the latest in the nuts and bolts of how the body comes to mind.

In attempting to answer this question, we will use, as a stepping stone, the same assumptions William James made when he tried to explain how we perceive our emotions, a process he thought required a mental representation of the body: perceptions, any perception, occur in the brain; and perceptions of the body include, of necessity, brain processes that depend on a particular object – the body-proper.

James, along with a host of contemporary physiologists, already knew for a fact that there were nerve pathways conducting impulses from the body to the brain. He also had an inkling, given the then-emerging evidence for brain specialization, that the parts of the brain related to bodily perception would be distinct from those linked to visual or auditory perceptions. Today, we have no reason to doubt James's conjecture, and plenty of evidence to show that his account is fundamentally correct.

We have, however, many new developments to report on this score.[3] First, we now know that the details of James's basic arrangement are far more intricate than what might have been imagined a century ago. For example, the body uses chemical signals as well as neural signals to communicate with the brain; and the range of information conveyed to the brain is wider than expected, from the concentration of chemical molecules to the contractions of muscles anywhere in the body.

Second, while the brain does represent, with fidelity, body states that are actually occurring, it can do far more than that: it can also modify the representation of an ongoing state, and, most dramatically, it can simulate body states before they occur or body states that do not occur at all.

Third, the new knowledge has profound implications for our understanding of consciousness and of social behavior.

In what follows, we will address each of these developments in order.

Let us begin by clarifying that whenever we use the term 'body,' we mean 'body-proper,' so as to leave aside the brain. The brain is also a part of the body, of course, but it happens to have a particular status: it is the part of the body toward which every other body part is communicating, and that can communicate to every other part.

Misconceptions abound regarding how the body talks to the brain. For instance, those who are unacquainted with neuroscience (and, regrettably, some who are) assume incorrectly that the body operates as a single unit, a lump of flesh connected to the brain by live wires called nerves. Many also mistakenly believe that the main communication occurs between the body's organs – the viscera – and the brain, via the autonomic nervous system. Another erroneous belief is that the body-brain communication goes one way, from body to brain, but not in the reverse direction.

The reality is quite different.

First, rather than being one unit, the body has numerous separate compartments. To be sure, the viscera to which so much attention is paid – the heart, the lungs, the gut, the mouth, the tongue, the throat, and the equally vital but less recognized organ, the skin, which envelops our entire organism – are essential, but all of the body's compartments are

3 See Antonio Damasio, *Looking for Spinoza* (New York: Harcourt, 2003), for an overview.

indispensable for its normal operation. And the communication between viscera and brain is not confined to the autonomic nervous system. There are other neural channels. This communication is not even confined to nerves alone: there is a chemical channel as well.

The chemical bath in which all body cells live and of which the blood is an expression – the internal milieu – also ends up sending signals to the brain, not via nerves but via chemical molecules, which impinge directly on certain parts of the brain designed to receive their messages. The range of information conveyed to the brain in this manner is extremely wide. It includes, for example, the state of contraction or dilation of smooth muscles (the muscles that form the walls of the arteries, the gut, and the bronchi); the amount of oxygen and carbon dioxide concentrated locally in any region of the body; the temperature and the pH at various locations; the local presence of toxic chemical molecules; and so forth.

There is more to the body, however, than viscera and internal milieu. There are also striated muscles. When these muscles are connected to two bones articulated by a joint, the shortening of these muscles generates movement. Picking up an object, walking, talking, breathing, and eating are all actions that depend on muscular contraction. But note that whenever those contractions occur, the configuration of the body changes: except for moments of complete immobility, the image of the body in space is changing continuously.

The secret behind the changes is simple. In order to control movement with precision, the body must instantly convey information on the state of every striated muscle to the brain, using efficient nerve pathways, which are evolutionarily more modern than those that convey signals from the viscera and internal milieu. These pathways arrive in brain regions dedicated to sensing the state of these muscles. (The only partial exception to this scheme of things has to do with the heart, which is also made of striated muscles, and whose contractions serve to pump blood, but whose signals are segregated to brain sites dedicated to the viscera.)

However, just as important as the body-to-brain inputs described above is the fact that the brain also sends messages to the body. This fact is often forgotten. While body states are being continuously mapped in the brain, many aspects of those body states were caused by brain signals to the body in the first place. Just as with the communication from the body to the brain, the brain communicates with the body via neural channels – nerves whose messages lead to the contraction of muscles and the execution of actions – and via chemical channels. Examples of the latter include hormones, such as cortisol, testosterone, or estrogen. The release of hormones results in different modes of operation for the internal milieu and the viscera.

The idea here is that the body and brain are engaged in a continuous interaction that unfolds in time, within different regions of the body and within mental space as well. Mental states cause brain states, which cause body states; body states are then mapped in the brain and incorporated into the ongoing mental states. A small change on the brain side of the system can have major consequences for the body state (think of the release of a hormone); likewise, a small change on the body side (think of a knife cut, or a tooth infection, or the rupture of an ulcer) can have a major effect on the mind once the change is mapped as a nociceptive state and perceived as acute pain.

Curiously, German and British physiologists described the outlines of this basic arrangement over a century ago, but its importance for the understanding of both neurobiology and cognitive science was largely ignored until recently. And its intricate neuroanatomical and neurophysiological details have only been uncovered in the past few years.[4]

Those details reveal that the state of the body's interior is conveyed via neural channels dedicated to specific brain regions. Specific nerve-fiber types – C-fibers – bring signals from every nook and cranny of the body into specific parts of the central nervous system, such as the lamina-I section of the posterior horn of the spinal cord, at every level of its length, or the pars caudalis of the trigeminal nerve. The brain regions charged with handling the signals as they march toward the higher levels of the brain are also specific. Together with chemical information available in the bloodstream, these messages convey to the brain the state of a good part of the body's interior – all the visceral/chemical body components beneath the skin's outer perimeter. Complementing this interior sense, or interoception, is information regarding the state of striated muscles anywhere in the body. Messages from the striated muscles use different kinds of nerve fibers and different stations of the central nervous system all the way into the higher levels of the brain. The upshot of all this signaling is a multidimensional picture of the body in the brain and in the mind.

That the body, in most of its aspects, is continuously represented in the brain is thus a well-proven fact. The organism requires that sort of ongoing representation for rather transparent reasons: in order for the brain to coordinate physiological states in the body-proper, which it does without our being consciously aware of what is going on, the brain must be informed about the various physiological parameters at different regions of the body. The information must be faithful and current if it is to permit optimal controlling responses: call this information-processing network the 'body loop.'

But this is not the only network that links mind and body – there is another we call the 'as-if body loop.' Some fifteen years ago, Antonio proposed that in certain circumstances, as an emotion unfolds, the brain rapidly constructs maps of the body comparable to those that would result were the body actually changed by that emotion. The construction can occur well ahead of the emotional change, or even instead of the change. In other words, the brain can simulate a certain body state as if it were occurring; and because our perception of any body state is rooted in the body maps of the somatosensing regions, we perceive the body state as actually occurring even if it is not. (This functional arrangement can work for emotion because there is no need for fidelity of information concerning the body states that define an emotion provided the kind of emotion in question can be detected without ambiguity.)

At the time the 'as-if body loop' hypothesis was first advanced, the evidence we could muster in its favor was circumstantial. First, it made sense for the brain to know about the body state it was about to produce. The advantages of this sort of 'advance simulation' were obvious in the phenomenon of 'efferenz-copie.' Efferenz-copie is what allows

4 A. D. Craig, "How Do You Feel? Interoceptors: The Sense of the Physiological Condition of the Body," *Nature Reviews* 3 (2002): 655 – 666; Damasio, *Looking for Spinoza*.

motor structures that are about to command the execution of a certain movement, to inform visual structures of the likely result of that forthcoming movement. For example, when our eyes are about to move toward an object at the periphery of our vision, the visual region of the brain is forewarned of the impending movement and is ready to smooth the transition to the new object without creating a blur.

Second, it seemed obvious that simulating a body state without actually producing it reduces processing time and saves energy.

Third, the neuroanatomical structures needed for the as-if body loop to work were known to exist. The hypothesis required that the brain structures in charge of triggering a particular emotion be able to connect to the structures in which the body state corresponding to the emotion would be mapped. For example, the amygdala (a triggering site for fear) and the ventromedial prefrontal cortex (a triggering site for compassion) would have to connect to somatosensing regions such as the insular cortex, SII, and SI, where ongoing body states are continuously represented. We knew that such connections existed, thereby rendering possible the implementation of the hypothetical mechanism.

In recent years, more support for this hypothesis has come from several quarters, for example, from a series of remarkable experiments by Giacomo Rizzolatti and his colleagues. These experiments identified a class of nerve cells, known as 'mirror neurons,' by means of implanted electrodes in monkeys. In these experiments, a monkey would watch an investigator perform a variety of actions.[5] When a monkey saw the investigator move his hand or mouth, neurons in the monkey's brain regions related to hand or mouth movements became active, 'as if' the monkey were performing the action. But in reality, the monkey remained immobile.

Mirror neurons are, in effect, the ultimate 'as-if body' device. The mirror-neuron system achieves conceptually what we hypothesized as the 'as-if body loop' system: the simulation, in the brain's body maps, of a body state that is not actually taking place in the organism. The fact that the body state the mirror neurons are simulating is not the subject's does not minimize the power of this functional resemblance. On the contrary, it stands to reason that if a complex brain can simulate someone else's body state, it can simulate one of its own body states. Take, for example, a state that has already occurred in the organism: it should be easier to simulate since it has already been mapped by precisely the same somatosensing structures that are now responsible for simulating it. In fact, we suggest that the as-if system applied to others would not have developed had there not been an as-if system applied to the brain's own organism.

The nature of the brain structures involved in the process reinforces the suggestive functional resemblance between the as-if body loop and mirror neurons. For the as-if body loop, we hypothesized that neurons in areas engaging emotion – the premotor/prefrontal cortex (in the case of compassion), the anterior insular cortex (in the case of disgust), and the amygdala (in the case of fear) – would activate regions that normally map the state of the body and, in turn, move it

5 G. Rizzolatti, L. Fadiga, L. Fogassi, and V. Gallese, "Resonance Behaviors and Mirror Neurons," *Archives Italiennes de Biologie* 137 (1999): 85 – 100; V. Gallese, "The Shared Manifold Hypothesis," *Journal of Consciousness Studies* 8 (2001): 33 – 50.

to action. In humans such regions include the somatomotor complex in the rolandic and parietal operculum as well as the insular cortex. All of these regions have a dual somatomotor role, the insular cortex providing an especially good example of this functional duality. That is, these regions can hold a map of the body state, a sensory role, and they can participate in an action as well. By and large, this is what Rizzolatti's neurophysiologic experiments with monkeys uncovered. This discovery is quite consonant as well with human studies using magnetoencephalography (the studies of Rita Haari) and functional neuroimaging (again by the Rizzolatti group and by Tania Singer and her colleagues). Our own studies based on neurologic lesions point in the same direction.[6]

Explanations of the existence of mirror neurons have emphasized, quite appropriately, the role that mirror neurons can play in allowing us to understand the actions of others by placing us in a comparable body state. As we witness an action in another, our body-sensing brain adopts the body state we would have were we ourselves moving, and it does so, in all probability, not by passive sensory patterns, but rather by a preactivation of motor structures – ready for action yet not quite allowed to act – and in some cases by actual motor activation.

We must wonder, however, how such a complex physiologic system evolved. We doubt it arose *de novo*, simply because of the manifest advantage of better knowing the body state of others and, through it, the mind state of others. Instead, we suspect that the mirror system developed from an earlier 'as-if body loop' system, which complex brains used to simulate their own body states for a clear and immediate advantage: rapid and energy-saving activation of the maps of certain body states, which were, in turn, associated with relevant past knowledge and cognitive strategies. Eventually, the as-if system was applied to others and prevailed because of the equally obvious social advantages one could derive from knowing the body states of others, which are connected, of course, to their mental states.

In brief, we regard the remarkable evidence for mirror neurons as support for the 'as-if body loop' mechanism of placing the body in mind. In turn, we consider the 'as-if body loop' system within each organism as the precursor to the mirror-neuron system.

The as-if body loop, the body loop, and mirror neurons all point to a few remarkable features regarding the perception of the body during the experience of an emotion: The emotion ends up felt in our flesh. The process unfolds in time and is both sensory and motor. The sensing of body changes leads to motor activations that, in turn, can be sensed. All of these steps have the power to evoke related knowledge held in memory.

There is a peculiar relationship between the object perceived, our body, and the brain. The body and brain inhabit the same organism, and the relationship between the two can be entire-

6 R. Haari, N. Forss, S. Avikainen, E. Kirveskari, S. Salenius, and G. Rizzolatti, "Activation of Human Primary Motor Cortex During Action Observation: A Neuromagnetic Study," *Proceedings of the National Academy of Sciences* 95 (1998): 15061–15065; T. Singer et al., "Empathy for Pain Involves the Affective but not Sensory Components of Pain," *Science* 303 (2004): 1157–1162; R. Adolphs, H. Damasio, D. Tranel, G. Cooper, and A. Damasio, "A Role for Somatosensory Cortices in the Visual Recognition of Emotion as Revealed by Three-Dimensional Lesion Mapping," *Journal of Neuroscience* 20 (2000): 2683–2690.

ly circular. Feelings of emotions can help illustrate the situation.

Feelings of emotions are perceptions. They are, in the general scheme of things, comparable to other perceptions. For example, actual visual perceptions correspond to external objects whose physical characteristics impinge on our retinas and modify transiently the sensory maps in the visual system. Feelings of emotions also have an object at the origin of the process, and the physical characteristics of the object also prompt a chain of signals that impinges on maps inside the brain.

In other words, just as in the case of visual perception, a part of feelings of emotion is due to the object, and a part is due to the internal construction the brain makes of it. But something is quite different in the case of feelings, and the difference is not trivial. In feelings, the object at the origin of the process is inside the body rather than outside. Feelings of emotion are just as mental as any other perception, but a sizable part of the objects being mapped are states of the living organism in which the feelings arise.

As if this difference does not complicate things enough, there is another wrinkle in the process: feelings of emotion are linked to an object called the body, but they are also linked to the emotionally competent object that initiated the emotion-feeling cycle. A spectacular seascape is an object, but so is the body state that results from beholding that seascape, and it is the latter object at the origin of the emotional process that we perceive in the resulting feeling state.

In feeling, the brain can act directly on the very object that it is perceiving, because the object at the origin is inside the body. It can do so by modifying the state of the body, or by altering the transmission signals from it. Thus, the object at the origin, on the one hand, and the brain map of that object, on the other, can exert mutual influences in a sort of reverberative process that is not to be found in the perception of an external object. We can look at a painting we admire as intensely as we wish, for as long as we wish, and react emotionally to it. But nothing will happen to the painting itself. Our thoughts about it will change, but the object remains intact.

By contrast, in the feeling of emotion, the object itself – the body – can be changed radically. In other words, the feeling of emotion is not merely a passive perception or a flash in time. For a period of seconds or even minutes after a feeling begins, a dynamic engagement of the body, conducted almost certainly in a reiterative fashion, leads to a dynamic variation of the perception. Part of the variation may even be due to the homeostatic necessity of controlling the motor upheaval caused by the emotive process.[7] In brief, the body in the mind undergoes continuous transitions.

The fact that the body of a given organism can be fully represented in the brain of that organism opens important possibilities. The first relates to consciousness, specifically with the part of the process called the self. Elsewhere we have argued that the construction of the self would simply not be possible if the brain did not have available a dynamic representation of its body.[8] Con-

7 D. Rudrauf and A. Damasio, "A Conjecture Regarding the Biological Mechanism of Subjectivity and Feeling," *Journal of Consciousness Studies* 12 (8 – 10) (2005): 236 – 262.

8 Damasio, *The Feeling of What Happens*; J. Parvizi and A. Damasio, "Consciousness and the Brainstem," *Cognition* 79 (2001): 135 – 160.

sciousness is about the relation between a given organism and the objects perceived in its mind. In the mental process depicting the self, the integrated body representation serves as a stand-in for the organism. There is an invariant aspect to the body representation – its components and the schema according to which they are interconnected – and a variable aspect – the dynamic changes the components constantly undergo. Eventually the body representation behaves as an anchor for the construction of the self – a mental stand-in for the individual, for his or her personhood and identity.

These body representations have another major implication: after allowing us to represent our own actions and emotional states, actual or simulated, they allow us to simulate the equivalent states of others. And because we have established a prior connection between our own body states and their significance, we can subsequently attribute the same significance to the states of others that we come to simulate. The body in mind helps us construct our selves and then allows us to understand others, which is nothing short of astounding.