The Mind Body Problem and The Second Law of Thermodynamics

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ABSTRACT: Cartesian mind body dualism and modern versions of this viewpoint posit a mind thermodynamically unrelated to the body but informationally interactive. The relation between information and entropy developed by Leon Brillouin demonstrates that any information about the state of a system has entropic consequences. It is therefore impossible to dissociate the mind's information from the body's entropy. Knowledge of that state of the system without an energetically significant measurement would lead to a violation of the second law of thermodynamics.

KEY WORDS: Mind, body, entropy, information, dualism, second law of thermodynamics

For much of the 19th and 20th centuries, it wasn't considered professionally respectable for scientists, especially biologists and experimental physicists, to talk about the mind. They were somehow supposed to formulate an understanding of the world in which we live in total ignorance of that aspect of existence that we experience most directly, our minds. Theoretical physicists since the 1920s have been allowed to engage in their *weltschmertz* about mind and the meaning of quantum mechanical measurement, but that was an activity to be engaged in by consenting adults in private.

Present day discussions date back to Rene Descartes (1596—1690) who argued that a human being is a union of two aspects: the body, a purely mechanical entity obeying the laws of physics, and the mind or soul which is a pure thinking substance for which the laws of physics need not be considered. Descartes held the view that the pineal gland in the head was the site of interaction of body and soul. His somewhat mechanistic view is summarized in the *Encyclopedia of Philosophy.*

> The picture Descartes offers is that of the soul directly moving the pineal gland and thus affecting the "animal spirits" which he considered the hydraulic transmission system of mechanical changes in the body; consonant with his views on the conservation of motion, it is only the direction, and not the speed, of movement of these spirits that is affected by the soul. This is the direction of action of the *will.* In the opposite direction, changes in the body — such as the effect of external objects in the sense organs — are transmitted to the pineal gland by the spirits and can there affect the soul by causing sensations in it.

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Embodied within the Cartesian view is the idea that the activities of the mind cannot violate the conservation laws of physics but only effect choices, i.e., direction. With the Cartesian view, biology became the study of the body, psychology emerged as the study of the mind, and physics continued as the study of inanimate matter. The entire scheme worked quite well except for the problem of how mind and body can act on each other. In any case, biologists became firmly attached to the mechanistic view that their task was to explain the activities of living organisms in terms of physics and chemistry. The most cavalier statement of this philosophy are in the writings of the physiologist Emil DuBois-Reymond (1818—1896). He and his colleagues, von Helmholtz, Ludwig and von Brucke, attempted to reduce all of physiology including behavior to applied physics and chemistry.

While late 19th century biologists were successfully ignoring the mind in their research paradigms, a certain mentalism was constantly inserting itself in theoretical physics. Under the leadership of Ernst Mach in the late 19th and early 20th centuries, a school of scientists philosophers arose which considered only sensations and theories, thus denying the reality of matter in an atomic sense. This eventually led to logical positivism which flourished for the first half of the twentieth century.

Most physicists in the late 1800s and early 1900s were committed to the reality of matter interacting through a series of forces and being totally independent of the observer. Then the introduction of the Theory of Relativity in 1905 followed by Quantum Mechanics in the 1920s led to a privileged view of the observer. In relativity theory, observations became dependent on the motion of this observer. In quantum mechanics, the reduction of a probability distribution to an event involves an observation which is the awareness of the result by a human mind. That is, the outcome of every experiment is described by a series of possible results, each of which has some probability of occurring. Only when a human observer reads the meter, or looks at the film or otherwise becomes conscious of the result does the actual outcome "exist."

An equally significant but less well known perspective on the mind body problem comes from thermodynamics. It has been much slower in unfolding and we are only now is a position to fully grasp the problem. In the following words, J. C. Maxwell (1831—1879) introduced what has become known as Maxwell's demon or the sorting demon:

> . . . a being whose faculties are so sharpened that he can follow every molecule in his course, and would be able to do what is at present impossible to us . . . Let us suppose that a vessel is divided into two portions, A and B by a division in which there is a small hole, and that a being who *can see the individual molecules* opens and closes this hole, so as to allow only the swifter molecules to pass from A to B, and and only the slower ones to pass from B to A. He will, thus, without expenditure of work raise the temperature of B and lower that of A, in contradiction to the second law of thermo-

dynamics. (The full passage is quoted by J. H. Jeans, "Dynamical Theory of Gases," 3rd ed., p. 183, Cambridge University Press, New York, 1921.)

For many years the paradox of the demon troubled students of the foundations of physics.

The crux of the paradox lay in the fact, unknown to Maxwell in 1871, that the box was filled with black body radiation, and the demon regardless of the sharpness of his faculties had no way of sensing the molecules. He was also unaware that radiation was quantized so that a minimum amount of energy would be required for an observation. The paradox of the violation of the second law remained until Brillouin (1951) exorcised the demon in the following way. He reasoned that the demon in order to know when to open the door would have to see the molecules. This vision requires photons which would have to be sorted out from the black body radiation that filled the chamber. Brillouin went on to show that the requirement for a significant measurement requires a photon more energetic than kT, the average energy of black body photons. The act of the measurement requires the expenditure of energy equal or greater than that recoverable from the supposed violation of the second law, thus restoring the range of that law.

The Brillouin analysis was based on information theory and theory of measurement. It was later worked out in more detail (Brillouin, 1956), and the development of information theory led to the notion that even "entropy," that most hard-nosed steam engine concept, was at its root mentalistic bearing on the observer's knowledge of the microstate of the system. The Brillouin analysis of the Maxwell demon leads to one further conclusion. Any knowledge of the microstate of a system of molecules that could be obtained without a measurement could be used to violate the second law of thermodynamics. Thus, if the demon could by some extrasensory non-energy requiring act know the molecular velocities, then the demon could violate the second law. Clearly, any ESP which, without a measurement, confers knowledge of the microstate going beyond equilibrium averages, i.e., the Maxwell-Boltzmann distribution, could result in a violation of the second law.

Post-Cartesian philosophers have taken four points of view about the mind body problem. (1) The Cartesian duality with separation of mind and matter and residual ambiguity about their interaction. (2) The view of idealists that only minds exist and have a common ground in the mind of God. A leading exponent of this view was Berkeley. (3) The materialist position that only matter exists and mental activity is just a highly complex form of physical activity. Hobbes is an early modern holding this theory. (4) The view that mind and matter are varied aspects of the core stuff of the universe which is neither mind nor matter. Spinoza developed this outlook immediately after Descartes view was known.

For 19th century science, the materialist viewpoint provided a milieu to function free from concern with metaphysical problems which were quietly ignored. Twentieth century physics began to demand a reintroduction of the mind seen forcefully in the writings of such physicists as Schrödinger (1984), Margenau (1984), and Wigner (1967).

The dualist position has recently been restated in terms of modern neurophysiology (Eccles and Robinson, 1985; Popper and Eccles, 1977). The modern dualists look to the neural network and central nervous system rather than the pineal gland for the mind body interaction. This reflects four centuries of advances in our understanding of behavioral psychology. The contemporary focus is on neural functions or neuromuscular functions as the most sensitive site to examine in mind brain theory.

Mind in dualist doctrine must be non-material and cannot exert force on material objects, for this would be a source of energy in contradiction to the conservation of energy. This would leave for mind the role of choosing between energetically equivalent alternatives, a perfectly plausible role within the first law of thermodynamics. But to select alternatives which are different microstates without taking an energy expending measurement would, following Brillouin's analysis, constitute a Maxwell demon and would in principle contradict the second law of thermodynamics. For information about the state of the system without a measurement would allow us to sort molecules and violate the second law.

To make this more tangible, consider the motor cortex where signals originate in the form of action potentials, electrochemical "waves" that move down the long filamentous axons to the neuromuscular functions. At the membranes of the very large number of cortical neurons there are continuous thermal fluctuations of ionic activity and membrane resistance to ion flow. These fluctuations are the inevitable result of thermal noise and may be compared to the more familiar Brownian motion. The inside of the cells are oppositely charged relative to the outside and the variable membrane resistance is generally high enough to prevent any appreciable trans-membrane flow of ions which would decrease the trans-membrane voltage. An action potential originates when a critical value is reached for the membrane resistance or trans-membrane potential. The resistance suddenly decreases causing a further decrease at neighboring points on the membrane. This collapse of resistance spreads thus propogating down the entire axon in the form of a travelling wave. The cell subsequently pumps up a voltage difference across the membrane, and is then ready to fire again. All this happens on a scale of very few milliseconds.

Here is where the non-material mind must do its choosing between energetically equivalent alternatives. And what it must do is somehow selectively manipulate the ions near the membrane surface, and/or the

molecules of the resisting membrane, in such a fashion as to induce somewhere the catastrophic depolarization that initiates an action potential or travelling "spike" that will make the desired muscles move. But knowing which ions and molecules will induce a depolarization, with zero energy added to them, is (aside from being spectacularly difficult) something that itself would require an expenditure of energy to learn. For this information could be used to do work and thus violate the second law by converting heat into work. Thus the parallel with Maxwell's sorting demon peering out at a cloud of wizzing molecules.

Accepting dualism involves either giving up the second law of thermodynamics or limiting that law to situations not involving mind. I don't think that this would radically effect physics, but it makes a large difference to biophysics. It allows us to think of mind as related to the kind of knowledge a system has of its own state without taking a measurement.

Physics has dealt with the restrictions involved when an observer makes measurements on an external system. Both the Brillouin and Heisenberg uncertainties focus on the mind of the observer obtaining information about the state of matter of the observed system. A kind of mind body problem threads its way through all of modern physics.

However, the question of how a system obtains knowledge of its own state, with or without a measurement, has not been dealt with in contemporary physics. Resolving that question may provide an approach to the problem of interest. In any case, the existence of non-energy requiring mental states influencing the physical states of the organism involved with those mental configurations would violate the most global statement of the second law.

Mind body dualism thus is in direct contradiction to the second law of thermodynamics. I believe it very significant that principles of physics and philosophy can be brought into such direct relationship. In the end a valid theory must resolve such contradictions. It is important to stress the degree to which the mentalistic aspects of current physics have profound philosophical implications.

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