Chapter 7

Varieties of Mechanisms

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1. Why explore Mechanistic Variety?

A common worry about the utility of philosophical analyses of mechanism is that the term “mechanism” is applied to such a staggeringly diverse collection of things that nothing informative can be said about it as a general category. This is especially true for those like us (Glennan forthcoming; see also Chapter 1; Illari & Williamson 2012) who have argued for a conception of mechanism that is expansive enough to allow most anything scientists have called mechanisms to fall under its extension. In response to such worries, we have argued that, while the things scientists (and philosophers) call mechanisms are heterogeneous, there are enough commonalities to allow for an informative analysis of mechanisms. Such an analysis can show what mechanisms are, and distinguish them from things that are not mechanisms.

Even if this analysis is successful, it is important for advocates of expansive conceptions to explore the varieties of mechanisms. The class of mechanisms is a heterogeneous lot, and exploring the nature and scope of these variations will give us insight into both metaphysical and methodological questions about mechanisms. There are (at least) two ways we might explore this variety. One is to look at exemplars of mechanisms that are studied in various scientific domains. The chapters in Part IV collectively exemplify this approach, and they do much to illustrate the special techniques, challenges and opportunities for mechanistic research within those domains. In this chapter, though, we will take a different approach. Our goal will be to describe a set of taxonomic dimensions along which we can characterize the varieties of mechanisms that exist within the natural and social world. This system of classification will often cut across disciplinary and domain boundaries.

As we explore the varieties of mechanisms, we need to contrast our project with another related project. Our goal in this chapter is focused on the varieties of mechanisms that exist in the world, rather than the variety of philosophical or methodological approaches that have gone by the name of "Mechanism" (or "Mechanicism" or "Mechanical philosophy").[1] There are certainly varieties of Mechanical philosophies just as there are varieties of mechanisms, and some philosophers have offered taxonomies of those varieties (see also Chapters 3 and 5 for historical discussions). It is, moreover, easy to slip between varieties of mechanisms and varieties of Mechanical philosophies, because different kinds of philosophical approaches will often assume or privilege certain varieties of mechanisms. We shall return to the issue of the relationship between mechanisms and Mechanical philosophies in the conclusion of our chapter.

2. The Dimensions of Mechanistic Variety

Any attempt to provide a scheme for classifying things must begin with a specification of the set of things to be classified. For us, that specification is embodied in minimal mechanism (see Chapter 1):

> A mechanism for a phenomenon consists of entities (or parts) whose activities and interactions are organized so as to be responsible for the phenomenon.

We start with this permissive characterization, not because it is better or "more correct" than less permissive ones, but because its permissiveness allows us to treat more restrictive conceptions as varieties of mechanisms.

How might one fruitfully sort out the vast array of things that count as mechanisms under the minimal definition? Our proposal is that a set of classificatory dimensions can naturally be read off the characterization of minimal mechanism.[2] Specifically a mechanism can be classified according to (1) the kind of phenomena for which it is responsible, (2) the kinds of entities, activities and interactions that comprise the mechanism, and (3) the way in which these entities, activities and interactions are organized. To these three dimensions, we add another: (4) the mechanism's etiology, i.e., the way it came to exist and have the properties it does. A mechanism's etiology is logically independent of its current constitution and properties, but there are interesting historical and causal dependencies between how a mechanism came to be, what it is made of, how it is organized, and what it does.

Within each of these four dimensions, there is great variety, and we cannot hope in this short piece to do more than offer a few examples of that variety, but it should be enough to illustrate our main point – namely that attending to the varieties of mechanisms will help illuminate both metaphysical and methodological debates. In identifying these four dimensions as dimensions, we are suggesting that they are to a large extent independent. For instance, mechanisms with very different kinds of entities, activities and interactions can have similar kinds of organization, or mechanisms with very different etiologies can be responsible for similar kinds of phenomena. On the other hand, our decision to treat entities and activities as lying within a single dimension reflects our understanding that entities or parts have a comparatively narrow range of activities and interactions in which they can engage. In this and other ways, the independence of these dimensions is not complete, and indeed understanding the ways in which, e.g., particular kinds of organization are characteristic of mechanisms with certain sorts of parts, is crucial to understanding the taxonomic space.

3. Varieties of phenomena

It is a truism among new mechanists that mechanisms are individuated by their phenomena or behavior. All mechanisms are mechanisms for. This usage is common in scientific and technological contexts. For instance, one speaks of mechanisms for protein synthesis, thermal regulation, or signal amplification. Mechanisms are classified as mechanisms of a certain kind if they produce the same kind of phenomena, so for instance, artificial and natural hearts are both hearts in the sense of being mechanisms for pumping blood within a circulatory system, even if the material constitution and internal operations are quite different.

There is no non-pragmatic standard by which to determine if two mechanisms are responsible for the same kind of phenomena. If two factories produce cars, one Fords and the other Volvos, or one sedans and the other SUVs, do they produce the same kind of thing or different? Obviously there is no proper answer to this question apart from some criteria of sameness, and such criteria will depend upon one's interests. But while we cannot offer an absolute standard for type-identity of phenomena, we can say much about structural features of phenomena by which we might classify them. These will show us that very disparate phenomena may be, in some respects, of similar kinds, and these similarities will bear on a variety of methodological and metaphysical issues.

Consider for example the question of the regularity of the mechanism's phenomenon (see Chapter 12). Machamer, Darden and Craver (MDC), in their much quoted definition of mechanism (Machamer et al. 2000), argued that mechanisms produce regular changes from start or set-up conditions to finish or termination conditions. A paradigm of a mechanism of this kind is protein synthesis. Given appropriate start conditions (presence of appropriate substrates, promoter regions, etc.), transcription of DNA will be initiated, leading through a sequence of steps to synthesis of proteins in the ribosome (the termination condition). Such a process is regular in the sense that it happens many times in the life of a cell, but it is far from universal – because various things can interfere with protein production. For instance, gene regulation can inhibit production of certain proteins, or the cellular machinery can become damaged.

The regularity of a mechanism's behaviour provides an important way of classifying mechanisms by their phenomena. While early characterizations, like MDC, impose a regularity requirement, our approach is to see that different varieties of mechanisms are different in the degrees and respects of their regularity.

One sense in which mechanisms can be regular is that the phenomena they are responsible for can recur. Recurrence comes in two basic varieties. The same token mechanism can exhibit the phenomenon on multiple occasions, and the phenomenon can be exhibited by multiple tokens of the same type of mechanism. Protein synthesis recurs in both of these ways. The same cellular machinery continually produces proteins over its lifetime, and there are many cells producing the same proteins. In other cases, you can have one kind of recurrence without the other. Apoptosis is a kind of mechanism that is responsible for programmed cell death. Many cells die this way, but each cell dies only once. On the other hand, token mechanisms, like the Old Faithful Geyser in Yellowstone National Park, can repeatedly exhibit the same kind of phenomena. Among mechanisms with recurrent phenomena, we can also distinguish between the more or less regular. For instance, we can characterize mechanisms by the probability with which start-up conditions actually lead to termination conditions (see Chapter 13).

Issues about regularity and recurrence are important in both methodological and metaphysical debates. For instance, one of the epistemological arguments for a regularity requirement on mechanisms is that if mechanisms are not in certain ways regular, then we will not be able to discover them. Experimental techniques in the sciences depend upon the fact that the same phenomena recur across many tokens of the same kind of mechanism. Because of this, for instance, one can study the mechanism of protein synthesis in a few cells of some species of model organism, and apply those conclusions to protein synthesis in cells of organisms in a wide variety of taxa. Arguably, the distinction between the historical and experimental sciences is that the experimental, much more than the historical, study recurrent phenomena. Historians (of both natural and human history) are often concerned with the explanation of singular events, and these events are often produced by mechanisms that are non-recurrent, or "one-off." For instance, natural historians may be interested in the causes of the Cambrian explosion, while historians of human civilization will be interested in the causes of distinctive events in human history, like the fall of the Roman Empire or the stock market crash in 1929. Investigation of these "ephemeral mechanisms" require distinctive methodologies (Glennan 2010; see also this volume Chapter 31).

Regularity and recurrence also play in metaphysical debates about the relationship between mechanisms, causes and laws. Recurrent mechanisms are the foundation of the new mechanist's account of the nature of laws. Laws in the higher-level sciences, if such exist, are thought to be effects – descriptions of the behavior of recurrent and regular mechanisms. At the same time, the idea of the existence of one-off mechanisms is essential if one thinks, as Glennan does, that causal claims are claims about the existence of mechanisms. This is required because not all causally connected events are produced by mechanisms that are regular or recurrent.

Another useful way to classify mechanistic phenomena is by the kind of relationship a phenomenon bears to the entities, activities and interactions that are responsible for it. Craver and Darden (2013) have suggested that sometimes mechanisms *underlie* phenomena, whereas other times they *produce* them. When a mechanism underlies some phenomenon, the mechanism's phenomenon is constituted by the collective activities and interactions of its parts, and for this reason such phenomena are called **constitutive.** In contrast, when a mechanism produces some phenomenon, that phenomenon is a (causal) result of the activities and interactions of the mechanism's parts, rather than being made of them. For this reason, we call such phenomena **non-constitutive**. The contrast between these two kinds of phenomena can be seen by comparing protein synthesis to the mechanism responsible for muscle contraction. Protein synthesis can be seen as a paradigm of a productive, non-constitutive, mechanism, because the proteins are made by, but not made of, the organized activities and interactions of the parts of the mechanism. Muscle contraction seems quite different. Muscles consist of cells called myocytes, which contain within them bundles of fibrils, which can shorten via the sliding of filaments made of proteins. When a muscle contracts, it does this because the cells of which its tissues are made contract, and this in turn happens because of the sliding filaments within the fibrils within the cell. Here it seems that the result of the mechanism is not some product made by the mechanism; the contracting of the muscle just is the contracting of its cells and the fibrils within them. This "just is" relation is a constitutive one.

Attending to the distinction between these kinds of phenomena can be helpful in sorting out a variety of metaphysical and epistemological issues. Metaphysical debates about the nature of causation, production and difference making, and causal chains are concerned chiefly with the "horizontal" production of non-constitutive phenomenon (Bogen 2004; Campaner 2013; Glennan forthcoming, chapter 7; see also this volume Chapters 10, 11 and 12; Kincaid 2012; Salmon 1984). On the other hand, mechanisms for constitutive phenomena have been at the center of discussions of "vertical" relations between parts and wholes in science (Craver 2007; Gillett & Aizawa 2016; see also this volume Chapters 9 and 14; Leuridan 2012; Winther 2009), which offer a new perspective on both metaphysical and methodological versions of debates about reduction and emergence. There has also been discussion of experimental methods for identifying working parts of constitutive mechanisms (Craver & Darden 2013) and of the challenges of integrating accounts at these different levels of mechanisms (Stinson 2016; see also Chapter 28).

4. Varieties of entities, activities, and interactions

Perhaps the most obvious way to classify kinds of mechanisms is by the constituents of which they are made. According to minimal mechanism these constituents are of two kinds – first the entities which are working parts of the mechanism, and second the activities and interactions in which these entities engage. The varieties of entities in mechanisms are diverse, ranging from DNA and mRNA in protein synthesis, through people and institutions such as Central Banks in economic mechanisms, to electrons and star cores in astrophysics. The same mechanism can include entities of notably different sizes. For instance, it appears that the mechanism responsible for core collapse in super-novae involves interactions between parts that range in size and mass between the subatomic and stellar cores with masses greater than our sun (Illari & Williamson 2012). Relatedly, the mechanisms responsible for some phenomenon may include entities of quite different kinds. For instance, the mechanisms that account for the diversity and abundance of flora in urban landscapes will involve artifacts in the built environment (like buildings and bridges) and the social and physical actors that build them, as well human and non-human fauna in the area, the nutrients within the soil and the sun and rainwater that sustains growth.

Just as mechanisms can be classified by the kinds of entities of which they are made, so too can they be classified by the kinds of activities and interactions in which the parts of mechanisms engage. It is one of the important insights of the new mechanist literature that concepts like “activity,” “interaction” and “cause” are abstract. Proper characterization of mechanisms requires one to use more specific concepts like “pushing,” “folding,” “binding,” "trading" and "collapsing" (Bogen 2008; Machamer et al. 2000). These specific activity concepts tell one much more about how and under what conditions mechanisms bring about their phenomena.

It is not enough though to distinguish between the abstract category of activities and interactions, and specific sorts of activities and interactions. Rather, activities and interactions can be characterized in a hierarchy of increasingly less abstract ways, corresponding to increasingly concrete and determinate varieties of activities and interactions. For example, many activities and interactions are involved in protein synthesis, but each one is an activity or interaction of a particular kind. Transcription is a very general activity, but any particular transcription is a transcription of a particular coding strand of DNA, into a matched strand of mRNA, which will be more determinate. Similarly, protein folding is the folding of a polypeptide chain – a chain of amino acids – into a functional protein. Specific foldings take many forms, going through at least three stages to form secondary, tertiary and quaternary protein structure.

Glennan (forthcoming, chapter 2) has argued that the parallel point needs to be made about entities. The concept of entity is extremely abstract, and classifications of kinds of entities will form hierarchies of increasingly concrete and determinate forms. For instance, mRNA and proteins are different kinds of entities, but each of these kinds have a variety of more determinate kinds that fall under them. The same is true with functionally specified entities: all promoters have features in common that make them the kind of entity they are, but they come in many more determinate forms, promoting the transcription of different coding strands of DNA.

Entity and activity varieties provide us one way of classifying mechanisms into kinds. We can lump mechanisms by the kinds of entities which are their parts, and also by the kinds of activities that those parts engage in. Some mechanism classifications emphasize similarities in entities, while others emphasize similarities in activities. For example, biochemical mechanisms are largely grouped together as similar based on their entities; and competitive mechanisms are largely grouped based on their activities and interactions; while social mechanisms share a bit of both.

The kinds of entities and kinds of activities involved in a mechanism constrain but do not completely determine each other. This is crucial to discovery methods that involve using knowledge of an entity to identify its activity, or vice versa (see Chapter 19). Particular activities are activities of particular entities, and a particular entity can only take part in some activities, while a particular activity can only be produced by some entities, but entities don't have to have proper activities. Generally quite different kinds of entities may engage in similar activities, and particular kinds of entities may engage in very different sorts of activities and interactions. Think of all the things that mouths or screwdrivers can do, or of the many different kinds of entities that one can use to break a window or plug a leak. Indeed, whether something counts as an entity or activity at all is not something that can be answered except locally, in the context of particular phenomena. We take this to be Dupré's point when he argues that nothing is an object *tout court*, but only at a particular timeframe (Dupré 2012). On a long timeframe, Dupré argues, even mountains are processes (which we take to be activity-like), because on a geological timeframe, even mountains are constantly changing. Something similar might be said for at least some activities and entities in mechanisms, which exist at a particular timescale, depending on the phenomenon that the mechanism is for. Cells and tissues are sufficiently stable that particular cells or tissues often count as entities in many mechanisms for bodily phenomena. Nevertheless, they are sufficiently changeable that they do not in mechanisms for other phenomena, and may count instead as whole mechanisms or even systems – which are in their turn decomposable into *both* entities and activities.

5. Varieties of Organization

What a mechanism does, and so how we discover it and how we use it in explanation, depends not just on the entities and activities of which it is made, but on how these constituents are organized. Electrical circuits nicely illustrate this fact: the very same resistors or capacitors can exhibit very different resistance or capacitance depending upon whether they are wired in parallel or in series. Similarly, the developmental processes by which fertilized eggs divide and develop into embryos and ultimately mature organisms depend upon variations in concentrations of proteins within different regions of the egg. The fact, for instance, that a mature fruit fly has its wings and body segments where it does depends crucially upon the locations and rates at which gene products express within the developing embryo.

We treat mechanistic organization as a separate dimension of mechanistic variety, because it can vary largely independently of the kinds of entities and activities that constitute the mechanism. Consider for example forms or organization like positive and negative feedback loops. In positive feedback loops, a mechanism produces a change in some property of the system, and this change in turn feeds back into the system, amplifying the effect. In contrast, in negative feedback loops, the changing property feeds back in a way that dampens the effect. These and other forms of organization can be found in all manner of mechanistic processes and system – electrical, molecular and chemical, genetic, climatological, economic and social. It is the fact that such forms of organization induce predictable patterns of behaviour in mechanisms that allows for the development of representational and modelling techniques like dynamical systems theory, control theory and information theory, that are largely independent of the particular kind of entities or activities involved (see Chapter 20).

These kinds of organizational varieties can be called topological and functional. They show how parts of mechanisms and their activities are arranged – spatially, temporally and causally. These kinds of features are often captured in mechanism diagrams (see Chapter 18) or via mathematical formalisms like structural equation models or Bayes nets, which indicate which parts are connected to which, and the functional forms of such dependencies.

The variety of topological and functional organizations of mechanisms are essentially limitless, and we shall not try to survey them further here. We do, however, want to call attention to a few more basic ways to classify mechanistic organization that are of both methodological and ontological import. To begin, we can classify mechanism by the number of parts that they have. Muscular skeletal mechanisms, for instance, have relatively few parts (muscles, bones, cartilage, etc.) – few enough that scientists can identify each of those parts along with its role in the mechanism. In contrast, in molecular mechanisms like the mechanism of protein synthesis, there are many parts -- e.g., many segments of mRNA and many proteins – and operations are completed many times over. Whether a mechanism has few or many parts has important consequences for the techniques scientists use to describe, manipulate and explain them. For instance, in mechanisms of protein synthesis, diagrams represent token entities and activities of a process that occurs many times over. Description of what the mechanism does will be not simply in terms of producing a protein, but in producing proteins in various concentrations and at various rates. This is very different from a representation of the parts of a circuit in an electronic amplifier, where the wiring diagram explicitly identifies and locates each part.

We can also classify mechanisms by the degree to which their parts are uniform. Some mechanisms are composed of a small set of largely uniform parts, in the way that Lego structures may be made out of a large number of similar blocks. Other mechanisms have a variety of different parts with different capacities and roles. For instance, at the lowest molecular level, the components of DNA, RNA and proteins are small in number, and each of these building blocks (nucleotides, amino acids) is more or less identical, with the structural and functional diversity of proteins arising from the many different ways in which these simple building blocks can be combined. At higher levels of mechanistic organization in multi-cellular organisms we often see much more structural and functional diversity in parts. Locomotion in animals, for instance, requires the orchestration of very different types of entities and activities – muscular, skeletal, pulmonary, respiratory, neurological, and so on.

Finally, we can classify mechanistic organization by what brings about and maintains relationships between parts. At one extreme, which we call induced organization, these relationships are imposed by an external agent, like when a host arranges the seating of guests at a dinner party; at the other, which we call affinitive organization, these relationships arise from the affinities that parts bear to each other, like when the guests at the dinner party seat themselves. In such a case, the arrangements of the guests and who interacts with whom will be determined in part by chance, but also by who each guest is disposed to sit with. All mechanistic organization is to some degree affinitive, because of the simple fact that different entities have different capacities to act and interact with each other. However, sometimes, as in many chemical processes, reactions occur largely due to random interactions between molecules with different kinds of affinities, whereas in other cases, like the case where protein concentrations vary from the front to middle to back of a developing egg cell, the organization was induced by prior processes that set the next stage in the developmental mechanism. All of these forms of organization matter to how we mechanistically explain, and to how we discover mechanisms, especially since we have become able to recognise and model forms of organisation that recur in many mechanisms (see Chapter 20).

6. Varieties of Etiology

Because mechanisms are localized in space and time, they must have etiologies – that is to say there must be some causal process that led up to their existence. There is a difference between what caused a mechanism to come into being and how it works now, though as we shall show in this section, there are often connections between a mechanism's etiology, on the one hand, and what it is made of and how it is organized, on the other.

While mechanical philosophy owes much in its origins to analogies with machines of human construction, the etiology of such mechanisms is typically unlike that of mechanisms responsible for naturally occurring phenomena. Mechanical devises like windmills or cars have what we call designed-and-built etiologies. This is to say that an agent, the designer, identified some phenomena they wanted to produce (like the grinding of corn or moving passengers across roads), and then set about to collect and arrange a set of parts so that their activities and interactions will in fact bring about the desired result. It is not just the artifacts of human engineering that can be designed and built. Many social, political and economic systems also are "engineered" in this way, and there is no requirement that designers and builders must be human agents.

Most mechanisms, however, evolve over time. Evolved etiologies are by no means limited to biological systems. In the most basic sense, evolved mechanisms are those that are built and modified over time, so that the present characteristics of the mechanism have emerged gradually from earlier stages or versions of the mechanism. While the idea of evolved mechanisms brings most immediately to mind biological mechanisms, abiotic systems and processes like stars, volcanoes and weather systems also have evolved etiologies in our sense, as do many social, legal and economic mechanisms – like property or commodity markets or systems regulating property, marriage and child-rearing.

There are a variety of different kinds of processes that can underlie the evolution of mechanisms and mechanical systems. For instance, in stellar evolution, the gradual changes in stars from one stage to another depend mainly upon the star's mass and the concentrations of various elements within the stellar core. As a star consumes hydrogen in fusion, gradually its properties will change. Evolutionary biology is concerned with the etiology of populations of reproducing organisms (and their traits), and there appear to be a number of processes – selection, mutation, migration, drift – which can drive this evolution. We believe that these represent varieties of etiological mechanisms, though whether and in what sense they are mechanisms is a matter of some debate (see Chapter 22). Similarly, when we speak of developmental mechanisms, we are describing mechanisms by which an organism and its component mechanisms evolve in the developing embryo (see Chapter 25).[3]

One other way that a mechanism can come to be is by the operation of ephemeral mechanisms. Ephemeral mechanisms are mechanisms in which the relationship between the parts of the mechanism that are responsible for the phenomena are short lived, unstable, and thrown together by happenstance. The mechanisms responsible for one-off events, like forest fires, car crashes, and romantic liaisons are typically ephemeral, but seldom do enduring mechanisms arise from such processes. In a very different context, Donald Davidson imagined the possibility of lightning striking a tree and somehow miraculously rearranging the tree to create an exact molecule-by-molecule replica of himself, which he called Swampman. Were such miraculous events to occur, the process by which the mechanisms within Swampman came to be would be ephemeral in an extreme way.

While we distinguish these three kinds of etiologies, the etiologies of particular mechanisms typically involve several of these elements in concert. For instance, while biological organisms and the mechanisms that operate in them are the product of evolutionary processes, it is clear that many events that impact the outcome of those processes will be the result of ephemeral mechanisms – for instance, mechanisms responsible for one-off mutations or for environmental changes that lead to extinctions. Many artifacts and technologies have designed-and-built etiologies, but the design and build process can be iterated, so present versions are either evolutionary modifications of earlier versions, as when we upgrade the plumbing in our houses, or newly designed and built tokens of a type, but where the design of the type itself has been modified as the result of an evolutionary process. For instance, my new iPhone was designed and built, but its design is deeply constrained by earlier iterations of iPhones.

While a mechanism's constituents and organization are to some degree independent of its etiology, there are clearly connections. What a mechanism does and how it does are often constrained by its history, and traces of its history are evident in the present mechanism. How we set about discovering the mechanism and using it in explanation and in attempts to control the world by altering the operation of the mechanism, can be affected by that history. Perhaps most obviously, evolved and ephemeral mechanisms will tend to rely on affinitive forms of organization, because there is no external agent to impose organization on them. We could not effectively alter the operation of the mechanism without taking this into account. Similarly, if Simon's argument is correct, evolved systems will tend to have "modular" designs (Simon 1996; see this volume Chapter 14). Also, evolved systems will contain vestiges of earlier versions of the system that have become entrenched; this is obviously true of populations of organisms evolving by natural selection, but it is equally true of my iPhone, or for that matter, the organization of Britain's National Health Service. Effective policy or technological change needs to consider this.

7. Upshots

After this too brief exploration of the varieties of mechanism, we would like to reflect on the philosophical significance of this classificatory project, and to discuss how it is related to other attempts to classify mechanisms and mechanical philosophy.

To begin, let us consider whether and in what sense these varieties of mechanisms are real. Our language has been realist. Mechanisms are things in the world, and we can place them into categories according to the different properties they have. Nonetheless, our realism is tempered. The dimensions of mechanistic variety do not allow us to sort mechanism tokens neatly into kinds. The properties by which we sort cross cut. Mechanisms may have similar patterns in the kind of phenomena they produce (e.g., in being regular or constitutive) while involving very different kinds of activities. Or, again, mechanisms made with very different kinds of entities can be organized in similar ways, and mechanisms that produce the same kind of phenomena may have very different etiologies. Another problem for realism is vagueness. How many parts does one need to have to be a many-parted mechanism, or with what probability must a start-up condition lead to a termination condition in order to have us count a mechanism as regular? A third problem is that mechanisms will often be hybrids involving multiple varieties within each of these dimensions. Consider for instance, the varieties of entities and activities involved in mechanisms responsible for mood disorders, or the variety of organizational motifs in gene regulatory networks.

However, the fact that that there are many ways to carve up the world, does not mean that there isn't a world out there that constrains and makes sense of our carvings. We think our account is consistent with what Mitchell calls a "pluralist realist approach to ontology, which suggests not that there are multiple worlds, but that there are multiple correct ways to parse our world, individuating a variety of objects and processes that reflect both causal structures and our interests." (Mitchell 2009 p. 13; see also Wimsatt 1994). (For further discussion, see also Chapter 15.) While Mitchell mentions "interests," we should also add abilities, since how we parse the world will depend upon the tools we have. Take for instance the distinction between few and many parted mechanisms. This distinction is not only vague; it is largely determined by our cognitive and computational resources. Many parted mechanisms require different techniques for discovery, representation, and control – but this is because of our abilities rather than any intrinsic feature of the mechanism. More generally, we think that the way we classify mechanisms into varieties reflects the models we use to represent them, and that suitability of such models depends both on token mechanisms in the world and upon our interests and epistemic resources (Glennan forthcoming, chapter 4).

We turn now to a discussion of the relation of our account of mechanistic variety to other taxonomic efforts in the literature. As we noted at the outset, care needs to be taken to distinguish kinds of mechanisms, which are things in the world, from kinds of (capital "M") Mechanisms, which are philosophical and scientific claims or views about the role of mechanisms and mechanistic reasoning. This distinction is easily lost in taxonomic discussions, since mechanistic philosophical projects typically implicitly or explicitly presuppose a conception of what mechanisms are in the world.

Let us begin with Levy's taxonomy, which is of big "M" Mechanisms. He identifies three distinct but related philosophical projects, that he calls "Causal Mechanism (CM)," "Explanatory Mechanism (EM)," and "Strategic Mechanism (SM)" (Levy). CM is a metaphysical project intended to give an account of causation in terms of mechanisms. EM is a thesis about explanation to the effect that good explanations must cite information about mechanisms, while SM aims to draw attention to the heuristics used in mechanism discovery. The projects of EM and SM are epistemological and methodological. Quite rightly, Levy observes that Causal Mechanism of the sort proposed by Glennan must embrace a permissive conception of mechanisms in the world (like our minimal mechanism) if it is to have any hope of making the claim that causal connections are all or mostly mediated by mechanisms. Similarly, he observes that Strategic Mechanism, which he associates most prominently with (Bechtel & Richardson 1993), adopts a narrower conception of mechanisms, in which they are machine-like, and where decomposition and localization are powerful strategies. Explanatory Mechanism, which he associates most prominently with MDC and Craver 2007, also focuses on a somewhat narrower conception of mechanism, especially those that are always or for the most part regular, and have hierarchical organization.

Andersen (2014a) offers a broadly similar distinction between two projects, which she calls Mechanism$_2$ ("Mechanisms as an ontology of the world"), which aims to use mechanisms to give a complete account of what there is, including an account of causation, and Mechanism$_1$ ("Mechanisms as integral to scientific practice"), which focuses on the practices of discovery, representation and explanation associated with hierarchically organized mechanisms. Roughly, Andersen's Mechanism$_2$ and Levy's CM identify metaphysical or ontological projects, while Andersen's Mechanism$_1$ and Levy's EM and SM identify explanatory, epistemological and methodological projects.[4]

Nicholson explores the concept of mechanism in biology, and argues that the word "mechanism" has principally been used to refer to machine-like structures in the world "machine mechanisms," "a step-by-step explanation of … a causal process," and to "Mechanicism" – "the philosophical thesis that conceives organisms as machines…" (Nicholson 2012 p. 153) The first of the theses refers to a kind of little m mechanism, while the last of these is clearly a big M Mechanism (see Chapter 5). The middle of these is neither, but it is associated with what Nicholson calls "the Mechanismic Program," and which most philosophers now call "the New Mechanism" and is close to Andersen's Mechanism$_1$ and Levy's Explanatory Mechanism.

Kuorikoski's taxonomy distinguishes two kinds of small-m mechanisms – "computational causal systems" and "abstract forms of interaction." The former he takes to be the sort of mechanisms that have been chiefly of interest in recent discussions of mechanisms in biology (and we surmise in EM, SM, and Mechanism$_1$). The latter is the concept Kuorikoski sees at work in discussions of mechanisms in the social science literature. The former kind of mechanisms are the sorts of mechanisms amenable to decomposition and localization. The latter refer to mechanisms where these strategies fail, but which can be characterized abstractly in terms of certain kinds of organization. He cites as examples selection mechanisms in evolution, various kinds of market mechanisms, crowding out, and self-fulfilling prophecies. (As Kuorokoski notes, abstract form of interaction (AFI) mechanisms are not themselves abstract, but the explanations of such mechanisms are.)

We find that there is much that is informative in these kinds of attempts to taxonomize mechanisms and Mechanisms, but there are clear limitations of these approaches – limitations that are mitigated by more carefully attending to the varieties of mechanisms. These attempts all try to identify a few kinds of mechanisms, and to illustrate how these different kinds of mechanisms show up in different scientific domains or are appropriate for different projects. For instance, we notice a frequent distinction between a "broad" and a "narrow" conception of mechanism, where the narrow conception is "machine like" and the broad one is not.

We find this approach problematic because it is unclear how narrow a narrow conception should be, and any narrow conception can be broadened in many different directions. In particular, these accounts suppose a clear univocal conception of what a machine is, but machines themselves are massive in their variety. A calculator is a machine, and so is a Watt governor, and how different are their properties!

We also doubt that we can identify some kinds of mechanisms that are important for ontological and metaphysical projects, and others that are the kinds that scientists talk about. As we note above, Levy and Andersen suggest that Mechanism$_2$/Causal Mechanism requires a broad conception of mechanism; while this is true so far as it goes, we think that the distinctions between varieties of mechanisms we make here will be central to creating a broad account of mechanism that still recognises important variations. For instance, if we do not clearly distinguish between constitutive and non-constitutive phenomena, we will not be able to sort out the relationships between part-whole and causal forms of dependence, which are often important. At the same time, there are other interesting projects that, in spite of being metaphysical, might still focus on rather narrow forms of mechanisms. For instance, we might imagine that distinctions along the dimensions we have offered would be of assistance in sorting out various forms of emergence. Similarly, we can observe that very broad conceptions of mechanisms, like Kuorikoski's AFIs, can be methodologically significant. Illari (2011) also argues for the need for a relatively broad understanding of mechanisms to characterise an important role for evidence of mechanism in causal inference in medicine (see also Clarke et al. 2014).

We can moreover do much to explicate some of the proposed taxonomies of mechanisms by reference to our account of mechanistic varieties. Take for instance Kuorikoski's notion of mechanisms as abstract forms of interaction. From our perspective, the sorts of mechanisms Kuorikoski identifies are mechanism varieties that are identified by the kinds of organization they have. Different kinds of markets (e.g., perfect markets, monopolies and oligopolies, and markets exhibiting various kinds of market failures) will be the kind of markets they are in virtue of how they are organized. Monopolies, for instance, have only one seller, and we can make predictions about how that market will behave in light of that fact.

In a recent unpublished paper, Levy and Bechtel have argued that it is time to move to "Mechanism 2.0." They describe structures and processes that biologists are seeking to understand and that appear to be mechanisms (in our sense of minimal mechanism) but for which the tools of discovery, representation and explanation described by new mechanists of the last 20 years do not quite work. They suggest that it is best to stop worrying about whether these structures and processes are or are not mechanisms by some definition, and instead to explore the various ways in which these biological mechanisms break the narrow mold. We certainly concur, and we hope that our approach provides some tools that will help in that exploration.

Notes

[1] As we noted in Chapter 1, the word "mechanism" is used both to refer to worldly mechanisms and to philosophical or methodological theories or approaches that are mechanistic. We will continue to follow the convention we adopted there of referring to the former with lower case "m", and the latter with upper case "M".

[2] Much of the terminology used in this taxonomy is introduced and elaborated in more detail in Chapter 5 of (Glennan forthcoming).

[3] In biology, the word "evolution" is typically used to refer to the change in populations and their characters over time, and contrasted with development, which is responsible for changes in individual organisms from conception to maturity. But both evolutionary and developmental mechanisms are kinds of etiological mechanisms, and the mechanisms that result from both of these processes have evolved (as opposed to designed and built) etiologies.

[4] Andersen seems to us to move between big M and little m mechanisms, presumably because she thinks the philosophical projects presuppose particular conceptions of mechanisms. She provides three additional conceptions of mechanism (3-5), which are mechanisms "that are ontologically 'flat,' or at least not explicitly hierarchical in character: equations in structural equation models of causation, causal-physical processes, and information-theoretic constraints on states available to systems"(Andersen 2014 p. 284). These are more clearly small-m mechanisms (though obviously structural equations are not in the world).

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