Mechanisms, Multilevel

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Synonyms

Hierarchy, Levels of Organization

Definition. *Mechanisms* are entities and activities organized such that they produce or underlie a phenomenon of interest. An entity or activity (A) is at a *lower level* of mechanisms than an entity or activity (B) when A is a component entity or activity in the mechanism for B. Consequently, if A is at a lower mechanism level than B, then A is a part of B, and A is organized together with other components such that together they give rise to B. A mechanism is *multilevel* when its component entities and activities are themselves decomposable into mechanisms.

Characteristics. In many areas of biology, explanatory models describe mechanisms at multiple levels. Mechanisms are decomposed into entities and activities organized together in the behavior of the mechanism as a whole [see mechanism, conserved; mechanism, dynamic]. In multilevel mechanisms, these entities and activities are decomposable into lower-level mechanisms. Each decomposition adds a level. Multilevel mechanisms exhibit more than one iteration of this component-subcomponent relationship.

The mechanism of osmoregulation, the maintenance of fluid and electrolyte balances in the blood, can be described at multiple levels. Humans, for example, continually lose water to the environment by breathing and sweating. They also consume water and electrolytes in food and drink. This behavior is partly controlled by (higher-level) environmental and social factors, such as ambient temperature, the presence or absence of water, and the appropriateness of drinking and eating in different social settings. This behavior is also controlled by internal mechanisms that coordinate behavioral responses, such as searching for

and consuming water, and physiological mechanisms, such as the regulation of urine concentration in the kidney. Osmoregulation is thus decomposed into two coupled but distinct systems, one driving behavioural output, and the other regulating the kidney's filtration of the blood. The behavior of these systems can described at the system level in terms of curves relating changes in plasma osmolality to the volume of water consumed and to urine volumes and concentrations. However, one can also describe mechanisms responsible for the shapes of those curves: changes in plasma osmolality activate cells in the periventricular region of the hypothalamus which, via anatomical connections to the anterior pituitary, regulate the release of vasopressin, a circulating hormone that acts on the kidneys to increase urine concentration. Again, one might describe this last stage in terms of a curve relating plasma vasopressin concentrations and urine concentrations, or one might look more deeply into the molecular mechanisms by which vasopressin alters that conformation of aquapores in the loop of Henle of an individual nephron. And so the story could continue, should one wish. In each step, what is taken to be a single activity at one level is decomposed into interacting components in a mechanism at a lower level.

Contrasts. Levels of mechanisms are contrasted with levels of aggregates, mere size levels, levels of complexity, and Marr's levels of analysis.

Aggregates are summed properties, as the mass of a pile of sand might be thought to be a simple sum of the masses of the individual grains. In levels of aggregates, the higher-level, aggregate property does not depend on how the component parts are organized. The behavior of the whole is unaffected if all of the parts are spatially rearranged, or if the system is disaggregated and put back together again. The parts do not act together or interact with one another in the production of an aggregate (Wimsatt 1996). Though true aggregates are vanishingly rare in nature, concentrations fall close to the aggregate end of the spectrum. The concentration of sodium in a volume of water, for example, does not depend upon the precise

locations of the ionic constituents and would remain the same if all the sodium were removed from the water, shuffled, and replaced. In levels of mechanisms, in contrast, the components are *organized* spatially, temporally, and causally such that the property of the whole is not a simple sum of the properties of the parts but the product of parts plus their organization (Craver 2001). As a result, the components cannot be reorganized or dis- and re-aggregated without affecting how the system behaves. One could not replace the pituitary gland with a kidney and maintain the function of the osmoregulatory system.

Levels of mechanisms are also distinct from *mere size levels*. Two items are at the same size level when they are of sufficiently similar sizes. The commonly referenced hierarchy of biology might be understood in terms of size: molecules are smaller than cells, which are typically smaller than tissues, which are typically smaller than organs, organisms, populations, communities, and ecosystems.[1] Churchland and Sejnowski (1988, 742) emphasize size in their classic account of levels. Wimsatt (1986), in the most sophisticated account of size-levels to date, describes levels as peaks of regularity and predictability appearing at more or less discrete size scales. Size levels and levels of mechanisms are alike in some respects. It follows from the definition component that components are no larger than the wholes they compose; so a hierarchy of mechanisms will also exhibit a size hierarchy. The crucial difference, however, is that levels of mechanisms are compositional while mere size levels need not be. For example, the human heart is at a different size level than an atom of U^{238}, but the heart is not at a higher mechanism level than the atom because hearts are not composed of U^{238}. Failure to distinguish size levels from mechanism levels lies at the heart of widespread misunderstandings about the nature of interlevel causation (Craver and Bechtel 2007) [See Interlevel Causation].

[1] The intuitive mapping breaks down, however, given that organs in different organisms can be vastly different sizes, populations of different kinds of organisms can range from the size of the head of a pin to the size of a continent, and so on.

Biologists also speak of *levels of complexity*. If complexity is understood in terms of the amount of detail required to describe a system, then models of mechanisms that span multiple levels are, by definition, more complex than those that do not. Multilevel descriptions include more detail about how the mechanism works. Nonetheless, the behavior of a mechanism as a whole is often quite a bit simpler on this measure than would be the detailed description of all of the components and their interactions with one another. The Hardy-Weinberg equilibrium, a relatively simple feature of a population "at rest," can be maintained by very complex individual interactions among organisms and between organisms and their environment [see complexity]

Finally, levels of mechanisms are distinct from *Marr's levels*, the computational, algorithmic, and hardware levels of description (Marr 1981). Unlike levels of mechanisms, Marr's levels are not part-whole levels. The hardware is not part of the algorithm it implements, and the algorithm is not part of the computation it executes. Rather, these levels are three ways of describing one and the same mechanism. Marr's are levels of description, not levels of organization (Churchland and Sejnowski 1988).

Integrating Levels of Mechanisms. One goal in sciences that seek multilevel mechanisms is to integrate findings across multiple levels. Integration has two main components: cross-level manipulation, which is used to establish a component's explanatory relevance, and demonstration, which is used to establish an explanation's sufficiency.

Cross-level manipulation is a matter of showing that the items at one level make a difference to the items at another level (Craver 2007). In bottom-up experiments, one intervenes to alter, inhibit, or stimulate the behavior of a putative component, and detects the effects, if any, of that intervention on the behavior of the mechanism as a whole. Gene knockouts and pharmacological interventions are often undertaken for this purpose. In top-down experiments, one intervenes to activate or alter the behavior of a mechanism as a

whole, and one detects the behavior of one or more putative components. Functional neuroimaging studies often follow this design, as do a host of studies using biological indicators such as immediate early genes. Such experiments establish that items at level A depend upon items at level B in the sense that one can change A by changing B. They are useful, for example, in establishing that a given item is a component in a mechanism for a given phenomenon. [see experiments]. (One can also learn about cross-level dependencies without experimental intervention, for example, by tracking correlations and temporal sequences.)

Yet it does not suffice for a multilevel explanation that one merely trace the strands of cross-level influence in a mechanism. One must also show that one's model of how the relevant components are spatially, temporally, and actively organized accounts for the diverse features of the higher-level phenomenon. One must establish that if a mechanism were made of just this set of components, organized in just this way, then it would behave just as the target mechanism in fact behaves. Such *demonstration* is the focus of classical models of interlevel reduction [see reduction]. However, such demonstration, in the absence of knowledge about cross-level manipulation, might offer only a how-possibly explanation (what would be an explanation if only it were correct) or the correlational shadows of the correct explanation (a pseudo-explanation with irrelevant components, activities, and organizational features). Cross-level manipulation is required to ensure that the interlevel demonstration is grounded on true premises about real components in the system.

Are there really levels of mechanisms? Simon (1969) uses the parable of the watchmakers, Tempus and Hora, to argue that one should expect nearly decomposable hierarchical structures among evolved systems. Hora builds watches by first building stable components out of the basic parts and then combining the components to form watches. Tempus, in contrast, builds watches out of the basic parts directly, without building

intermediate components. Each is subject to regular interruption, a selective force that causes each watchmaker to lose every non-stable (non-component) assembly. With each interruption, Hora loses the work on a single component. Tempus, in contrast, must start a new watch from scratch. Hora will build more watches. On the analogy between watchmaking and evolution, Simon argues that evolved structures are likely to exhibit levels of decomposable structure. Some criticize the analogy on the grounds that co-evolved parts tend to lose their individuality. One might also object that evolution is not a watch-maker but a tinkerer that gradually shapes how mechanisms work by producing variant organisms with different fitness levels and selecting among them. Steel (2007) reformulates Simon's example to show that creatures with parts that can be manipulated independently of the other parts in a system (that have modular architectures [see modularity]) are more likely to be successful in evolutionary contexts. If so, one would expect evolution to favour creatures with systems capable of being altered independently of one another, making it probable that they are decomposable, and so hierarchical, in structure.

Cross-references

See complexity; mechanism; mechanism, conserved; mechanism, dynamic, interlevel causation; modularity.

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