

**Ronald Endicott, “Multiple Realizability” (Final Draft)
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Multiple realizability is a key issue in debates over the nature of mind and reduction in the sciences. The subject consists of two parts: “multiplicity” and “realizability.” “Multiplicity” designates a kind of variability in the mechanism and materials from which a particular type of thing can be made. “Realizability” designates a specific relation that exists when there is the stated variability.

Realizability

Apart from the broad folk notion of realization meaning that a thing is “made real,” philosophers apply several technical notions to paradigm cases such computational states realized by engineering states, minds realized by brains, and persons realized by their bodies. The technical notions fall into three broad traditions: “mathematical,” “logico-semantic,” and “metaphysical.”

The mathematical tradition equates realization with a form of mapping between objects. Generally speaking, x mathematically realizes y because elements of y map onto elements of x . The notion is useful for many purposes, for example, when constructing a formal model of a particular domain. However, since mapping extends to models as well as reality, it fails to distinguish between “simulated” versus “genuine” realizations. Heavenly stars can be mapped onto grains of sand, but grains of sand do not realize heavenly stars in any genuine sense. Similarly, the mental states described by a cognitive program can be mapped onto unthinking groups of things, but unthinking groups of things do not realize mental states in any genuine sense (Block, 1978). Hence, to capture what is essential to genuine realization, William Lycan (1987) adds ideas about evolutionary function, while David Chalmers (1994) emphasizes facts about causal structure. To present Chalmers’ idea, and cast in terms of a computational model that informs the literature cited, a set of mental properties that constitute a cognitive program is realized by a set of engineering properties possessed by that system if and only if (a) there is a one-to-one mapping between instances of the sets of properties, and (b) the engineering

has the causal structure to satisfy the computational state transitions required by the program.

The logico-semantic tradition translates realization into an interpretation of symbolic objects. Generally speaking, *x* semantically realizes *y* because *x* can be interpreted to meet the conditions for satisfying the term ‘*y*.’ Thus, logicians say that a set of objects is the realization of a formal language when the objects satisfy the predicates of that language (Tarski, 1936/1956). Being a matter of semantic interpretation, this notion of realization might appear irrelevant to paradigm cases of realization whereby one thing (engineering or brains) generates or produces another thing (computation or minds). Yet Daniel Dennett (1978) addresses such cases by employing a method of agent interpretation, in effect turning the interpretation of symbols into an interpretation of rational symbol systems. Roughly, a set of mental properties that constitutes a system’s cognitive program is realized by a set of engineering properties possessed by that system if and only if (a) the system’s behavior supports an interpretation according to which instances of the computational properties are internal symbols involved in the operations of the system, and (b) it is rational for the system to possess those symbols and operations under the stated interpretation.

Finally, the metaphysical tradition views realization as a species of determination between objects. Generally speaking, *x* metaphysically realizes *y* because the properties of *x* determine the properties of *y*. Yet, unlike other forms of determination, philosophers see a very close connection in paradigm cases of metaphysical realization. Regarding the particulars, some philosophers add that instances of realized and realizing properties occur at the same time, with the former composed out of the latter (Tye, 1995). Regarding the properties, Stephen Yablo (1992) applies the notion of determinables and determinates by maintaining that a realized property stands to a realizing property as the determinable color red stands to its more determinate color scarlet. So human neurophysiology is a way of being a mind, like scarlet is a way of being red. In a different vein, Sydney Shoemaker (2001) employs metaphysical and set-theoretic notions by viewing the causal powers of a realized property as a subset of the causal powers of its

realizing property. So mental abilities are a mere portion of the causal capacities of the appropriate engineering systems.

However, many philosophers explain realization in terms of functionalism, the leading doctrine in the philosophy of mind. On this view, mental processes are understood by the functions they perform and not by the materials that realize the processes. On one popular version, each mental property is a higher-order property whose nature is defined by the possession of a lower-order physical property that plays an associated functional role. To present this idea in computational format, a set of mental properties that constitutes a system's cognitive program is realized by a set of engineering properties possessed by that system if and only if (a) the mental properties are higher-order properties that require lower-order physical properties to play their associated functional roles, and (b) the engineering properties of the system play the required functional roles.

Multiple Realizability

Multiple realizability is a kind of variability in materials that philosophers call "property variability" or "compositional plasticity." Functionalists have this variability in mind when they observe that different physical properties can play the same functional role in different individuals. Indeed, this observation is commonplace in computer science. Thus, Alan Turing judged that the specific physical properties of an engineering system are unimportant for a theory of computation because the same computational function can be performed by systems with different engineering:

Importance is often attached to the fact that modern digital computers are electrical, and that the nervous system is also electrical. Since Babbage's machine was not electrical, and since all digital computers are in a sense equivalent, we see that this use of electricity cannot be of theoretical importance ... If we wish to find [computational] similarities we should look rather for mathematical analogies of function (Turing, 1950, p.439).

That is, while an instance of a given physical property may be sufficient to realize a computational property, as when the human brain computes addition, nevertheless that

same physical property is not necessary. Other systems with quite different physical properties can compute addition -- someone with a different neurophysiology, an artificial machine with a microprocessor, and so on. So the key to property variability is that sufficient conditions for the realization of higher-level properties are not necessary conditions.

Property G is lawfully sufficient for property F if, as a matter of physical law, F is realized when G is realized. But G is not a necessary condition for F if F can be realized without G. For example, G is sufficient but not necessary for F if F is a computational function that can be realized on some occasion without the property G of having a human neural assembly but with the property H of having an artificial microprocessor. To incorporate this idea into a formal definition in which A is a set of realized properties and B its realizing base:

Property F in set A has variability with respect to set B if and only if there exist properties G and H in B such that:

- (i) it is possible that G and F but not H are realized, and, as a matter of law, if G is realized then so is F;
- (ii) it is possible that H and F but not G are realized, and, as a matter of law, if H is realized then so is F
- (iii) there is no property K in set B such that, as a matter of law, F is realized if and only if K is realized (Endicott, 1994).

Clauses (i) and (ii) jointly express a minimal form of property variability, while the addition of clause (iii) expresses a form of deep property variability by guaranteeing that the variability of F with respect to G and H is not a superficial fact that masks an underlying common property, that is, a property in B that is lawfully coextensive with F.

Property variability also comes in degrees. Being a planet has many physico-chemical realizations (all possible minerals constituting large dense bodies in orbit), while being jade has only two such realizations (jadeite and nephrite). Accordingly, there is the project of explaining how variability arises and why. Dennett (1991) appeals to the forces of evolution, claiming that the brain developed variability in how it realizes cognitive functions to enhance the organism's ability to adapt to a changing environment. Robert

Batterman (2000) offers a more general explanation based upon the notion of “universality” in physics, which concerns the procedure of finding similarities in behavior among physically diverse systems.

But however property variability is explained, it appears widespread. Neural plasticity is well-documented (Johnson, 1993). In particular, the brain is capable of “compensatory plasticity” in which areas in the brain formerly dedicated to one cognitive task can, after injury or disease, become dedicated to another cognitive task (Rauschecker, 1995). The brain is also capable of “experience-dependent plasticity” in which the basic wiring of the brain is refined by an individual’s sensory experience, creating individual differences in how the brain realizes mental functions (King, 1999). At a more abstract level, functional properties are variable with respect to different physical properties, shapes can be shared by different kinds of matter, and the same spatial patterns can be discerned among physically distinct structures.

Subsequent Debate over Identity and Reduction

Hilary Putnam (1967/1975) and Jerry Fodor (1974/1981) developed an argument concerning special sciences like psychology that was then extended by David Hull (1974) to the biological sciences. As a result, it became the dominant opinion among philosophers in the late-twentieth century that property variability supplies adequate evidence against type-identity and physical reduction. The type identity theory maintains that mental properties are identical with physical properties. And physical reductionism is the doctrine that all scientific theories reduce to basic physical theories. Below is an outline of Putnam and Fodor’s “multiple realizability argument”:

- (1) If a mental property F is identical with or reducible to a physical property G, then, as a matter of law, F is realized if and only if G is realized (they must be lawfully coextensive).
- (2) This requirement that identical properties be lawfully coextensive is not met in cases where property variability applies, because F can be realized without G.
- (3) So mental property F is not identical with or reducible to physical property G.

Yet the issue is not settled. There are several responses, which divide into three main areas of discussion: variability, the notion of a property, and reduction versus identity.

Variability Reexamined. Jaegwon Kim (1972) challenges premise (2) by observing that physical differences between individuals who share the same psychology does not imply that no physical property is realized when and only when a given mental property is realized. In other words, the minimal form of property variability expressed by clauses (i) and (ii) in the previous definition of variability does not imply the deep property variability captured by clause (iii) that rules out mental-physical identities. Moreover, Kim believes that the world reveals inter-level identities along with minimal property variability. For example, temperature is identical with mean kinetic energy in ideal gases, yet two aggregates of molecules with the same temperature will differ physically by having constituent molecules with different positions and directions. Accordingly, reductionists are optimistic that neuroscience will discover mental-physical identities, perhaps like the correlation between specialized “Hubel-Wiesel cells” and the detection of edges in a visual field, or the identification of visual awareness with 40-70 Hz oscillations in the cortical system (Crick and Koch, 1990/1997). Indeed, Patricia Churchland (1986) foresees that portions of psychology and neuroscience will co-evolve to a point where they reductively converge because their methodologies are interdependent, as when neuroscientists employ psychofunctional criteria to identify brain structures, thereby establishing mental-physical correlations.

Anti-reductionists counter that, while mere physical differences do not guarantee that each mental property is not coextensive with some physical property, deep variability remains extremely plausible given the functional nature of mental phenomenon and the actual record of how cognitive systems are built in a physically variable way. Consider again the case of computation. Having devised computational mechanisms that exhibit quite different engineering properties --from electrical charges passing through silicon pathways to light signals flashing across optical channels -- scientists cannot point to a single necessary and sufficient physical condition for any computational function. So it

seems unlikely that computation is like temperature in ideal gases, whose necessary and sufficient physical condition is mean kinetic energy.

Moreover, anti-reductionists claim that neuroscientific discoveries only establish mental-physical correlations, not coextensions that support property identity. Thus, various systems of computer vision carry out algorithms for edge detection, which shows that the activity of Hubel-Wiesel cells is sufficient but not necessary for that function. Furthermore, even if artificial systems are discounted and psychological theory is restricted to biological systems such as mammals, and even if neuroscience employs psychofunctional criteria to identify mammalian brain structures, those identifications must be compatible with compensatory and experience-dependent plasticity as well as any other physical variations that arise from evolution (Rosenberg, 2001). This makes the identification of particular types of mental functioning with coextensive physical functioning empirically unlikely.

Reconceptualized Properties. Many reductionists challenge premise (2) in Putnam and Fodor's argument by reconceptualizing the pertinent properties. On the side of the mental, David Lewis (1969) suggests that mental properties are lawfully coextensive with physical properties when the former are narrowly conceived species-specific properties. Thus, unlike pain per se, which might be realized in physically different ways across various species, pain in human beings might be lawfully coextensive with a human neurophysical property (see also Kim, 1972, 1992/1993). On the side of the physical, Kim (1978) suggests that mental properties are lawfully coextensive with physical properties when the latter are broadly conceived disjunctive properties. Thus, the property of having pain is lawfully coextensive with the disjunctive property of having a particular human neural assembly or a particular extraterrestrial neural assembly, and so on. Here the disjunctive property includes every possible realization of pain.

Yet, regarding species-specific mental properties, anti-reductionists counter that psychological theory also requires more general properties to explain cross-species generalizations. Moreover, they argue that even if theories are restricted to species-specific properties, there remains the fact that variability occurs within a species and even the same individual over time (Horgan, 2001). As for disjunctive physical properties, some critics deny that they exist because they do not guarantee meaningful statements

similarity among objects or plausible statements about the causal powers of objects (Teller, 1983). Others argue that disjunctive predicates do not always express natural kinds, yet projectible natural-kind predicates are needed for scientific prediction and explanation (Block, 1997).

Reduction versus Identity. Finally, rather than cast doubt upon premise (2) in Putnam and Fodor's argument, some philosophers promote views of reduction that do not require the identities at issue in premise (1). Granted, on the traditional account of scientific reduction associated with Ernest Nagel, one theory reduces to a more basic theory when the former can be deduced from the latter by means of connecting principles that express property identities. But there are other accounts that advertise no requirement concerning lawful coextensions of properties which support inter-theoretic identities, including variations on approximate reduction (Paul Churchland, 1979; Bickle, 1998) and physicalist interpretations of functionalism (Kim, 1998).

Critics counter that, among other problems, traditional connecting principles resurface within these alternatives (Endicott, 1998; Marras, 2002). In general, critics also add that to the extent such accounts avoid property identities, they are best understood as a models of scientific replacement, not reduction. So, in the end, philosophers have proposed many notions of reduction. But the fundamental metaphysical question remains: whether the properties of special and physical sciences are identical, or whether, because of multiple realizability, they fail to be identical.

See also [Computationalism; Dennett, Daniel C.; Fodor, Jerry A.; Functionalism; Mind-Body Problem; Nagel, Ernest; Physicalism; Putnam, Hilary; Reduction; Reductionism in the Philosophy of Mind; Turing, Alan M.](#)

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